# Efficacy of Fosetyl-Al for Control of Some Bacterial Diseases on Ornamentals

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**ABSTRACT**

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Several factors, including pH and timing and number of applications, affect the efficacy of fosetyl-Al for controlling bacterial disease on ornamentals. Although pH may be a factor in the efficacy of fosetyl-Al for sensitive bacteria such as strains of *Xanthomonas campestris* pv. *dieffenbachiae* from *Syngonium,* sensitivity to pH alone cannot adequately explain the response of bacteria to exposure to fosetyl-Al in vitro. Disease control appears to be based on surface factors rather than chemical changes within the leaf tissue, since bacterial populations following leaf infiltration reach similar numbers whether plants are treated with fosetyl-Al or water. Disease control varied unpredictably when applications were made on 4- to 10-day intervals up to five times before inoculation. Results of 7 yr of testing suggest that fosetyl-Al does not give consistent or reliable control of bacterial disease on ornamentals.

Additional keywords: *Erwinia* spp., *Pseudomonas cichorii, Xanthomonas campestris*

Controlling bacterial diseases of ornamentals with chemicals is difficult because of the lack of efficacious, nonphytotoxic bactericides (1). In the past, plant producers relied on antibiotics such as streptomycin sulfate (Agri-Strep 21.2%) and copper compounds such as cupric hydroxide (Kocide 101 77WP). New compounds have been tested, but none has shown activity equal to that of either antibiotics or copper compounds (1).

Recent studies have investigated the potential use of fosetyl-Al (Aliette) for bacterial disease control (2-4). Fosetyl-Al is a fungicide used in the ornamentals industry to control pythiaceous fungi (*Phytophthora* and *Pythium* spp.). This fungicide is unique because it is ambimobile and can be applied to plant foliage or roots for disease control. In preliminary reports, preventive sprays of fosetyl-Al at rates between 960 and 4,790 mg a.i./L reduced certain diseases caused by xanthomonads (2-4). Although fosetyl-Al controlled some diseases in some tests, results were erratic. Phytotoxicity was an additional problem when fosetyl-Al was applied to plants that were also treated with copper compounds, either separately or together (5).

The objective of this research was to evaluate the role of pH in the efficacy of fosetyl-Al and the effect of the timing and number of applications on control of some bacterial diseases of ornamentals. In addition, tests were performed to investigate the mode(s) of action of fosetyl-Al in bacterial disease control. Preliminary results have been published (6).

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## MATERIALS AND METHODS

**General conditions.** Most of the test plants were obtained as liners or rooted cuttings from commercial producers. Plants were established in a potting medium of Canadian peat and pine bark (1:1 by volume) amended with recommended rates of micronutrients (Micromax) and fertilizer (Osmocote 19:6:12, Grace-Sierra Crop Protection) for each species of plant (7). Greenhouse temperatures ranged from 15 to 35 C and light intensity from 200 to 420 $\mu mol \cdot m^{-2} \cdot s^{-1}$, depending on the time of year. The plants studied are listed in Table 1.

Inoculum was prepared from 48-hr cultures grown at approximately 25 C on nutrient agar amended with 0.5% sucrose (NAS). Bacteria were removed from culture dishes with a sterilized cotton swab and suspended in sterilized 0.01 M $MgSO_4$. The suspension was adjusted spectrophotometrically to $10^8$ cfu/ml (50% transmittance at 600 nm).

Plants in most tests were pretreated for 24 hr before inoculation with intermittent mist (15 sec every 30 min for 12 hr/day). This mist was continued for the duration of each trial.

Plants were inoculated with a pump-action hand sprayer and then placed in polyethylene bags for 24 hr, with the mist treatment continuing over the top of the bags. Plants in tests performed in 1990, 1991, and 1992 were inoculated similarly except that the mist treatment was discontinued for 2 hr directly after inoculation and plants were not enclosed in polyethylene bags.

**Efficacy trials.** Tests were conducted over a 7-yr period from 1986 to 1992. Results of 32 of these tests are reported in Table 1. Most tests were performed with fosetyl-Al (Aliette 80WP) at 1,920 mg a.i./L; a few used 960 or 4,790 mg a.i./L. Plants were sprayed to runoff and allowed to dry either once or twice before inoculation and then weekly thereafter, for a total of three to six applications. Disease severity was rated based on the number of lesions per plant or the percentage of leaf area with symptoms, depending on the host-pathogen combination.

A separate experiment compared a buffered formulation of fosetyl-Al (pH 5.8) with the 80WP formulation (pH 3.3) and cupric hydroxide (Kocide, pH 8.0). Tests were performed as described above, with three or four applications per experiment before disease evaluations. The host-pathogen combinations were *Hedera helix* with *Xanthomonas campestris* pv. *hederae, Dieffenbachia maculata* with *X. campestris* pv. *dieffenbachiae, Syngonium podophyllum* with a *Syngonium* strain of *X. c. dieffenbachiae,* and *Pilea spruceana* with *X. campestris.* For each host-pathogen combination, 12 plants per treatment were arranged in a randomized complete block design. The number of lesions per plant was determined about 3 days after the final bactericide application. Data were subjected to analysis of variance, and means were separated by Duncan's new multiple range test ($P = 0.05$).

**Effect of application frequency and interval.** Preinoculation treatment schedules with fosetyl-Al were compared for control of *X. c. hederae* on *H. helix* (English ivy). Twelve plants per treatment were arranged in a randomized complete block design. Applications of 4,790 mg a.i./L were made on weekly intervals five, four, three, two, one, or zero times before inoculation. Each test received either one or two applications after inoculation, depending on disease progress. Lesions were counted 10–14 days after inoculation. This experiment was performed three times. Data were analyzed by analysis of variance, and means were separated by Duncan's new multiple range test ($P = 0.05$).

The effect of the interval between applications was tested on two host-pathogen combinations: English ivy with *X. c. hederae* and *Ficus benjamina* (weeping fig) with *X. c. fici.* Fosetyl-Al at 4,790 mg a.i./L was applied at 4-, 7-, and 10-day intervals. Noninoculated and inoculated control treatments and a cupric hydroxide treatment (1,190 mg a.i./L applied weekly) also were included. Treatments were applied once before inoculation and two to four times after inoculation. Each host-pathogen combination was tested twice, with 12 replicates per treatment arranged in a randomized complete block design. Data were subjected to analysis of variance, and means were separated by Duncan's new multiple range test ($P = 0.05$).

**In vitro evaluations.** Bacteria were grown on NAS for 48 hr, suspended in sterile distilled water, and added at the rate of $10^6$ cfu/ml of test solution to fosetyl-Al at 0, 500, 750, or 1,000 mg a.i./L in aqueous suspension (pH 5.6, 3.5, 3.6, and 3.4, respectively). After 30 min, the bacteria were dilution-plated onto the surface of five dishes of NAS per treatment to yield about 100 colonies per dish. The number of colonies after 2–5 days was recorded, and the percentage recovery was determined relative to the control. Fourteen strains of *X. campestris* (representing eight pathovars), two strains of *Pseudomonas cichorii,* and

**Table 1.** Summary of efficacy trials with fosetyl-Al for control of some bacterial diseases of ornamentals

| Pathogen/host | Rate of fosetyl-Al (mg a.i./L) | Control[a] (%) | |
|---|---|---|---|
| | | Fosetyl-Al | Cupric hydroxide |
| *Erwinia chrysanthemi*/philodendron | 3,840 | 18 | 67 |
| | 3,840 | 8 | 12 |
| *Pseudomonas cichorii*/ficus | 2,400 | 41 | 71* |
| *P. cichorii*/chrysanthemum | 2,400 | 0+ | 89* |
| *P. cichorii*/geranium | 2,400 | 0 | 59 |
| *Xanthomonas campestris* pv. *begoniae*/begonia | 2,400 | 0 | 47* |
| *X. c. dieffenbachiae*/anthurium | 4,790 | 30* | NT |
| | 4,790 | 50* | 50* |
| *X. c. dieffenbachiae*/dieffenbachia | 1,920 | 43* | 61* |
| | 4,790 | 0 | 92* |
| | 4,790 | 47* | 43* |
| *X. c. dieffenbachiae*/*Syngonium* | 1,920 | 0 | 35* |
| | 1,920 | 23 | 31* |
| | 1,920 | 51* | 34* |
| | 1,920 | 41* | 63* |
| | 3,840 | 50* | 46* |
| | 3,840 | 48* | NT |
| | 4,790 | 24 | NT |
| *X. c. fici*/ficus | 1,920 | 59* | 93* |
| *X. campestris*/*Fittonia* | 1,920 | 12 | 0+ |
| | 2,400 | 35* | 0 |
| *X. c. hederae*/ivy | 800 | 50* | 88* |
| | 960 | 67* | 78* |
| | 2,400 | 61* | 62* |
| | 2,400 | 33 | 62* |
| | 4,790 | 77 | 67 |
| *X. c. hederae*/schefflera | 1,920 | 36 | 42 |
| *X. c. malvacearum*/hibiscus | 1,920 | 0+ | 0 |
| *X. c. pelargonii*/geranium | 2,400 | 47 | 45 |
| | 2,400 | 3 | 31* |
| *X. campestris*/*Pilea* | 960 | 0+ | 90* |
| | 1,920 | 43 | 86* |
| | 1,920 | 57* | 43* |

[a] Percentage control for separate trials. Figures are given for fosetyl-Al or cupric hydroxide compared to inoculated control plants. An asterisk indicates a significant reduction in disease compared to inoculated control plants at $F \geq 0.001$ according to analysis of variance. A plus sign indicates a significant increase in disease compared to inoculated control plants at $F \geq 0.001$ according to analysis of variance. NT = not tested.

five strains of *Erwinia* spp. were tested. Because some of the strains grew after exposure to fosetyl-Al at 1,000 mg a.i./L, higher rates were occasionally included. Tests were performed twice on some strains to verify results.

Because fosetyl-Al is an acidic compound, the role of pH in the survival and growth of a variety of plant-pathogenic bacteria was evaluated. The pH of nutrient broth was adjusted to values between 4.5 and 6.5 in 0.25-unit increments. Five spectrophotometric tubes (5 ml) at each pH level were inoculated with 10–100 bacteria, vortexed, and placed on a rotary-action shaker. After 3 days, the transmittance of each tube was recorded with a spectrophotometer (600 nm). Noninoculated tubes served as controls for each pH level. The lowest pH that produced a cloudy tube (transmittance less than 90%) of each strain was thus determined. This test was performed twice with two strains of *P. cichorii* and 20 strains of *X. campestris* representing 10 pathovars.

**Growth of *X. campestris* in vivo.** The host-pathogen combinations used in these trials were *D. maculata* with a dieffenbachia strain of *X. c. dieffenbachiae, S. podophyllum* with a *Syngonium* strain of *X. c. dieffenbachiae, Anthurium* sp. with an anthurium strain of *X. c. dieffenbachiae,* and fiddleleaf ficus (*F. lyrata*) with *X. c. fici.* The bacterial concentration was adjusted to $10^4$ cfu/ml in 0.01 M $MgSO_4$. Inoculum was injected with a hypodermic needle through the lower leaf surface into panels of tissue about 1–2 $cm^2$ in area (one panel for each of 10 leaves per plant).

Two leaf disks (5 mm in diameter) per treatment were collected with a cork borer from inoculated leaves. Disks were combined, ground in a scintered glass tissue grinder, and diluted with sterilized 0.01 M $MgSO_4$. Five dishes of NAS were inoculated with 0.1-ml aliquots, and bacterial colonies were counted after 3–5 days, depending on the strain. Data are reported as cfu/$cm^2$ of host tissue.

Fosetyl-Al at 4,790 mg a.i./L was applied to runoff on 25 and 29 May and 1 June 1991. Plants were inoculated on 4 June, and samples were taken 0, 1, and 4 days after inoculation. This test was repeated with fungicide treatments applied on 14, 20, and 28 June 1991, inoculations on 2 July, and sampling 1 and 3 days after inoculation.

## RESULTS

**Efficacy trials.** On average, fosetyl-Al gave 58% control of *X. c. hederae* on English ivy, compared to 72% with cupric hydroxide. Results were inconsistent or poor for other pathogens (Table 1). Fosetyl-Al provided significant control of *X. c. dieffenbachiae* on *Syngonium* in four of seven trials, whereas cupric hydroxide gave significant disease control in all five tests in which it was included. Cupric hydroxide reduced Pseudomonas leaf spot on chrysanthemum, ficus, and geranium an average 73%, whereas fosetyl-Al failed to give significant disease control in any trial and even increased disease on chrysanthemum. Fosetyl-Al increased disease severity in three tests and did not provide a significant level of control in 16 tests. Cupric hydroxide increased disease severity in only one test and did not provide a significant level of control in seven tests (Table 1).

Fosetyl-Al gave better control of *X. c. hederae* on English ivy than buffered fosetyl-Al, but the two treatments did not differ in control of the other three pathogens (Table 2). Buffered fosetyl-Al gave better control of *X. c. dieffenbachiae* than cupric hydroxide but was equal to or less effective than cupric hydroxide in the other three trials (Table 2). In the *Pilea* trial, only cupric hydroxide provided significant disease control.

**Effect of application frequency and interval.** The three trials that evaluated the effect of number of preinoculation applications of fosetyl-Al yielded inconsistent results. In test 1, the plants that received the most applications had significantly more disease than the inoculated control plants, and only plants sprayed three times before inoculation had a significant decrease in disease severity compared to the inoculated control plants (Table 3). In test 2, the best control was achieved with five applications, which was also the only treatment that differed significantly from the control. In the third test, all fosetyl-Al treatments except the three-application treatment provided similar and significant ($P = 0.05$) control of *X. c. hederae* on English ivy. In a similar experiment on dieffenbachia with *X. c. dieffenbachiae,* no treatment reduced disease significantly (*data not shown*).

The interval between applications had variable effects on the severity of disease on weeping fig. In the first test, the best control was achieved with the 10-day interval, although it did not differ significantly from the control (Table 4). The 4-day interval resulted in significantly more disease than the inoculated control plants. In the second test, the 4-day interval performed the best among fosetyl-Al treatments, although only cupric hydroxide resulted in significant disease control. In the first test on English ivy, none of the treatments provided a significant level of control, while in the second test, disease control increased as the interval between applications decreased (Table 4).

**In vitro evaluations.** The recommended rate of fosetyl-Al for bacterial control is 1,900–3,800 mg/L. Exposure to fosetyl-Al at 1,000 mg a.i./L completely inhibited recovery of xantho-

**Table 2.** Effect of fosetyl-Al, buffered fosetyl-Al, and cupric hydroxide on severity of Xanthomonas leaf spot of four foliage plant species

| Treatment[a] | Rate (mg a.i./L) | Mean number of lesions[b] | | | |
|---|---|---|---|---|---|
| | | *Hedera helix*[c] | *Dieffenbachia maculata* | *Syngonium podophyllum* | *Pilea spruceana* |
| Noninoculated control | | 0 a | 0 a | 0 a | 0 a |
| Inoculated[d] control | | 16.3 bc | 39.0 d | 34.2 c | 25.4 b |
| Buffered fosetyl-Al | 4,790 | 17.9 c | 14.5 b | 22.1 b | 18.8 b |
| Fosetyl-Al | 4,790 | 5.0 a | 25.5 bc | 20.4 b | 20.0 b |
| Cupric hydroxide | 920 | 8.6 ab | 31.4 cd | 16.2 b | 3.1 a |

[a] Treatments were applied for 3 or 4 wk, with one application before inoculation.
[b] Mean number of lesions was rated 3–4 wk after inoculation. Means followed by the same letter do not differ significantly at the 0.05 level according to Duncan's new multiple range test.
[c] Plants were inoculated 3 days after the first chemical application.
[d] Plants were inoculated with the following pathovars of *Xanthomonas campestris: X. c. hederae* (*H. helix*), *X. c. dieffenbachiae* (*D. maculata* and *S. podophyllum*), and an unnamed pathovar (*P. spruceana*).

**Table 3.** Effect of preinoculation applications of fosetyl-Al on the severity of Xanthomonas leaf spot of *Hedera helix* caused by *Xanthomonas campestris* pv. *hederae*

| Treatment[a] | Preinoculation applications (no.) | Mean number of lesions[b] | | |
|---|---|---|---|---|
| | | Test 1 | Test 2 | Test 3 |
| Fosetyl-Al | 5 | 50.0 c | 7.8 a | Not tested |
| | 4 | 21.2 ab | 17.3 ab | 13.4 a |
| | 3 | 14.2 a | 11.4 ab | 19.2 ab |
| | 2 | 22.7 ab | 12.7 ab | 11.4 a |
| | 1 | 20.0 ab | 10.6 ab | 8.7 a |
| Water | 5 | 30.4 b | 23.9 b | 25.8 b |

[a] Fosetyl-Al (Aliette 80WP) was applied at the rate of 4,790 mg a.i./L.
[b] Plants were inoculated 3 days after the final fosetyl-Al application. Disease was rated 3 wk after inoculation. Means (number of lesions per plant) followed by the same letter do not differ statistically at the 0.05 level according to Duncan's new multiple range test.

monads and pseudomonads (Table 5). Some of the strains of *X. c. dieffenbachiae* from *Syngonium* and *Anthurium, X. c. pelargonii, X. c. begoniae,* and the unnamed *X. campestris* pathovar from *Pilea* were completely inhibited on the medium amended with fosetyl-Al at 500 mg a.i./L. One strain of *X. c. fici* grew at 750 mg a.i. of fosetyl-Al per liter, but all other strains of this pathovar were inhibited at this rate. Strains of *P. cichorii* showed some reduced sensitivity to fosetyl-Al at 750 mg a.i./L, although their recovery was greatly reduced. Recovery of the two strains of *X. c. dieffenbachiae* from *Syngonium* was not significantly affected by exposure to buffered fosetyl-Al at 1,000 mg a.i./L (*data not shown*), although exposure to as little as 500 mg a.i. of the unbuffered fosetyl-Al per liter resulted in complete inhibition (Table 5).

In contrast, all of the *Erwinia* strains grew on the medium amended with fosetyl-Al at 750 mg a.i./L in at least one test (Table 5). *E. carotovora* appeared to be most sensitive to fosetyl-Al and grew only slightly on the medium amended with 1,000 mg a.i./L. Recovery of *E. chrysanthemi* was sometimes reduced at 1,000 mg a.i./L but was completely inhibited at 1,500 mg a.i./L. Recovery of *E. amylovora* on medium amended with 1,000 mg a.i./L was reduced in some tests and completely inhibited in others. The overall ranking of these plant pathogens in sensitivity to fosetyl-Al shows that xanthomonads are most sensitive (especially strains from *Syngonium,* geranium, begonia, and *Pilea*), *P. cichorii* is moderately sensitive, and *Erwinia* spp. are least sensitive.

The pH values for solutions of fosetyl-Al were about 3.4–3.6 for concentrations from 500 to 1,000 mg/L, while the value for the buffered fosetyl-Al was about 6.5 over the same range of concentrations. Minimum pH for growth in vitro varied by bacterial strain (Table 6). Most strains of *X. campestris* pathovars grew at a minimum pH of 4.75 or 5.0, whereas the two strains from *Syngonium* required a significantly higher minimum pH of 5.75. Strains of *P. cichorii* grew at a minimum pH of 5.0. *E. chrysanthemi* was most tolerant of low pH and grew well at pH 4.5.

**Growth of *X. campestris* in vivo.** Growth of *X. campestris* in the four host species tested was not significantly or consistently affected by foliar treatment of the plant with fosetyl-Al. In the first test, populations of *X. c. dieffenbachiae* were $10^2$ times greater in anthurium plants treated with fosetyl-Al than in water-treated plants. *X. c. fici* populations were about 10 times greater in the fosetyl-Al treatment (Table 7). In the second test, none of the bacterial populations showed any response to the fosetyl-Al treatments. Additional tests performed with at least one of the host-pathogen combinations used in this experiment also failed to show consistent effects of fosetyl-Al on bacterial populations (*data not shown*).

**Table 4.** Effect of fosetyl-Al application interval on severity of Xanthomonas leaf spot of *Ficus benjamina* (caused by *Xanthomonas campestris* pv. *fici*) and *Hedera helix* (caused by *X. campestris* pv. *hederae*)

| Treatment[a] | Days between applications | *F. benjamina*[b] Test 1 | *F. benjamina*[b] Test 2 | *H. helix*[b] Test 1 | *H. helix*[b] Test 2 |
|---|---|---|---|---|---|
| Noninoculated control | | 0 a | 0.2 a | 0 a | 0 a |
| Inoculated control | | 25.0 b | 22.6 bc | 9.9 a | 43.8 c |
| Fosetyl-Al | 4 | 74.4 c | 24.7 bc | 5.6 a | 13.6 b |
| | 7 | 32.2 b | 34.2 c | 2.3 a | 20.8 b |
| | 10 | 15.0 ab | 32.2 c | 2.2 a | 32.9 bc |
| Cupric hydroxide | 7 | 27.2 b | 7.8 ab | 3.1 a | 25.0 bc |

[a] Fosetyl-Al (Aliette 80WP) was applied at the rate of 4,790 mg a.i./L., and cupric hydroxide (Kocide 101 77WP) was applied at the rate of 920 mg a.i./L. Treatments were applied for 3 or 4 wk.

[b] Plants were inoculated 3 days after the first chemical application. Mean number of lesions was rated 3 wk after inoculation. Means followed by the same letter do not differ significantly at the 0.05 level according to Duncan's new multiple range test.

**Table 5.** In vitro percentage recovery of phytopathogenic bacteria exposed to fosetyl-Al at 500, 750, or 1,000 mg a.i./L[a]

| Bacterium identification | Strain number | Concentration (mg a.i./L) 500 | 750 | 1,000 |
|---|---|---|---|---|
| *Erwinia amylovora* | E74 | 100 | 81 | 25[b] |
| | E75 | 79 | 27 | 0 |
| | E76 | 100 | 100 | 67[b] |
| *E. carotovora* | E34 | 100 | 83 | 0 |
| *E. chrysanthemi* | E32 | 95 | 82 | 65[b] |
| *Xanthomonas campestris* pv. *begoniae* | X843 | 0 | 0 | 0 |
| *X. c. dieffenbachiae* (anthurium) | X269 | 0 | 0 | 0 |
| *X. c. dieffenbachiae* (dieffenbachia) | X186 | 53 | 0 | 0 |
| *X. c. dieffenbachiae* (*Syngonium*) | X162 | 0 | 0 | 0 |
| | X434 | 0 | 0 | 0 |
| *X. c. fici* | X151 | 70 | 0 | 0 |
| | X217 | 100 | 45 | 0 |
| *X. c. hederae* | X261 | 85 | 0 | 0 |
| | X324 | 98 | 0 | 0 |
| | X445 | 92 | 0 | 0 |
| *X. c. pelargonii* | X847 | 0 | 0 | 0 |
| | X848 | 0 | 0 | 0 |
| *X. campestris*, unnamed pathovar (from *Pilea*) | X312 | 0 | 0 | 0 |
| *Pseudomonas cichorii* | P133 | 63 | 4 | 0 |
| | P134 | 100 | 8 | 0 |

[a] Recovery on nutrient agar and sucrose (0.5%) after 3–5 days, following a 30-min exposure to aqueous fosetyl-Al suspensions compared to a sterile water control.

[b] No bacteria were recovered at 1,500 mg a.i./L.

## DISCUSSION

Early reports on the mode of action of fosetyl-Al suggested that the compound did not directly inhibit target fungi (9,12). However, research by Fenn and Coffey (10,11) supported a direct mode of action. When fosetyl-Al was incorporated into culture media low in phosphate, *Phytophthora* spp. were inhibited by phosphorous acid ($H_3PO_3$) at rates between 69 and 552 mg/L (10). In addition, an $H_3PO_3$-tolerant isolate of *Phytophthora capsici* was not inhibited by fosetyl-Al, which further supported the hypothesis of a direct mode of action (11).

Guest (13) reported that host defense response to infection by *Phytophthora* spp. increased when plants were treated with fosetyl-Al and postulated that a combination of direct and indirect activity accounted for the control of Phytophthora diseases with fosetyl-Al. Recently, Matheron and Matejka (14) demonstrated the lack of effect of fosetyl-Al on propagules of *Phytophthora* spp., while the fungicide provided good disease control. Overall it appears that a combination of direct and indirect actions is needed to explain the efficacy of fosetyl-Al against these oomycetes (17).

The action of fosetyl-Al against bacterial pathogens also appears to be both direct and indirect. In vitro tests with fosetyl-Al indicate a direct effect: rates of 500–1,000 mg a.i./L inhibit growth of most of the test bacteria on culture media. Part of the direct effect results from the fact that the pH on the leaf surface decreases when fosetyl-Al is applied. However, another mechanism must be active because efficacy trials in-

dicate that buffered fosetyl-Al is often as effective as unbuffered fosetyl-Al. The degree of control observed in greenhouse trials did not always match the sensitivity displayed by specific bacteria to either pH or the concentration of fosetyl-Al in in vitro tests. Although pH may be one factor in the efficacy of fosetyl-Al for sensitive bacteria such as strains of *X. c. dieffenbachiae* from *Syngonium,* pH sensitivity cannot adequately explain the relative recovery of other bacteria exposed to fosetyl-Al. When these bacterial pathogens were introduced directly into their host plants, the effect of fosetyl-Al was generally lost, indicating that the effect may be limited to the leaf surface. Consequently, it is possible that an interaction between the host and fosetyl-Al may influence the development of some bacterial diseases.

Leaf spot diseases of ornamentals appear to be the best targets for use of fosetyl-Al as a bactericide, although some systemic diseases also could be reduced. Trials on *Syngonium* showed variable control, and the efficacy may have been affected by the stage of disease progress in each test. When *Syngonium* plants were systemically infected before fosetyl-Al was applied, control was poor, but when the pathogen was not systemic in the host before treatment, good control was achieved (tests with an asterisk in Table 1).

Many commercial producers combine pesticides to increase disease control. Currently, there is no indication that mixing fosetyl-Al and copper compounds enhances disease control, although two experimental combinations of copper and fosetyl-Al (supplied by Rhone-Poulenc) gave excellent results in preliminary trials (A. R. Chase, *unpublished*). To ensure safe use, these mixtures were buffered to a pH of 6.0 to reduce available copper. Phytotoxicity is a serious problem on many plants when fosetyl-Al and copper products are used together or even when they are applied in separate sprays seven or fewer days apart (5). Because an interval shorter than 7 days may be necessary on some plants under certain environmental conditions, use of copper and acidic compounds on the same crop is not recommended.

Bacterial disease control seems to be more or less independent of the rate of fosetyl-Al within the bounds tested (960–4,800 mg a.i./L). Ritchie and Bennett (15,16) showed that fosetyl-Al applied at rates up to 4,790 mg a.i./L gave poor control of bacterial leaf spot of pepper (*Capsicum annuum*) caused by *X. c. vesicatoria.* Weekly application is standard for bacterial disease control with pesticides, including fosetyl-Al, but is certainly not standard for other uses of fosetyl-Al, where application is generally monthly (8). Control of *Phytophthora parasitica* on tomato was improved when multiple applications were made before infection (8). In the present study on bacterial diseases, multiple applications before inoculation sometimes gave better control but as frequently resulted in increased disease severity or did not differ significantly from a single preinoculation application.

Fosetyl-Al has been used successfully for control of pythiaceous fungi (8,14, 18). However, difficulties in obtaining consistent results from trial to trial indicate that the degree of control achieved against bacterial diseases is not as high, and the margin for error is too small to recommend use of fosetyl-Al for control of bacterial disease on ornamental crops.

**Table 6.** Summary of in vitro pH growth studies for *Erwinia* spp., *Pseudomonas cichorii,* and pathovars of *Xanthomonas campestris*

| Bacterium identification | Strain number | Host of origin | Minimum pH for growth in vitro[a] |
|---|---|---|---|
| *E. carotovora* | E34 | *Syngonium podophyllum* | 5.00 |
| *E. chrysanthemi* | E32 | *Aglaonema commutatum* | 4.50 |
| *P. cichorii* | P133 | *Ficus lyrata* | 5.00 |
| *P. cichorii* | P134 | *Schefflera arboricola* | 5.00 |
| *X. campestris* pv. *begoniae* | X322 | *Begonia semperflorens* | 4.75 |
| | X331 | *Begonia* sp. | 4.75 |
| *X. c. dieffenbachiae* | X269 | *Anthurium andraeanum* | 5.00 |
| | X328 | *Anthurium* sp. | 4.75 |
| | X174 | *Dieffenbachia maculata* | 4.75 |
| | X186 | *D. maculata* | 4.75 |
| | X162 | *Syngonium podophyllum* | 5.75 |
| | X434 | *S. podophyllum* | 5.75 |
| *X. c. fici* | X208 | *F. benjamina* | 4.75 |
| | X217 | *F. benjamina* | 4.75 |
| *X. campestris,* unnamed pathovar | X180 | *Fittonia verschaffeltii* | 4.75 |
| | X225 | *Fittonia verschaffeltii* | 4.75 |
| *X. c. hederae* | X261 | *Hedera helix* | 5.00 |
| | X37 | *Brassaia actinophylla* | 4.75 |
| *X. c. malvacearum* | X108 | *Hibiscus rosa-sinensis* | 4.75 |
| | X262 | *H. rosa-sinensis* | 4.75 |
| *X. c. pelargonii* | X231 | *Pelargonium* × *hortorum* | 4.75 |
| | X238 | *Pelargonium* × *hortorum* | 4.75 |
| *X. campestris*, unnamed pathovar | X33 | *Pellionia pulchra* | 4.75 |
| | X312 | *Pilea mollis* | 4.75 |

[a] Bacteria were added to culture tubes containing nutrient broth adjusted to different pHs between 4.5 and 6.5.

**Table 7.** Recovery[a] of *Xanthomonas campestris* pathovars from foliage plants sprayed with fosetyl-Al or water

| Treatment[b] | *Anthurium* sp. 'Southern Blush'[c] | *Dieffenbachia maculata*[d] | *Ficus lyrata*[d] | *Syngonium podophyllum*[c] |
|---|---|---|---|---|
| Test 1 | | | | |
| Water | $9.60 \times 10^2$ | $1.25 \times 10^6$ | $8.40 \times 10^4$ | $3.60 \times 10^3$ |
| Fosetyl-Al | $1.12 \times 10^5$ | $1.26 \times 10^6$ | $7.08 \times 10^5$ | $1.20 \times 10^3$ |
| Test 2 | | | | |
| Water | $3.47 \times 10^7$ | $5.36 \times 10^7$ | $5.40 \times 10^5$ | $1.52 \times 10^6$ |
| Fosetyl-Al | $2.51 \times 10^7$ | $3.10 \times 10^7$ | $2.64 \times 10^5$ | $6.87 \times 10^5$ |

[a] Colony-forming units of bacteria per square centimer of plant tissue.
[b] Plants were sprayed with fosetyl-Al (4,790 mg a.i./L) or water 7, 4, or 2 days before inoculation and were sampled 7 days after inoculation.
[c] *X. campestris* pv. *dieffenbachiae* strains originally isolated from each host genus were used on *Anthurium, D. maculata,* and *S. podophyllum.*
[d] *X. c. fici* was used on *F. lyrata.*


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