Control of Pineapple Heart Rot, Caused by *Phytophthora parasitica* and *P. cinnamomi*, with Metalaxyl, Fosetyl Al, and Phosphorous Acid

K. G. ROHRBACH, Plant Pathologist, University of Hawaii, Honolulu 98622, and S. SCHENCK, Plant Pathologist, Castle and Cooke Foods, P.O. Box 490, Wahiawa, HI 96786

ABSTRACT

Rohrbach, K. G., and Schenck, S. 1985. Control of pineapple heart rot, caused by *Phytophthora parasitica* and *P. cinnamomi*, with metalaxyl, fosetyl Al, and phosphorous acid. Plant Disease 69: 320-323.

Metalaxyl and fosetyl Al controlled pineapple heart rot, caused by *Phytophthora parasitica* and *P. cinnamomi*, and root rot, caused by *P. cinnamomi*. Preplant seed material dips with metalaxyl at 600 ppm and fosetyl Al at 1,200 ppm resulted in significant control. Phosphorous acid, a hydrolysis product of fosetyl Al, at 3.36–6.72 kg/ha resulted in significant heart rot control and increased plant growth because of root rot control. In greenhouse studies, downward translocation of both fosetyl Al and phosphorous acid occurred within 24 hr and resulted in root rot control.

Heart and root rots of pineapple (*Ananas comosus* (L.) Merr.) in Hawaii are caused by the soilborne fungi *Phytophthora parasitica* Dastur and *P. cinnamomi* Rands. Symptoms of the diseases were described by Mehrlich (8). *Pythium* sp. may also cause root rot of pineapple (7).

Control of heart rot has been reported with other materials (9). The introduction of two new systemic materials, metalaxyl (Ridomil) and fosetyl Al (Aliette), brings about the possibility of also controlling the root rot phase. Both fungicides have been reported to control heart rot on pineapple in other countries (1,5,6). When applied either as a preplant dip for vegetative seed material or as a postplant spray, fosetyl Al reduced mortality caused by heart rot (1,5,6). In addition, fosetyl Al increased total root masses and weights of surviving plants (1).

Because of the serious economic impact of heart and root rots in Hawaii when high rainfall occurs, further testing was necessary to determine effective minimum rates and the most effective application methods. Since only phosphorous acid, the hydrolysis product of fosetyl Al, was present in pineapple leaves and fruit at harvest (J. Hylin, *unpublished*), the role of phosphorous acid in disease control was examined. Results of these studies are reported.

MATERIALS AND METHODS

Field test plantings and fungicide applications. Pineapple seed material consisted of crowns for preplant dip treatments and developing crowns or slips for postplant applications. Plants were grown according to standard cultural conditions for Hawaii (2). Fungicides were applied as preplant dips in fungicide-water mixtures. Postplant sprays were applied with a compressed-air sprayer with double fan nozzles (50.8-cm spacing) to cover the double-row pineapple bed (2). Heart rot was evaluated by mortality counts at monthly intervals after planting or after a disease outbreak. Root rot was measured by fresh plant weights.

Field plot design. Test plantings were located in areas with previous heart and root rot history and high rainfall. When rainfall was low, tests were irrigated from overhead to induce disease. Experimental designs were randomized complete blocks or Latin squares with four to six replicates per treatment and 24–60 plants per plot.

Greenhouse tests. Basal leaves of pineapple crowns were removed to expose adventitious roots. Crowns were placed in water for 1 mo for root development. Fungicides were applied either by inverting the rooted crowns and dipping the upper ends of the leaves in the fungicide mixture or by replacing the culture water with fungicide mixture for 24 hr. Roots were inoculated by placing a 5-mm V-8 juice agar plug of a 1-wk-old culture of *P. cinnamomi* in the root mass at the base of each crown.

Root rot was assessed 1 mo after

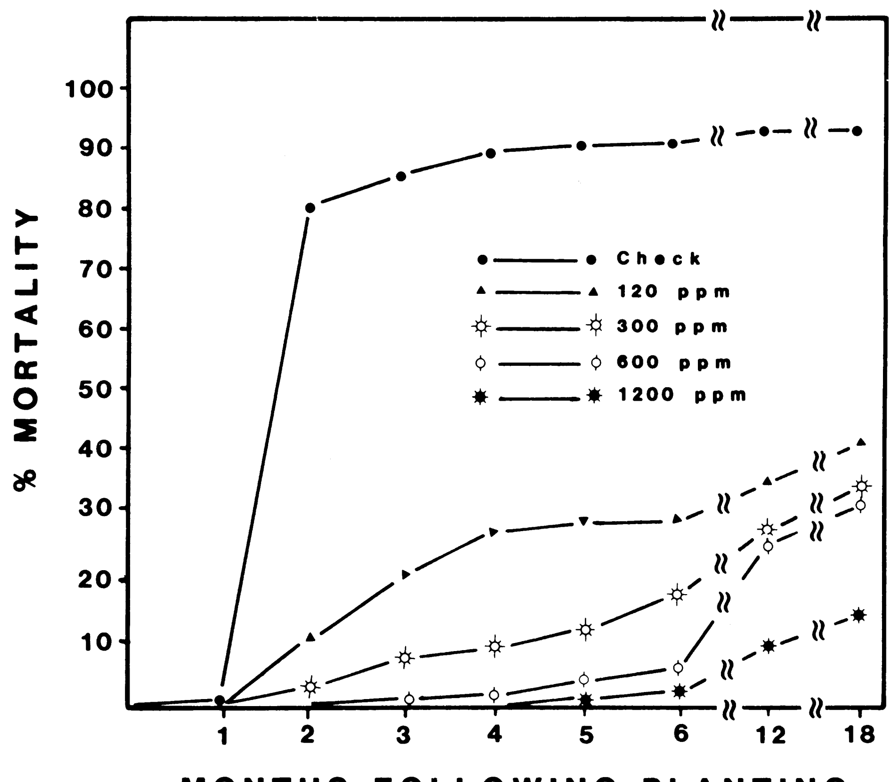

Fig. 1. Effects of metalaxyl preplant pineapple crown dips on heart rot mortality caused by *Phytophthora parasitica* (significant negative correlation between metalaxyl rate and mortality at 99% level).

Journal Series Paper 2833 of the Hawaii Institute of Tropical Agriculture and Human Resources, Honolulu.

Accepted for publication 20 October 1984.

inoculation on a scale of 0–3, where 0 = no disease, primary and secondary root tips white, older portions of primary roots white to slightly brown, active root growth apparent; 1 = slight root rot, up to 10% of the primary root tips rotted, reduction in secondary roots; 2 = moderate disease, 10–70% of the primary root tips rotted, very few secondary roots; and 3 = severe root rot, 71–100% of the primary and secondary roots rotted and no active growth. After visual assessment, roots were removed, dried at 100 C, and weighed.

Laboratory tests. Fosetyl Al and technical phosphorous acid (H_3PO_3) were tested in vitro using 2% V-8 juice agar as a substrate. Fungicides were added to autoclaved and cooled test media at concentrations (ppm) comparable to field use rates. Test fungi were *P. cinnamomi, P. parasitica,* and *Ceratocystis paradoxa* (de Seynes) Moreau. Radial growth was measured after 4 days. Agar plugs showing no growth were transferred to plates containing V-8 juice agar to detect fungistatic vs. fungicidal action. Presence or absence of growth was determined 5 days later.

RESULTS

Field preplant dip treatments. Both metalaxyl and fosetyl Al effectively controlled pineapple heart rot when applied as preplant dips to crowns. Metalaxyl provided control at 300–1,200 ppm (Fig. 1). The 600-ppm rate appeared to lose effectiveness between 6 and 12 mo, whereas the 1,200-ppm rate continued to give control for 18 mo. Fosetyl Al preplant dips at 600–4,800 ppm resulted in control; however, control was less effective at 600 ppm when there was greater than 55% mortality (Fig. 2). In additional tests, 600 ppm provided economic heart rot control (less than 10% mortality) when mortality in the untreated check plots was moderate (less than 36%).

Phosphorous acid also controlled heart rot when applied as a preplant dip (Table 1). Preplant dip rates of the two chemicals containing milliequivalent PO_3 levels performed with equal effectiveness.

The fungicidal activity of metalaxyl and fosetyl Al was not affected when they were mixed with benomyl or propiconazole (CGA-64250, Tilt 3.6 EC).

Fosetyl Al applied as a preplant dip at 1,200 and 2,400 ppm significantly

Table 1. Effects of fosetyl Al and phosphorous acid, applied as preplant dips and foliar sprays, on percent mortality of pineapple crowns caused by *Phytophthora parasitica* 3 mo after planting

Treatment	Rate	Mortality[a] (%)
Fosetyl Al preplant dip	600 ppm	24.3
	1,200 ppm	6.3
Phosphorous acid preplant dip	420 ppm	9.1
	840 ppm	4.2
Fosetyl Al spray	3.36 kg/ha[b]	39.6
Phosphorous acid spray	2.24 kg/ha[b]	49.3
Untreated check	···	59.7

[a] Significant negative correlation between fosetyl Al and phosphorous acid preplant dip rates and mortality at 99% level.
[b] Applied in 2,805 L of water per hectare.

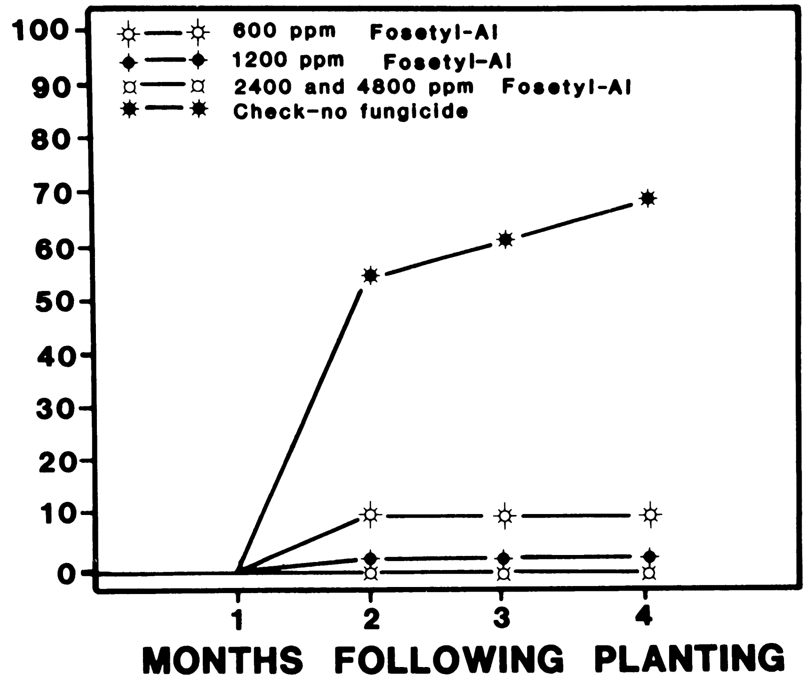

Fig. 2. Effects of fosetyl Al preplant pineapple crown dips on heart rot mortality caused by *Phytophthora parasitica* (significant negative correlation between fosetyl Al rate and mortality at 95% level).

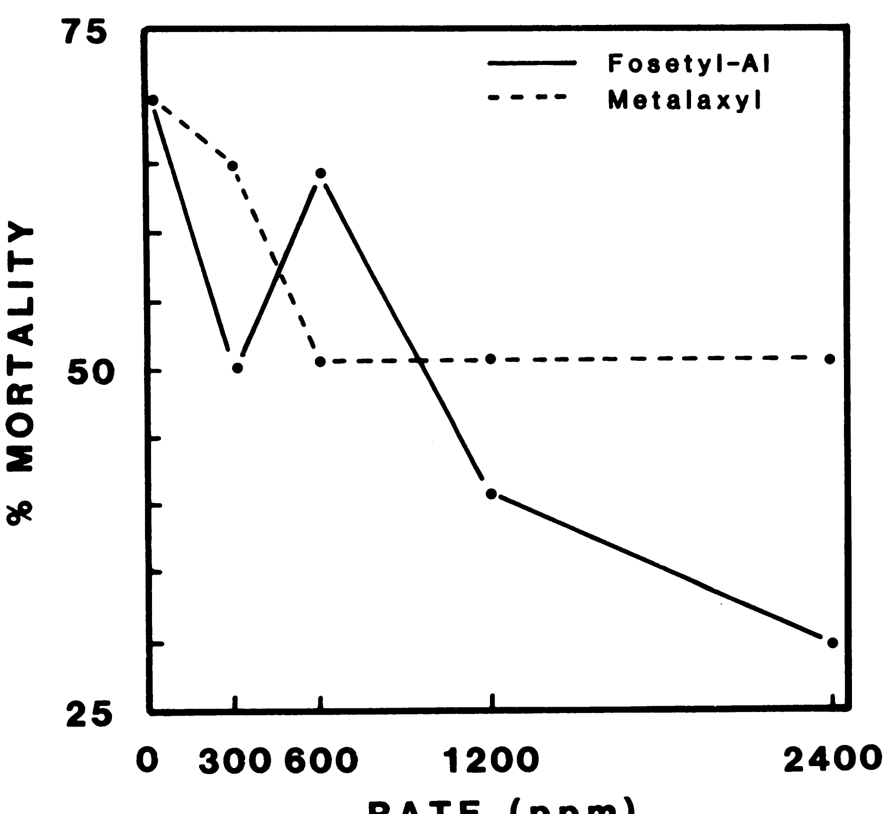

Fig. 3. Effects of different rates of fosetyl Al and metalaxyl preplant dips on butt rot of pineapple crowns caused by *Ceratocystis paradoxa* (significant negative correlation between fosetyl Al rate and mortality at 99% level).

Table 2. Effects of fosetyl Al, applied as bimonthly foliar sprays initiated on 5-mo-old pineapple plants, on heart rot caused by *Phytophthora cinnamomi* and plant weights 12 mo after planting

Treatment	Rate[a] (kg/ha)	Plant weight (kg)	Mortality[b] (%)
Fosetyl Al	1.12	0.36	10.0
	3.36	0.60	0
	6.72	0.64	1.0
Captafol	8.96	0.34	18.0
Untreated check	···	0.32	59.0

[a]Applied in 2,805 L of water per hectare.
[b]Significant negative correlation between fosetyl Al rate and plant mortality at 99% level.

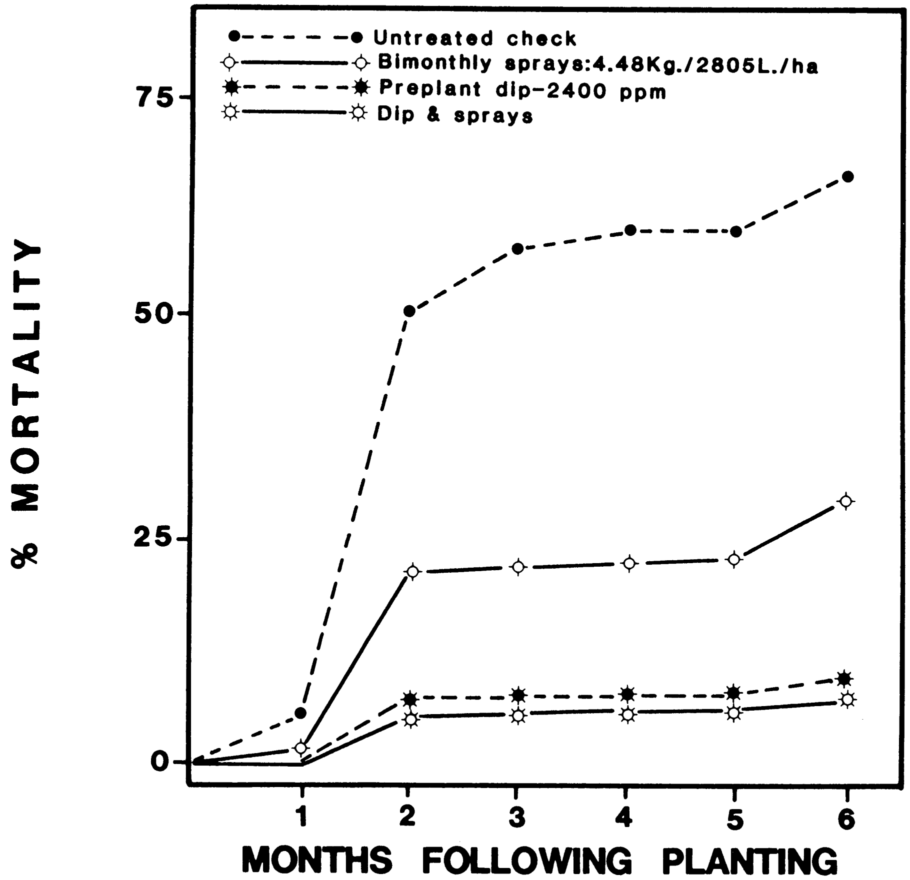

Fig. 4. Effects of preplant pineapple crown dips and/or foliar sprays of fosetyl Al initiated at planting on heart rot mortality caused by *Phytophthora parasitica* (significant negative correlation between fosetyl Al rate and mortality at 99% level).

Table 3. Effects of greenhouse foliar and root applications of fosetyl Al and time of inoculation on root rot 1 mo after inoculating rooted pineapple crowns with *Phytophthora cinnamomi*

Treatment	Rate (g/L)	Inoculation time (days after treatment)	Root rot index[a]	Dried root weight (g)
Crown leaves dipped	2.4	0	2	0.85
		1	0	1.75
		3	0	1.40
Roots in solution for 24 hr	2.4	0	0	1.40
		1	0	1.70
		3	0	1.70
Crown leaves dipped	1.2	1	2	1.30
Roots in solution for 24 hr	1.2	1	0	1.45
Untreated check	0.0	0	3	0.37

[a]0 = No disease, primary and secondary root tips white, older portions of primary roots white to slightly brown, active root growth apparent; 1 = slight root rot, up to 10% of primary root tips rotted, reduction in secondary roots; 2 = moderate disease, 10–70% of primary root tips rotted, very few secondary roots; and 3 = severe root rot, 71–100% of primary and secondary roots rotted, no active growth.

reduced butt rot of pineapple crowns caused by *C. paradoxa* (Fig. 3); however, no concentration of metalaxyl tested significantly reduced butt rot.

Field foliar treatments. Foliar sprays of fosetyl Al applied bimonthly to growing plants effectively controlled heart rot caused by *P. cinnamomi*. All foliar sprays were applied in 2,805 L of water per hectare. Rates of 3.36–6.72 kg/ha were effective in reducing plant mortality caused by heart rot. In addition, stunting caused by root rot was controlled, since treated plants weighed more than check plants. Although captafol reduced mortality, plant weights were not increased (Table 2). In additional tests, 2.24 and 4.48 kg/ha applied bimonthly and 4.48 kg/ha applied every 3 mo were compared and proved equally effective. Mortality in the untreated checks was 59.0 and 43.2%, respectively.

Foliar sprays were less effective than preplant dip applications when made to newly planted material that was not yet actively growing (Fig. 4, Table 1). Foliar sprays of metalaxyl applied immediately after planting were also less effective.

Greenhouse studies. Fosetyl Al also controlled root rot in the greenhouse. Application of fosetyl Al at 1.2 or 2.4 g/L to the leaves of rooted crowns 24 hr before inoculation resulted in lower root rot ratings and greater root weights than inoculation immediately after treatment (Table 3). Root rot was more severe when fosetyl Al rates were reduced below 0.6 g/L (Fig. 5). Phosphorous acid also resulted in root rot control but was slightly less effective than fosetyl Al at milliequivalent PO_3 rates (Fig. 5).

Laboratory tests. Both fosetyl Al and phosphorous acid at rates of 0.3–2.4 g/L were highly inhibitory to *P. parasitica* and *P. cinnamomi* in vitro. Phosphorous acid at 2.4 g/L was lethal, but both materials were inhibitory to *C. paradoxa* at 1.2 and 2.4 g/L (Table 4).

DISCUSSION

Both metalaxyl and fosetyl Al were highly effective in controlling pineapple heart rot when applied as preplant crown dips. These results confirmed previous reports on pineapple (1,4,5). Foliar treatments with fosetyl Al were very effective on heart rot as well as root rot on established plants but not as effective on newly planted crowns.

Rapid downward systemic activity of fosetyl Al was demonstrated by the occurrence of root protection within 24 hr of treatment in greenhouse studies on established plants. Foliar field sprays of fosetyl Al on established plants also confirmed downward systemic activity, as evidenced by increased root growth resulting from root rot control.

Although phosphorous acid has been reported as the major residue product from hydrolysis of fosetyl Al (11), the

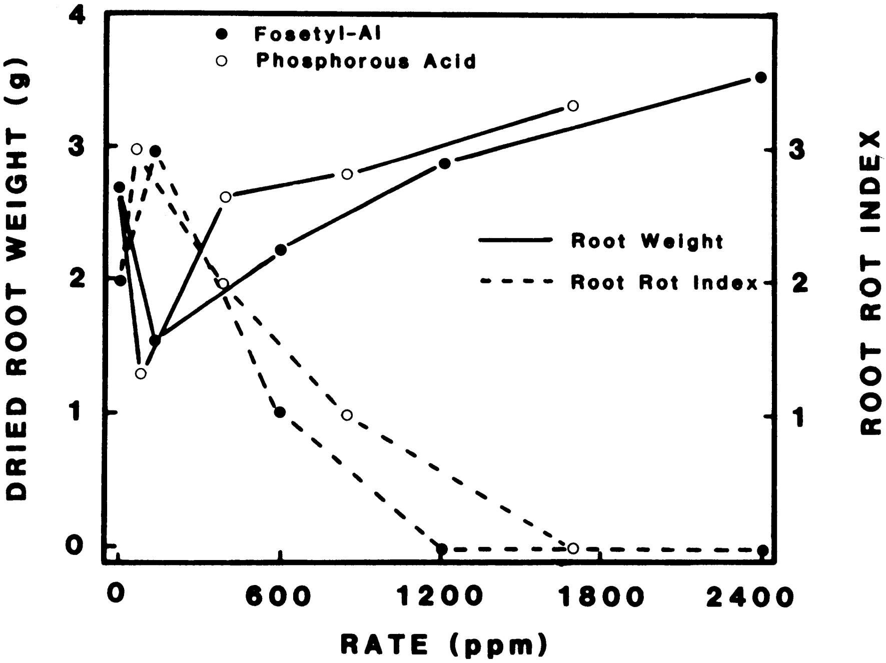

Fig. 5. Effects of different rates of foliar sprays of fosetyl Al and phosphorous acid 1 mo after treatment on root rot caused by *Phytophthora cinnamomi*. Pineapple crowns were inoculated 24 hr after treatment (significant negative correlation between fosetyl Al and phosphorous acid rate and root rot index and root weights).

Table 4. In vitro effects of fosetyl Al and phosphorous acid on radial growth (mm) of three pineapple pathogens 2 days after planting

Treatment Organism	Rate (g/L) 2.4	1.2	0.6	0.3	0.0
Fosetyl Al					
Phytophthora cinnamomi	0+[a]	1.0	2.0	2.0	13.1
P. parasitica	0+	1.0	2.8	4.2	10.0
Ceratocystis paradoxa	0+	11.5	21.5	24.0	24.0
Phosphorous acid					
P. cinnamomi	0	0+	1.0	1.3	13.0
P. parasitica	0	0+	0+	1.0	11.0
C. paradoxa	0+	1.0	17.5	20.3	22.3

[a]+ = Regrowth when plug was transferred to V-8 juice agar.

high and comparable field control of heart rot with phosphorous acid applications was unexpected. Additionally, in greenhouse studies, excellent systemic activity and root rot control of *P. cinnamomi* occurred. Phosphorous acid was present in pineapple plant and fruit tissues up to 7 mo after the last application; this correlates with control periods of 4–6 mo. The presence of phosphorous acid residues in pineapple for long periods after application indicates that PO_3 may not be metabolized as a P source in pineapple.

The high degree of activity of H_3PO_3 and fosetyl Al against *P. cinnamomi* and *P. parasitica* on pineapple and in vitro are in general agreement with the results obtained recently by Fenn and Coffey (4) with Phytophthora disease of *Persea indica*.

In addition to control of heart rot and root rot, fosetyl Al provided some control of butt rot of pineapple crowns caused by *C. paradoxa*.

Farih et al (3) discussed the in vitro activity of fosetyl Al on *P. cinnamomi, P. parasitica*, and *P. citrophthora*. They also reported that low concentrations (0.01–0.1 g/L) had little or no effect on mycelial growth, zoospore and chlamydospore germination, and germ tube growth but were inhibitory to chlamydospore and zoospore formation. Higher concentrations (up to 1 g/L) resulted in generally low to high levels of inhibition. Our data on mycelial growth is generally in agreement with those of Farih et al (3). The high in vitro inhibition of mycelial growth of *P. cinnamomi* and *P parasitica* by both fosetyl Al and phosphorous acid at rates of 0.3–1.2 g/L coincides with rates resulting in control in the greenhouse and field and with the results of Fenn and Coffey (4). Thus, postulation of a unique control mechanism (3,10) other than inhibition of growth and sporulation is not necessary.

LITERATURE CITED

1. Beach, B. G. W., Chalandon, A., Gallinelli, G., and Horrière, D. 1979. The control of various *Phytophthora* diseases in tropical crops with aluminum tris/(ethyl phosphonate). Pages 319-329 in: Proceedings of the British Crop Protection Conference on Pests and Diseases. 891 pp.
2. Collins, J. L. 1960. The Pineapple. Interscience Publishers, New York. 294 pp.
3. Farih, A., Tsao, P. H., and Menge, J. A. 1981. Fungitoxic activity of fosetyl-aluminum on growth, sporulation, and germination of *Phytophthora parasitica* and *P. citrophthora*. Phytopathology 71:934-936.
4. Fenn, M. E., and Coffey, M. D. 1984. Studies on the in vitro and in vivo antifungal activity of fosetyl-Al and phosphorous acid. Phytopathology 74:606-611.
5. Frossard, P. 1978. Lutte contre la pourriture du coeur a Phytophthora de l'Ananas. Fruits 33:183-191.
6. Frossard, P., Haury, A., and Laville, E. 1977. Résultats préliminaires concernant l'activity de l'ethyl/phosphite d'aluminium (LS 74-783) sur les maladies à Phytophthora des agrumes, de l'avocatier et de l'ananas. Phytiatr. Phytopharm. Rev. Fr. Med. Pharm. Veg. 26:55-61.
7. Klemmer, H. W., and Nakano, R. Y. 1964. Distribution and pathogenicity of *Phytophthora* and *Pythium* in pineapple soils in Hawaii. Plant Dis. Rep. 48:848-852.
8. Mehrlich, F. P. 1934. Control of Phytophthora heart rot of pineapple plants. Phytopathology 24:173-196.
9. Pegg, K. G. 1969. Pineapple top rot control. Queensl. Agric. J. 95:458-459.
10. Vegh, I., Baillot, F., and Roy, J. 1977. Etude de l'activite de l'ethyl/phosphite d'aluminium (LS 74-783) vis-à-vis de *Phytophthora cinnamomi* Rands, agent du dépérissement des arbustes d'ornement. Phytiatr. Phytopharm. Rev. Fr. Med. Pharm. Veg. 26:85-95.
11. Williams, D. J., Beach, B. G. W., Horrière, D., and Marechal, G. 1977. LS-74-783, a new systemic fungicide with activity against phycomycete diseases. Pages 565-573 in: Proceedings of the British Crop Protection Conference on Pests and Diseases. 1,045 pp.