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Science

F I N D I N G S

“Science affects the way we think together.”

Lewis Thomas

THE SCOURGE OF THE YELLOW TREES: TACKLING SWISS NEEDLE CAST IN THE COAST RANGE



Some stands are heavily infected with Swiss needle cast, and can lose up to 60 percent growth per year.

“Stop it at the start, it’s late for medicine to be prepared when disease has grown strong through long delays.”

—Ovid, 43 B.C.–17 A.D.

Across the Pacific Northwest, about 2.5 million hectares of commercial timberland are occupied by young stands of Douglas-fir. The growth, yield, and overall health of these plantations are still of vital importance to the economy and environments of Washington and Oregon. Thus the steady increase of Swiss needle cast (SNC) across the area, first in plantations and more recently in natural stands, puts fear in the hearts of tree growers throughout the region. In the areas of most severe impact, tree growth can be reduced by as much as 50 percent.

The fungus that causes the disease—*Phaeocryptopus gaeumannii*—is native to the Pacific Northwest, attacking only Douglas-fir. So why blame the Swiss? The disease was first observed in Europe after Douglas-fir plantations were established in Switzerland, and was described in the scientific literature in 1925. During the first survey for SNC in the Western United States and Canada in 1938, it was found only at low, nondamaging levels in many locations.

What has brought it to damaging levels in an area where it presumably resided without severe effects, for many centuries?

“The basic rule of epidemiology is that if you make conditions sufficiently favorable for the host, you’ll probably end up with an epidemic on your hands,” says Randy Johnson, research geneticist

I N S U M M A R Y

Swiss needle cast (SNC), the yellowing disease of Douglas-fir evident in many parts of Pacific Northwest Coast Range forests, is caused by a fungus endemic to the region. The disease apparently caused no significant widespread injury until the 1970s, when Christmas tree growers began to report needle loss. Since the late 1980s, SNC has become increasingly severe in plantations of Douglas-fir in coastal Oregon and Washington, and more recently, in older naturally established stands.

In severely affected stands, symptoms of SNC include yellowing and premature loss of older foliage. In response to the outbreak, forestry organizations came together in 1996 to fund research that would (1) determine why this supposedly benign native disease became so virulent, (2) determine the impact the disease is having on forest stands, and (3) develop possible means to mitigate the impacts of the disease. The research is now coordinated through the Swiss Needle Cast Cooperative.

The Pacific Northwest Research Station has led the effort in examining the genetic variation in SNC tolerance/resistance and has assisted organizations in using these results in applied breeding programs. The Station also collaborates in research documenting the impact of the disease on tree growth and wood properties.

with the Pacific Northwest (PNW) Research Station in Corvallis, Oregon. “But to date our research suggests many factors have combined responsibility for the epidemic, chief among which are weather fluctuations, and more extensive plantings of Douglas-fir close to the coast.” Johnson also works with the Swiss Needle Cast Cooperative (SNCC) to determine causes, effects, and trends of the disease.

To the list of causative factors, Alan Kanaskie, forest pathologist with the Oregon Department of Forestry, would add the high density of Douglas-fir plantation plantings, the use of less tolerant offsite seed in such reforestation efforts as the Tillamook Burn, and possible indirect effects of soil-plant nutrient balances.

“No single one of these factors has caused the epidemic alone, so resolving one of them is not going to shut down Swiss needle cast,” Kanaskie says. “The approach of the SNCC is to continue to conduct research and disseminate information as rapidly as possible to forest landowners and managers. This disease is such a big factor in our management plans that we have to keep at it.”

Purpose of PNW Science Findings

To provide scientific information to people who make and influence decisions about managing land.


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KEY FINDINGS



- Families of Douglas-fir that grow well on healthy sites tend to be the ones that grow well in SNC-affected areas. These families also have better-than-average foliage color and density. Thus, the best way to breed for increased tolerance is to select for the trait of increased growth in the presence of the disease.
- The better growing families adapt to the disease by tolerance, not resistance. These families tend to shed infected needles more quickly than others, possibly as a defense mechanism.
- The disease continues to intensify in coastal Oregon, slowing in the north, but increasing in the south. In severely affected areas, growth rates are more than halved.
- The SNC affects water relations within trees, decreasing circulation of water and nutrients in sapwood. In addition, the reduction of earlywood is greater than the reduction of latewood. Although this change in proportion appears to increase stiffness of wood, it comes at the expense of growth rate.



Credit:xxx

Healthy Douglas-fir trees (left) retain up to 4–5 years of needles on a branch; Douglas-fir with severe Swiss needle cast (right) retains only a single year of needles.

THE FUNGUS LET LOOSE

So how does this fungus—native, harmless for centuries as far as we know—actually work? First, a look at its symptoms.

“Symptoms of SNC include premature loss of foliage, abundant fungal fruiting bodies on needles, yellowing of foliage, narrow sapwood, and reduction in diameter and height growth,” Johnson says. “Although a range of symptom severity can be observed, the magnitude of growth loss associated with various foliar symptoms has until recently been largely uncertain.” Growth loss, however, is clearly an outcome.

In the Coast Range, healthy Douglas-fir typically retain at least four annual batches, or cohorts, of needles, and sometimes more. In the most severe cases of SNC, only one annual cohort may be present. The remainder fall off as the incidence of fruiting bodies on the undersides of needles increases.

“The disease impedes gas exchange in the needles by blocking the stomata, or openings, with its fruiting bodies,” explains Dan Manter, a research plant physiologist with the PNW Research Station in Corvallis. “Physiological studies have documented that a relatively small amount of the SNC

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fungus may have a major impact on the carbon assimilation and growth of infected trees.” The fungus grows in the intercellular spaces of the needle, which is apparently where it gets its nutrients, and eventually forms fruiting bodies. The fruiting bodies emerge through the stomates and release spores in the spring and summer. The amount of fungus and number of fruiting bodies increase with age of the needle until the needle is dropped.

“This reduction in growth results in a second phase of disease where the associated declines in wood growth further exacerbate the impacts on needle function by limiting water supply to all needles, infected or

not, growing on the diseased tree,” Manter explains. This can add up to a decline in growth of 23 percent, or a 30- to-60 pound reduction in the annual uptake of carbon dioxide by infected trees.

The implications for a severely infected tree are obvious. No needles, no photosynthesis, few needles, reduced photosynthesis, meaning a reduction in the energy needed to keep the tree growing.

“Damage from SNC has been recorded for stands from the coast to the Cascade mountains in Oregon and Washington,” Kanaskie says. “In general, stands closer to the coast have more damage than stands farther inland,

and observed damage has been most severe within about 18 miles of the coast, although not all stands within that distance are severely damaged.”

On the north Oregon coast, particularly in the Tillamook area, where infestation is most severe, other geographic and climatic factors come into play. High maximum temperatures in November, low maximum temperatures in June, high precipitation in June, steep slopes, low and medium slope position, and southerly or westerly aspects all play a role, Kanaskie says. In British Columbia, high rainfall in May through July was positively correlated with high levels of SNC.

TREE HEALTH, WOOD ECONOMICS

One of the goals of the SNCC is to establish the level of impact the disease has on tree growth, in order to understand the extent of economic impact in a Douglas-fir dominated region of the country.

With the disease now affecting plantations and older naturally established stands of Douglas-fir, the urgency of assessing damage levels and establishing mitigation approaches through management has increased. Various studies have sought to assess effects on volume growth. On the north Oregon coast, a 1996 study estimated that volume growth loss was 23 percent in 10- to 30-year old plantations, with some older plantations suffering more than 60 percent loss.

In an industry dominated by production of structural lumber, effects on wood properties are just as important as growth loss. “Observations suggest that SNC increases

the proportion of latewood—which grows in summer—relative to earlywood, which grows in spring,” Johnson explains. “This shift in early/latewood proportions would be a logical outcome given that previous experimental work has demonstrated that the earlywood production is mostly dependent on old foliage, and the latewood mostly on the new foliage.” Simply put, SNC causes premature loss of older foliage, thereby more heavily reducing the growth of earlywood.

Johnson notes that the increase in latewood proportion appears to increase the stiffness of the wood, but comes at the expense of growth rate.

The Oregon Department of Forestry established a trial near Beaver, Oregon, in the Coast Range, in 1996, to examine the effectiveness of the fungicide chlorothalonil (trade named Bravo) for reducing damage from SNC in a severely infected stand. The stand

is located about 7 miles from the coast, in the “fog belt” that is typically highly affected by the disease.

“The 5 years of spraying did not achieve complete control of the disease, for significant amounts of the fungus were present in the needles of the sprayed trees during the fifth year of spraying,” Kanaskie says. “Nonetheless, needle retention increased for the last 3 years of spraying: the unsprayed trees carried about 1.9 years of foliage, whereas the treated trees had 2.8 years of foliage.” The difference in foliage quantity was most pronounced in spring before foliage emerged. Therefore, Johnson explains, during spring and early summer when the new foliage is maturing, the trees in the sprayed plots were at a greater growth advantage because they had considerably more foliage involved in photosynthesis than the unsprayed trees. This advantage was much less once the new foliage had matured.

CARBON AND WATER EFFECTS OF SNC

A companion study examined the percentage of wood, water, and gas in earlywood and latewood, according to Johnson, in order to check wood qualities against levels of infection by SNC.

Compared with unsprayed trees, sprayed trees showed increased radial growth rates, lower percentages of latewood, lower ring density, and higher moisture content. “It appears that the sapwood of trees with severe SNC have a diminished capacity to transport water internally, relative to healthy trees,” Johnson says.

Water transport is affected by level of SNC infection, according to this study. “We hypothesize that the decreased moisture content of diseased trees may be caused by their poor carbon economy, resulting in insufficient energy from photosynthesis to reverse the embolisms, or bubbles, that interfere with water transport in the sapwood,” explains Barb Gartner, an OSU professor collaborating in this research.

Although the exact mechanism for reversing embolisms is not known, the researchers believe the reduction in moisture content

could result from the tree’s poor vigor, preventing a buildup of energy sufficient to counteract the many embolisms that occur on a daily basis during the growing season.

One final finding of the study in the Beaver area was that SNC apparently reduced earlywood cell wall thickness. “The weakest portion of the wood is the earlywood, and the reduced cell wall thickness found in this study suggests that the ‘weakest link’ may have been further weakened,” Johnson notes. The implications are not clear since

WRITER’S PROFILE

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the increased latewood may offset this reduction, although it could affect the strength of veneers used for plywood and other panel products.

Thus the disease has considerable economic ramifications in the Pacific Northwest. But let's put it under a powerful microscope and see what the DNA says.

With conditions right to allow increasing numbers of Douglas-fir trees to fall prey to the disease, it was only a matter of time before the inevitable laws of epidemiology kicked in.

But some trees still manage to thrive. How?

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LAND MANAGEMENT IMPLICATIONS

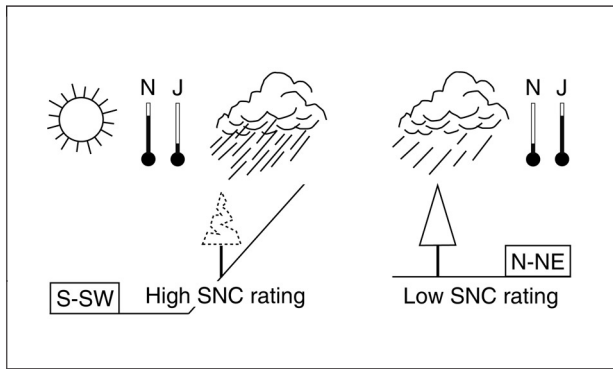
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- Reforestation efforts in coastal areas have switched from the use of predominantly Douglas-fir to mixed conifers, with only a small proportion of Douglas-fir. In the most heavily affected areas, replanting should contain no Douglas-fir, as this is SNC's sole host.

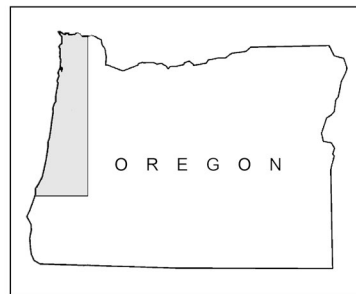
- Families with healthy foliage can be selected as early as age 2, allowing tree breeding programs to progress faster. Seed sources local to the coastal belt generally provide the best levels of tolerance.

- The SNCC has quickly facilitated exchange of information for tree breeders, growers, and managers; long-term plots, trials, and monitoring will continue via the cooperative.

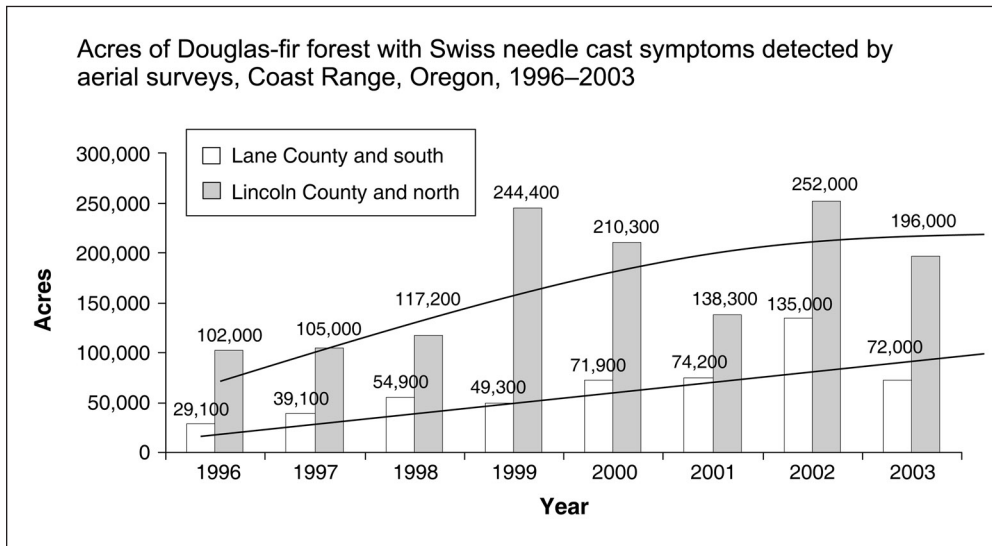
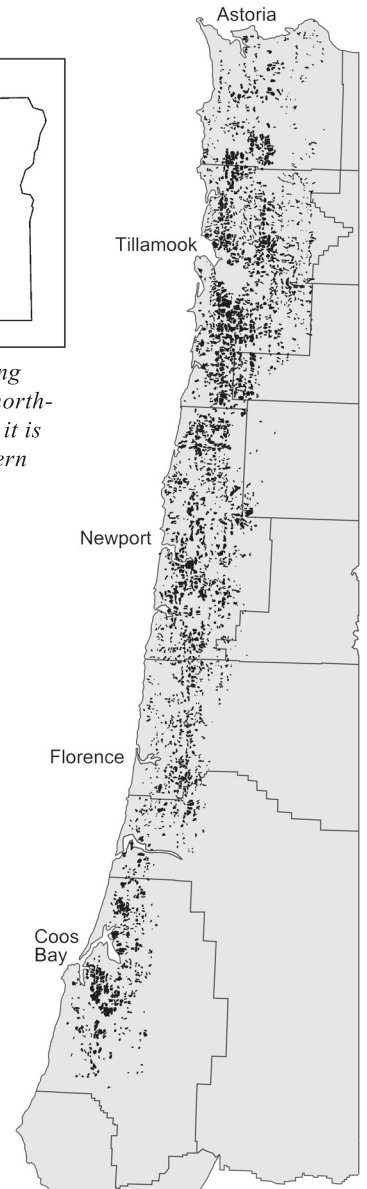
- Alternative management strategies under trial include vegetation management, nutrient amendments, thinning, and fungicide and sulfur applications.



Ideal conditions for spread of SNC include higher than normal winter temperatures, lower than normal summer temperatures, heavier rainfall, and a south-south-westerly aspect. The opposite conditions tend not to encourage spread of the fungus.



While SNC infection is holding steady or decreasing in the northern part of the Coast Range, it is spreading through the southern areas.



Swiss needle cast has shown an increase in Coast Range area affected, particularly since the mid-1990s. Although infection rates are stabilizing in the north, they continue to spread in the south.

TOLERANCE, RESISTANCE, AND FAMILY TRAITS

Johnson's key role in the SNCC has been to provide the genetic research sought by tree growers. "Understandably, they were hoping for a silver bullet, that we would do some breeding trials and discover that the secret was a resistant strain. Not so," Johnson explains.

The "secret," instead, is tolerance.

"We have found that families that grow well on healthy sites tend to be the ones that grow well in the presence of the disease," Johnson says. "This is not surprising; vigor is often correlated with disease and pest tolerance or resistance." These families also tend to have denser, greener foliage.

In two separate studies, no family differences were found in the amount of fungus within a needle, implying that the better growing families, and families with better crown health, adapt to the disease by tolerance (continued growth in the presence of the disease), not

resistance (actually hindering the growth of the fungus).

This helps explain why the disease showed up most damagingly in the Tillamook Burn area. Replanting of hundreds of thousands of acres there last century was done with seeds from numerous sources, many of which were likely outside the coastal Douglas-fir region. Trees from the Cascade Range, for example, had had little reason to develop the tolerance to stave off the spread of the fungus, so were ill-prepared genetically to deal with the presence of the fungus in an area highly conducive to its thriving.

"There was a tendency in our study for the more tolerant families to shed heavily infected needles more quickly than the less tolerant families," he explains. "This could be a possible defense mechanism since heavily infected needles—those with over half their stomates clogged—are photosynthetic sinks,

not sources." So it's not the amount of fungus in the needles so much as it is how the tree deals with it.

Seed orchards comprised of the best parents—the top 10 percent—could increase growth rates in the presence of the disease by 30 percent, according to ongoing progeny tests. These numbers would offset the 28-percent growth reduction expected in stands retaining only 2 years of needle cohorts. Growth rate in the presence of the disease, then, is the trait for which breeding programs will select, according to Johnson.

The same studies have been used to determine whether families with healthy foliage can be selected as early as age 2, or whether breeders need to wait until later in stand and tree development. Data suggest that foliage health characteristics can be selected at very young ages, thus speeding up the breeding program.

MANAGEMENT ADJUSTMENTS AND OPTIONS

As for what's being done about it, this is a classic case of seeing adaptive management in action, without bothering to call it that," Johnson says. "Most of my clients would admit that the denser plantings of Douglas-fir in the Spruce-Hemlock zone were at least partially to blame for the epidemic. So they're adapting. They're looking to breeding programs to develop sources of SNC-tolerant seed. They're not replanting Douglas-fir in the most heavily infected areas. They're mixing in immune species such as hemlock, redcedar, red alder, and spruce in the moderately affected areas."

Not all alternative species are easy to establish—spruce and redcedar are difficult to grow with commercial success. Clearcutting does not solve the problem, especially in severely affected areas, where the spore load from surrounding stands will simply re-infect newly-planted Douglas-fir.

Regeneration of mixed-species stands reduces the numbers of hosts but appears to have little effect on damage to individual Douglas-fir trees, Kanaskie points out. Low-severity stands should be regenerated only from local or genetically tolerant seed sources; high-severity stands should carry no more than 20 percent Douglas-fir.

Vegetation management—reduction of competing brush and undergrowth—cannot offset the effects of SNC on tree growth, but may provide a smallhead start to new seedlings interplanted in affected areas. The SNCC is

experimenting with effects of pre-commercial thinning, and the Oregon Department of Forestry is collaborating with Oregon State University's Doug Maguire to explore the interaction between SNC and commercial thinning. Precommercial thinning of severely damaged stands does not appear to pay its way, unless there is a large component of species other than Douglas-fir present, Kanaskie says.

Other approaches that are being tried include fertilization with various plant nutrients, foliar applications of sulfur, artificial pruning, and uneven-age silviculture. The jury is still

out on all these approaches, and Johnson is not convinced that any of them will provide singularly useful results.

"The point to remember here is that industry and the state are making adjustments in their management, continuing to learn, continuing long-term studies and the monitoring of the disease's progress and spread," Johnson says. "They realize some of the methods being investigated are not economically feasible, and also that SNC may be cyclical, and we've just never seen it, or helped it along, before. They're learning all the time, and adapting to a challenging situation wherever they can."

FOR FURTHER READING

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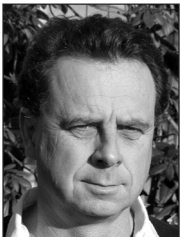
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