Chemical Control of Rhododendron Dieback Caused by *Phytophthora heveae*

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ABSTRACT

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Shoots of hybrid rhododendron cv. Roseum Elegans were protected from *Phytophthora heveae* when sprayed with captafol (0.6 g a.i./L), captan (1.2 g a.i./L), or mancozeb (0.96 g a.i./L) 1–5 days before zoospore inoculation. Chlorothalonil (1.35 g a.i./L), cupric hydroxide (0.53 g a.i./L), or dodine (0.4 g a.i./L) did not adequately control dieback. The systemic fungicides, CGA-48988 (Subdue, 0.96 g a.i./L) and LS 74-783 (Aliette, 0.96 g a.i./L), prevented shoot infection of rhododendron when applied as drenches to 2-yr-old plants, 5–8 days before inoculation. Captafol and mancozeb, at 3.84 g a.i./L, were not phytotoxic on cv. Catawbiense Album and Purple Splendour. Tenacity of the fungicides was evaluated by using a leaf disk assay from plants treated and placed under overhead irrigation (0.8 cm/day). Disks from mature leaves of Roseum Elegans were protected 7–28 days by captan, chlorothalonil, and mancozeb, but disks from young leaves were not protected at 7 days. Disks from young leaves treated with LS 74-783 were protected up to 28 days, but disks from mature leaves were not protected. Captafol and CGA-48988 protected plants from infection for 56 days after treatment. In vitro toxicity of captan, chlorothalonil, and mancozeb to linear extension of *P. heveae* was similar ($ED_{50} = 4.0\ \mu g/ml$). Captafol was more toxic ($ED_{50} = 0.17\ \mu g/ml$), although rate of inhibition was only half that for captan and mancozeb.

Additional key words: hybrid rhododendron, *Phytophthora cactorum, P. citricola, P. nicotianae* var. *parasitica*

In North Carolina, rhododendron dieback, caused by *Phytophthora cactorum* (Leb. & Cohn) Schroet., *P. citricola* Sawada, *P. heveae* Thomp., and *P. nicotianae* Breda de Haan var. *parasitica* (Dast.) Waterh., has reached epidemic proportions on container-grown hybrid rhododendron in some nurseries (3). Symptoms include light to dark brown lesions on young leaves and stems that expand rapidly. Year-old plants may be killed; stem dieback is more common in older plants. Sporangia form overnight on moist lesion surfaces resulting in secondary inoculum (sporangia or zoospores) that is disseminated during irrigation or rain (3). Growers prune out infected shoots and avoid late afternoon irrigations to control the disease. Fungicides are used as sprays to prevent infection, but little information is available on the relative efficacy and phytotoxicity of these materials on *Rhododendron* spp.

Because *P. heveae* was one of the first dieback fungi isolated during a recent survey of rhododendron nurseries (3), fungicide evaluations were done with this species.

MATERIALS AND METHODS

Efficacy tests. Two-year-old hybrid rhododendron cv. Roseum Elegans, each with 20–30 shoots with young leaves and stems (ie, terminal shoots with light green, flexible tissue and incomplete expansion), were sprayed to runoff with captafol (0.6 g a.i./L), captan (1.2 g a.i./L), chlorothalonil (1.35 g a.i./L), cupric hydroxide (0.53 g a.i./L), dodine (0.4 g a.i./L), or a coordination product of zinc ion and manganese ethylene bisdithiocarbamate, mancozeb (0.96 g a.i./L). The foliage was allowed to dry overnight. Two experimental materials, aluminum ethylphosphonate (LS 74-783, Aliette, Rhodia Inc.; 0.96 or 3.36 g a.i./L) and *N*-(2,6-dimethylphenyl)-*N*-(methoxyacetyl)-alanine methyl ester (CGA-48988, Subdue, Ciba-Geigy Inc.; 0.12 or 0.96 g a.i./L) were applied as 500-ml drenches to the container medium of plants growing in pine bark/sand (1:1, by

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volume) in 7.6-L containers. Previous experiments (2) with these materials had demonstrated their systemic activity in azalea (*Rhododendron obtusum* Planch) 6 days after drenching. Plants were inoculated in the greenhouse 1 or 5 days after spraying and 5 or 8 days after drenching.

Zoospore inoculum of *P. heveae* was prepared by growing the fungus on lima bean extract broth (50 g of frozen lima beans per liter, clarified by filtration through a 1-cm layer of Celite) for 7–14 days. Cultures were rinsed three times in sterile distilled water and chilled at 4 C for 25 min to stimulate zoospore release. Inoculum was calibrated with a hemacytometer and adjusted to 3,000 zoospores/ml. Plants with dry foliage were sprayed to runoff with a hand-pressurized sprayer. Immediately after inoculation, plants were misted 6 sec every 6 min in the greenhouse for 48 hr. Shoot infection was evaluated in 3–5 days, after which no new infections developed. Each fungicide treatment was applied to four replicate plants. Experiments were repeated one to four times, depending on the fungicide being evaluated.

Fungicide tenacity. In a second series of experiments, the tenacity of the fungicide was evaluated. Plants were sprayed or drenched with the test fungicide and then moved to a lath house after the foliage had dried. Plants were subjected to 2 hr of overhead irrigation per day (0.8 cm/day). At weekly intervals after treatment, young and mature leaves were removed from the plant and used in a leaf disk assay. Leaf disks (17-mm diameter) were cut from the leaves, placed in a moist chamber in the laboratory, and inoculated with 1,000 zoospores of *P. heveae*. Disks were incubated on the lab bench at 25 ± 2 C. There were three replications of four disks each per age-group per fungicide. Leaf disks not protected by fungicides became water-soaked and necrotic 2 days after inoculation. Infection counts were taken 5 days after inoculation.

Dosage-response relations. Linear extension of *P. heveae* from a 9-mm-diameter agar disk on cornmeal agar incorporated with various concentrations of selected fungicides was measured in vitro after 5 days at 25 C.

Phytotoxicity studies. Hybrid rhododendrons cv. Catawbiense Album and Purple Splendour with young leaves and stems were sprayed to runoff with captafol and mancozeb at four times the rate used in control studies (3.84 g a.i./L). Plants wre not irrigated 24 hr before or after spraying. Maximum greenhouse temperature averaged 31 ± 3C during the 3 days.

RESULTS AND DISCUSSION

Efficacy tests. Efficacy of fungicides in protecting hybrid rhododendron from infection by *P. heveae* varied greatly. Unprotected plants cv. Roseum Elegans developed lesions 2–3 days after inoculation. Shoot infection was 55% in unsprayed plants and ranged from 0 to 43% on sprayed plants (Fig. 1A). Captafol, captan, and mancozeb each prevented infection on rhododendrons inoculated 1 day after application. Shoot infection on plants sprayed with cupric hydroxide and dodine was 17 and 43%, respectively. These two materials were not tested further.

In a second experiment, the two systemic fungicides CGA-48988 and LS 74-783 (and chlorothalonil were evaluated along with captan, captafol, and mancozeb. Plants inoculated 8 days after drenching with CGA-48988 (0.12 g a.i./L) had 89% shoot infection (Fig. 1B). Although rate of application is 6.7-fold greater than the rate needed for control of azalea root rot caused by *P. cinnamomi* (2), the concentration of CGA-48988 reaching the foliage did not prevent infection. No infection was observed in plants drenched with LS 74-783 at 3.36 g a.i./L, although this rate is about 7.5-fold greater than the rate used in root rot experiments. Plants inoculated 1 day after spraying with chlorothalonil had 10% shoot infection. Although this level of control was significantly better than the unsprayed plants (98% infection), captan, captafol, mancozeb, and LS 74-783 gave better control of dieback.

In a third experiment, inoculation of plants drenched 5 days earlier with CGA-48988 at 0.96 g a.i./L caused only 9.3% shoot infection compared with 82% in the untreated plants. The effectiveness of LS 74-783 was not diminished when the rate was lowered to 0.96 g a.i./L as only 0.6% shoot infection occurred. Plants inoculated 5 days after spraying with captafol or captan did not become infected; 22 and 5.3% shoot infection was observed in plants sprayed with chlorothalonil and mancozeb, respectively (Fig. 1C).

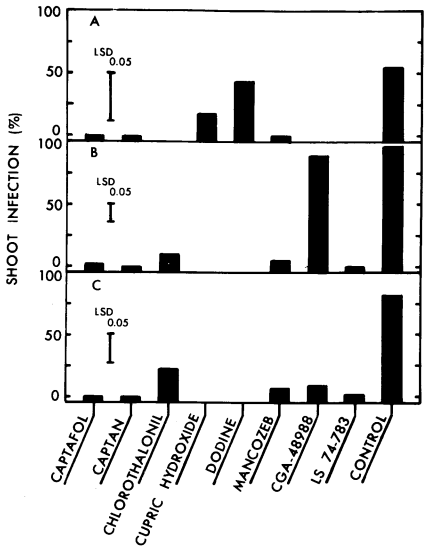

Fig. 1. Efficacy of several fungicides for control of rhododendron dieback on cv. Roseum Elegans caused by *Phytophthora heveae*: **(A)** Foliage of plants was inoculated by spraying with 3,000 zoospores/ml 1 day after spraying or 8 days after drenching the test fungicide. **(B)** CGA-48988 was applied at 0.12 g a.i./L and LS 74-783 was applied at 3.36 g a.i./L. **(C)** Plants inoculated 5 days after spraying or drenching the test fungicide. CGA-48988 and LS 74-783 were applied at 0.96 g a.i./L.

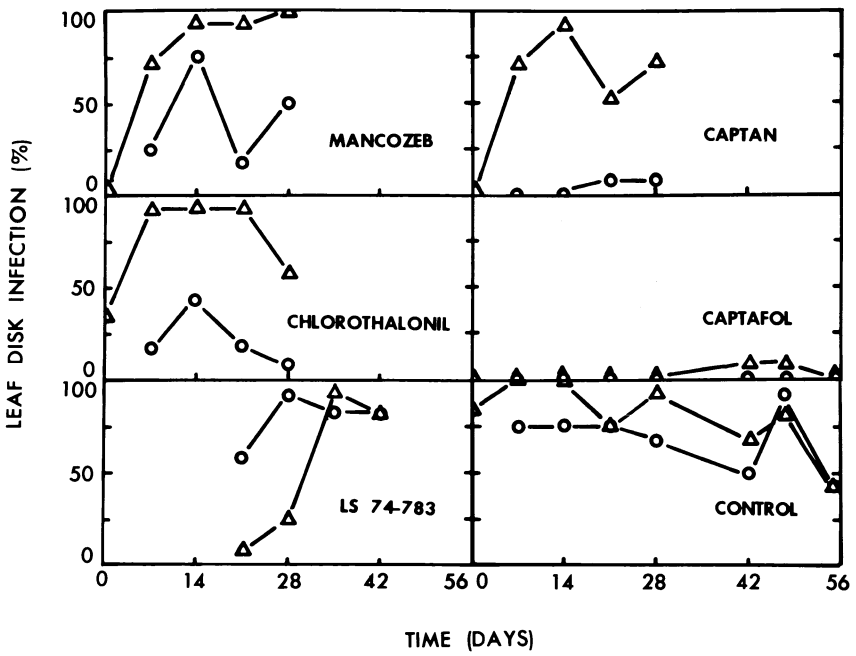

Fig. 2. Fungicide tenacity for six fungicides on hybrid rhododendron cv. Roseum Elegans over 56 days. Plants were sprayed or drenched with the test fungicide and placed in a lath house with daily overhead irrigation (0.8 cm/day). Young (Δ—Δ) and mature (o—o) leaves were removed weekly and leaf disks inoculated with *Phytophthora heveae* to determine infection.

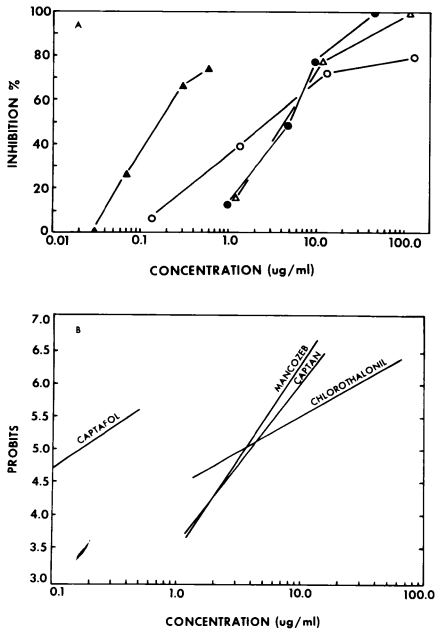

Fig. 3. Dosage-response curve for *Phytophthora heveae*. Inhibition of linear extension on cornmeal agar incorporated with captafol (▲), captan (Δ), chlorothalonil (o), mancozeb (•). **(A)** Semilogarithmic plot. **(B)** Log-probit plot. Correlation coefficients were significantly positive at $P \leq 0.01$.

Fungicide tenacity. Differences in tenacity of the fungicides were detected when Roseum Elegans plants were subjected to daily overhead irrigation. Infection of leaf disks cut from young leaves 7 days after spraying fungicides was 72, 72, and 92% for captan, mancozeb, and chlorothalonil, respectively (Fig. 2). This high incidence of infection was observed over a 28-day sampling period and indicates that these materials wash off the foliage of plants or become ineffective under daily irrigation. Untreated plants had 100% leaf disk infection at 7 days. On later sampling dates, infection of leaf disks from untreated plants varied from 42–100%. Captafol was the most tenacious fungicide tested in a spray application, with young or mature leaves protected for 56 days (Fig. 2). Albuquerque et al (1) used captafol (Difolatan 80 W) in 0.5% sprays at weekly intervals to control *P. heveae* causing leaf blight of Brazil nut (*Bertholletia excelsa*). After 4 wk no new lesions developed on trees.

The systemic materials provided protection for varied lengths of time. CGA-48988 (0.96 g a.i./L) was as persistent as captafol in both young and mature leaves with protection up to 69 days after drenching. This long interval of protection was due in part to the high rate of material applied. Further experiments are needed to determine the lowest effective rate of CGA-48988 for dieback control. Nurserymen would benefit from CGA-48988, because both roots (2) and shoots would be protected from *Phytophthora*. In addition, foliar leaching during irrigation should not occur.

Protection of young leaves with LS 74-783 (0.96 g a.i./L) lasted 21–28 days after drenching, but control was lost after 35 days (Fig. 2). Acropetal translocation of LS 74-783 was directed to the young leaves but not mature leaves, as evidenced by the greater infection counts on disks from mature leaves at 21–28 days.

Captafol, captan, chlorothalonil, and mancozeb protected mature leaves longer than young leaves from *P. heveae* in the leaf disk bioassay. After 7 days, mature leaf disk infection was only 0, 0, 16, and 25% for captafol, captan, chlorothalonil, and mancozeb, respectively (Fig. 2). Untreated mature leaves had 75% infection. In general, fungicides were more tenacious on mature leaves than on young leaves. Under nursery conditions, however, mature leaves of hybrid rhododendron are not attacked by *P. heveae* or the other dieback species of *Phytophthora* (3), so fungicide coverage is not as critical on mature portions of the plant.

Dosage-response relations. Typical S-shaped dosage-response curves were found for inhibition of linear extension of *P. heveae* on cornmeal agar incorporated with captafol, captan, chlorothalonil, or mancozeb (Fig. 3A). Curves were straightened by log-probit plots to compare rate of inhibition (slope) and ED_{50} values of the fungicides (4). Captafol was most toxic with an ED_{50} of 0.17 μg/ml (Fig. 3B). The ED_{50} values of 4.0, 3.4, and 3.6 μg/ml for captan, chlorothalonil, and mancozeb, respectively, were similar. Captafol and chlorothalonil had similar rates for inhibition of *P. heveae* with slope values of 1.3 and 1.1, respectively. Captan and mancozeb, however, inhibited *P. heveae* at twice the rate (slope values 2.4 and 2.9, respectively) of captafol and chlorothalonil. Coefficients of determination (r^2) were 0.92 or greater for all fungicides tested. Although captafol was 20 times more toxic to *P. heveae* in vitro than the above fungicides, differences in length of protection afforded rhododendrons may be due in greater part to the tenacity of the fungicide. Similar dosage-response curves were found for captafol and mancozeb when tested against *P. cactorum* (Leb. & Cohn) Schroet., *P. citricola* Sawada, and *P. nicotianae* Breda de Haan var. *parasitica* (Dast.) Waterh. (Benson, *unpublished*).

Kelley (5) found that as little as 1 μg/ml of CGA-48988 was completely inhibitory to *P. heveae* in vitro. In another study, Zentmyer et al (6) found complete inhibition of an avocado isolate of *P. heveae* at 5 μg/ml. I did not test the dosage-response relation of CGA-48988 to *P. heveae*, but in studies with *P. cinnamomi* from roots of rhododendron, in vitro inhibition ranged from an ED_{50} of 0.04 μg/ml for chlamydospore inhibition to an ED_{50} of 0.14 for sporangium inhibition (2).

Phytotoxicity studies. Although a heavy residue was evident on plants after spraying with captafol or mancozeb, no phytotoxicity symptoms developed on cv. Catawbiense Album or Purple Splendour within 30 days. Used at rates several times those effective for root rot control, the systemic fungicides LS 74-783 and CGA-48988 also were not phytotoxic on cv. Roseum Elegans.

Conclusion. The results demonstrate that captafol, captan, chlorothalonil, mancozeb, LS 74-783, and CGA-48988 have an inherent toxicity toward *P. heveae*. These fungicides will protect young tissue of hybrid rhododendron from infection, but fungicide tenacity or persistence is a critical factor in actual nursery usage. Captafol was the most tenacious fungicide tested on host tissue, and CGA-48988 was the most persistent fungicide tested in host tissue for controlling rhododendron dieback.

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LITERATURE CITED

1. ALBUQUERQUE, F. C., M. L. R. DUARTE, G. R. MANCO, and H. M. SILVA. 1974. [Leafblight of Brazil nut (*Bertholletia excelsa*) caused by *Phytophthora heveae*.] Requeima das folhas da castanheira do Para (*Bertholletia excelsa*) causada por *Phytophthora heveae*. Pesqui. Agropecu. Bras., Ser. Agron. 9:101-105.
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., and R. K. JONES. 1980. Etiology of rhododendron dieback caused by four species of *Phytophthora*. Plant Disease 64:
4. DIMOND, A. E., J. G. HORSFALL, J. W. HEUBERGER, and E. M. STODDARD. 1941. Role of dosage-response curve in the evaluation of fungicides. Conn. Agric. Exp. Stn. Bull. 451. pp. 635-667.
5. KELLEY, W. D. 1976. In vitro effect of a new fungicide, GA-1-82, on *Rhizoctonia solani* and species of *Pythium* and *Phytophthora*. (Abstr. No. S-27) Proc. Am. Phytopathol. Soc. 3:338.
6. ZENTMYER, G. A., L. J. KLURE, and E. C. POND. 1978. A new canker disease of avocado caused by *Phytophthora heveae*. Plant Dis. Rep. 62:918-922.