Distribution, Severity, and Impact of Swiss Needle Cast in Douglas-Fir Christmas Trees in Western Washington and Oregon

E. MICHAELS and G. A CHASTAGNER, Western Washington Research and Extension Center, Washington State University, Puyallup 98371

ABSTRACT

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In 1981, 53 plantations of Douglas-fir (*Pseudotsuga menziesii*) Christmas trees in western Washington and Oregon were surveyed to determine the incidence and severity of Swiss needle cast caused by *Phaeocryptopus gaeumannii*. Presence of pseudothecia, loss of needles, and associated disease symptoms were tabulated for 50 randomly selected trees in each plantation. Diseased trees were found in 48 plantations, and 84% of all trees examined were diseased. Of these, 16% retained less than two full-year complements of needles and were reduced in commercial grade, indicating a potential grade loss for 600,000 trees within the region. Of the infected trees surveyed, 11% retained only current-year needles and were unmerchantable in 1981. Monetary loss within the region attributable to needle loss is estimated at $3.4 million for 1981.

Swiss needle cast of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), caused by *Phaeocryptopus gaeumannii* (Rohde) Petr., was discovered in 1925 in a plantation of 20-yr-old trees in Switzerland (8). The most obvious symptom of this disease is premature shedding of infected 1-yr-old and older needles (2). When attack is severe, only the needles produced during the current year remain on the tree. Needles become chlorotic in spring and summer a year or more after infection and are cast during summer. Small black pseudothecia, associated with stomata, are most visible on 1-yr-old and older needles during spring before bud break.

Swiss needle cast has been reported widely throughout Europe (2,4,7). During the early history of this disease, defoliation was so severe, especially in young plantations, that Douglas-fir was not planted or was planted only in mixed stands in some locations (2,15). Recently, the disease has been damaging in New Zealand and Australia (11–13).

In the United States, Swiss needle cast was first reported in the northeast (2,10). Christmas tree growers in the Lake States have reported damage throughout their production areas since 1970 (1,6,14,16). In the natural range of Douglas-fir, the disease was considered noninjurious and was of little concern (10). In the mid-1970s, however, growers of Douglas-fir Christmas trees in the Pacific Northwest began reporting needle loss that could be attributed to *P. gaeumannii*. The extent of the problem was unknown (9).

The Christmas tree industry in western Washington and Oregon harvests approximately 5.5 million trees annually, and production is increasing (5). Approximately 74% of these trees are Douglas-fir, and 65% are sheared trees grown in intensively managed plantations. Investigations in other regions have shown the extent of damage in single plantations, but no surveys have assessed damage over a large geographic area. Therefore, in 1981 a survey was conducted in western Washington and Oregon to determine disease distribution and severity of needle loss. To estimate the economic impact of Swiss needle cast, needle loss was related to commercial tree grade.

MATERIALS AND METHODS

The major Christmas tree production areas in western Washington and Oregon were mapped using membership lists provided by the Northwest and Puget Sound Christmas Tree associations. These areas extended from the southern border of Oregon to the northern border of Washington. Within each region, five or six plantations with no known history of Swiss needle cast were selected. A total of 53 plantations were surveyed, all containing harvestable-sized Douglas-fir and ranging in size from 2 to 48.5 ha. The sample included all management schemes: intensively managed sheared Douglas-fir plantations, lightly sheared natural stands (typical of production on the Olympic Peninsula near Shelton, WA), plantations to be-clear cut for wholesale marketing, and plantations in which individual trees were selected, as in "U-cut" management.

The plantations were examined during March and April when infected needles with pseudothecia were readily visible. Data collected at each plantation included site, slope, aspect, surrounding vegetation, seed source of trees, management practices (such as fertilization, pesticide use, shearing time and technique), and insect and disease problems other than Swiss needle cast.

At each plantation, we estimated the dimensions of a block of uniformly aged trees, then used a previously constructed grid system based on block size and shape to sample the block. Beginning at a randomly chosen corner, we selected 50 trees along diagonal lines paced across the block by stopping at predetermined distances and choosing the closest tree on the right. The closest branch approximately 1 m above the ground was selected from each tree, and retention of needles, designated by year of origin (1980 = current year, 1979 = 1-yr-old, 1978 = 2-yr-old, 1977 = 3-yr-old), was estimated and recorded on a scale of 0–10, with 0 denoting no needles retained and 10 denoting 91–100% of the needles produced in a given year retained. The presence of pseudothecia on needles was recorded for each year. The general appearance of the tree was also noted.

Christmas trees are graded U.S. Premium, U.S. No. 1, U.S. No. 2, and Cull, according to standards of the U.S. Department of Agriculture (17). The economic impact of Swiss needle cast was assessed by cutting 23 infected harvestable-sized trees in four plantations in southwestern Washington before bud break in April 1981. These trees were chosen to represent various levels of needle retention. After harvest, all trees were baled with Vexar netting and placed in cold storage (3 C). Trees were removed from storage in late May, placed on wooden stands, unbaled, randomly arranged, and numbered. For each tree, the retention of needles on internodes of 1980, 1979, and 1978 was rated on the 0–10 scale. At the same time, 10 persons with experience in grading trees for the Christmas tree industry rated each tree. No certified manner for scoring trees is set by the USDA, so a score sheet used by the Northwest Christmas Tree Association for Christmas tree contests was employed (Table 1). The various tree qualities described by the U.S. standards

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(17) and used in the grading process are awarded points up to 100, with U.S. Premium = 90–100 points, U.S. No. 1 = 60–89, U.S. No. 2 = 30–59, and Cull = 0–29. The judges were instructed to grade each quality on the score sheet and indicate the specific tree defects with appropriate letter codes.

Tree grades are based on many criteria (Table 1), only three of which are affected by Swiss needle cast. This disease may influence foliar "density" and cause the major defect "abnormal loss of needles" and the minor defect "barren lower whorl." Thus, only these three criteria were considered in estimating the effect of the disease on tree grade. The categories influenced by Swiss needle cast contribute a maximum of 50 points to the total score. Discoloration of needles occurs, but chlorotic needles have been cast by the time of harvest, so the "color" category was not included in disease-induced grading points.

To determine the influence of disease-induced needle loss on commercial tree grade, disease-influenced grading points were correlated with total needle retention values and with needle retention by year of origin, using standard and stepwise linear regression analyses, respectively. Total needle retention values were obtained by adding the retention values for needles produced during the last 3 yr. The stepwise linear regression was used to determine the relative importance of a specific year's needles to tree grade. The standard linear regression was used to determine threshold values for total needle retention values associated with reductions in tree grades. These data and the total needle retention values for diseased trees in the survey were used to estimate losses in grade and industrywide losses in dollar value.

RESULTS

Of the 2,650 trees sampled, 2,218 (84%) bore needles infected by *P. gaeumannii*. Diseased trees were located within 48 of the 53 plantations surveyed, with the disease-free plantations scattered throughout the areas surveyed (Fig. 1).

Within plantations containing diseased trees, the incidence of disease was usually high: 82–100% of sampled trees in 38 plantations and 62–81% in six. Disease incidence was lower in the four lightly sheared natural stands surveyed: 42–61% of sampled trees in two and 2–20% in two.

Most infected trees retained fewer needles than healthy trees and for a shorter time. Among healthy trees, 65.5% retained some needles for 4 yr and 34.5% retained needles for 3 yr. Only 23% of infected trees retained some needles for 4 yr, 52% retained some for 3 yr, 14% retained only portions of two age classes of needles, and 11% retained only current-year needles.

Needle retention for a given year was also reduced by infection (Fig. 2). Among infected trees, 45% had lost at least 50% of their 2-yr-old (1978) needles and 35% had lost at least 50% of their 1-yr-old (1979) needles. Among healthy trees, only 12% had lost at least 50% of their 2-yr-old needles and 90% had lost less than 10% of their 1-yr-old needles. Swiss needle cast had no apparent effect on needle retention of current-year (1980) needles.

The pattern of infection, based on the presence of pseudothecia, varied from tree to tree. Approximately 50% of the sampled trees had pseudothecia on all ages of needles. On the remaining infected trees, pseudothecia occurred on one or more age classes of needles without a consistent relationship to needle age.

Table 1. Score sheet, based on USDA Agricultural Marketing Service standards for grades of Christmas trees, used to grade individual trees

Category	Grade and points[a]					
Color	Good	(10)	Fair	(5)	Poor	(0)
Taper irregularities	None	(10)	Minor	(5)	Major	(0)
Sides (number good)	Four	(30)	Three	(15)	Two or one	(0)
Density	Heavy	(20)	Medium	(10)	Light	(0)
Major defects[b]	None	(15)	One	(10)	Two or more	(0)
Minor defects[c]	None	(15)	One	(10)	Two	(5)
					Three or more	(0)

[a] Maximum points = 100.
[b] Multiple leaders, multiple main stems, gooseneck, abnormal loss of needles, abnormal curling of needles.
[c] Gaps, unduly long branches, uneven density, broken branches, barren lower whorl.

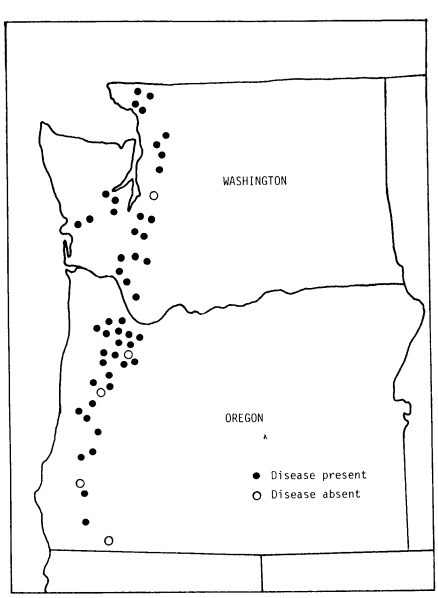

Fig. 1. Distribution of Swiss needle cast in Douglas-fir Christmas tree plantations in western Washington and Oregon; diagnosis based on presence of pseudothecia. Each dot represents one plantation surveyed during March and April 1981.

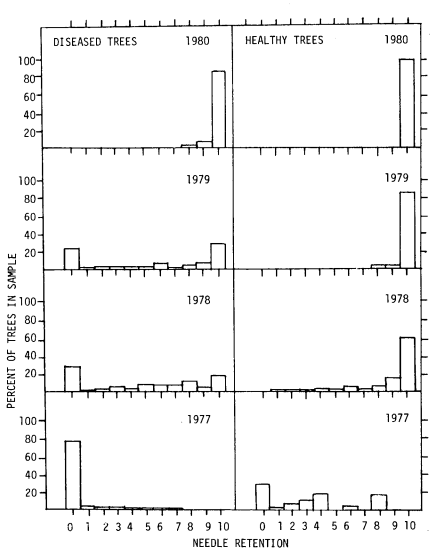

Fig. 2. Needle retention by year of needle origin on Swiss needle cast-infected and healthy Douglas-fir Christmas trees. Needle retention number is scaled in 10% increments: 0 = no needles retained, 10 = 91–100% of needles retained. Trees (2,218 diseased, 432 healthy) were sampled during March and April 1981.

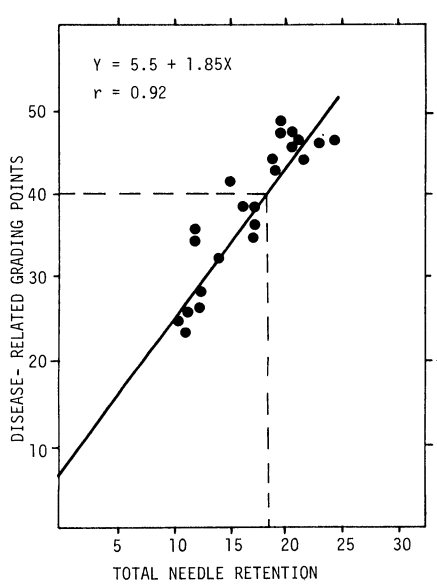

Fig. 3. Relationship between total needle retention and total disease-related grading points. Total needle retention was obtained by adding retention values (0–10) for the current year and for 1- and 2-yr-old needles. Disease-related grading points were obtained by combining point values for tree density and the defects abnormal loss of needles and barren lower whorl (maximum 50 points). Each dot represents one of the 23 graded trees. Dashed line relates needle retention to minimum point score required for U.S. Premium grade.

Table 2. Correlation coefficients between needle retention and disease-related Christmas tree grading criteria[a]

Needle retention by age of needles[b]	Criterion			
	Density	Barren lower whorl	Abnormal needle loss	Total loss due to Swiss needle cast
1 yr old	0.866	0.696	0.859	0.897
1 yr old + 2 yr old	0.886	0.758	0.870	0.921
1 yr old + 2 yr old + current year	0.887	0.758	0.878	0.921

[a] Twenty-three trees were graded by 10 industry representatives in May 1981. Disease-induced grade defects were identified according to USDA standards.

[b] Needle retention based on a scale of 0–10 for each age class of needles, with a maximum of 30 points for total retention: 0 = no needles retained, 10 = 91–100% of needles produced in a given year retained. No trees retained needles longer than 3 yr. Correlations were determined by stepwise linear regression. All r values are significant ($P = 0.01$).

The grading scores of the 23 preselected trees were reduced 2–26 points (50 points possible), with an average loss of 12.5 points for disease-related defects. There was a significant correlation between density, abnormal loss of needles, barren lower whorl, or the combined total of these criteria with total needle retention for the trees examined (Table 2).

The equation for the regression of disease-related grading score on total needle retention (Fig. 3) showed that the boundary between a U.S. Premium and a U.S. No. 1 tree, or the loss of 10 disease-related points from an otherwise perfect tree, corresponds with a needle retention score of approximately 19 of a possible 30. Total needle retention scores of 19 or below were recorded for 433 trees, 16% of the 2,650 sampled. This figure indicates that approximately 600,000 of the 3.6 million sheared Douglas-fir trees harvested within the surveyed area were reduced in grade because of needle loss in 1981.

DISCUSSION

Swiss needle cast is common in Christmas tree plantations in western Washington and Oregon. Incidence was relatively high in the majority of plantations sampled, but damage measured by needle loss varied greatly within and among plantations.

The production trend toward highly sheared trees grown in closely planted (av. 1.6 × 1.6 m spacing) rows results in trees with dense foliage and plantations with little space between trees as they mature. It has been suggested that dense foliage provides greater opportunity for infection (9). These factors may account for generally higher disease incidence in intensively managed plantations than in wild stands on the Olympic Peninsula, where trees are only lightly shaped or, if sheared, have fewer lateral branches and greater space between branch whorls.

Infection by *P. gaeumannii* is favored by high humidity (6,14). Four of the six plantations judged to be severely damaged, based on low overall levels of needle retention, were located on sites in low areas with apparently poor air drainage and high humidity. These plantations were surrounded by stands of mature Douglas-fir that were also infected. Trees in three of these plantations were also infected by *Rhabdocline pseudotsugae* Syd. In contrast, four of the five plantations free from disease were located in open areas, presumably with greater air movement.

No other cultural practices or insect or disease problems could be related to Swiss needle cast levels.

The importance of retention of 1-yr-old needles was demonstrated by the relationship between this parameter and disease-induced grading points (Fig. 3). The value of these needles may be in minimizing the visibility of the tree's main stem, which influences tree density category. Only nine of the trees evaluated for commercial grade bore 2-yr-old needles, and no tree had a retention score greater than 4 for 2-yr-old needles. If this experiment were repeated with trees bearing more 2-yr-old needles, the statistical importance of the 1-yr-old needles might be lessened somewhat. Retention of current-year needles was high for all graded trees, and little difference existed between healthy and diseased trees in the retention of these needles.

Most trees have defects not associated with Swiss needle cast that result in grade reductions. Wholesale buyers are often offered trees in a combined U.S. Premium/U.S. No. 1 category. Using data from the 23 graded trees, an average of 32.5 points was deducted from 100 because of defects not related to disease. The average healthy tree was in the lower range of the U.S. No. 1 grade (60–89 total points). The loss of an additional 12.5 points because of Swiss needle cast placed the average tree in the U.S. No. 2 grade (30–59 points). Trees of No. 2 quality sell for approximately 25% ($2.00) less than trees of No. 1 quality.

A discrepancy exists for trees with very low levels of needle retention between the grading scale used in this experiment and general industry trends. According to the point system used, retention of only one full-year complement of needles would not reduce a tree's score below the U.S. No. 2 grade. Growers indicate, however, that trees with such low needle retention are unmarketable. Of the trees in the survey, 11% retained only current-year needles. Based on this figure, approximately 400,000 of the harvestable-sized Douglas-fir in the two states would have been unmerchantable in 1981, representing a potential $3 million loss to growers. This amount plus the reduction in grade of the remaining 200,000 trees brings the total loss figure to approximately $3.4 million. These figures represent preharvest reductions in grade due to needle loss. Recent investigations indicate that the postharvest quality of Christmas trees is also reduced by Swiss needle cast (3).

The observations made in this survey suggest that Swiss needle cast has an important economic impact on growers of Douglas-fir Christmas trees throughout western Washington and Oregon. Retention of two annual age classes of needles on a tree is necessary to ensure preharvest quality, and absence of infected needles is necessary to ensure postharvest quality. Effective chemical disease control measures should be incorporated into a grower's management plans to make certain that a minimum of two years of needles are retained at harvest.

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