Effects of Swiss Needle Cast on Three Douglas-Fir Seed Sources on a Low-Elevation Site in the Northern Oregon Coast Range: Results after Five Growing Seasons

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ABSTRACT: *Douglas-fir* (Pseudotsuga menziesii var. menziesii) *seedlings grown from three seed sources were evaluated for 5 yr on a high-disease-hazard site for their relative tolerance to Swiss needle cast. The seed sources were: (1) seed collected from trees showing an apparent degree of tolerance to Swiss needle cast in natural stands in the coastal fog belt, (2) open-pollinated seed orchard seed collected from random single-pair crosses of parent trees in natural stands outside of the coastal fog belt, but west of the Oregon Coast Range summit, whose progeny demonstrated an apparent degree of disease tolerance in coastal Douglas-fir progeny test sites, and (3) standard reforestation seed purchased from a commercial vendor. There were no significant differences among seed sources in basal diameter and total height for all five growing seasons. Needle retention varied among seed sources over the 5 yr period, but current-year needle retention did not vary significantly after the fifth growing season, and retention of 1- and 2-yr-old needles was relatively low for all seed sources. The intense disease pressure on this site may have overwhelmed expression of disease tolerance among seed sources. We do not recommend planting Douglas-fir on such high-hazard sites. West J. Appl. For. 16(1):31–34.*

Key Words: *Phaeocryptopus gaeumannii*, *Pseudotsuga menziesii* var. *menziesii*, *Douglas-fir*, *Oregon.*

Over the past 10 yr or so, many Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) stands in the coastal fog belt of the northern Oregon Coast Range have been experiencing symptoms of severe decline characterized by reduced growth, yellowing foliage, premature needle loss, and in a few cases, mortality. Swiss needle cast, caused by the native fungus, *Phaeocryptopus gaeumannii*, appears to be the major factor responsible for this condition, as evidenced by pseudothecia (fruiting bodies) of the fungus emerging from and occluding the stomatal openings on the underside of Douglas-fir needles. Although the condition appears to be most severe in young plantations, older natural stands are being increasingly affected as well. Aerial surveys conducted by the Oregon Department of Forestry and the USDA Forest Service have shown a dramatic rate of increase in the area showing symptoms of Swiss needle cast in the Oregon Coast Range over the past few years (Kanaskie et al. 1999). Infection and damage are particularly severe in the vicinity of Tillamook, OR. On some sites, the severity of impacts from this disease seems to vary among individual trees in affected stands. This suggests the possibility of genetic differences within Douglas-fir populations as to their relative tolerance to Swiss needle cast (Johnson and Temel 1999).

Methods

To assess the potential for tolerance of Douglas-fir to Swiss needle cast, 50 seedlings grown from each of three Douglas-fir seed sources were planted in a common area. The site is located approximately 3 mi northeast of Tillamook, OR, on land managed by the Tillamook District of the Oregon Department of Forestry, and is within 8 mi of the Pacific Ocean. The elevation is 440 ft, and the aspect is south. The area is in the Sitka spruce (*Picea sitchensis*) zone described by Franklin and Dyrness (1973). Douglas-fir trees in the surrounding area are heavily impacted by Swiss needle cast.

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Three Douglas-fir seed sources were randomly assigned to treatment plots. The seed sources were: (1) seed collected from trees showing an apparent degree of tolerance to Swiss needle cast in natural stands in the coastal fog belt (field collection), (2) open-pollinated seed orchard seed collected from random single-pair crosses of parent trees in natural stands outside of the coastal fog belt, but west of the Oregon Coast Range summit, whose progeny demonstrated an apparent degree of disease tolerance in coastal Douglas-fir progeny test sites managed by the Tillamook District of the Oregon Department of Forestry (seed orchard collection), and (3) standard reforestation seed purchased from a commercial vendor (standard collection), which served as the control.

Two-year-old seedlings (1-1 planting stock for the seed orchard and standard seed sources, and plug-1 planting stock for the field collection seed source) were planted at a spacing of 10 × 10 ft during the winter of 1994. Each seed source plot contained 50 seedlings planted in five rows of 10 seedlings each. Plots were established in an existing 3-yr-old mixed western hemlock (*Tsuga heterophylla*) and Douglas-fir plantation. A buffer of Douglas-fir seedlings was planted around the perimeter of the study area to help assure uniform site conditions. Plastic-mesh tubes were placed over the seedlings at the time of planting for protection from browsing. Tubes were removed at the time of the first-year data collection because browsing did not occur and to reduce the potential for growth impacts caused by the tubes. Competing vegetation was controlled initially with herbicides for site preparation of the original unit and then periodically by manual cutting.

The following information was collected from each tree: (1) basal diameter (nearest 0.1 in.); (2) total height (nearest 0.1 ft); (3) foliage color ("normal" or slightly yellow to yellow); (4) presence of Swiss needle cast fruiting bodies (pseudothecia), based on a sample of 10 needles—5 from each side of the tree collected from the middle to the upper one-third of the crown; (5) and degree of needle retention for each of the three most recent growing seasons. Needle retention was estimated as one of the following classes: 0 = 0 to 10%, 1 = 11 to 20%, ..., and 9 = 91 to 100% of the needles retained (estimated on two branches on opposite sides of the tree at the middle to the upper one-third of the crown and then averaged). Beginning with the 1997 growing season, foliage color was also rated according the four crown-color classes described by Kanaskie and Maguire (1998): 1 = normal green, 2 = slightly yellow, 3 = moderately yellow, and 4 = extremely yellow or yellow-brown. Data were collected over a 5 yr period from late March through early May following each growing season (1994 through 1998).

A one-way analysis of variance was used to detect differences among seed source means for basal diameter, total height, and needle retention. Differences among individual means were determined with the least significant difference test. In the analysis of the needle retention data, class percentage mid-points were transformed using the acrsin √ percentage transformation before the analysis of variance was performed (Steel and Torrie 1980). Needle retention results are presented using the original scale of measurement. Chi-square tests were used to determine if foliage color and presence of Swiss needle cast fruiting bodies were independent of seed source. Analysis of variance, least significant difference, and chi-square tests were performed using the Statistix® statistical analysis software package (Analytical Software 1998). All tests for statistical significance were conducted at $P = 0.05$.

Results and Discussion

The results after five growing seasons are presented in Tables 1 through 5. Seedling survival was excellent. Only two trees died by the time measurements were taken after the fifth growing season. One of the trees that died was in the plot planted with the seed orchard source. The other was in the plot planted with the field collection source and died as a result of being cut accidentally during manual vegetation control in the summer of 1998.

There were no significant ($P = 0.05$) differences in basal diameter and total height among seed sources for all five growing seasons (Tables 1 and 2).

No significant ($P = 0.05$) differences in foliage color were detected among seed sources for the 1994 growing

Table 1. Basal diameter (in.) of Douglas-fir grown from three seed sources over five growing seasons (1994 through 1998) on a low-elevation coastal site near Tillamook, OR.

Growing season	Douglas-fir seed source: Field collection*	Seed orchard collection†	Standard collection
1994	0.54a††	0.51a	0.53a
1995	0.91a	0.88a	0.86a
1996	1.39a	1.39a	1.49a
1997	2.00a	1.98a	2.06a
1998	2.35a	2.48a	2.58a

* Seed collected from trees in natural stands that appeared to demonstrate a degree of tolerance to Swiss needle cast.
† Open-pollinated seed orchard seed collected from random single-pair crosses of parent trees in natural stands outside of the coastal fog belt, but west of the Oregon Coast Range summit, whose progeny appeared to demonstrate a degree of tolerance to Swiss needle cast in coastal Douglas-fir progeny test sites.
†† For each growing season, means followed by the same letter are not significantly different at $P = 0.05$.

Table 2. Total height (ft) of Douglas-fir grown from three seed sources over five growing seasons (1994 through 1998) on a low-elevation coastal site near Tillamook, OR.

Growing season	Douglas-fir seed source: Field collection*	Seed orchard collection†	Standard collection
1994	2.21a††	2.26a	2.40a
1995	4.20a	4.07a	4.21a
1996	6.04a	5.94a	6.15a
1997	8.30a	8.43a	8.64a
1998	10.63a	10.59a	10.86a

* Seed collected from trees in natural stands that appeared to demonstrate a degree of tolerance to Swiss needle cast.
† Open-pollinated seed orchard seed collected from random single-pair crosses of parent trees in natural stands outside of the coastal fog belt, but west of the Oregon Coast Range summit, whose progeny appeared to demonstrate a degree of tolerance to Swiss needle cast in coastal Douglas-fir progeny test sites.
†† For each growing season, means followed by the same letter are not significantly different at $P = 0.05$.

Table 3. Percentage of Douglas-fir grown from three seed sources with normal foliage color over five growing seasons (1994 through 1998) on a low-elevation coastal site near Tillamook, OR.

	Douglas-fir seed source		
Growing season	Field collection*	Seed orchard collection†	Standard collection
1994	74a††	78a	84a
1995	78a	80a	58b
1996	4a	2a	2a
1997	2a	4a	0a
1998	2a	4a	2a

* Seed collected from trees in natural stands that appeared to demonstrate a degree of tolerance to Swiss needle cast.
† Open-pollinated seed orchard seed collected from random single-pair crosses of parent trees in natural stands outside of the coastal fog belt, but west of the Oregon Coast Range summit, whose progeny appeared to demonstrate a degree of tolerance to Swiss needle cast in coastal Douglas-fir progeny test sites.
†† For each growing season, means followed by the same letter are not significantly different at $P = 0.05$.

season (Table 3). The field and seed orchard collections, however, had a significantly ($P = 0.05$) higher percentage of trees exhibiting "normal" foliage color than the standard collection for the 1995 growing season. All seed sources had a very low percentage of trees with normal foliage color for the 1996 through the 1998 growing seasons, and none of the differences were statistically significant. In addition, there were no significant differences among seed sources in the percentage of trees in each of the four crown-color classes (Table 4). There was, however, a notable decrease in the percentage of trees in the slightly yellow color class and a substantial increase in the percentage of trees in the extremely yellow or yellow-brown color class from the 1997 to the 1998 growing seasons.

The standard collection appeared to have a significantly ($P = 0.05$) lower percentage of trees infected with the Swiss needle cast fungus for the 1994 growing season than the other two seed sources. This may have been partially the result of collecting the data in late March when the fruiting bodies were not yet well developed and therefore difficult to detect on the current-year needles. For the 1995 through the 1998 seasons, however, all trees from all seed sources were infected.

There were no significant ($P = 0.05$) differences in retention of current-year needles among seed sources (Table 5) for the 1994 growing season. Retention of current-year needles was significantly ($P = 0.05$) higher for the field and seed orchard collections than the standard collection for the 1995 growing season. In addition, retention of 1-yr-old needles was significantly ($P = 0.05$) higher for the field collection than the seed orchard or standard collections. For the 1996 growing season, however, there were no significant ($P = 0.05$) differences in retention of current-year, 1-yr-old, or 2-yr-old needles among seed sources, with retention of 1- and 2-yr-old needles being quite low for all seed sources. Surprisingly, retention of current-year needles was significantly ($P = 0.05$) higher for the seed orchard and standard collections than the field collection for the 1997 growing season. Retention of 1- and 2-yr-old needles, however, did not differ significantly among seed sources, and retention levels were relatively low. For the 1998 growing season, there were no significant ($P = 0.05$) differences in retention of current-year needles among seed sources. The standard seed source retained a significantly ($P = 0.05$) higher percentage of the 1-yr-old needles than the other two seed sources. The percentage of 1-yr-old needles retained for all seed sources, however, was rather low. Retention of 2-yr-old needles did not differ significantly among seed sources, and retention levels were also low. Based on field observations in diseased stands, needle retention seems to be an important factor in the ability of individual trees to maintain reasonable growth despite being affected with Swiss needle cast (Maguire et al. 1998, Hansen et al. 2000).

Any differences among seed sources for most of the data elements measured essentially disappeared after the second growing season. Based on observations of disease progression in affected stands in the general area, the probability of any differences becoming evident on this site in the near future seems quite remote. Any natural tolerance to the disease that may exist among seed sources was probably being overwhelmed by intense disease pressure on this high-hazard site. Differences among seed sources may occur on low- to medium-hazard sites, but we did not study this. Also, only the visually assessed relative disease tolerance of the female-parent trees was used as the criteria for cone collec-

Table 4. Percentage of Douglas-fir grown from three seed sources in each crown-color class after the fourth and fifth growing seasons (1997 and 1998) on a low-elevation coastal site near Tillamook, OR.

	Douglas-fir seed source		
Crown-color class	Field collection*	Seed orchard collection†	Standard collection
1997 growing season			
Normal green	2a††	4a	0a
Slightly yellow	38a	43a	44a
Moderately yellow	48a	43a	54a
Extremely yellow or yellow-brown	12a	10a	2a
1998 growing season			
Normal green	2a	4a	2a
Slightly yellow	14a	16a	22a
Moderately yellow	31a	19a	34a
Extremely yellow or yellow-brown	53a	61a	42a

* Seed collected from trees in natural stands that appeared to demonstrate a degree of tolerance to Swiss needle cast.
† Open-pollinated seed orchard seed collected from random single-pair crosses of parent trees in natural stands outside of the coastal fog belt, but west of the Oregon Coast Range summit, whose progeny appeared to demonstrate a degree of tolerance to Swiss needle cast in coastal Douglas-fir progeny test sites.
†† For each growing season, means followed by the same letter are not significantly different at $P = 0.05$.

Table 5. Percentage of needles retained by Douglas-fir grown from three seed sources over five growing seasons (1994–1998) on a low-elevation coastal site near Tillamook, OR. Data are needle retention class mid-point mean percentages for needles produced on site.

	Douglas-fir seed source		
Age of needles	Field collection*	Seed orchard collection†	Standard collection
1994 growing season			
Current yr	95a††	95a	95a
1995 growing season			
Current yr	85a	87a	77b
1-yr-old	37a	27b	22b
1996 growing season			
Current yr	74a	78a	76a
1-yr-old	9a	7a	9a
2-yr-old	5a	5a	6a
1997 growing season			
Current yr	69a	85b	80b
1-yr-old	11a	14a	15a
2-yr-old	5a	5a	5a
1998 growing season			
Current yr	58a	63a	70a
1-yr-old	7a	6a	10b
2-yr-old	5a	5a	5a

* Seed collected from trees in natural stands that appeared to demonstrate a degree of tolerance to Swiss needle cast.

† Open-pollinated seed orchard seed collected from random single-pair crosses of parent trees in natural stands outside of the coastal fog belt, but west of the Oregon Coast Range summit, whose progeny appeared to demonstrate a degree of tolerance to Swiss needle cast in coastal Douglas-fir progeny test sites.

†† For each growing season, means followed by the same letter are not significantly different at $P = 0.05$.

tion for the field seed source. The relative disease tolerance of the male-parent trees, however, was unknown. Most likely, the male-parent trees were not very tolerant to elevated disease levels. Trees included in the seed orchard collection were based on an assessment of the relative disease tolerance of progeny in coastal test sites whose parent trees came from natural stands located outside of the coastal fog belt, but west of the Oregon Coast Range summit. Open-pollinated seed was collected in the seed orchard from crosses consisting of parent trees of the best-performing progeny. Because the seed orchard source was open-pollinated and was located east of the Coast Range in the Willamette Valley, the relative disease tolerance of the trees contributing the pollen was again unknown, but expected to be relatively low.

In general, low-elevation southerly aspects such as the site used in this study appear to exhibit more severe disease symptoms than higher-elevation northerly aspects. We do not recommend planting Douglas-fir on such high-disease-hazard sites. Establishment of Douglas-fir seed source trials on a variety of sites may have presented a clearer picture of the potential for expression of disease tolerance among Douglas-fir seed sources.

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