Landscape Survival of Fungicide-Treated Azaleas Inoculated with *Phytophthora cinnamomi*

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ABSTRACT

Benson, D. M. 1990. Landscape survival of fungicide-treated azaleas inoculated with *Phytophthora cinnamomi*. Plant Dis. 74: 635-637.

Containerized Hinodegiri azalea in a pine bark:sand medium were inoculated with oat grains colonized by *Phytophthora cinnamomi*. Plants were treated with three foliar sprays of fosetyl-Al (4.79 g a.i./L), with two drenches of metalaxyl (0.078 ml a.i./L), or left untreated over the next 61 days before being transplanted to pathogen-free landscape beds. The long-term growth and survival of plants in beds after discontinuation of fungicide treatment was compared to plants in a fourth group left untreated and uninoculated as a control. Only a few fungicide-treated, inoculated plants developed symptoms of Phytophthora root rot after 3 yr in the beds. Plant growth of fungicide-treated inoculated plants over the 3-yr period was comparable to that of untreated, uninoculated controls. However, untreated, inoculated plants were significantly smaller in size, and mortality reached 39% after 3 yr. Results suggest that application of fungicides to inoculated plants in containers was sufficient to prevent Phytophthora root rot after transplanting to pathogen-free landscape beds.

In many commercial nurseries, azaleas (*Rhododendron* sp.) and other ornamentals susceptible to root rot caused by *Phytophthora cinnamomi* Rands are often produced under an integrated management strategy that includes application of fungicides. Both fosetyl-Al and metalaxyl are effective in preventing Phytophthora root rot on azaleas grown in containers (2,4,5,10,12) and on azaleas planted in naturally infested landscape beds (3).

In practice, most ornamentals susceptible to *P. cinnamomi* receive no further fungicide treatment once they are sold and planted in the landscape. Information is not available on long-term disease development, growth, and survival of plants when fungicide treatment is discontinued.

The purpose of this research was to observe long-term disease development, plant growth, and survival of fungicide-treated azaleas inoculated with *P. cinnamomi* and planted into landscape beds without benefit of further application of fungicide.

MATERIALS AND METHODS

Plant material. Cuttings of Hinodegiri azalea (*Rhododendron obtusum* [Lindl.] Planch.) were rooted in a peat moss: perlite medium (1:1, v/v) in July 1985 and grown in the greenhouse until spring 1986. Plants were transplanted to a pine bark:sand medium (3:1, v/v) in 2.6-L containers in May 1986 and placed in an area with 50% shade cloth in a research nursery in Raleigh, North Carolina. The container medium was incorporated with micronutrient at 0.9 kg/m^3 and top-dressed with sulfur-coated fertilizer (21-6-12) at 0.5 kg/m^3 after transplanting. Sprinkler irrigation provided 0.9 cm of water per day as described previously (5).

Inoculum. A group of 54 plants were inoculated with *P. cinnamomi* on 7 August 1986. Isolates 100, 101, 116, 128, and 150, originally isolated from azalea

Paper 12482 of the Journal Series of the North Carolina Agricultural Research Service, Raleigh 27695-7601.

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Accepted for publication 2 February 1990 (submitted for electronic processing).

and rhododendron and known to be pathogenic to azalea (5), were grown singly on oat grains for 30 days, then mixed together and used as inoculum. Each plant in the group received 10 colonized oat grains per hole punched in the medium to a 5-cm depth at three locations around the edge of the root ball. A second group of 18 plants were not inoculated and served as a control.

Fungicide. Plants in the inoculated group were either given a fungicide treatment or left untreated as a control. Metalaxyl (Subdue 2EC) at a rate of 0.078 ml a.i./L was applied in a solution of 250 ml per 2.6-L container to each of 18 plants immediately after inoculation. Fosetyl-Al (Aliette 80W) at 4.79 g a.i./L was applied to run-off to 18 additional plants, as a foliar spray, in a hand-pressurized sprayer. Before application of fosetyl-Al, foliage of plants was allowed to dry for 1 hr after inoculated plants had been irrigated. The remaining 18 inoculated plants were used as the untreated control. Metalaxyl was reapplied on 6 October 1986. Fosetyl-Al was reapplied 8 September 1986 and 6 October 1986. Plants received no further fungicide applications. Plants from each treatment were placed on the container area in rows 30 cm apart with a 30-cm spacing between rows in a randomized complete block design with six replications.

Landscape beds. Two beds (3 × 30 m on a Cecil clay soil) with no history of *P. cinnamomi* were rototilled in preparation for planting. On 7 October 1986, plants from the container area were transplanted to the beds with three replications per bed and three plants per replication. Plants were approximately 1 m apart in rows with 3 m between rows. Sprinkler irrigation was used after transplanting to consolidate soil around the newly set plants and then throughout the growing season for the next 3 yr as needed to ensure approximately 2.5 cm of water per week. Beds were mulched with a 5-cm layer of pine bark. Weeds were controlled with directed sprays of glyphosate or by hoeing. Each spring, 11.3 kg of 10-10-10 (NPK) was broadcast over each bed.

Symptom development and plant growth. Plants were rated periodically during the next 3 yr for foliar symptom development on a scale where 1 = healthy foliage, 2 = initial symptoms (chlorosis, dwarfed leaves, poor shoot growth), 3 = severe symptoms (necrotic leaves, no shoot growth, stunted plants), and 4 = plant dead. Growth was assessed by measuring average plant height and width and expressed as the sum of half the height plus half the width. Plants that died of Phytophthora root rot were included as zero in the calculation.

Root assays. The day before transplanting and periodically thereafter over the 3-yr period, a root sample was collected from each plant and assayed to detect the presence of *P. cinnamomi*. Roots in each sample were washed free of debris, combined en masse, and cut into five clumps for placement on PPP medium (8). The number of samples yielding *P. cinnamomi* per treatment was used to calculate the percent of plants infected.

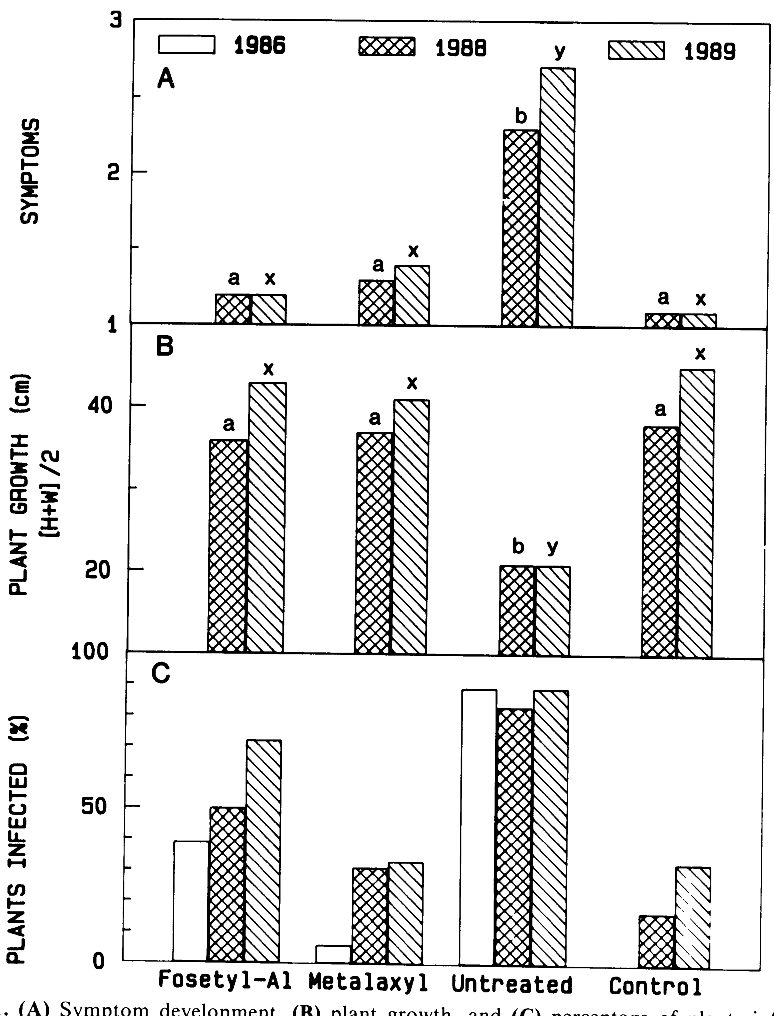

Fig. 1. (A) Symptom development, (B) plant growth, and (C) percentage of plants infected with *Phytophthora cinnamomi* for Hinodegiri azalea treated with either fosetyl-Al or metalaxyl and then transplanted to landscape beds for 3 yr beginning in the fall of 1986. Azaleas were inoculated with *P. cinnamomi* before being treated with fungicide. Additional plants were inoculated but left untreated (x-axis) or left uninoculated and untreated as a control (x-axis). Plants rated for symptoms on a scale where 1 = healthy foliage, 2 = initial symptoms of Phytophthora root rot (chlorosis, dwarfed leaves, poor shoot growth), 3 = severe symptoms (necrotic leaves, no shoot growth, stunted plants), and 4 = plant dead. Plant growth is the sum of one-half the average plant height plus one-half the average plant width, divided by two. Bars within year capped with the same letter are not significantly different according to the Waller-Duncan k-ratio t test; $k = 100$, $P = 0.05$. Plants infected is the percentage of the number in each group (fosetyl-Al treated, inoculated; metalaxyl-treated, inoculated; untreated, inoculated; or untreated, uninoculated control) of 18 plants from which *P. cinnamomi* was isolated.

RESULTS AND DISCUSSION

Symptom development was slight on fungicide-treated plants after the second and third year, and plant growth was comparable to that in uninoculated controls. After 3 yr, symptom severity indices on fungicide-treated plants were 1.2 and 1.4 for fosetyl-Al and metalaxyl-treated plants, respectively, but 2.7 in the untreated, inoculated control (Fig. 1A). Mortality increased from 6% in untreated, inoculated controls at the beginning of the second year to 39% by the end of the third year. Over this same period, mortality was 6% in metalaxyl-treated plants. No mortality was observed in fosetyl-Al treated plants or in the untreated, uninoculated controls.

Plant growth was not different between fungicide-treated and uninoculated plants in either the second or third years (Fig. 1B). On the other hand, untreated, inoculated control plants had grown much less than fungicide-treated plants. The removal of plants that died from Phytophthora root rot from the calculation still resulted in plant growth estimates for the untreated, inoculated controls that were less ($P = 0.05$) than those for the fungicide-treated plants.

At transplanting, 88% of the untreated, inoculated azaleas were infected with *P. cinnamomi*. This percent remained constant over the next 3 yr (Fig. 1C). Only 6% of the metalaxyl-treated plants were infected at transplanting, but this percentage increased to 33% after 3 yr (Fig. 1C). Thirty-nine percent of the fosetyl-Al plants were infected at transplanting time, and this percentage increased to 72% after 3 yr (Fig. 1C). None of the untreated, uninoculated controls were infected at transplanting, but 33% were infected after 3 yr. Thus, the percentage of plants infected increased about 33% for each treatment group over the three growing seasons except for the untreated, inoculated control group, where initial infection at transplanting was near 90% (Fig. 1C). The increase in number of plants infected may have occurred from subclinical infections already present on plants at transplanting, from movement of inoculum from untreated, inoculated plants during periods of high rainfall, or from naturally occurring inoculum in the landscape beds. Because the rate of increase in number of infected plants (about 11% per year over 3 yr) was comparable among fungicide-treated and untreated, uninoculated control plants, movement of inoculum and naturally occurring inoculum may be the most important sources of inoculum for new infections.

Metalaxyl and fosetyl-Al are known to prevent root infection if applied at the time of inoculation (4,5,10). However, the high level of disease control observed over three growing seasons was probably not caused by the residual activity of these fungicides in the potting medium (6) or their persistence in the plants. Because the half-life of metalaxyl in soils is 3–8 wk depending on soil type (1;13), azaleas treated with metalaxyl may have been protected during the initial growing season in the containers and during the fall of 1986 in the landscape beds. After this time, roots would have extended beyond the original root ball into untreated soil.

Fosetyl-Al has a half-life in soil of 0.3–1.9 days (7,9). Translocation of fosetyl-Al as phosphonate from foliage to roots is very limited compared to root uptake of phosphonate from soil applications of fosetyl-Al (11). Limited translocation of fosetyl-Al could explain the high initial infection percentage observed at transplanting for azaleas treated with this fungicide.

Thus, the excellent performance of fungicide-treated, inoculated plants after 3 yr must have been caused by a low initial infection level in the case of metalaxyl-treated plants and the failure of established infections in plants treated with fosetyl-Al to limit plant growth. In addition, the inoculum density of *P. cinnamomi* in the beds was too low to result in significant symptom development as evidenced by the low symptom severities for fungicide-treated and uninoculated, untreated controls.

Severity of Phytophthora root rot would no doubt have been much greater in naturally infested landscape beds. Benson (3) observed that about 90% of untreated azaleas transplanted to a landscape bed infested with *P. cinnamomi* (4 p/g soil) had symptoms of root rot within a year. In the present study, a greater environmental stress or a longer growing period than observed might have resulted in more severe root rot.

These results emphasize that use of fungicides in a preventive program for Phytophthora root rot while the plant is containerized will result in plant growth and survival comparable to disease-free plants after transplanting to pathogen-free landscape beds. Planting untreated, inoculated plants resulted in plants with progressive symptom development and mortality over the 3-yr period. On the other hand, plants treated with fosetyl-Al or metalaxyl performed as well as the untreated, uninoculated controls even though the only fungicide applications were made in the container-production phase. Selection of planting site and the provision for irrigation to avoid plant stress may be important conditions that determine azalea growth and survival in landscape beds after fungicide applications have been discontinued.

ACKNOWLEDGMENT

I thank Billy I. Daughtry for technical assistance.

LITERATURE CITED

1. Bailey, A. M., and Coffey, M. D. 1985. Biodegradation of metalaxyl in avocado soils. Phytopathology 75:135-137.
2. Benson, D. M. 1979. Efficacy and in vitro activity of two systemic acylalanines and ethazole for control of *Phytophthora cinnamomi* root rot of azalea. Phytopathology 69:174-178.
3. Benson, D. M. 1985. Fungicides for control of Phytophthora root rot of azalea in landscape beds. Plant Dis. 69:697-699.
4. Benson, D. M. 1986. Foliar application of Aliette for control of Phytophthora root rot of azalea, 1984-1985. Fungic. Nematicide Tests 41:163.
5. Benson, D. M. 1987. Occurrence of *Phytophthora cinnamomi* on roots of azalea treated with preinoculation and postinoculation applications of metalaxyl. Plant Dis. 71:818-820.
6. Benson, D. M. 1987. Residual activity of metalaxyl and population dynamics of *Phytophthora cinnamomi* in landscape beds of azalea. Plant Dis. 71:886-891.
7. Cohen, Y., and Coffey, M. D. 1986. Systemic fungicides and the control of oomycetes. Annu. Rev. Phytopathol. 24:311-338.
8. Eckert, J. W., and Tsao, P. H. 1962. A selective antibiotic medium for isolation of *Phytophthora* and *Pythium* from plant roots. Phytopathology 52:771-777.
9. Fenn, M. E., and Coffey, M. D. 1984. Studies on the in vitro and in vivo antifungal activity of fosetyl-Al and phosphorous acid. Phytopathology 74:606-611.
10. Lambe, R. C. 1983. Control of Phytophthora root rot with Aliette granules, 1982. Fungic. Nematicide Tests 38:170.
11. Ouimette, D. G., and Coffey, M. D. 1989. Phosphonate levels in avocado (*Persea americana*) seedlings and soil following treatment with fosetyl-Al or potassium phosphonate. Plant Dis. 73:212-215.
12. Schreiber, L. R., Krause, C. R., and Mayer, J. S. 1986. Foliar application of fosetyl-Al controls Phytophthora root rot of azalea, 1985. Fungic. Nematicide Tests 41:163.
13. Sharom, M. S., and Edgington, L. V. 1982. The adsorption, mobility, and persistence of metalaxyl in soil and aqueous systems. Can. J. Plant Pathol. 4:334-340.