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CYLINDROCLADIUM ROOT AND PETIOLE ROT CONTROL UPDATE

A. R. CHASE[1]
University of Florida, IFAS
Agricultural Research and Education Center
2807 Binion Road
Apopka, FL 32703

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Abstract. **Results of tests performed for control of Cylindrocladium root and petiole rot of spathiphyllum (*Spathiphyllum* sp.) are included. Addition of the quaternary ammonium product (Prevent) at the rate of 0.52 ml a.i./liter to a benomyl drench significantly improved disease control. Use of benomyl at rates of 0.9 g a.i./liter or greater does not improve disease control and results in marginal chlorosis and necrosis of treated plants. A benomyl drench solution (0.3 g a.i./liter) was stored for 72 hr without decreasing efficacy against cylindrocladium root and petiole rot of spathiphyllum. Two new compounds, prochloraz and triflumizole, have efficacies equivalent to or greater than that of benomyl at the same rates.**

Cylindrocladium root and petiole rot remains the single most serious disease of *Spathiphyllum* species and cultivars in Florida. Recently, the disease has been found in Hawaii, where losses are steadily increasing. *Cylindrocladium spathiphylli* was found causing root and petiole rot of *Spathiphyllum* sp. 'Clevelandii' in 1979 and described in 1980 (2). Since that time, the host range of the pathogen (3) and a taxonomic description (4) have been published. One of the first reports concerning chemical control of this disease was made by the author in 1982 (1). At that time, the best fungicide was benomyl (0.3 to 0.6 a.i./liter). The research program has continued since 1982 and has included chemical, nutritional, and environmental effects on severity of cylindrocladium root and petiole rot. The research reported here describes tests with several numbered compounds, which became available for testing in 1984. In addition, several other factors relating to efficacy of benomyl were tested during this period.

Materials and Methods

All tests were performed on spathiphyllum plants obtained from commercial producers. Plants were established in steam-treated (1.5 hr at 90°C) potting medium consisting of Canadian peat and pine bark (1:1, by volume) which was amended with 4.4 kg Osmocote 19:6:12, 4.0 kg dolomite, and 0.9 kg Micromax per cubic meter of medium. Plants were maintained in a greenhouse receiving a maximum of 1500 ft-c natural light with temperatures ranging from 16 to 35°C. Drench volume was adjusted to approximately 0.5 ml/cm^2. *Cylindrocladium spathiphylli* was grown 10-14 days on potato-dextrose agar medium (PDA, infusion from 250 g boiled potatoes, and 20 g each dextrose and agar/liter). Plants were inoculated with 10 ml/pot of a mycelial suspension (1 culture plate ground in 200 ml water in a Waring Blendor) and watered lightly. Noninoculated plants were treated similarly using a PDA plate alone. Disease severity was rated on a scale from 1 (no disease) to 5 (severe disease, dead) weekly starting as the first symptoms developed and continuing until the completion of the test.

Effects of quaternary ammonium products or soaps on efficacy of benomyl

Experiment 1. Two tests were performed with a surfactant (Aquagro, 10% a.i., Mallinckrodt, Inc., St. Louis, MO 63147) added to benomyl (Benlate 50WP, E. I. duPont de Nemours & Company, Inc., Wilmington, DE 19898) as a drench (0.3 or 0.6 g a.i./liter). Aquagro was added at the rate of 0.08 ml a.i./liter. Ten plates were used for each of the following treatments: 1) noninoculated control; 2) inoculated control; 3) inoculated, drenched with benomyl (0.3 g a.i./liter; 4) inoculated, drenched with benomyl (0.6 g a.i./liter); 5) inoculated, drenched with benomyl (0.3 g a.i./liter) and Aquagro; 6) inoculated, drenched with benomyl (0.6 g a.i./liter) and Aquagro; and 7) inoculated, drenched with Aquagro only. Plants were drenched starting 12 Oct. 1984 (Test 1) or 6 Dec. 1984 (Test 2) weekly for a total of 8 applications. They were inoculated 15 Oct. 1984 (Test 1) or 10 Dec. 1984 (Test 2) and rated 21 Nov. 1984 (Test 1) or 31 Jan. 1985 (Test 2).

Experiment 2. Two tests were performed using benomyl drenches amended with a quaternary ammonium product (Prevent, 100% a.i., H. Wilson Manufacturing Co., Jefferson, GA 30543). Ten plants each were used in each of the following treatments: 1) noninoculated control; 2) inoculated control; 3) inoculated, drenched with Prevent (0.52 ml a.i./liter); 4) inoculated, drenched with Prevent (1.56 ml a.i./liter); 5) inoculated, drenched with benomyl (0.3 g a.i./liter); 6) inoculated, drenched with Prevent (0.52 g a.i./liter) and benomyl (0.3 g a.i./liter); and 7) inoculated, drenched with Prevent (1.56 g a.i./liter) and benomyl (0.3 g a.i./liter). Treatments were applied weekly starting 8 Oct. 1984 (Test 1) or 6 Dec. 1984 (Test 2) for a total of 8 applications. Plants were inoculated 9 Oct. 1984 (Test 1) or 10 Dec. 1984 (Test 2) and rated 21 Nov. 1984 (Test 1) or 20 Feb. 1985 (Test 2).

Experiment 3. A final test was performed using benomyl (0.3 g a.i./liter) amended with various surfactant or quaternary ammonium compounds. Ten plants each were used in each of the following treatments: 1) noninoculated control; 2) inoculated control; 3) benomyl; 4) Aquagro (1.25 ml a.i./liter); 5) Physan (a quaternary ammonium product, 20% a.i., Consan Pacific, Inc., Whittier, CA 90608) (1.0 ml a.i./liter); 6) Prevent (0.13 ml a.i./liter); 7) Ivory Liquid (Proctor & Gamble, Cincinnati, OH, 45202) (5.0 ml/liter); 8) benomyl and Aquagro (rates above); 9) benomyl and Physan (rates above); 10) benomyl and Prevent (rates above); and 11) benomyl and Ivory (rates above). Treatments were applied weekly starting on 7 Feb. 1985 for a total of 10 applications. Plants were inoculated 8 Feb. and rated 11 Apr. 1985.

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[1]Associate Professor of Plant Pathology.

Effect of storage time on efficacy of benomyl

Experiment 4. A single test was performed to evaluate effect of storing a tank of benomyl (0.3 g a.i./liter) for up to 72 hr under the greenhouse conditions mentioned earlier. The following storage times were tested in addition to noninoculated and inoculated control treatments: 0, 1, 2, 4, 8, 24, 48, and 72 hr. The pH of the solution was recorded prior to use. Ten plants per treatment were drenched weekly starting 19 Feb. 1985 for a total of 9 applications. Plants were inoculated 18 Feb. and rated 11 and 18 Apr. 1985.

Evaluation of benomyl rates

Experiment 5. Ten plants each were used in each of the following treatments: 1) noninoculated control; 2) inoculated control; 3) benomyl (0.6 g a.i./ liter); 4) benomyl (1.2 g a.i./liter); and 5) benomyl (2.4 g a.i./liter). Plants were inoculated 15 Oct., treated weekly (8 times) starting 18 Oct. and rated 13 Dec. 1984.

Evaluations of experimental compounds

Experiment 6. Two trials were performed with benomyl dithianon (MF-711, 50WP, Mallinckrodt, Inc.) and prochloraz (MF-718, 50WP, Mallinckrodt, Inc.) and one with triflumizole (A-815, 50WP, UNIROYAL, Inc., Raleigh, NC 27609). All compounds were used at the rate of 0.6 g a.i./liter using 10 plants per treatment including noninoculated and inoculated controls. Treatments were applied 10 times weekly starting 5 Oct. (Test 1) or 26 Oct. 1984 (Test 2). Plants were inoculated 9 Oct. (Test 1) or 8 Nov. 1984 (Test 2) and rated 21 Nov. 1984 (Test 1) or 2 Jan. 1985 (Test 2).

Experiment 7. A single test compared 4 rates each of benomyl and prochloraz. Ten plants each were included in each treatment for noninoculated and inoculated controls and benomyl or prochloraz at 0.3, 0.6, 0.9, or 1.2 g a.i./liter. Plants were treated for a total of 8 weeks starting 18 Dec. 1984, inoculated 14 Dec. 1984, and rated 13 Feb. 1985.

Experiment 8. In the final test, both single and combination treatments of benomyl, prochloraz, and triflumizole were evaluated. Ten plants each were used in each of the following treatments: 1) noninoculated control; 2) inoculated control; 3) inoculated, drenched with triflumizole (0.15 g a.i./liter); 4) inoculated, drenched with triflumizole (0.3 g a.i./liter; 5) inoculated, drenched with triflumizole and benomyl (0.15 g a.i./liter each); 6) inoculated, drenched with triflumizole and prochloraz (0.15 g a.i./liter each); 7) inoculated, drenched with prochloraz (0.15 g a.i./ liter); 8) inoculated, drenched with prochloraz (0.3 g a.i./ liter); 9) inoculated, drenched with prochloraz and benomyl (0.15 g a.i./liter each); and 10) inoculated, drenched with benomyl 0.3 g a.i./liter). Treatments were applied weekly for 6 weeks starting 1 Apr., inoculated 2 Apr., and rated 7 and 16 May 1985.

Results and Discussion

Effects of quaternary ammonium products or soaps on efficacy of benomyl

Experiment 1. When Aquagro was used alone in the first test, it did not provide any disease control, but in Test 2 it did provide slight disease control when disease severity was less (Table 1). This could be due to increased water retention of the potting medium treated with Aquagro. Decreasing the water stress could result in a decrease in disease severity. There was no interaction between Aquagro and benomyl in either test (Table 1).

Table 1. Effect of adding Aquagro to benomyl for the control of cylindrocladium root and petiole rot of *Spathiphyllum* sp. (Expt. 1).

Treatment[z]	Rate (a.i./liter)	Mean disease severity rating[y] Test 1	Test 2
Noninoculated[x]	—	1.0 a[w]	1.0 a
Inoculated	—	5.0 c	3.9 c
Benomyl	0.3 g	3.4 b	1.1 a
Benomyl	0.6 g	1.8 a	1.0 a
Benomyl and Aquagro	0.3 g 0.08 ml	3.0 b	1.5 a
Benomyl and Aquagro	0.6 g 0.08 ml	1.8 a	1.1 a
Aquagro	0.08 ml	5.0 c	2.9 b

[z]Plants were drenched at the rate of 0.5 ml/cm^2 weekly starting on 12 Oct. (Test 1) or 6 Dec. 1984 (Test 2) for a total of 8 weeks.
[y]Mean rating for ten replicates according to the following scale: 1 = no disease, 2 = 1-25% diseased, 3 = 26-50% diseased, 4 = 51-75% diseased, and 5 = 76-100% diseased, usually dead.
[x]Test 1 plants were inoculated on 15 Oct. and rated on 21 Nov. 1984 and Test 2 plants were inoculated on 10 Dec. 1984 and rated on 31 Jan. 1985.
[w]Mean separation in columns by Duncan's new multiple range test, 5% level.

Table 2. Effect of Prevent and benomyl mixtures on severity of cylindrocladium root and petiole rot of *Spathiphyllum* sp. (Expt. 2).

Treatment[z]	Rate (a.i./liter)	Mean disease severity rating[y] Test 1	Test 2
Noninoculated[x]	—	1.0 a[w]	1.0 a
Inoculated	—	3.7 d	3.6 c
Prevent	0.52 ml	3.0 c	2.4 b
Prevent	1.56 ml	3.2 cd	2.2 b
Benomyl	0.3 g	2.8 c	1.8 b
Prevent and Benomyl	0.52 ml 0.3 g	1.6 b	1.3 a
Prevent and Benomyl	1.56 ml 0.3 g	1.6 b	2.0 b

[z]Plants drenched at the rate of 0.5 ml/cm^2 weekly starting on 8 Oct. (Test 1) or 6 Dec. 1984 (Test 2) for a total of 8 weeks.
[y]Mean severity rating for 10 replicates based on the following scale: 1 = no disease, 2 = 1-25% diseased, 3 = 26-50% diseased, 4 = 51-75% diseased, and 5 = 76-100% diseased, usually dead.
[x]Test 1 plants were inoculated on 9 Oct. and rated on 21 Nov. 1984 and Test 2 plants were inoculated on 10 Dec. 1984 and rated on 20 Feb. 1985.
[w]Mean separation in columns by Duncan's new multiple range test, 5% level.

Experiment 2. In both tests, Prevent provided a significant degree of disease control when used alone (Table 2). The degree of control was not as high as benomyl used alone and Prevent drenches should not supplant benomyl drenches. The combination treatment of benomyl and Prevent had significantly less disease than treatments receiving either component singly (Table 2). The difference between the 2 rates of Prevent was negligible and the lower rate should be used.

Experiment 3. In this test, none of the compounds added to the benomyl drench significantly improved disease control compared to the benomyl drench alone (Table 3). Use

Table 3. Effect of spray additives on efficacy of benomyl in controlling cylindrocladium root and petiole rot of *Spathiphyllum* sp. (Expt. 3).

Treatment[z]	Rate (a.i./liter)	Mean disease severity rating[y]
Noninoculated[x] control	—	1.1 a[w]
Inoculated control	—	3.9 c
Benomyl	0.3 g	1.5 a
Aquagro	1.25 ml	3.3 bc
Physan	1.0 ml	3.4 bc
Prevent	0.13 ml	2.7 b
Ivory soap	5.0 ml (formulated)	3.6 c
Benomyl and Aquagro	0.3 g 1.25 pt	1.2 a
Benomyl and Physan	0.3 g 1.0 ml	1.1 a
Benomyl and Prevent	0.3 g 0.13 ml	1.0 a
Benomyl and Ivory soap	0.3 g 5.0 ml (formulated)	1.6 a

[z]Plants were drenched at the rate of 0.5 ml/cm² weekly starting on 7 Feb. 1985 for a total of 10 applications.
[y]Mean rating for ten replicates according to the following scale: 1 = no disease, 2 = 1-25% diseased, 3 = 26-50% diseased, 4 = 51-75% diseased, and 5 = 76-100% diseased, usually dead.
[x]Plants were inoculated on 8 Feb. and rated on 11 Apr. 1985.
[w]Mean separation in columns by Duncan's new multiple range test, 5% level.

of these products alone also failed to provide control of this disease with the exception of Prevent. Although Prevent gave a moderate degree of disease control when used alone, addition to the benomyl drench did not result in improved control. This may be due to the lower rate of Prevent used in this test compared to the first two.

Effect of storage time on efficacy of benomyl

Experiment 4. Over a period of 8 weeks, benomyl was as effective when used after 72 hr under greenhouse conditions as it was when used freshly prepared (Table 4). The pH of the solution ranged from 7.12 to 7.14 during the trial, but did not alter significantly over a 72 hr period.

Table 4. Effect of storing a solution of benomyl on efficacy in controlling cylindrocladium root and petiole rot of *Spathiphyllum* sp. (Expt. 4).

	Mean disease severity rating[y]	
Treatment[z]	11 Apr.	18 Apr.
Noninoculated control[x]	1.0 a[w]	1.0 a
Inoculated control	3.1 b	3.2 c
Fresh solution	1.4 a	1.6 ab
Stored 1 hr	1.2 a	1.5 ab
Stored 2 hr	1.5 a	1.6 ab
Stored 4 hr	1.0 a	1.4 ab
Stored 8 hr	1.4 a	1.5 ab
Stored 24 hr	1.7 a	1.9 b
Stored 48 hr	1.5 a	1.8 ab
Stored 72 hr	1.2 a	1.4 ab

[z]Plants were drenched at the rate of 0.5 ml/cm² weekly starting on 19 Feb. 1985 for a total of 9 applications. Benomyl was used at the rate of 0.3 g a.i./liter.
[y]Mean rating in Apr. 1985 for ten replicates according to the following scale: 1 = no disease, 2 = 1-25% diseased, 3 = 26-50% diseased, 4 = 51-75% diseased, and 5 = 76-100% diseased, usually dead.
[x]Plants were inoculated on 18 Feb. 1985 and rated as indicated.
[w]Mean separation in columns by Duncan's new multiple range test, 5% level.

Fig. 1. Marginal chlorosis and necrosis of *Spathiphyllum* sp. treated with 8 weekly drench applications of 1.2 g a.i./liter benomyl.

Evaluation of benomyl rates

Experiment 5. Rates of benomyl of 1.2 or 2.4 g a.i./liter caused severe phytotoxicity to *Spathiphyllum* sp. (Fig. 1). Symptoms included marginal chlorosis and necrosis with affected tissue first turning gray and then tan with time. Disease severity was significantly affected by increasing rates of benomyl: 4.0, 1.9, 1.2, and 1.0 for 0, 0.6, 1.2, and 2.4 g a.i./liter, respectively. Although disease control was significantly better for plants treated with the 1.2 g rate, it should not be used due to phytotoxicity.

Evaluations of experimental compounds

Experiment 6. In the first test, both prochloraz and benomyl provided excellent control of cylindrocladium root and petiole rot (Table 5). In the second test, prochloraz and triflumizole provided excellent control, while benomyl failed to control the disease. Under conditions of high disease pressure, benomyl occasionally fails to provide control of this disease. Dithianon did not provide a high enough degree of control in either test to warrant further testing.

Experiment 7. Comparisons of different rates of benomyl and prochloraz resulted in a similar level of control (Table 6). However, benomyl at rates of 0.9 g a.i./liter or above resulted in marginal necrosis on up to 80% of the plants.

Experiment 8. Of all treatments included on the final trial, only plants treated with benomyl alone developed the same level of disease as the inoculated control plants (Table

Table 5. Efficacy of some fungicides on *Spathiphyllum* sp. artificially inoculated with *Cylindrocladium spathiphylli*. (Expt. 6).

Treatment[z]	Rate (a.i./liter)	Mean disease severity rating[y] Test 1	Test 2
Noninoculated[x]	—	1.0 a[w]	1.0 a
Inoculated	—	4.2 c	5.0 c
Triflumizole	0.6 g	—	1.0 a
Dithianon	0.6 g	2.8 b	2.6 b
Prochloraz	0.6 g	1.0 a	1.0 a
Benomyl	0.6 g	1.0 a	3.7 bc

[z]Plants were drenched at the rate of 0.5 ml/cm² starting on 5 Oct. (Test 1) or 26 Oct. 1984 (Test 2) weekly for a total of 10 weeks.
[y]Mean disease severity for 10 replicates rated as follows: 1 = no disease, 2 = 1-25% diseased, 3 = 26-50% diseased, 4 = 51-75% diseased, and 5 = 76-100% diseased, usually dead.
[x]Plants were inoculated on 9 Oct. and rated on 21 Nov. 1984 for Test 1 and inoculated on 8 Nov. 1984 and rated on 2 Jan. 1985 for Test 2.
[w]Mean separation in columns by Duncan's new multiple range test, 5% level.

Table 6. Effect of use of benomyl or prochloraz on efficacy and phytotoxicity on *Spathiphyllum* sp. artificially inoculated with *Cylindrocladium spathiphylli* (Expt. 7).

Treatment[z]	Rate (a.i./liter)	Mean disease severity rating[y]	% plants with marginal necrosis
Noninoculated[x]	—	1.2 a[w]	0
Inoculated	—	3.2 d	0
Benomyl	0.3 g	1.8 bc	0
Benomyl	0.6 g	1.2 a	10
Benomyl	0.9 g	1.1 a	80
Benomyl	1.2 g	1.3 ab	70
Prochloraz	0.3 g	1.9 c	0
Prochloraz	0.6 g	1.8 bc	0
Prochloraz	0.9 g	1.3 ab	0
Prochloraz	1.2 g	1.3 ab	0

[z]Plants were drenched at the rate of 0.5 ml/cm² weekly starting on 7 Feb. 1985 for a total of 8 weeks.
[y]Mean disease severity rating for 10 replicates rated as follows: 1 = no disease, 2 = 1-25% diseased, 3 = 26-50% diseased, 4 = 51-75% diseased, and 5 = 76-100% diseased, usually dead.
[x]Plants were inoculated on 14 Dec. 1984 and rated on 13 Feb. 1985.
[w]Mean separation in columns by Duncan's new multiple range test, 5% level.

7). In this case, both prochloraz and triflumizole gave good to excellent control of cylindrocladium root and petiole rot when used alone or in combination with each other of benomyl. Optimal disease control was achieved with a combination of prochloraz showing the best overall disease control.

Summary

In general, the following conclusions can be drawn from the preceding tests for chemical control of Cylindrocladium root and petiole rot of *Spathiphyllum* species and cultivars:

1. Addition of Prevent at the rate of 0.52 ml a.i./liter (equivalent to 0.52 gal/100 gal) to a benomyl drench solution gives improved disease control compared to use of benomyl alone.
2. A solution of benomyl (0.3 g a.i./liter, equivalent to 0.5 lb. Benlate 50WP/100 gal) can be maintained under greenhouse conditions for up to 72 hr without a significant loss in efficacy.
3. Benomyl should not be used on *Spathiphyllum* spp. at rates of 0.9 g a.i./liter (equivalent to 1.5 lb. Benlate 50WP/100 gal) or above since phytotoxicity develops on treated plants.
4. Prochloraz provides superior control and triflumizole provides equivalent or superior control when used at the same rates for cylindrocladium root and petiole rot of *Spathiphyllum* spp.

Table 7. Efficacy of benomyl, prochloraz, and triflumizole used singly and in combination for control of cylindrocladium root rot of *Spathiphyllum* sp. (Expt. 8).

Treatment[z]	Rate (a.i./liter)	Mean disease severity rating[y] 7 May	16 May
Noninoculated[x]	—	1.1 a[w]	1.2 a
Inoculated	—	3.7 d	4.0 c
Triflumizole	0.15 g	1.6 ab	1.9 b
Triflumizole	0.3 g	1.9 b	2.1 b
Triflumizole and Benomyl	0.15 g 0.15 g	1.4 ab	1.6 ab
Triflumizole and Prochloraz	0.15 g 0.15 g	1.6 ab	1.9 b
Prochloraz	0.15 g	1.4 ab	1.6 ab
Prochloraz	0.3 g	1.3 ab	1.5 ab
Prochloraz and Benomyl	0.15 g 0.15 g	1.1 a	1.2 a
Benomyl	0.3 g	2.5 c	3.8 c

[z]Plants were drenched at the rate of 0.5 ml/cm² weekly starting on 1 Apr. 1985 for a total of 6 applications.
[y]Mean rating in May 1985 for ten replicates according to the following scale: 1 = no disease, 2 = 1-25% diseased, 3 = 26-50% diseased, 4 = 51-75% diseased, and 5 = 76-100% diseased, usually dead.
[x]Plants were inoculated on 2 Apr. 1985.
[w]Mean separation in columns by Duncan's new multiple range test, 5% level.

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