Effectiveness of Fosetyl-Al Against *Phytophthora parasitica* on Tomato

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ABSTRACT

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Multiple prophylactic foliar sprays of fosetyl-Al (12 g a.i./L, optimum concentration) were more effective than a single application in reducing root rot of potted tomato plants inoculated with *Phytophthora parasitica*. Fosetyl-Al provided little or no control of root rot when applied to the plants after inoculation with a suspension of zoospores. Efficacy of fosetyl-Al decreased as the interval between treatment and inoculation increased; little control was obtained when 3–4 wk passed between final application and inoculation with *P. parasitica*. The evidence indicated that the concentration of the fungicide in the plant needed to be maintained over a long period of time with multiple applications to control the disease.

Root rot caused by *Phytophthora parasitica* Dast. is one of the most important diseases of processing tomatoes (*Lycopersicon esculentum* Mill.) in central and northern California (6), where over 75,000 ha are grown annually. Because root rot is usually associated with wet, poorly drained soils, careful water management and other cultural means can reduce the severity of the disease. However, there is interest in the tomato industry for research on the potential use of fungicides in fields that historically suffer losses to root rot.

Results of several trials on tomato root rot control with one experimental fungicide, fosetyl-Al, conducted by many county farm advisors in California have been erratic (*unpublished*). This material has excellent systemic activity against several diseases caused by *Phytophthora* spp. in a variety of crops (1,2,7). Fosetyl-Al is particularly attractive to growers because its basipetal movement in the plant allows it to be effective for root disease control when applied to the foliage with standard spray equipment.

The manufacturer's (Rhône-Poulenc Sanitaire, Lyon, France) experimental protocol for tomato root rot control called for a single foliar application applied at about the four-leaf stage. Because infection of tomato roots by *P. parasitica* can occur at any time during the growing season and because tomato plants are small at the four-leaf stage, it was uncertain whether the concentration of fosetyl-Al in the plant at that time would provide sufficient protection long enough to result in yield increases. The purpose of this study was to examine the efficacy of single and multiple applications of fosetyl-Al on Phytophthora root rot control in potted tomatoes and to determine the length of time the fungicide effectively reduces disease.

MATERIALS AND METHODS

All experiments were conducted in the greenhouse (22–27 C) using U.C. mix (1:1 mixture of fine sand and peat). The experimental unit in all tests was a single tomato plant (cv. FM 2078, a processing type) planted in a 8-cm-diameter plastic pot. The plants were watered twice a day for 3 days after inoculation and once a

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day thereafter. Treatments in all experiments were completely randomized and replicated six times.

For inoculation with *P. parasitica*, the plants were gently removed from the pots and washed free from potting mix. Roots were submerged either in water (noninoculated control) or in a 600-ml suspension of zoospores (1×10^4 zoospores per milliliter) for 1 hr. To produce zoospores, the fungus (originally isolated from roots of tomato plants in northern California) was grown in V-8 juice broth for 2 days, washed three times in sterile distilled water, and incubated for an additional 2 days at room temperature (5). The cultures were then washed again in water and chilled for 30 min at 5 C to induce zoospore release.

Fosetyl-Al was applied in water to the upper and lower surfaces of the leaves of the plants with a hand sprayer until runoff (about 2–3 ml per application). The potting mix in each pot was covered with paper to prevent accidental runoff into the pots, since activity of the fungicide in the soil was not under examination. To determine the most efficacious rate of fosetyl-Al, two applications were made a week apart, starting when the plants were 5 wk old, at rates from 2 to 12 g a.i./L, with intermediate increments of 2 g. Controls were left untreated. The plants were inoculated with *P. parasitica* (as described above) 1 wk after the second application. Then, 4 wk later the plants were lifted from the soil and the tops and roots were dried in an oven and weighed separately. The experiment and all subsequent experiments were repeated at least once. Root samples were collected from all experiments and placed in sterile water for the detection of *P. parasitica*.

The effect of the number of applications of fosetyl-Al at a rate of 12 g a.i./L was similarly studied. One, two, or three applications were made at weekly intervals so that the final application of the multiple treatments coincided with the single application. The plants were 4 wk old at the time of the initial treatment. Plants were inoculated with *P. parasitica* 1 wk after the final fungicide applications and were harvested 4 wk after inoculation.

The duration of activity of fosetyl-Al was determined in plants that received two or three weekly applications of the fungicide at 12 g a.i./L. The plants were 5 wk old at the time of the final application of each treatment. Plants were inoculated with *P. parasitica* 1, 2, 3, or 4 wk after the final fungicide application and were harvested 5 wk after the final inoculation.

The eradicant property of fosetyl-Al was studied in plants treated with 12 g a.i./L 1 and 2 wk before or after inoculation with *P. parasitica*. Plants were inoculated at 6 wk of age and harvested 6 wk later.

RESULTS

Trends were similar between duplicated trials in all experiments except one, and in that case results of both trials are presented. Because no additional information was discerned from analyses of root and top weights as separate variables, only the total dry weights are presented.

The most effective rate of fosetyl-Al was reached at about 8–12 g a.i./L (Fig. 1). The highest rate of the fungicide was used for all subsequent experiments. No rate of fosetyl-Al provided complete control of Phytophthora root rot. For example, the average dry weight of the plants treated with 12 g a.i./L of fosetyl-Al was only 56% of the weight of the noninoculated plants. No phytotoxicity symptoms were observed in treated plants, and weights of the noninoculated plants treated with fosetyl-Al at any rate did not differ significantly from the noninoculated, nontreated controls (*data not given*). In all experiments, *P. parasitica* was readily identified on discolored roots from inoculated plants.

Increasing the number of applications of fosetyl-Al improved its ability to control Phytophthora root rot. The total dry weights of plants inoculated with *P. parasitica* and treated with fosetyl-Al were positively correlated with the number of applications of the fungicide (Fig. 2). The average dry weight of inoculated plants treated with three applications of fosetyl-Al was 62% of the weight of noninoculated plants.

As the interval between fosetyl-Al treatment and inoculation with *P. parasitica* increased, the efficacy of fosetyl-Al decreased (Fig. 3). The time between the final application of fosetyl-Al and inoculation with *P. parasitica* was negatively correlated with the average total dry weights of the inoculated plants. The slopes of the two correlations (two and three applications of fosetyl-Al) were significantly different ($P = 0.05$). Three applications of the fungicide resulted in greater dry weights of inoculated plants than did two applications. The average dry weights of nontreated plants inoculated at 6, 7, 8, or 9 wk of age were 5.8, 6.3, 6.8, and 6.4 g, respectively.

Two applications of fosetyl-Al at 12 g a.i./L before inoculation with *P. parasitica* were more effective in controlling Phytophthora root rot than two applications after inoculation (Table 1). In one trial, the average dry weight of plants treated with two applications of the fungicide after inoculation was not significantly different ($P = 0.05$) from the weight of the nontreated inoculated plants. The average dry weights of plants treated before inoculation in the two trials were 62 and 68% of the weights of the noninoculated controls.

DISCUSSION

Multiple applications of fosetyl-Al were more effective against *P. parasitica* on tomato plants than a single dose. Only three applications of the fungicide were

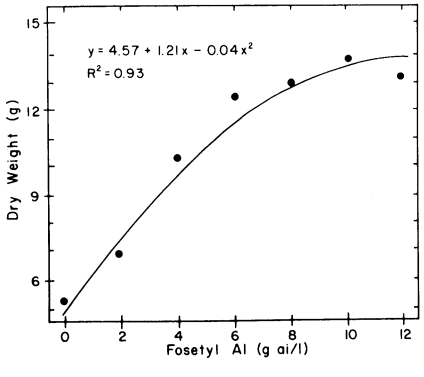

Fig. 1. Relationship between average dry weight of tomato plants inoculated with *Phytophthora parasitica* and rate of fosetyl-Al. Significant at $P = 0.05$. Average dry weight of nontreated, noninoculated plants was 23.5 g.

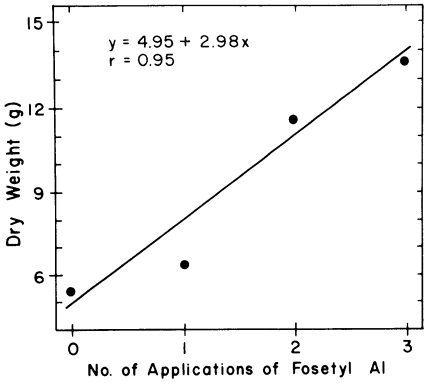

Fig. 2. Relationship between average dry weight of tomato plants inoculated with *Phytophthora parasitica* and number of applications of fosetyl-Al (12 g a.i./L). Significant at $P = 0.05$. Average dry weight of nontreated, noninoculated plants was 21.9 g.

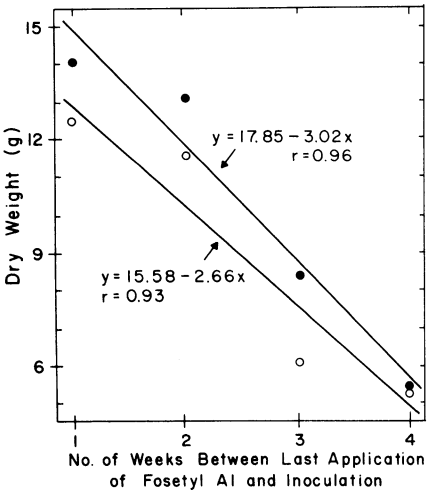

Fig. 3. Relationship between average dry weight of tomato plants inoculated with *Phytophthora parasitica* and interval between last of two applications (o) or of three applications (•) of fosetyl-Al (12 g a.i./L). Slopes of the two treatments are significantly different ($P = 0.05$). Average dry weight of nontreated, noninoculated plants was 25.7 g.

included in this study because the small pots limited the period of plant growth. The evidence suggests, however, that maintaining the concentration of the fungicide in the plant over a long period of time by multiple applications is the most effective use of fosetyl-Al. The breakdown products of fosetyl-Al, which may be responsible for the fungitoxic activity of the fungicide (3,4), apparently do not persist in significant quantities for a long period of time in young tomato plants.

The effective rates of fosetyl-Al (measured by weight increases in *Phytophthora*-inoculated plants) apparently reached a plateau at about 8–12 g a.i./L. The high rate of the treatments, 12 g a.i. of fosetyl-Al, which was used for most of the experiments in this study, is roughly equivalent to 4.5 kg a.i./ha, the high end of the range of recommended rates in the field. Even with three applications at this rate, fosetyl-Al failed to provide a high degree of control of root rot. Plants treated with fosetyl-Al and inoculated with *P. parasitica* were only 56–68% of the weight of noninoculated controls. The protection fosetyl-Al conferred to the plants was consistent, however, and allowed highly significant correlations between treatments and plant growth responses. The relatively high level of inoculum used in this test may have resulted in more severe disease than usually occurs in the field.

The efficacy of fosetyl-Al decreased as the interval between treatment and inoculation increased. Although three applications were more effective than two, both treatments provided little control when 3–4 wk passed between final treatment and the time the plants were challenged with the fungus. For unknown reasons, the efficacy of three applications of fosetyl-Al decreased at a faster rate than that of two applications, despite, presumably, a higher concentration of the fungicide in the tissue with three applications. Evidently, the material is diluted by the fast growth of the plant to levels that are not toxic to *P. parasitica*. Foliar applications made before inoculation with *P. parasitica* were much more effective than applications made after inoculation, indicating that treatments in the field will have to be started before the onset of disease. The most effective use of fosetyl-Al for control of root rot in tomato appears to be early and sustained treatment.

Table 1. Control of Phytophthora root rot of tomato with two applications of fosetyl-Al before or after inoculation with *Phytophthora parasitica*[z]

Treatment	Trial 1		Trial 2	
	Av. plant dry weight (g)	Percent reduction in dry weight compared with noninoculated plants	Av. plant dry weight (g)	Percent reduction in dry weight compared with noninoculated plants
None, inoculated	6.3 d	67	5.3 c	70
Fosetyl-Al before inoculation	12.8 b	32	11.2 b	37
Fosetyl-Al after inoculation	7.6 c	60	6.2 c	65
None, noninoculated	18.9 a	···	17.9 a	···
LSD ($P = 0.05$)	1.05		1.26	

[z] Fosetyl-Al (12 g a.i./L) applied 1 and 2 wk before or 1 and 2 wk after inoculation by submerging the roots in a suspension of zoospores.

ACKNOWLEDGMENT

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