Infection Period of *Phaeocryptopus gaeumannii* on Douglas-Fir Needles in Western Washington

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ABSTRACT

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Swiss needle cast is a major disease of Douglas-fir grown as Christmas trees in western Washington and Oregon. To determine when needles are infected by *Phaeocryptopus gaeumannii* in western Washington, trees were introduced or removed from a spray program using known effective fungicides. Spray applications were made monthly during a 52-wk period during 1980–1981. Single applications were made weekly from May through July in 1981. Results indicate that needles are infected shortly after budbreak and that single applications of chlorothalonil provide effective disease control if applied during shoot elongation in early spring.

About 5.5 million Christmas trees are produced in western Washington and Oregon annually. Production of plantation-grown trees has increased during recent years; Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) accounts for 74% of all trees harvested (3). *Phaeocryptopus gaeumannii* (Rohde) Petrak, the cause of Swiss needle cast, can severely reduce the quality of Douglas-fir Christmas trees because the needles are prematurely cast (1,9).

Swiss needle cast has been known to occur in natural stands of Douglas-fir in western North America since 1938 (1). It has been serious where Douglas-fir has been introduced but has generally been considered harmless in western North America (1). Recently, the disease has caused serious losses in plantation-grown Christmas trees throughout western Washington and Oregon (7).

In areas where Douglas-fir has been introduced, disease control has been contingent on selecting climatically adapted strains of Douglas-fir (1,6) and applying protectant fungicides during infection periods. In these areas, studies have shown that infection occurs shortly after budbreak and repeated applications of fungicides are required during this period to control the disease (1,2,5,9).

In contrast, work on the epidemiology of the disease in western Washington indicated that there were two principal infection periods, late summer and winter, and repeated applications of fungicides were required during these periods to provide disease control (B. A. Fatuga, *unpublished*).

Developing effective chemical control measures depends on thoroughly understanding when infection occurs. Because multiple periods of infection had been reported in western Washington and but single periods elsewhere, studies were begun in 1980 to verify when infection occurs in western Washington.

MATERIALS AND METHODS

Cover sprays of protectant fungicides known to control Swiss needle cast were used during the study to protect trees during different times of the year to determine when infection occurs. During 1980–1981, a mixture of benomyl (1.1 kg a.i./ha) and mancozeb (4.0 kg a.i./ha) plus Bio-Film (118.3 ml/ha) was applied to trees every 4 wk for 1 yr, starting on 29 April. To determine if multiple periods of infection occur, trees were added and removed monthly from the spray program (Tables 1 and 2).

This experiment was established in a plantation of sheared 6-yr-old Douglas-fir Christmas trees near Vadar, WA. Trees were about 2 m tall and planted on 1.8-cm centers. A randomized complete block experimental design with five blocks was used. Each block contained 26 sets of five trees. The five trees within each set were separated from other sets of trees by one or more trees within the same row and by one or more rows of unsprayed trees.

Applications were made with a Solo (Model 425) backpack sprayer equipped with a single 8003 LP tee-jet nozzle at 1.1 kg/m^2. About 312 ml of mixture was applied to each tree. Sets of trees in each block that were not sprayed served as checks.

To determine the infection period precisely and to establish an optimum time for fungicide application, a plot was established in a 7-yr-old Douglas-fir Christmas tree plantation near Rochester, WA, during 1981. In this plot, the trees were about 1.8 m tall and planted on 1.5-m centers. The plot design was a randomized complete block with 11 blocks. Chlorothalonil (Bravo 500F, 9.4 L/ha) was applied as described previously. On 8 May, one tree in each block was sprayed and each week through 30 July, a new tree was sprayed. The length of a

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single current season's terminal shoot on a lateral branch about 1.2 m above the ground was recorded from each quadrant of each tree at the time the tree was sprayed.

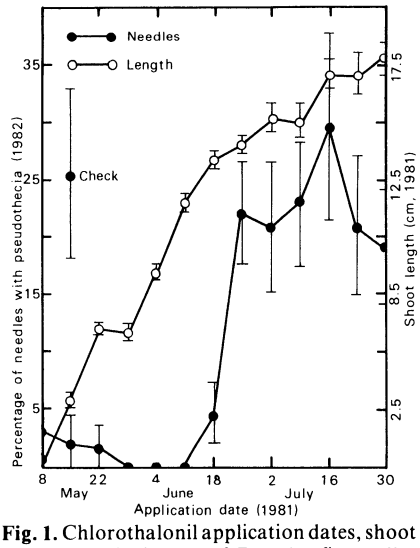

Fig. 1. Chlorothalonil application dates, shoot length, and incidence of Douglas-fir needles with *Phaeocryptopus gaeumannii* pseudothecia.

To monitor disease incidence, it was necessary first to determine the general distribution of the disease on the trees. Terminal growth on four lateral branches located 0.6, 1.2, and 1.8 m below the top of the tree was collected on 1 April 1981 from two unsprayed trees in each block of the plot established in 1980. The four branches from each height were collected from different quadrants of the tree. Needles were removed and 10 needles were selected randomly, mounted on cards with cellophane tape, and examined with a dissecting microscope for pseudothecia. Differences in the numbers of needles with pseudothecia were analyzed using analysis of variance and Duncan's multiple range test.

Samples were collected from the 1980 plots on 14 April 1981 and on 22 March 1982 for the 1981 plots. Four terminal shoots were collected from each tree about 1.2 m from the top. The 20 samples from each set of five trees in the 1980 plots were placed in a single plastic bag and the four samples from individual trees in the 1981 plots were placed in a single bag. Samples were stored at 5 C until they were examined microscopically. The incidence of needles with pseudothecia was determined by removing all the needles from the shoots in each bag. From these, 20 needles were selected randomly and examined for pseudothecia.

RESULTS

There was no significant difference in incidence of needles with pseudothecia among samples of needles obtained from different quadrants of individual trees. Samples collected 0.6 m below the top of the tree, however, had a significantly lower ($P = 0.05$) incidence of needles with pseudothecia compared with samples collected 1.2 or 1.8 m from the top; these were 80, 93, and 93%, respectively.

By comparing the disease incidence on trees receiving various systematic fungicide applications throughout the year, it was concluded that in 1980, infection occurred during late May through June. Trees that did not receive a

Table 1. Initiation of cover sprays and incidence of Douglas-fir needles with *Phaeocryptopus gaeumannii* pseudothecia on 14 April 1981[a]

Application date													Needles with pseudothecia[b] (%)
1980									1981				
29 April	29 May	24 June	23 July	20 Aug.	18 Sept.	15 Oct.	12 Nov.	9 Dec.	5 Jan.	2 Feb.	4 March	1 April	
+	+	+	+	+	+	+	+	+	+	+	+	+	2.0 x
−	+	+	+	+	+	+	+	+	+	+	+	+	8.0 x
−	−	+	+	+	+	+	+	+	+	+	+	+	3.0 x
−	−	−	+	+	+	+	+	+	+	+	+	+	79.0 y
−	−	−	−	+	+	+	+	+	+	+	+	+	94.0 z
−	−	−	−	−	+	+	+	+	+	+	+	+	98.0 z
−	−	−	−	−	−	+	+	+	+	+	+	+	91.0 yz
−	−	−	−	−	−	−	+	+	+	+	+	+	96.0 z
−	−	−	−	−	−	−	−	+	+	+	+	+	99.0 z
−	−	−	−	−	−	−	−	−	+	+	+	+	94.0 z
−	−	−	−	−	−	−	−	−	−	+	+	+	94.0 z
−	−	−	−	−	−	−	−	−	−	−	+	+	97.0 z
−	−	−	−	−	−	−	−	−	−	−	−	+	98.0 z
−	−	−	−	−	−	−	−	−	−	−	−	−	97.0 z

[a] Cover sprays of tank mixtures of benomyl (2.2 kg), mancozeb (4.4 kg), and Bio-Film (292.3 ml) were applied in the equivalent of 935.3 L of water per hectare. + = Tree sprayed and − = tree not sprayed.
[b] Numbers followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

Table 2. Termination of cover sprays and incidence of Douglas-fir needles with *Phaeocryptopus gaeumannii* pseudothecia on 14 April 1981[a]

Application date													Needles with pseudothecia[b] (%)
1980									1981				
29 April	29 May	24 June	23 July	20 Aug.	18 Sept.	15 Oct.	12 Nov.	9 Dec.	5 Jan.	2 Feb.	4 March	1 April	
−	−	−	−	−	−	−	−	−	−	−	−	−	97.0 x
+	−	−	−	−	−	−	−	−	−	−	−	−	96.0 x
+	+	−	−	−	−	−	−	−	−	−	−	−	16.0 y
+	+	+	−	−	−	−	−	−	−	−	−	−	9.0 yz
+	+	+	+	−	−	−	−	−	−	−	−	−	5.0 zv
+	+	+	+	+	−	−	−	−	−	−	−	−	3.0 zv
+	+	+	+	+	+	−	−	−	−	−	−	−	1.0 zv
+	+	+	+	+	+	+	−	−	−	−	−	−	0.0 v
+	+	+	+	+	+	+	+	−	−	−	−	−	1.0 zv
+	+	+	+	+	+	+	+	+	−	−	−	−	0.0 v
+	+	+	+	+	+	+	+	+	+	−	−	−	1.0 zv
+	+	+	+	+	+	+	+	+	+	+	−	−	0.0 v
+	+	+	+	+	+	+	+	+	+	+	+	−	2.0 zv
+	+	+	+	+	+	+	+	+	+	+	+	+	2.0 zv

[a] Cover sprays of tank mixtures of benomyl (2.2 kg), mancozeb (4.4 kg), and Bio-Film (292.3 ml) were applied in the equivalent of 935.3 L of water per hectare. + = Tree sprayed and − = tree not sprayed.
[b] Numbers followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

protective spray on or before 24 June had a high incidence of disease (Table 1). The disease was not controlled on trees sprayed from mid-July 1980 through April 1981. Similarly, trees sprayed only during the May and June period were as disease-free as those receiving sprays every month of the year (Table 2).

During 1981, a single application of chlorothalonil between 29 May and 11 June provided complete control of Swiss needle cast on needles of newly emerging shoots (Fig. 1). Shoots during this period elongated from 3 to 12 cm (about one-sixth to two-thirds of their total length). Applications of chlorothalonil on or after 25 June were ineffective and the incidence of needles with pseudothecia was not significantly different from the unsprayed check trees. These data indicate the infection period in 1981 was similar to that in 1980. Limited data on the growth of shoots in 1980 indicated the tree phenology in these 2 yr was also similar.

DISCUSSION

The epidemiology of Swiss needle cast in western Washington is similar to that reported from areas where Douglas-fir has been introduced. Infection on needles is apparently influenced to a greater extent by the susceptibility of the host tissue than by the presence of inoculum. Pseudothecia on needles from trees in our 1981 plot had the capacity to release ascospores from April through September (E. Michaels and G. A. Chastagner, *unpublished*). Yet, the infection period as determined by protective fungicide applications was limited to a relatively short period when shoots and needles began to elongate. Others (1,2) have reported release of large numbers of ascospores during this period. Hood and Kershaw (5) have shown that in New Zealand, susceptibility of needles decreases shortly after emergence.

Delineating the infection period has drastically reduced the number of fungicide applications needed for disease control. Previous work indicated that two infection periods occurred after ascospore release in late April through May and in October and that a minimum of five applications was required to provide disease control (B. A. Fatuga, *unpublished*). Several applications (two or three) are recommended in areas outside the natural range of Douglas-fir even though there is only a single infection period (2,4,8,9). Multiple applications in these areas may be required because of greater precipitation, which may reduce residual activities of the fungicides.

Residual and redistribution properties of the fungicide used may also influence numbers of applications required. A single application of chlorothalonil just after initial budbreak gave partial control (Fig. 1), indicating its redistribution and residual activity in our 1981 test was sufficient to protect elongating needles for 6 wk. Further testing would be required to determine if the other fungicides registered for use, ie, benomyl and mancozeb, would give similar results.

Whether the duration of the infection is influenced by yearly changes in environmental factors needs to be determined. Based on 2 yr of observations, however, we suggest that chlorothalonil be applied shortly after shoot growth begins. The anticipated 4–6 wk of residual activity should provide protection through the period when the needles are susceptible to infection.

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