Silvicultural Decision Guide for Swiss Needle Cast in Coastal Oregon and Washington

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Swiss needle cast, a foliage disease caused by the native pathogenic fungus *Nothophaeocryptopus gaeumannii (*formerly *Phaeocryptopus gaeumannii)*, has emerged as a significant disease of Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) in the coastal Pacific Northwest since the 1990s. Swiss needle cast symptoms include chlorotic (yellowish) foliage, low needle retention, thin crowns and reduced tree growth (Figure 1). The fungus occurs wherever its only host, Douglas-fir, is grown. The disease, however, is only noticeable when the fungus causes significant defoliation of 2- and 3-year-old needles. This is an important point for managers — the fungus may be present and yet have no effect on Douglas-fir productivity.

Nothophaeocryptopus gaeumannii lives inside the needles of Douglas-fir and only impacts needle function when fungal fruiting bodies (called pseudothecia) emerge into and plug the stomates (air pores on the underside of a needle), blocking gas exchange (Figure 2). When too many of the stomates on a needle get plugged, the needle dies and is cast (dropped) from the branchlet.

Although first identified on Douglas-fir growing in Switzerland in the early 20th century, forest pathologists in North America found the fungus was common in native Douglas-fir stands but was not causing problems. The disease emerged in Christmas tree plantations in Washington and Oregon in the 1970s, and by the 1990s it had intensified in coastal Oregon and Washington Douglas-fir plantations. In January 1997, private forest landowners, federal and state agencies, and the Oregon State University College of Forestry joined forces to research the disease and develop management practices. This group, the Swiss Needle Cast Cooperative, has coordinated monitoring and developed tools to help landowners manage the disease.

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The aerial detection survey for coastal Oregon (Figure 3) began in the spring of 1996 and identified 131,088 acres with obvious symptoms of Swiss needle cast. By 1999, 295,000 acres (out of 2.9 million acres surveyed) of private, federal and state lands were visibly affected by SNC. From 2000 to 2015, the quantity of affected acreage increased, peaking at 589,851 acres in 2015. The decreases following this peak are likely due to hotter and drier early summer weather in subsequent years, as well as liquidation or conversion of diseased plantations to nonsusceptible species in the most infected zones.

Swiss needle cast is now considered one of the top threats to Douglas-fir plantations in western Oregon, Washington and southwest British Columbia, especially in coastal areas. SNC causes needle loss, and there is a direct relationship between needle retention and tree growth when retention is below three years (Figure 4). Needle retention quantifies how many years of leaves are retained on tree branchlets. As needle retention decreases, there is a corresponding reduction in tree diameter and height growth, allowing needle retention to be used as a proxy for disease impacts. The most heavily infected stands are estimated to be losing about 50% of their potential cubic volume growth. Economic losses are commensurate.

Here, we synthesize our knowledge of silvicultural approaches to SNC, addressing recognition of risk. It has become abundantly clear that a one-size-fits-all approach does not work for SNC, and that management is nuanced and site-specific. Forest managers must consider their options and not ignore SNC.

Figure 1. Chlorotic (yellowing) and thin Douglas-fir tree crowns due to Swiss needle cast. Note the green western hemlock trees.

Credit: Dave Shaw, © Oregon State University

Figure 2. Small, black pseudothecia plugging stomates on a Douglas-fir needle.

Credit: Gabriela Ritokova, © Oregon State University

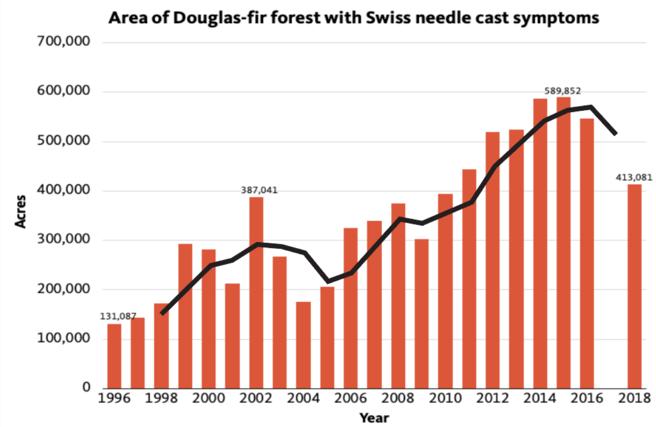

Figure 3. Area of Douglas-fir forest in western Oregon with symptoms of Swiss needle cast detected during aerial surveys conducted in 1996–2018. Trend line is a three-year rolling average.

Credit: Oregon Department of Forestry

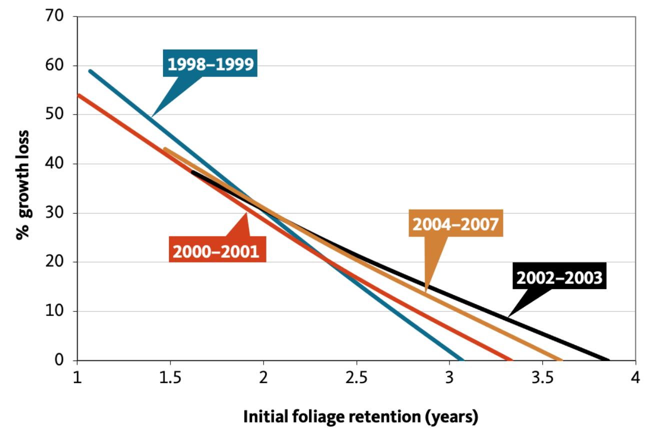

Figure 4. The percent growth losses associated with level of needle retention.

Credit: Doug Maguire, Center for Intensive Planted-Forest Silviculture, Oregon State University

Silviculture decision guide

We recommend a three-step process for deciding how to respond to SNC in forest plantations: a site hazard assessment, followed by a stand impact assessment and, finally, silvicultural decisions.

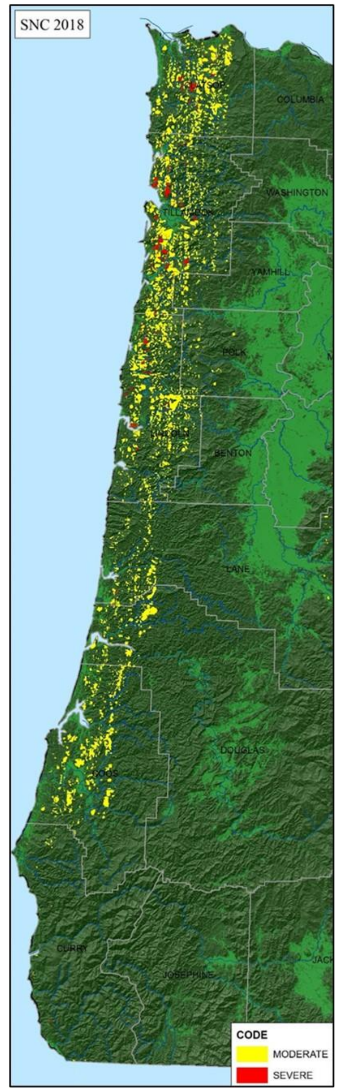

Figure 5. Oregon aerial detection survey results for 2018. Red represents severe symptoms; yellow, moderate.

Credit: Oregon Department of Forestry

Site hazard assessment

The most important climatic factors influencing the disease vary with geographic location. Therefore, a site hazard assessment is critical to understanding risk. Tools to assist in site hazard assessment (Table 1) include aerial detection surveys, ground-based plot data, and our general knowledge of the relationship between disease and geographic location.

Aerial detection survey data

The Oregon Department of Forestry, the Washington Department of Natural Resources and the U.S. Forest Service Forest Health Protection group conduct a spring aerial detection survey for Swiss needle cast. They map stands with visible symptoms and post their maps on the Forest Service website (https://www.fs.usda.gov/detail/r6/forest-grasslandhealth/insects-diseases/?cid=stelprdb5286951) (Figure 5).

The data does not necessarily confer knowledge of growth impacts as much as the potential for growth impacts based on disease symptom expression. It is possible to have impacts from SNC anywhere Douglas-fir grows. But if aerial detection reveals visible symptoms, the likelihood of impact is much greater. In British Columbia, the Ministry of Forests has also begun aerial detection surveys.

Plot data

Plot networks have been installed in Oregon, Washington and British Columbia to monitor the disease in support of the aerial survey. The general area most at risk from growth impacts includes coastal Oregon with growth impacts mostly decreasing with increasing distance from the coast. Coastal Washington, particularly in the southwest, is also at risk. Finally, southwest British Columbia has become an area of increasing concern.

Maps have been produced from spatial interpolation of needle retention and disease severity ratings across 106 SNCC monitoring plots in coastal Oregon and southwest Washington, providing a coarse estimate of where disease can be expected to be a problem (Figures 6, 7).

Models of SNC severity and needle retention

Needle retention is associated with both disease severity and growth impacts, so maps of needle retention have been used to reflect the risk of disease impacts. The Swiss Needle Cast Cooperative also features several models (http://sncc.forestry.oregonstate.edu/models) based on principles of disease epidemiology.

Table 1. Tools for site hazard assessment

Aerial detection survey

Aerial surveyors map the location and size of stands with visible disease symptoms.

Use: Provides insight into whether a location has displayed visible symptoms. May be at risk for growth impacts.

Plot data inference

On-the-ground tree measurement plots.

Use: Plot networks allow tree growth impact monitoring, validation of aerial detection survey, as well as data on the distribution of disease severity and needle retention.

Models and maps

Models and maps may be based on data from plot networks or predictable geographic distribution of influential variables.

Use: Allows prediction of where disease may cause growth impacts to stands.

Geographic information

Climate and weather patterns, in conjunction with topographic position and coastal influences, provide clues to potential disease severity on a site.

Use: Lower elevation and closer to the coast are most at risk. In the western Cascade foothills, low-elevation sites that receive high summer rainfall are most at risk.

Distance from coast, elevation and geographic location

Although the precise causes of the disease vary by geographic location, wet needles during budbreak and shoot elongation (May, June, July) enhance fungal germination, and warm winter temperatures speed disease development. Swiss needle cast is more severe in low-elevation coastal areas than in higher-elevation inland areas.

Nevertheless, the lower-elevation areas of the western Cascades foothills in Oregon exhibit some disease. In British Columbia, the disease is also significant in the rainforest valleys of the lower elevations in the Fraser River region, especially near Chilliwack.

The site hazard assessment is a critical but qualitative step, providing a good basis for understanding the potential for impacts within an area.

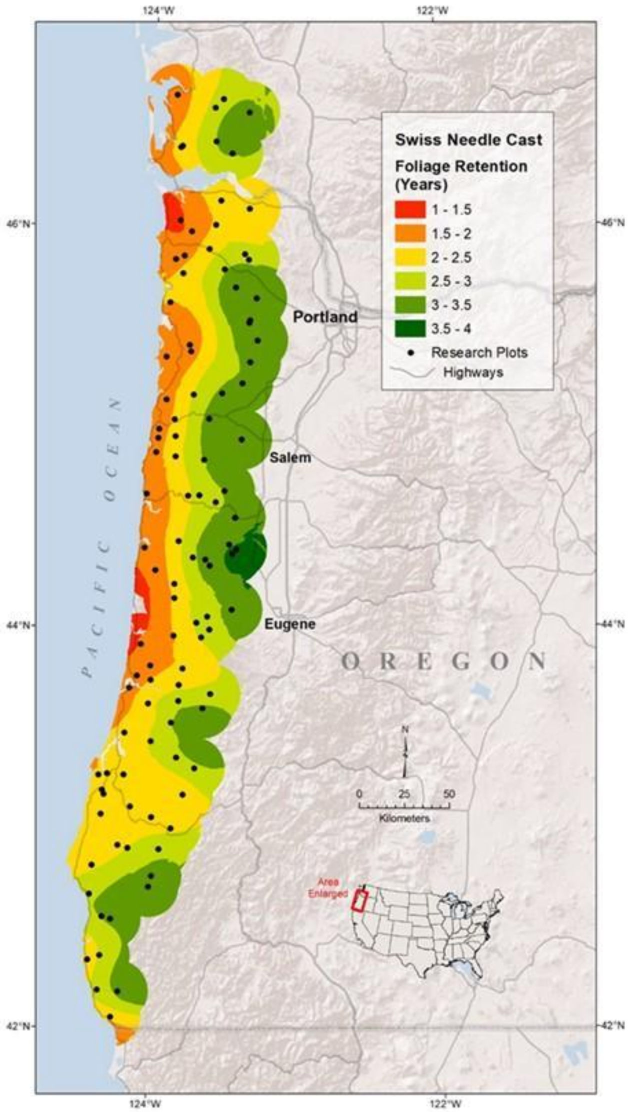

Figure 6. Douglas-fir foliage retention in plantations within 35 miles of the coast. Dots represent locations of Swiss Needle Cast Cooperative research and monitoring plots.

Credit: Randy Comeleo, Environmental Protection Agency

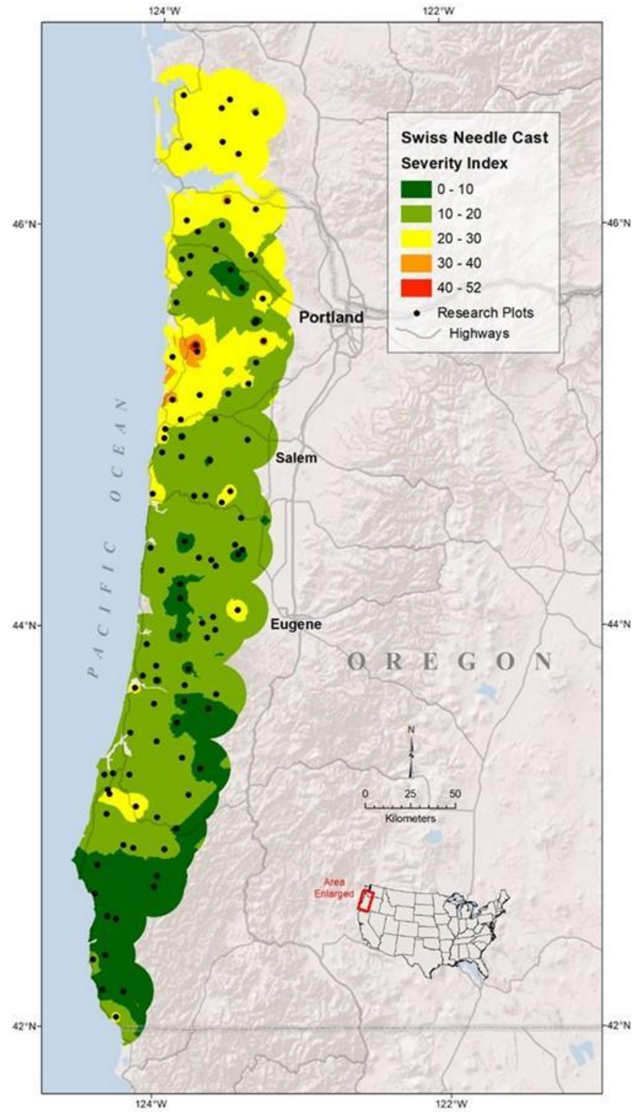

Figure 7. Swiss needle cast disease severity in coastal plantations within 35 miles of the coast. Dots represent locations of Swiss Needle Cast Cooperative research and monitoring plots.

Credit: Randy Comeleo, Environmental Protection Agency

Stand impact assessment

A quantitative assessment of stand impacts is necessary if the manager believes that deviation from standard forestry practices may be required. First, a visual assessment of stand conditions, including needle retention, stand/crown color and crown fullness, can be used to determine if growth losses are likely. If so, then confirmation of the presence of *N. gaeumannii* should be done. Once these criteria are completed, we recommend a quantitative stand assessment to clearly demonstrate if growth impacts are occurring and to what degree.

Visual assessment of stand symptoms

Trees moderately to severely impacted with SNC typically show symptoms most clearly in April and May, just before and during budbreak. Symptoms include low needle retention, yellowish crown color (chlorotic), sparse crown and reduced growth (Figures 8, 9). Although these are most obvious in spring, severely impacted trees show symptoms all year.

Needle retention

Estimates of needle retention should come from the mid- to upper mid-crown of dominant and co-dominant trees, preferably on the south side of the tree. In older stands with recessed crowns, this can be done with binoculars. Estimates can be obtained from any number of dispersed trees whose condition is judged representative of the stand.

On a mid-crown lateral branch, needle retention is estimated by summing the proportions of retention on each annual needle cohort.

In the example shown in Figure 10B, the current year is estimated to hold 100% of its needles (proportion = 1.0), the second year is estimated to have 90% of its needles (proportion = 0.9), and the third year is estimated to have 30% of its needles (proportion = 0.3). The estimated needle retention for a sample branch is 1.0 + 0.9 + 0.3 = 2.2 years.

Needle retention may not be possible to estimate on very young trees due to their lack of older side branches.

Stand or crown color

The color of a tree crown or aggregated stand is not easy to assess, although a sickly yellow tree may seem obvious. Angle of view, sunny or cloudy conditions, time of day, and season all influence crown color. Assess crown color at midday in the spring prior to budbreak in April. Trees may lose their yellowish appearance after bud break and needle shed. Do not assess the stand from the roadside, as trees adjacent to the road may not represent the stand. If possible, view the stand from a high point with the sun behind you during midday.

Figure 8. Differences in crown characteristics of Douglas-fir impacted by Swiss needle cast on left (seed source southwest Oregon), and trees not impacted by Swiss needle cast on right (seed source southwest coastal Washington).

Credit: Dave Shaw, © Oregon State University

Crown sparseness

Crown sparseness, a qualitative estimate, is a good indicator of foliage loss, although it can be difficult to assess, especially in older trees. However, in pre-crown closure trees, crown sparseness may provide a better estimate of the impact of disease than needle retention.

Figure 9. Thin chlorotic crown with low needle retention due to Swiss needle cast.

Credit: Dave Shaw, © Oregon State University

Verify presence of the fungus that causes Swiss needle cast

Crown color, crown fullness and needle retention are influenced by SNC but can also be influenced by soil nutrient deficiencies, other pathogens or insects, root diseases or weather events. To ensure that SNC is the cause of the crown condition, look for signs of the fungus.

The key signs are the pseudothecia that plug the stomates (Figure 2). If abundant pseudothecia are present on 1- and 2-year-old needles, then it is likely the fungus is causing disease. In particular, we use 2-year-old needles as an indicator since abundant fungus on two-year-old needles leads to reduced needle retention.

To verify that *Nothophaeocryptopus gaeumannii* is present, look at the underside of a 2-year-old needle. This requires at least a 10x hand lens; a 20x lens may be better, especially one that has a light system. With a small hand lens, it is possible to hold the needle during a sunny day in such a way that the light on the needle shines through the needle and accentuates the black pseudothecia from behind.

Quantitative assessment of growth impacts

Due to the association between Douglas-fir needle retention and stand volume growth, one method to estimate a stand's performance is to collect a representative estimate of needle retention from dominant/co-dominant trees within a stand. Using this value and the relationship exhibited in Figure 4, you can estimate the stand's cubic-volume growth loss relative to a healthy stand.

Analysis of infected stands has shown that despite the general association between Douglas-fir needle retention and stand volume growth, some infected stands may still be growing relatively well. Because diseased trees exhibit both height and diameter growth loss, an experienced manager may be able to assess recent height or diameter growth relative to what would be expected for the same type of stand in the absence of SNC. This requires a stand cruise and increment coring of trees to determine recent five-year growth rates. The SNCC has developed software (https://sncc.forestry.oregonstate.edu/stand-growth-assessment-tool)to aid such an assessment.

Silvicultural decisions

Disease-related silvicultural decisions depend on disease levels, stand age, and stand structure and composition, and are important at the time of plantation establishment or for existing stands (Table 2).

Alternative or mixed-species management

The decision to plant Douglas-fir or an alternative species is a critical choice for landowners at the time of stand establishment or regeneration. This is a decision based on disease hazard, future value and other factors. If Douglas-fir is the preferred species, all the evidence points to local seed sources as most tolerant to disease. We recommend against moving seed from drier climates to wetter climates, or from higher elevations to lower elevations.

Genetic resistance to SNC has been the focus of much early research and testing. There appears to be no “resistance” to the disease. However, there is variation in disease tolerance, as expressed in the ability to retain foliage and grow better in areas with light to moderate disease pressure.

There appear to be clear gains in using improved seed stock with known tolerance to SNC in regions with moderate to low disease impacts. We recommend against planting Douglas-fir stock, even if tolerant, where disease pressure is high. Tolerant stock may grow deceptively well for some years, but the trees could experience severe impacts under specific climate conditions and stop growing before they reach merchantable size.

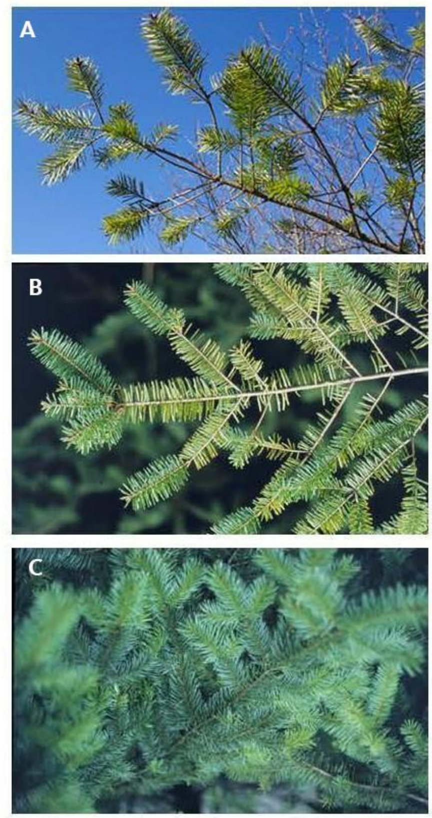

Figure 10. Examples of needle retention (NR) from top to bottom: A) NR=0.9 year of needles retained; B) NR=2.2 years; and C) NR=4.0 years.

Credit: Doug Mainwaring, Oregon State University

Table 2. Silvicultural treatments for Douglas-fir and their effects, how Swiss needle cast responds and recommendations for control

Silvicultural treatment	Effect	SNC response	Recommendation
Alternative or mixed species management	Maintains non-susceptible species	No response	When it makes economic sense and to avoid dependency on Douglas-fir
Vegetation management	Improves seedling growth	No response	May be worth doing, but not to control fungus
Thinning	Maintains longer crowns, greater needle mass per tree	No response	May be worth doing, but not to control fungus
Fungicides	Protects foliage from colonization by the fungus	Can be effective. Annual application required.	Not recommended in forest plantations due to expense, toxicity
Fertilization	Provides more nutrients for tree growth	May or may not impact the fungus	Not recommended due to expense, lack of positive results
Pruning	Removes lower branches and foliage	Removes healthiest and densest foliage from tree	Not recommended

Table 3. Alternative tree species to Douglas-fir in coastal Pacific Northwest and their pros and cons

Value of logs or wood is not considered.

Tree species	Pros	Cons
Western hemlock	Fast-growing alternative, can manage more trees/acre and volume/acre than Douglas-fir	Wounds lead to decay. (Commercial thinning not recommended.) Log values currently lower than Douglas-fir.
Sitka spruce	Fast-growing whitewood, adapted to region	Significant problem with tip weevil makes growing Sitka spruce outside of fog belt uneconomical.
Western redcedar	High-value alternative, grows well in most sites	Usually difficult to establish due to heavy browse from deer and elk. May not grow fast enough.
Red alder	Fast growing, shorter rotation	Only recommended for certain sites. Lower volume/acre than coniferous alternatives.

If disease hazard is high, an alternative species is a better option. Typical alternatives to Douglas-fir include western hemlock, Sitka spruce, western redcedar or red alder (Table 3). Each of these species has both positive and negative attributes and is not appropriate for every site. Sitka spruce, in particular, appears to be a poor choice anywhere but the most coastally exposed sites due to severe tip weevil incidence.

Mixed-species stands do not diminish Douglas-fir's chances of being infected or the degree to which it becomes infected. In heavily infected stands, other species, such as western hemlock, red alder or western redcedar, will provide economic insurance against poorly performing Douglas-fir. Distance from the coast, generally corresponding to the current gradient of SNC symptom severity, might be a simple metric for mixed species planting (see Figures 6 and 7), with no Douglas-fir in the near-coast environment. Managers could mix Douglas-fir into the planting regime as distance from the coast increases and disease levels abate.

Vegetation management

There is no evidence that vegetation management decreases disease severity or improves the growth of infected trees beyond the benefits of greater resource availability due to the diminished cover of competitor species. However, the reduced yield expected for infected Douglas-fir trees may make the economic cost of vegetation management disadvantageous.

Thinning

Analyses of thinned infected stands have found that thinning does not reduce disease severity. Nevertheless, light to moderately infected stands will respond to thinning with increased diameter growth; severely infected stands may not. The response to thinning may be delayed relative to that of healthy stands, and the subsequent growth won't match that of healthy stands. The economics of thinning are not considered in this discussion, but in infected stands, the benefits of thinning are likely to be more structural than economic.

Because SNC negatively affects growth, thinning from below generally retains the largest and healthiest Douglas-fir trees displaying the greatest tolerance. If alternative species are mixed in the stand, they can be retained as insurance for future stand viability in the event of poor Douglas-fir performance. The reduced growth rates of Douglas-fir in mixed-species stands may allow other species to grow faster and should be considered during thinning operations.

One approach for choosing between Douglas-fir and alternative species in a pre-commercial thinning has been developed by Stimson Lumber Co. foresters. The "D-minus" rule involves giving a fast-growing tree such as western hemlock a size credit against adjacent Douglas fir that may not grow as fast. Depending on disease severity at the site, a hemlock that is smaller in DBH than an adjacent Douglas-fir would be retained, and the Douglas-fir would be removed because analysis has shown that the hemlock will ultimately outgrow the Douglas-fir. The diameter differential varies depending on disease severity and tree diameter.

Fungicides

Fungicide use is common in Douglas-fir Christmas tree plantations. Chlorothalonil (Bravo) and sulfur have been assessed in forestry plantations, where they have been used as a protectant.

Bravo is effective, but any fungicide must be used every spring to maintain needle retention because new foliage is colonized by the fungus each year. Expense and toxicity, especially to aquatic animals, make general use prohibitive.

Sulfur has shown marginal effectiveness, and treatment is expensive and must be done in the spring when wet weather can make the application logistically difficult and potentially ineffective. Again, only current year foliage is protected.

If fungicides are being considered, check the Pacific Northwest Plant Disease Management Handbook (https://pnwhandbooks.org/plantdisease/host-disease/fir-douglas-pseudotsuga-menziesii-needle-cast-swiss) for currently registered fungicides.

Fertilization

Several studies have looked at N only and N-P-K+ custom blends. Results from 20-year-old stands show that on average, no increase or decrease in disease severity is associated with fertilization. One seedling study showed an increase in disease severity associated with high N, and high foliar nitrogen concentrations are already associated with SNC-infected stands across the Coast Range of Oregon. The cause-effect relationships are uncertain. Because fertilization has become expensive, it should be reserved for stands where a positive response is expected. Therefore, SNC-infected stands should be disqualified as candidates for fertilization.

Pruning

Although there have been no studies of pruning and SNC, pruning is not recommended since needle retention in the lower crown is greatest in SNC-infected trees. Furthermore, capturing the cost of pruning requires sufficient diameter growth, and SNC-infected trees will not provide it.

To retain or not to retain ...

Some pre-merchantable stands are performing so poorly it is unclear whether they will reach merchantable size in an acceptable amount of time. Based on observation and anecdotal information, stands meeting this description are growing in zones where SNC pressure has been high for years, and periodic improvement in conditions seems unlikely. The authors are unaware of poorly performing stands that “turn the corner.” This should be kept in mind when stands are being regenerated.

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