Effectiveness of Metalaxyl and Fosetyl Al Against *Phytophthora parasitica* on Sweet Orange

L. W. TIMMER, Professor, and W. S. CASTLE, Associate Professor, University of Florida, Institute of Food and Agricultural Sciences, Citrus Research and Education Center, 700 Experiment Station Road, Lake Alfred 33850

ABSTRACT

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In a 3-yr study, metalaxyl and fosetyl Al were evaluated as soil drenches, trunk paints, and foliar sprays for control of *Phytophthora parasitica* in newly planted sweet orange trees on sweet orange rootstock. After application of metalaxyl as a soil drench or trunk paint, fungitoxic activity, as determined by bioassay, persisted for 3–4 mo in twigs and roots during the first 2 yr. In the third year, activity was less, probably because of dilution of the fungicide in the larger trees. Fungitoxic activity was less when metalaxyl was applied as a foliar spray. Application of fosetyl Al by all methods only occasionally produced fungitoxic activity detectable by bioassay. Both fungicides reduced foot rot incidence, but none of the treatments increased growth of the trees compared with untreated controls, indicating that root rot may have been of minor importance.

Several disease problems have severely limited the choice of citrus rootstocks for Florida growers. Rough lemon (*Citrus jambhiri* Lush.) rootstock, which once accounted for more than 60% of the citrus trees in Florida, is now rarely used because of its susceptibility to citrus blight (13). Carrizo citrange (*Poncirus trifoliata* Raf. × *C. sinensis* (L.) Osb.) has been widely used to replace rough lemon, but it is also susceptible to blight (13). The future of the other major rootstock in Florida, sour orange (*C. aurantium* L.), is uncertain because of its intolerance to citrus tristeza virus. On sites infested with the burrowing nematode (*Radopholus citrophilis* Huettel), only the resistant rootstocks, Milam (*C. jambhiri* variant), Carrizo citrange, or Ridge Pineapple sweet orange (*C. sinensis*) are presently suitable (7).

There has been little interest in the use of sweet orange as a rootstock because of its lack of drought tolerance and its susceptibility to Phytophthora foot and root rot (1). With good management, however, trees on sweet orange rootstock produce relatively large crops of high-quality fruit. Sweet orange rootstock is resistant to citrus blight and to tristeza virus, which are increasingly serious problems in Florida citrus. Presently, most Florida citrus groves are irrigated so that drought susceptibility is no longer a major factor in rootstock selection. Furthermore, two systemic fungicides, metalaxyl and fosetyl Al, are available that are highly effective in preventing and curing *Phytophthora* infections (2–4, 9,10), but no work has been done to demonstrate the effectiveness of these fungicides in Florida orchards or on sweet orange rootstock elsewhere.

The purpose of this study was to determine whether trees on sweet orange rootstock could be established and maintained using minimal applications of metalaxyl or fosetyl Al and to ascertain the longevity of fungicidal activity on young trees in the orchard.

MATERIALS AND METHODS

Plant materials and experimental design. Pineapple sweet orange trees on Ridge Pineapple sweet orange rootstock were grown in 6-L containers in the potting medium Pro-Mix BX (Premier Brands, Inc., New York, NY). Several days before transplanting to the field site, half of the trees were inoculated with *Phytophthora parasitica* Dast. by pouring 10 ml of a zoospore suspension (10^5 zoospores per milliliter) around the base of each tree. The potting medium was watered twice daily for 3 days after inoculation.

Trees were used as replants in a mature grove near Auburndale, FL, on an Astatula fine sand, a well-drained sandy soil typical of those in the central Ridge area of the state. The experiment consisted of three factors: fungicide (metalaxyl vs. fosetyl Al vs. untreated), application method (soil drench vs. trunk paint), and inoculation (inoculated vs. uninoculated) arranged as a $2^2 \times 3$ factorial. In the second year, an additional set of trees in each replicate received foliar sprays of fosetyl Al. In the third year, the trunk paint treatment was replaced with a foliar spray treatment. The experiment was established as a randomized complete block design with 12 single-tree replicates per treatment in April 1981.

Fungicide applications. Soil drenches were applied in 40 L of water in soil rings 1.2 m in diameter formed around the base of each tree. Metalaxyl (Ridomil 2E) was applied at 75 mg a.i./L and fosetyl Al (Aliette 80WP) at 400 mg a.i./L. Trunk paint applications were made by brush with metalaxyl or fosetyl Al, each at 60 mg a.i./ml. The entire trunk of each tree was painted avoiding runoff into the soil. Foliar sprays were applied until runoff, using metalaxyl at 1 g a.i./L or fosetyl Al at 30 g a.i./L. Application dates are given in Figure 1.

Evaluation of fungitoxic activity and fungal populations. Fungitoxic activity in twigs and roots was determined by a previously described bioassay (9). Three twigs or roots 3–5 mm in diameter were collected from each of the 12 uninoculated trees in each replicate of each treatment. Two cross sections about 5 mm long were cut from each twig or root and placed in a moist chamber with the cut surface upright. A 30-μl drop of a zoospore suspension of about 5×10^4 zoospores of *P. parasitica* per milliliter was added to the cut surface, and the tissue pieces were incubated 24 hr at 28 C. Tissue pieces were then inverted onto a selective medium (11) and incubated 72 hr at 28 C. The radius of the colony growing out from the tissue pieces was measured and the colony area calculated. Data were expressed as the percent reduction in colony area compared with the untreated control.

Propagule densities of *P. parasitica* in soil were determined in the untreated controls to estimate the background populations in the grove during the experiment. Four soil cores 2.5 cm in diameter and 30 cm deep were taken in the root zone around each of the 12 inoculated and 12 uninoculated control trees. The four cores from each tree were bulked and mixed. Ten grams of soil was added to 90 ml of 0.25% agar, and 1 ml was plated on each of 10 plates.

The selective PARP medium (6) was used, except 125 instead of 250 mg of ampicillin per liter was used and 25 mg of hymexazol per liter was added. Plates were incubated for 3 days at 28 C and the

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Phytophthora colonies counted. Population densities were expressed as propagules per gram dry weight. Preplant population estimates were based on two samples collected at random within each of the 12 replicates.

Foot rot incidence and tree growth. The total number of trees lost to foot rot was recorded during the experiment. Trees that were more than 50% girdled were considered lost to the disease.

Trunk circumference measurements 15 cm above the bud union were made annually. Growth was expressed as the increase in trunk cross-sectional area from 1981 to 1983. Since a freeze in January 1982 caused some damage to the trees, only the six replicates with the least freeze injury were included in the growth data presented.

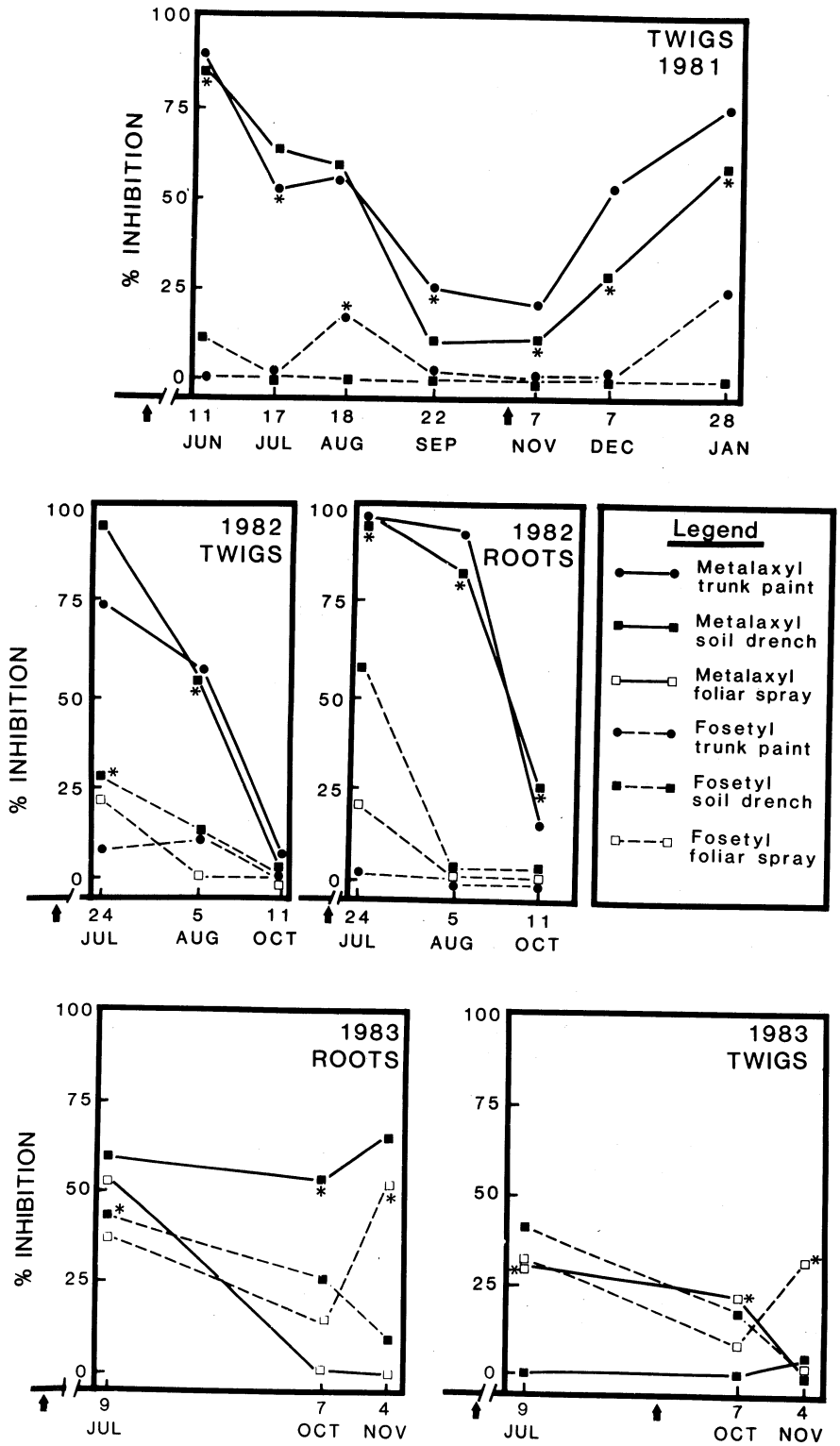

Fig. 1. Fungicidal activity in twigs and roots of treated trees as measured by the percent reduction in colony area compared with twigs and roots from untreated trees in a bioassay using *Phytophthora parasitica* zoospores. All points with asterisks and those above them represent significant reductions in colony area from the untreated controls by Student's *t* test, $P \leq 0.05$. Arrows indicate times of fungicide application—21 May 1981, 14 October 1981, 24 June 1982, 2 June 1983, and 1 September 1983.

RESULTS

Fungitoxic activity. The first applications in 1981 resulted in a high degree of fungitoxic activity in twigs of trees treated with metalaxyl (Fig. 1). Activity remained high through August but declined by early fall. A second application increased activity through the fall. Soil drench and trunk paint applications of fosetyl Al did not significantly decrease colony area of the fungus in the bioassay except on one occasion in 1981.

In 1982, trees receiving soil drench and trunk paint applications of metalaxyl had a high degree of fungitoxic activity in twigs and roots for 2 mo after application but had no significant activity after 4 mo (Fig. 1). Foliar, trunk paint, or soil drench applications of fosetyl Al only occasionally produced significant reductions in colony area of the fungus in the bioassay.

In 1983, trees treated with soil drenches of metalaxyl had no detectable fungitoxic activity in twigs but had significant activity in the roots at all assay dates. Trees receiving foliar sprays of metalaxyl had low but detectable activity in twigs and roots on one assay date. Soil drenches and foliar sprays of fosetyl Al significantly reduced colony area of the fungus in the bioassay on some sampling dates, but behavior was inconsistent.

Propagule densities, foot rot incidence, and tree growth. On 4 March 1981, before the initiation of the experiment, the population was estimated at 0.82 propagules per gram of soil. Populations fluctuated during the experiment but were lower than densities of 10–20 propagules per gram observed at other locations in Florida (L. W. Timmer, *unpublished*) and those in orchards on sweet orange rootstock in California (J. A. Menge, *personal communication*). Preplant inoculation had no significant effect on propagule densities of *P. parasitica* during the experiment, but there were significant differences between sampling dates (Table 1).

Foot rot incidence was generally low. Only four of 45 trees (8.9%) were lost in the untreated controls during the 3 yr of the experiment. One of the 48 trees treated with fosetyl Al and none of the 48 trees treated with metalaxyl succumbed to foot rot.

The increase in trunk cross-sectional area during the 3 yr of the experiment was 11 cm^2 in the untreated control, 12.3 cm^2 in the fosetyl Al-treated trees, and 13 cm^2 in the metalaxyl-treated trees. There was no significant effect of fungicide, application method, or of preplant

inoculation on tree growth. No significant interaction among factors was detected.

DISCUSSION

Fungicidal activity. Results of this study support previous work (2–4,9,10) showing that metalaxyl is highly effective for control of *Phytophthora* infection on citrus and is best applied as a soil drench or trunk paint. Fungitoxic activity, as detected by bioassay, reached high levels in twigs shortly after applications in summer and declined with time. Interestingly, however, activity was initially low after a fall application and increased with time, possibly because low temperatures slowed uptake or transport of the fungicide to the tree canopy or because mature foliage had less transpirational activity.

Movement of metalaxyl within the plant is primarily acropetal (2–4,9,10), but fungitoxic activity was detected in roots after application of trunk paints in 1982 and foliar sprays in 1983, indicating that some basipetal movement also occurs.

We found no detectable fungitoxic activity in twigs after soil drench applications of metalaxyl to 3-yr-old trees. Davis (2,3) likewise found no activity in trunk bark after soil drench application of metalaxyl to 5-yr-old trees. He attributed the lack of activity to the failure of the fungicide to penetrate clay soil sufficiently. Our study was conducted in sandy soil, and the lack of detectable activity is more likely attributable to dilution of fungicide in the large tree canopy.

In this study and in those of Davis (2,3), detection of fungitoxic activity in citrus tissues after applications of fosetyl Al was inconsistent, but significant reductions in the colony area of *P. parasitica* were observed in some cases. At present, we are uncertain whether the bioassay used in these studies is an appropriate procedure for evaluation of fungitoxic activity and persistence in fosetyl Al-treated trees. The mechanism of action of fosetyl Al has not been completely elucidated. Earlier work (8,12) indicated that fosetyl Al acted by inducing resistance in the host plant. However, Fenn and Coffey (5) demonstrated that the activity of fosetyl Al is paralleled by the fungitoxic activity of H_3PO_3, which is the primary degradation product of fosetyl Al. The parent compound inhibits zoospore germination only at high concentrations (4). However, if H_3PO_3 is the primary fungitoxicant in vivo, more fungitoxic activity might be expected in the bioassay of trees treated with fosetyl Al.

Table 1. Populations of *Phytophthora parasitica* in untreated soil from beneath inoculated and uninoculated sweet orange trees on sweet orange rootstock during the course of the experiment

Sampling date	Propagules per gram of soil		
	Uninoculated	Inoculated[y]	Mean
9 September 1981	2.76	3.81	3.30 ab[z]
30 June 1982	4.40	3.11	3.75 a
29 October 1982	0.18	0.00	0.08 c
14 June 1983	0.51	0.34	0.43 bc

[y] Propagule density beneath inoculated trees was not significantly different from that beneath uninoculated trees on any sampling date.
[z] Mean separation by Duncan's multiple range test ($P \leq 0.05$).

Effects on disease and tree growth. Growers commonly experience small, annual tree losses to foot rot on the sandy soils of the central Ridge of Florida as in this study. Thus, continual replacement of trees is required. Grove care costs are increased out of proportion to percentage loss by the expense incurred in attending to scattered replacement trees. Applications of metalaxyl twice a year as a soil drench or trunk paint—one at the beginning of the summer rainy season in late May or early June and a second in late August or early September—can maintain effective fungicide concentrations in plants and may eliminate tree losses in soils where *Phytophthora* populations are low. Although fosetyl Al was not readily detectable in the bioassay, it may also perform satisfactorily. It is likely to be most effective when applied as a foliar spray after the trees develop a sufficiently large canopy. Thus sweet orange may be a suitable rootstock for use on sandy soils that sustain only low to moderate populations of *P. parasitica*.

The lack of a tree growth response to fungicide application would indicate that feeder root rot is of minor importance. However, it is also possible that the minimal program used here was insufficient to provide adequate control of feeder root loss. The importance of the root rot phase of the disease on sweet orange as well as other rootstocks has never been ascertained. More research is needed to relate population densities of *P. parasitica* to root rot damage and to determine if fungicide applications would be needed to reduce root rot as well as foot rot losses.

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