Control of Phytophthora Root and Foot Rot of Citrus with Systemic Fungicides Metalaxyl and Phosethyl Aluminum

R. M. DAVIS, Assistant Professor, Texas A&I University Citrus Center, Weslaco 78596

ABSTRACT

Davis, R. M. 1982. Control of Phytophthora root and foot rot of citrus with systemic fungicides metalaxyl and phosethyl aluminum. Plant Disease 66:218-220.

Soil drenches of metalaxyl (100 mg a.i./L) and foliar sprays of phosethyl aluminum (2,000 mg a.i./L) reduced root rot of potted sour orange seedlings inoculated with *Phytophthora parasitica*. Metalaxyl at a higher rate (200 mg a.i./L) was phytotoxic to potted citrus but not to field trees. Lesions caused by *P. parasitica* on the trunks of 2-yr-old trees were controlled with foliar sprays of phosethyl aluminum or treatments with metalaxyl as either a soil drench or trunk paint. Metalaxyl as a trunk paint was the only treatment that arrested development of lesions on 5-yr-old trees. In a bioassay using zoospores of *P. parasitica*, systemic fungicidal activity was detected in bark disks from the trunks of 2-yr-old trees for at least 12 wk following application of metalaxyl as a trunk paint. Activity of metalaxyl as a soil drench was detected for 6 wk and activity in phosethyl aluminum treatments for 8 wk. Activity in trunks of 5-yr-old trees treated with metalaxyl as a bark paint was detected for at least 21 wk. Little or no activity was found in 5-yr-old trees treated with phosethyl aluminum or soil drenches of metalaxyl.

Measures for controlling citrus trunk lesions caused by *Phytophthora parasitica* Dast. are largely preventive. When infection does occur, application of a fungicide to the infection site after removal of the bark is the recommended treatment. However, this technique is laborious and becomes uneconomical when attempted on a large scale. Two promising new fungicides with systemic activity offer foot rot control without the expensive labor involved in tree surgery. One fungicide, metalaxyl, has been used experimentally and commercially to control Phytophthora diseases (1,5,7).

Accepted for publication 8 June 1981.

The publication costs of this article were defrayed in part by page charge payment. This article must therefore be hereby marked "*advertisement*" in accordance with 18 U.S.C. §1734 solely to indicate this fact.

0191-2917/82/03021803/$03.00/0

Timmer (5) applied metalaxyl as a soil drench or trunk paint to containerized citrus and showed that systemic activity against *P. parasitica* persisted for several weeks. Recently, another systemic fungicide, phosethyl aluminum [aluminum tris (-0-ethyl phosphonate)], became available for experimentation with pythiaceous fungi. Phosethyl aluminum is reported to have curative effects in citrus against *P. parasitica* (2).

In this study I report on the efficacy of metalaxyl and phosethyl aluminum treatments in controlling root rot and arresting development of lesions caused by *P. parasitica* on the trunks of citrus trees in the field. A comparison of the duration of systemic activities of metalaxyl and phosethyl aluminum was made using a bioassay.

MATERIALS AND METHODS

Phytophthora root and foot rot control. Fungicides were applied to 10-wk-old sour orange (*Citrus aurantium* L.) seedlings grown in 10-cm-diameter pots of heat-sterilized soil. Metalaxyl 2EC was applied as a soil drench of 100 ml/pot; phosethyl aluminum 30WP was sprayed on the foliage of seedlings until runoff. Controls were left untreated. Seedlings were inoculated with *P. parasitica* 14 days after fungicide application. After the seedlings were washed free of potting mix, roots of seedlings were submerged for 1 hr in 600 ml of water containing 1,000 zoospores of *P. parasitica* (isolated from an active lesion on Texas citrus) per milliliter. Zoospores were produced and suspended in water by the method of Menyonga and Tsao (3). Roots of seedlings not inoculated with *P. parasitica* were submerged in water for 1 hr. Each fungicide was reapplied 3 wk later. Total dry weights and percentages of healthy roots were recorded 12 wk after inoculation. Discolored or necrotic roots were considered to be infected with *P. parasitica*.

Trunks of 2- and 5-yr-old grapefruit (*C. paradisi* Macf.) trees on sour orange rootstock were inoculated with *P. parasitica* to study the efficacy of the fungicides on foot rot control. One 5-mm plug of *P. parasitica* grown on V-8 juice agar was placed in each of two wounds made with a sterilized cork borer drilled through the bark of the trunk. Inoculation sites were wrapped with plastic tape to prevent desiccation. Controls received sterile V-8 juice agar. Fungicides were applied 3 wk before and 5 wk after the inoculations. Metalaxyl was applied as either a soil drench (15 L in a 1-m^2 basin followed by an irrigation) or a trunk paint

(15 ml/tree). Phosethyl aluminum was sprayed on the foliage with a handgun until runoff. Treatments were replicated nine times in three-tree plots arranged in randomized complete block designs. The bark surrounding the inoculation sites was removed 60 days after inoculation to measure the extent of the discoloration of the cambial surface that is typical of *Phytophthora* lesions.

Relative activity of fungicides in a bioassay. The systemic activity of metalaxyl and phosethyl aluminum was tested in a bioassay developed by Timmer (4). Fungicides were applied to 2-yr-old grapefruit trees in 6-L containers and to 5-yr-old grapefruit trees in the field. Each fungicidal treatment was replicated on nine trees of each age. Periodically after treatments, two 5-mm-diameter disks cut from the bark of the trunk of treated trees were placed in petri dishes containing moist filter paper. A 30-μl suspension of zoospores of *P. parasitica* at 4×10^4 zoospores per milliliter was applied to the cambial surface of each disk. After an incubation at 23–27 C for 24 hr, the disks were inverted and placed on pimaricin-vancomycin-pentachloronitrobenzene-hymexazol (6) media and incubated again at 23–27 C. Colony diameters were measured after 48 hr. Inhibition of colony growth because of the fungicide in the tissue was expressed as the reduction of growth of *P. parasitica* compared with colony growth from disks cut from untreated trees.

RESULTS

Phytophthora root and foot rot control. Both metalaxyl and phosethyl aluminum provided root protection against *P. parasitica* on seedlings. Total dry weights of seedlings inoculated with *P. parasitica* and treated with phosethyl aluminum or the low rate of metalaxyl were significantly greater than weights of untreated, inoculated seedlings (Table 1). The high rate of metalaxyl was phytotoxic; dry weights of uninoculated seedlings were reduced when treated with metalaxyl at 200 mg a.i./L. Phytotoxic symptoms included extensive root necrosis, chlorotic leaf margins, and leaf drop. No phytotoxicity symptoms were observed with phosethyl aluminum or the low rate of metalaxyl. *Phytophthora* severely reduced the number of healthy roots on untreated seedlings, but root systems on seedlings treated with phosethyl aluminum or with the low rate of metalaxyl were healthy.

Both fungicides effectively inhibited *P. parasitica* on the trunks of the 2-yr-old trees. The trunk paint with metalaxyl was the most effective treatment, as all *Phytophthora* lesions were inactive at the time of measurement (Table 2). Lesions on 5-yr-old trees were not significantly reduced by phosethyl aluminum or soil drenches of metalaxyl (Table 2). However, both rates of metalaxyl as a trunk paint effectively arrested lesion development. There were no phytotoxicity symptoms with any material on trees of either age.

Relative activity of fungicides in a bioassay. All fungicides in tissue from the 2-yr-old containerized trees significantly inhibited *P. parasitica* by the fourth week following treatment (Table 3). Fungicidal activity in tissue from trees treated with metalaxyl as a soil drench inhibited *P. parasitica* for 6 wk. Significant activity in trees treated with phosethyl aluminum was found in the eighth week following treatment. Metalaxyl as trunk paint was the most effective treatment; significant activity was found in tissue for at least 12 wk. The high rates of metalaxyl both as a trunk paint and soil drench caused various degrees of chlorosis on the margins of leaves. One container-grown tree treated with the high rate of metalaxyl as a trunk paint dropped most of its leaves.

Metalaxyl as a trunk paint was the only treatment that exhibited long-term fungicidal activity in bark tissues of the 5-yr-old field trees (Table 4). Systemic activity was found with phosethyl aluminum at 3 wk following fungicide application, but little activity was found thereafter. There were no phytotoxicity symptoms on any trees.

Table 1. Effect of fungicide treatment on growth and percentages of healthy roots of sour orange seedlings inoculated with *Phytophthora parasitica*

Fungicide[y]	Rate (mg a.i./L)	Total dry wt (g)[z]		Healthy roots (%)[z]	
		Control	Inoculated	Control	Inoculated
None	...	4.3 a	2.1 c	92 a	34 b
Metalaxyl	100	4.0 a	3.6 ab	82 a	81 a
Metalaxyl	200	2.8 bc	1.9 c	30 b	32 b
Phosethyl aluminum	2,000	4.1 a	3.8 a	90 a	85 a

[y] Metalaxyl was applied in 200 ml of water per 10-cm container, and phosethyl aluminum was sprayed on the foliage until runoff. Fungicides were applied 14 days before and 21 days after inoculation with *P. parasitica*.

[z] Each value is the mean of 10 replicates. Means separated by Duncan's multiple range test, $P = 0.05$.

Table 2. Effect of fungicide treatment on development of trunk lesions caused by *Phytophthora parasitica*

Fungicide[y]	Treatment	Rate	Lesion diam (cm)[z] on tree aged	
			2 yr	5 yr
None	...	...	5.4 a	6.2 ab
Metalaxyl	Soil drench	1.25 g a.i./m^2	4.2 b	6.5 a
Metalaxyl	Soil drench	2.5 g a.i./m^2	0.7 c	5.2 ab
Metalaxyl	Trunk paint	60 g a.i./L	0.0 c	1.75 c
Metalaxyl	Trunk paint	90 g a.i./L	0.0 c	0.8 c
Phosethyl aluminum	Foliar spray	2.4 g a.i./L	3.3 b	5.9 ab
Phosethyl aluminum	Foliar spray	4.8 g a.i./L	0.8 c	4.7 b

[y] Fungicides applied 3 wk before and 5 wk after inoculation with *P. parasitica*. Lesions measured 60 days after inoculation.

[z] Each value is the mean of 18 replicates. Means in each column separated by Duncan's multiple range test, $P = 0.05$.

Table 3. Duration of systemic activity in the trunks of 2-yr-old containerized grapefruit trees following fungicide application

Fungicide	Treatment	Rate	Inhibition (%) of *Phytophthora parasitica*[z] Days after fungicide treatment					
			14	28	42	56	70	84
None	...	...	0 d	0 c	0 e	0 c	0 b	0 b
Metalaxyl	Soil drench	1.25 g a.i./m^2	27 bc	53 b	50 bc	21 b	21 b	5 b
Metalaxyl	Soil drench	2.5 g a.i./m^2	33 bc	100 a	67 b	12 bc	23 b	23 b
Metalaxyl	Trunk paint	60 g a.i./L	100 a	100 a	100 a	67 a	84 a	71 a
Metalaxyl	Trunk paint	90 g a.i./L	100 a	100 a	100 a	80 a	100 a	91 a
Phosethyl aluminum	Foliar spray	2.4 g a.i./L	17 cd	100 a	14 de	24 b	2 b	6 b
Phosethyl aluminum	Foliar spray	4.8 g a.i./L	37 b	100 a	30 cd	31 b	0 b	13 b

[z] Percentage of reduction in colony area compared with the untreated control in a bioassy using *P. parasitica* zoospores. Means in each column separated by Duncan's multiple range test, $P = 0.05$.

Table 4. Duration of systemic activity in the trunks of 5-yr-old grapefruit trees in the field following fungicide application

Fungicide	Treatment	Rate	Inhibition (%) of *Phytophthora parasitica*[z] Days after fungicide treatment				
			21	35	63	105	147
None	...	...	0 c	0 b	0 b	0 b	0 b
Metalaxyl	Soil drench	1.25 g a.i./m^2	1 c	2 b	0 b	0 b	0 b
Metalaxyl	Soil drench	2.5 g a.i./m^2	4 c	3 b	0 b	0 b	0 b
Metalaxyl	Trunk paint	60 g a.i./L	100 a	80 a	93 a	66 a	60 a
Metalaxyl	Trunk paint	90 g a.i./L	100 a	100 a	93 a	100 a	97 a
Phosethyl aluminum	Foliar spray	2.4 g a.i./L	14 bc	0 b	0 b	0 b	0 b
Phosethyl aluminum	Foliar spray	4.8 g a.i./L	34 b	8 b	2 b	0 b	0 b

[z] Percentage of reduction in colony area compared with the untreated control in a bioassay using *P. parasitica* zoospores. Means in each column separated by Duncan's multiple range test, $P = 0.05$.

DISCUSSION

Both metalaxyl and phosethyl aluminum effectively reduced root rot on potted seedlings. Phytotoxicity symptoms were observed with high rates of metalaxyl, but the fungicide was probably excessively concentrated in the small pots. No phytotoxicity symptoms were observed in field trees with any of the materials.

Systemic fungicides offer a new dimension in control of foot rot lesions that have been difficult to treat with contact fungicides because the fungus spreads beneath the bark. Foliar sprays of phosethyl aluminum and metalaxyl as either a soil drench or bark paint significantly stopped lesion development on 2-yr-old trees. The most effective treatment for trunk lesions was the bark paint with metalaxyl, which was concentrated at the area of *Phytophthora* development. This was the only treatment that controlled *P. parasitica* on the 5-yr-old trees.

Data from the bioassay indicate that uptake and movement of both fungicides occurred in the small containerized trees but that little material moved into the trunk region of the 5-yr-old field trees treated with soil drenches of metalaxyl or sprayed with phosethyl aluminum. More than two applications of metalaxyl as a soil drench or phosethyl aluminum foliar sprays may be necessary for good foot rot control. In addition, better timing of application may improve the effectiveness of phosethyl aluminum, because the small amount of activity found in the trunk suggested by the bioassay data may indicate problems with foliar uptake, downward translocation, or both.

The relative ineffectiveness of soil drenches with metalaxyl in controlling lesions on the 5-yr-old trees may indicate poor uptake by the roots resulting from poor downward movement of the fungicide through the heavy clay soils of south Texas. The shallower root systems of the 2-yr-old trees may have come into better contact with the fungicide. Increased effectiveness of metalaxyl as a trunk paint was apparent in all trees. The bioassay data suggest that metalaxyl moves quickly through the bark and is present in relatively high concentrations for long periods.

ACKNOWLEDGMENT

I thank Howard S. Wilhite for technical assistance.

LITERATURE CITED

1. Biehn, W. L., Young, T., Dill, T. R., Snow, J., and Seifried, E. B. 1978. CGA-48988, a unique fungicide for control of the Oomycetes. (Abstr.) Phytopathol. News 12:142.
2. Laville, E. 1979. Use of a new systemic fungicide, Aliette, in the control of citrus gummosis due to *Phytophthora*. Fruits 34:35-41.
3. Menyonga, J. M., and Tsao, P. H. 1966. Production of zoospore suspensions of *Phytophthora parasitica*. Phytopathology 56:359-360.
4. Timmer, L. W. 1977. Preventive and curative trunk treatments for control of Phytophthora foot rot of citrus. Phytopathology 67:1149-1154.
5. Timmer, L. W. 1979. Preventive and systemic activity of experimental fungicides against *Phytophthora parasitica* on citrus. Plant Dis. Rep. 63:324-327.
6. Tsao, P. H., and Guy, S. O. 1977. Inhibition of *Mortierella* and *Pythium* in a *Phytophthora*-isolation medium containing hymexazol. Phytopathology 67:796-801.
7. Zentmyer, G. A., and Ohr, H. D. 1978. Systemic soil fungicides for control of Phytophthora root rot and stem canker of avocado. (Abstr.) Phytopathol. News 12:142-143.