Response of *Phytophthora* spp. to Metalaxyl in Forest Tree Nurseries in the Pacific Northwest

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ABSTRACT

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Effects of metalaxyl on composition of *Phytophthora* spp., survival of *Phytophthora* in roots and soil, and severity of root disease of Douglas-fir were investigated at two commercial forest tree nurseries. One application suppressed root rot. Of three *Phytophthora* spp. isolated from treated seedlings (*P. megasperma, P. drechsleri, and P. pseudotsugae*), only *P. pseudotsugae* decreased in isolation frequency because of the chemical. Survival of *Phytophthora* spp. in infected seedlings remained high after treatment. At one nursery, 10 mo after the first application, *Phytophthora* spp. were isolated from 92% of the seedlings across fungicide treatments, whereas at the second nursery, isolation frequencies from seedlings were 77, 70, 29, and 13%, respectively, after zero, one, two, and three applications. *Phytophthora* was recovered from previously healthy seedlings 8 wk after they were transplanted into naturally infested, metalaxyl-treated soil.

Phytophthora root rot of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) seedlings is a serious problem in poorly drained soils in forest tree nurseries in Oregon and Washington (6,10,12). Six species of *Phytophthora* have been implicated (*P. cinnamomi* Rands, *P. cryptogea* Peth. & Laf., *P. megasperma* Drechs. emend Hamm & Hans. (7), *P. drechsleri* Tucker, *P. pseudotsugae* Hamm & Hans. (8), and *P. cactorum* (Leb. & Cohn.) Schr.). Two or three species are generally present in any nursery with root rot problems. Until recently, modified cultural practices (improved drainage and abandoning areas of chronic root rot) provided the only effective control. Fungicides and fumigants have not been effective.

Metalaxyl (Subdue), a new systemic fungicide, is effective in suppressing Phytophthora root rot on a number of crops (1–3,11) and is labeled for use in conifer nurseries. Several authors have reported eradication of *P. cinnamomi* or *P. cactorum* from infected woody plants after treatment with metalaxyl (2,3,11). In preliminary tests on Douglas-fir, however, *Phytophthora* spp. were recovered readily from treated trees (P. B. Hamm and E. M. Hansen, *unpublished*). Treatment with metalaxyl in Pacific Northwest nurseries usually is not initiated until symptoms appear and *Phytophthora* has been identified as the causal agent. Thus, the ability of *Phytophthora* to survive in infected seedlings after fungicide treatment is important to nursery managers and foresters because previous work shows reduced outplanting survival of infected seedlings (10). This concern, and the need for additional means of reducing Phytophthora root rot damage in Pacific Northwest nurseries, prompted this study. We monitored survival of *Phytophthora* in roots and soil, composition of *Phytophthora* spp. in seedlings, severity of root disease, and survival of metalaxyl-treated, infected seedlings after outplanting following zero, one, two, or three applications of metalaxyl. A preliminary report has been published (5).

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MATERIALS AND METHODS

Metalaxyl was applied in two recently established forest nurseries in western Oregon. At each location, three randomized blocks were established in beds containing diseased 1-yr-old Douglas-fir seedlings (avg. 269 and 344 seedlings per square meter at nurseries A and B, respectively). Blocks included the eight rows of a bed and were 9 m long. Each block contained three or four treatments (zero, one, two, or three applications of metalaxyl 2EC [0.7 kg a.i./ha in 474 L of water]), each separated by a 1-m buffer. First applications were made on 18 May and 9 April 1982 at nurseries A and B, respectively; second and third applications followed after 3 and 6 mo. At nursery B, all areas were treated with metalaxyl before plot establishment, and consequently, there was no untreated control at this site. At each nursery, seedlings in each treatment were sampled 0, 1, 3, 4, 6, 7, and 10 mo after the first metalaxyl application to determine survival of *Phytophthora* spp. At each sampling, all seedlings were collected from one randomly selected row within each treatment from each block. Seedlings were washed and root rot severity was rated on a scale of 1–4, indicating the percentage of the root system killed (1 = 0–25%, 2 = 26–50%, 3 = 51–75%, and 4 = 76–100%). Direct isolations of *Phytophthora* on selective media were attempted, as described previously (10), from the first 25 living symptomatic seedlings encountered in each sampled row.

Survival of *Phytophthora* in soil after metalaxyl treatment was determined by the following method: Five liters of soil was collected from throughout all blocks 1 mo after each fungicide application and composited by treatment for each nursery. After each collection, untreated healthy (asymptomatic) bare-root seedlings were transplanted to plastic tubes (450-ml capacity) in lots of 10, one lot for each soil treatment. Tubes were randomized in the greenhouse and watered to saturation daily. After 8 wk, seedlings were washed and rated for root rot severity, then isolations for *Phytophthora* were attempted.

Survival of *Phytophthora* spp. in treated seedlings after outplanting was determined by removing the remaining seedling row in each block at both nurseries in early February 1983. Thirty trees from each treatment at each nursery, plus 30 untreated healthy controls, were then interplanted randomly (approximate spacing of 0.3 × 0.3 m) on forest sites of compatible seed zone. One-third of the seedlings (10 from each treatment plus 10 controls) were collected after 1 (March), 3 (May), and 6 (August) mo. Isolations for *Phytophthora* spp. were attempted for each collection.

Isolation success of *Phytophthora* spp., frequency of recovery of individual *Phytophthora* spp., and root rot severity ratings were compared among treatments for each nursery after analyses of variance. Arc sine transformations were

made when appropriate. Orthogonal tests of contrast were carried out to compare no treatment vs. treatments, one treatment vs. multiple treatments, and two vs. three treatments (13).

RESULTS

Survival of *Phytophthora* in roots and soil. *Phytophthora* was isolated from about 90% of the living seedlings at both nurseries at time zero (Fig. 1). At nursery A, isolation frequency was significantly less ($P = 0.05$) from treated than from untreated seedlings throughout the study. After 10 mo, however, isolation frequency from seedlings treated once rose to nearly equal those not treated (77% for no treatment and 70% for one treatment), whereas isolation frequency from seedlings that received two (29%) and three (13%) treatments remained low. In contrast, at nursery B, *Phytophthora* was readily isolated, regardless of the number of treatments, throughout the study (average of all treatments 92% at 10 mo).

Transplanting healthy trees into nursery soil provided a test for the presence of *Phytophthora* in soil after fungicide treatment. At nursery A, no seedlings became infected in soil collected in June (1 mo after first application). After transplanting in September, 1 mo after the second application, 60% of the trees were infected in control soil, 20% in soil with one metalaxyl treatment, and 5% in soil that received two applications (treatments 2 and 3). In December (1 mo after the third application), 50% of the seedlings in control soil were infected, compared with 10, 0, and 0% in soil with one, two, or three metalaxyl treatments. At nursery B, the only infections were on seedlings transplanted into soil from treatments 2 (30%) and 3 (10%) 1 mo after the third application.

Changes in *Phytophthora* population. *P. megasperma* group 2 (9), *P. pseudotsugae*, and *P. drechsleri* were present in both nurseries, occasionally in the same tree, although *P. pseudotsugae* was infrequent at nursery A and rare at B. Initially, *Phytophthora* spp. were recovered from 32% of the trees at nursery A and from 9% at nursery B.

P. megasperma declined in frequency at both nurseries during the study, whereas *P. drechsleri* increased, regardless of treatment. Only *P. pseudotsugae* was differentially affected by fungicide application. Frequency of isolation of *P. pseudotsugae* for treated (composited) vs. untreated controls at nursery A averaged 0.4 and 6.0% after 1 mo, 0 and 0% after 3 mo, 0.7 and 14.1% after 4 mo, 0 and 7.4% after 6 mo, 1.6 and 7.4% after 7 mo, and 0 and 9.9% after 10 mo. Figure 2 illustrates the population fluctuations of *P. megasperma* and *P. drechsleri* from all trees over time.

Survival of *Phytophthora* after outplanting. Isolation frequencies for *Phytophthora* spp. over the three sampling times averaged 60.0, 31.7, 28.0, and 12.0% for treatments 0, 1, 2, and 3, respectively, from nursery A and 78.7, 75.7, and 83.3% from nursery B for treatments 1, 2, and 3, respectively. Average isolation frequency (all treatments) from trees from both nurseries only slightly decreased from sample 1 to sample 3 (from 35.0 to 27.3% at nursery A and from 76.3 to 68.0% at nursery B).

Tree response. Initially, between 50 and 75% of the root systems of the surviving seedlings were dead (average root rot severity rating 2.3 at nursery A and 2.1 at B). As the most severely diseased trees died and the survivors regenerated new roots above the dead ones, average root rot ratings of surviving trees at both nurseries improved over time, regardless of treatment (Fig. 3). Metalaxyl applications further improved root rot ratings (significantly so at samplings after 3, 6, and 7 mo [$P = 0.05$]), although at harvest, there were no differences between root rot severity ratings of treated and untreated seedlings. In untreated seedlings, a large improvement in root rot ratings was delayed until September (month 4), compared with June (month 1) for seedlings treated with metalaxyl. At nursery B, the change in root rot ratings was identical for all treatments at all sample times.

DISCUSSION

Previous reports have shown metalaxyl to be effective in eradicating *P. cinnamomi* or *P. cactorum* (2,3,11). This study showed that *Phytophthora* was not eradicated from trees or soil, even after three applications of metalaxyl. The test was severe, however; 1-yr-old trees already extensively infected were treated. Three species of *Phytophthora*, differing in sensitivity to the fungicide, were involved. Nevertheless, we found surviving trees had more healthy roots if treated than if untreated. New infections were reduced or eliminated and further increase in disease severity was immediately stopped (Fig. 1). It seems likely that earlier application of the fungicide, perhaps a single treatment in late fall or early winter of the first year, would have prevented the initial increase of root rot with more dramatic final results.

Variability was higher than expected.

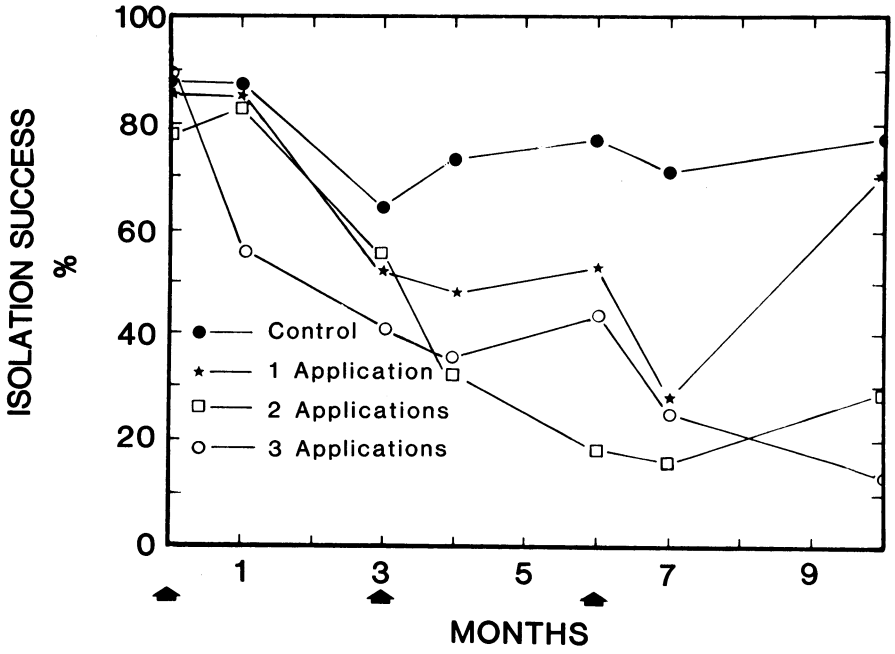

Fig. 1. Average frequency of isolation of *Phytophthora* spp. after zero, one, two, or three applications of metalaxyl at nursery A. Arrows indicate treatment times. Each data point is based on 75 seedlings.

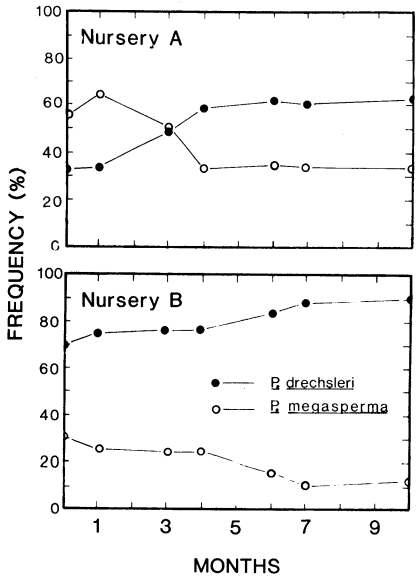

Fig. 2. Isolation frequency of two *Phytophthora* spp. over a 10-mo period. Values represent frequency of isolation from about 300 trees at nursery A and 225 trees at nursery B at each sampling, regardless of number of metalaxyl applications.

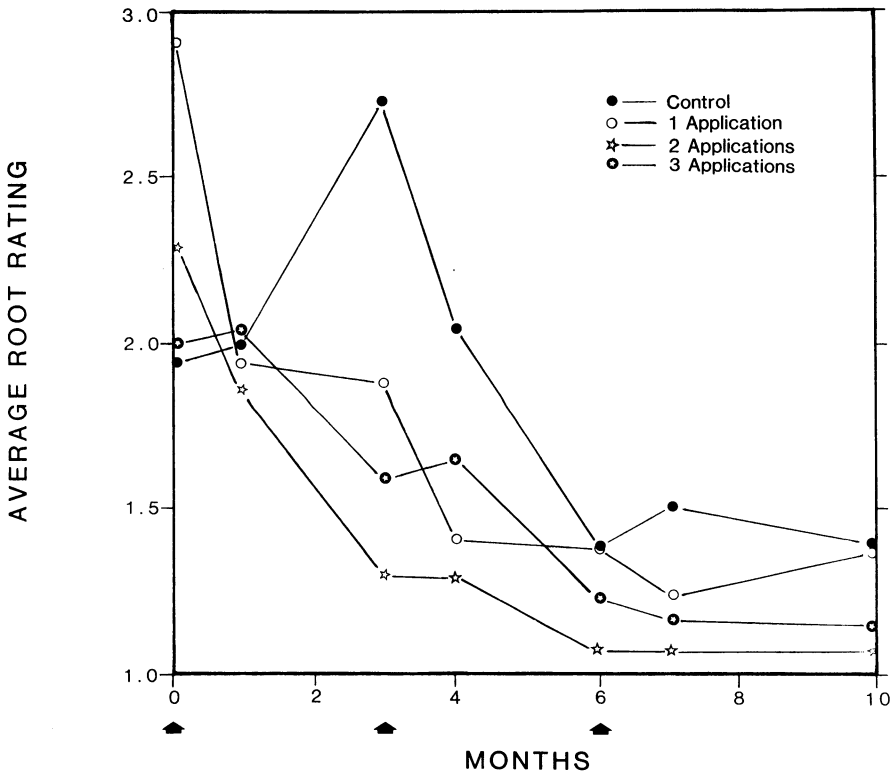

Fig. 3. Average root rot ratings of living Douglas-fir seedlings at nursery A after zero, one, two, or three applications of metalaxyl. Ratings of 1, 2, 3, and 4, respectively, indicate 0–25, 26–50, 51–75, and 76–100% of root systems killed. Arrows indicate treatment times.

Although all blocks were established in one general area of each nursery and matched visually for uniform disease rating initially, they varied widely in subsequent disease severity. Variability in distribution of *Phytophthora* spp. also occurred in nursery B, where 90% of the isolates from one block throughout the 10 mo were *P. megasperma*, whereas 90% from another nearby block were *P. drechsleri*.

There were important differences between nurseries, particularly in isolation success, although comparisons were hampered by loss of untreated areas at nursery B. In general, fungicide treatments were more effective at nursery A than at B. Nursery A is on a decomposed granite soil, generally quite coarse, although tending to form a "plow pan." There had been no obvious *Phytophthora* problem before unusual winter flooding of the seedlings 5 mo prior to study establishment. Nursery B, in contrast, is on a clay loam river terrace with drainage further impaired by land planing. Douglas-fir seedlings had not been grown in this area previously. *Phytophthora* was undoubtedly present before planting. Both nurseries were established on land with a long general agricultural cropping history, a condition thought to be conducive to establishment of *P. megasperma* (4).

Isolation frequencies of *Phytophthora* from infected seedlings transplanted to forest sites remained high 6 mo after outplanting from nursery B (average of all treatments 68%), whereas recovery from seedlings from nursery A was similar to that from samples taken before outplanting (77, 70, 29, and 13% at 10 mo vs. 60, 32, 28, and 12% at 6 mo after outplanting for zero, one, two, and three treatments, respectively). Because of high levels of *Phytophthora* survival long after treatment, care should be taken to avoid transplanting healthy-appearing plants with infected roots from metalaxyl treatments to sites where Phytophthora root rot will be encouraged. Forest sites have been shown to be unfavorable for *Phytophthora* to spread, survive, and cause increased damage on infected seedlings (10), but in ornamental situations with poorly drained soils and summer irrigation, disease is likely to continue.

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