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# Chemical control of Phytophthora cinnamomi

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## SYNOPSIS
*Avocado root rot caused by* Phytophthora cinnamomi *Rands was controlled by phosetyl-Al and phosphorous acid. Boric acid and potassium aluminium sulphate injections improved tree condition in a five-year trial, although no significant improvement could be detected in an 18-month trial. Trees injected with potassium hydroxide responded positively and less roots were infected with* P. cinnamomi*. Trees injected with hydrogen peroxide, hypophosphorous or dibasic-ammonium phosphate did not improve significantly.*

## INTRODUCTION
Root rot of avocado caused by *Phytophthora cinnamomi* Rands is the most damaging disease in South African avocado orchards. The use of metalaxyl against this pathogen was the first significant step in the control of this disease and the next major breakthrough was the application of phosetyl-Al through stem injection (Darvas, Toerien & Milne, 1984) which resulted in a commercially acceptable control programme.

Although differences of opinion exist in explaining the mode of action of phosetyl-Al, it is generally accepted that phosphorous acid is the active compound (Fenn & Coffey, 1984). Besides phosphorous acid, a few inorganic compounds, for example copper and sulphur, are applied in the control of plant diseases.

In the present study, some of the results obtained with phosetyl-Al and phosphorous acid are reviewed and the tests with different inorganic compounds (potassium hydroxide, hydrogen peroxide, boric acid, the potash of alum, dibasic-ammonium phosphate and hypophosphorous acid) are presented in the control of root rot.

## MATERIALS AND METHODS
**Chemicals** - Water solutions of 10 per cent ai phosetyl-Al, 3 per cent phosphorous acid, 3 per cent potassium hydroxide, 3 per cent boric acid, 5 per cent hypophosphorous acid, 10 per cent dibasic-ammonium phosphate, 10 per cent aluminium potassium sulphate (alum), or 5 per cent hydrogen peroxide. Zinc was evaluated in 10 per cent chelate form (Farmchem), or as 5 per cent zinc sulphate.

**Tree injection** - Trees were injected as described by Darvas et al, 1984. With potassium aluminium sulphate, double the normal number of syringes was used per tree.

**Assay for *P. cinnamomi*** - Feeder root tips were collected after surface sterilisation with 0,1 per cent mercuric chloride and a triple wash in sterilised water, plated out on PARP-medium (Kannwishcher & Mitchell, 1978). Percentage infection was taken as the number of *P. cinnamomi* colonies grown out from the roots per total number of root tips plated out.

**Evaluation of tree condition** - Trees were rated on a scale from 0 (healthy) to 10 (dead), as described by Darvas et al, 1984.

**Statistical analysis** - One-way analysis of variance with Duncan's multiple range test (Steel& Torrie, 1960) was used to compare the treatments according to the number of feeder roots infected with P. cinnamomi. Wilcoxon's signed rank test (Steel& Torrie, 1960) was applied in analysing changes in tree condition.

**RESULTS**

An improvement in tree condition could be noted within one year after three injections with either phosetyl-Al or phosphorous acid (Figure 1). The tree usually responded faster with phosphorous acid than with phosetyl-Al.

No loss in the efficacy of these compounds was. detected where trees were treated by injection for seven years, as illustrated in Figure 2.

Changes in tree condition after six injections during an 18-month trial with different inorganic compounds, are compared in Figure 3. Tree condition improved significantly after injection of potassium hydroxide, phosetyl-Al or phosphorous acid. The condition of the control trees and trees injected with alum or hydrogen peroxide deteriorated. No significant improvement was noted with the application of boric acid, dibasic-ammonium phosphate or hypophosphorous acid.

In a five-year trial, the tree condition improved slightly after injecting either potassium hydroxide or hypophosphorous acid (Figure 4). The condition of trees treated with alum, boric acid or phosphorous acid improved significantly.

In trees treated with phosetyl-Al, potassium hydroxide, alum, hypophos-phorous acid or phosphorous acid, the percentage of feeder roots infected with P. cinnamomi was significantly lower than in the control trees (Figure 5).

Trees injected with phosphorous acid supplemented with boric acid and zinc chelate, responded significantly better than trees injected with phosphorous acid only (Figure 6). A similar effect was observed when phosetyl-Al was injected with boric acid and zinc sulphate.

Indications are that a synergistic effect exists between phosphorous acid and zinc chelate in both the tree condition and the incidence of P, cinnamomi isolated from the roots. Zinc sulphate reacts with phosphorous acid to form insoluble zinc phosphite, which is not suitable for injections. Aqueous solutions of phosetyl-Al can be mixed with zinc sulphate without any detrimental effect (Darvas, 1984).

## DISCUSSION

Although the application of phosetyl-Al lead to a new dimension in orchard management in which Phytophthora root rot is no longer a limiting factor in production, the danger that resistance could develop cannot be ignored. Phosetyl-Al has been injected at Westfalia Estate since 1980 and no relapse in root rot control has been detected. Indications are that resistance can develop with regular application (Vegh, Leroux, Le Berre & Lanen, 1985), making the need for an alternative compound for root rot control more urgent.

These results indicate that the injection of some inorganic compounds (potassium hydroxide, alum and boric acid) can control *P. cinnamomi.* This control is not as drastic as that obtained with phosetyl-Al or phosphorous acid. An improvement of one unit in tree rating per year can be observed with phosetyl-Al and even more so with phosphorous acid. With potassium hydroxide it is 0,7 units per year with very diseased trees (rating 7,5) and 0,1 units per year for trees with an initial rating of two. In the long term (five years) trees responded very well to the injection of boric acid or alum, while during the 18-month period, the change detected was not significant.

Hydrogen peroxide was included in the experiments, due to its reducing capacity analogous to the phosphite ion. In contrast with potassium hydroxide, no significant improvement in tree condition was observed with the injection of hydrogen peroxide. Therefore no simple relation between the chemical reducing capacity of a compound and its potential in controlling root rot exists.

Hypophosphorous acid would theoretically be oxidised to phosphite after injection. In these experiments, hypophosphorous acid was not able to improve tree condition. No phosphite could be detected in the leaves or roots of trees injected with hypophosphorous acid (Bezuidenhout, Darvas & Kotze, unpublished).

Injections with dibasic-ammonium phosphate did not improve tree condition and there was even a tendency of increased root rot, According to Darvas (personal communication), phosphoric acid was also not able to control this disease.

Hypothetically potassium hydroxide, aluma and boric acid could act in the tree as follows:

**Essential nutrients** - Avocado soils in Tzaneen are low in available zinc and boron. In experiments where phosphorous acid was injected with boric acid and zinc chelate, the authors observed a much better response in comparison to phosphorous acid only.

Boron has been found to confer resistance to powdery mildew in wheat (Schutte, 1967) and *Fusarium oxysporum* was more severe on boron deficient flax than on boron adequate plants (Keane & Sackston, 1970)

Our results suggest the existence of a synergistic effect between zinc and phosphorous acid on the disease. This agrees with the observation made by Darvas (1984) on the more rapid improvement in tree condition when phosetyl-Al is supplemented with zinc sulphate. There are some reports of beneficial effects of added zinc increasing host resistance (Singh &Aggarwal, 1979), but there are also publications showing the opposite effect (Graham, 1983). Welsh, Webb & Loneragan (1982) found that zinc deficient roots lost membrane integrity with a corresponding leakage of soluble organic substates into the environment, which may attract motile spores.

In the experiments the two potassium compounds, potassium hydroxide and potash alum, improved tree condition. Effects of potassium on diseases are often reported in relation to fungal root rots such as *Phytophthora* and *Pythium.* In these cases, yield responses to potassium appear to be due to compounding effects of concurrent increases in growth of the host and decreases in the levels of infection (Graham, 1983). In this context the adjustment of phosphorous acid by potassium hydroxide in some of the root rot formulations available in Australia, is significant.

**Plant defence** - A number of inorganic compounds stimulate phyto-alexin production (Bailey & Mansfield, 1982) and it can be expected that injection of potentially phytotoxic compounds, such as boric acid, may induce phyto-alexin synthesis. Preliminary observations by Labuschagne (personal communication) indicate that the production of water soluble antifungal compounds are stimulated by the injection of phosphorous acid.

**Direct effect** - Boric acid is a classical fungistatic compound with a wide spectrum of activity against microorganisms. Whether the concentration of boric acid is of such magnitude at the infection site that it will inhibit *P. cinnamomi,* remains to be investigated.

Should the mode of action of potassium hydroxide, alum and boric acid resemble that of phosphorous acid, there is a high probability that cross-resistance could occur against these compounds. This possibility should be investigated further.

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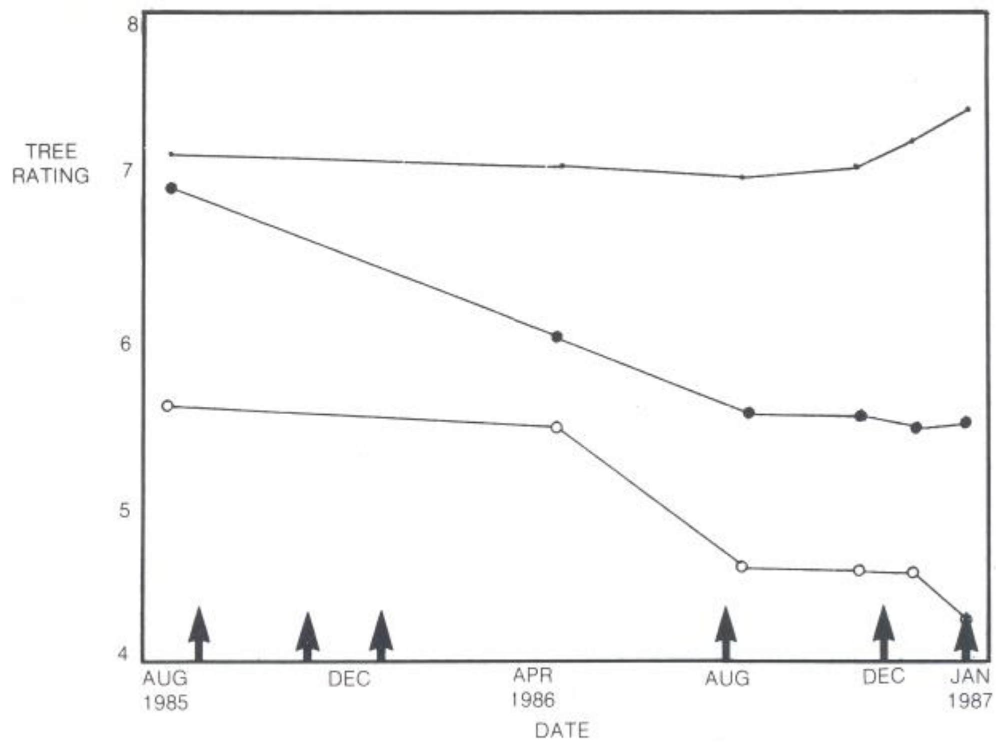


Fig 1 Changes in the condition of trees after injections with phosetyl-Al (o) or phosphorous acid (•) compared to the control (·). Time of application indicated by arrows.

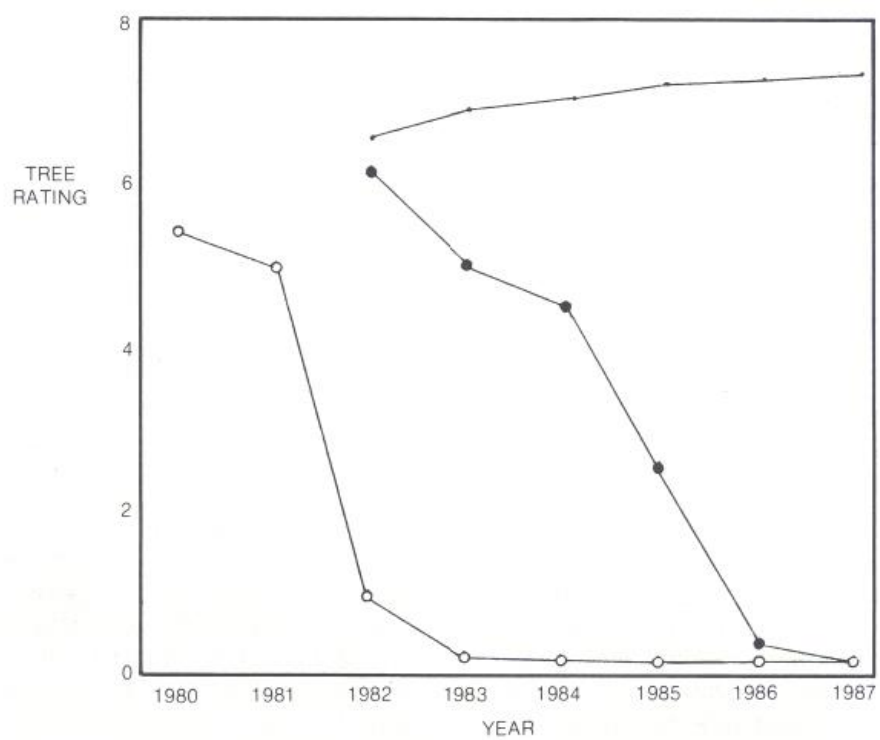


Fig 2 Changes in the condition of trees injected three times annually during a period of seven years with phosetyl-Al (o) or phosphorous acid (•) compared with the control (·).

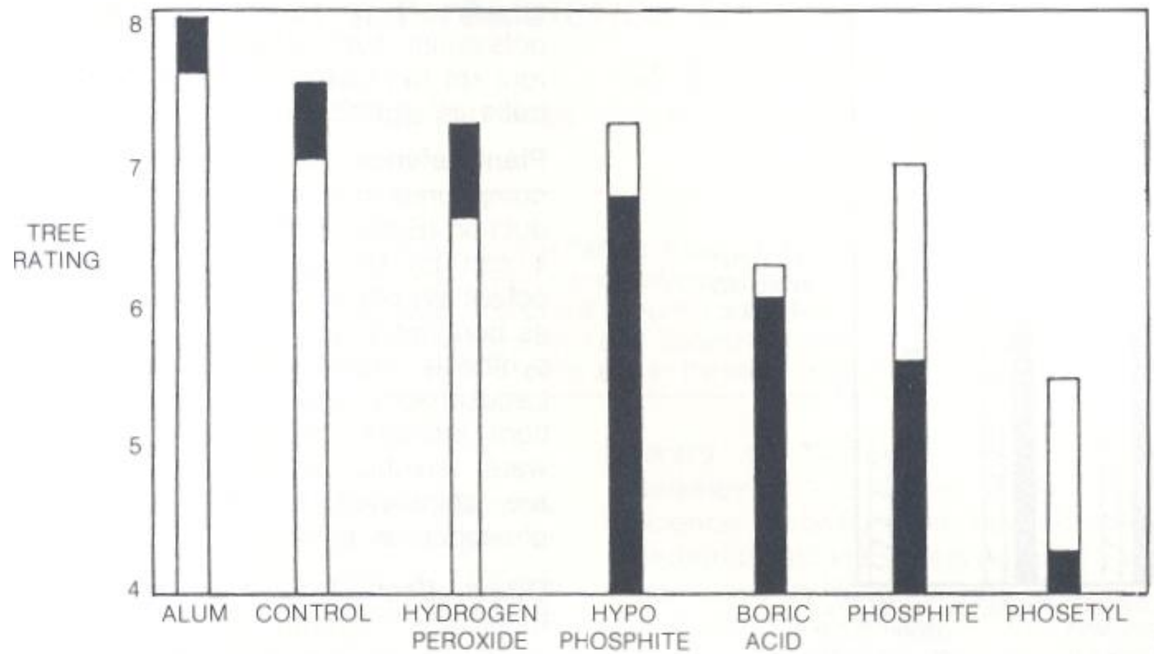


**Fig 3** Changes in tree condition 18 months after injection with different compounds. Initial tree rating □, tree rating after 18 months ■.

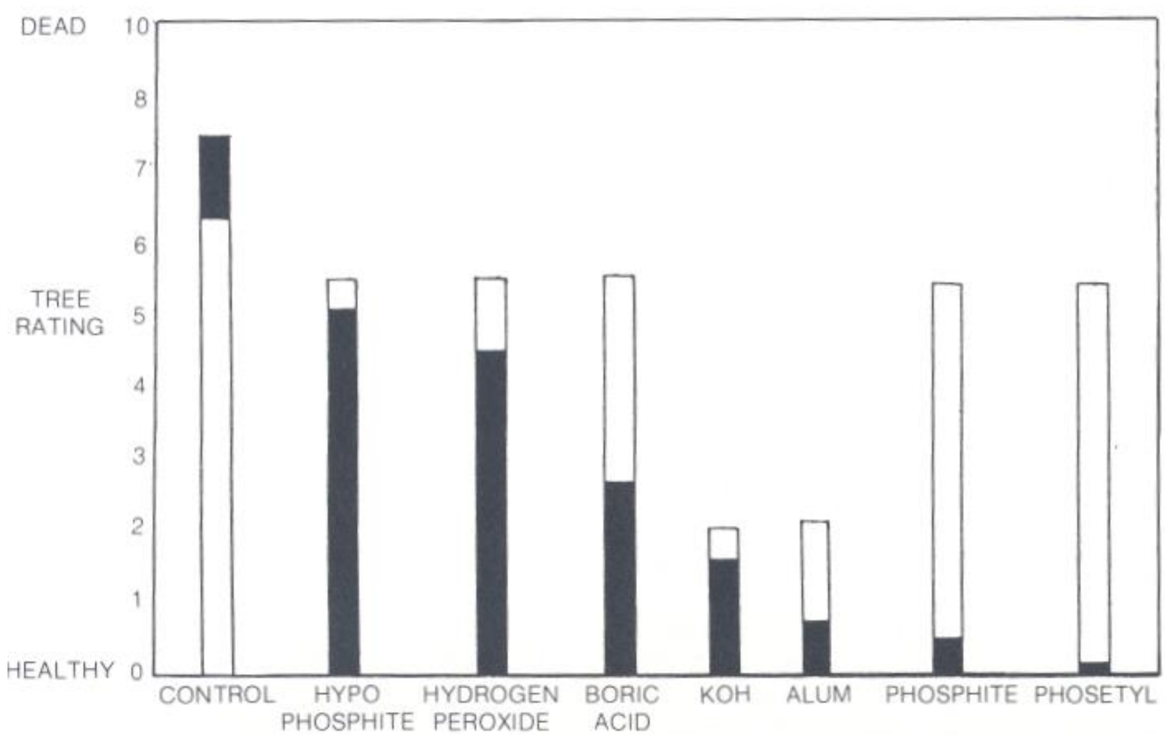


**Fig 4** Changes in tree condition after injecting different compounds during a five-year trial. Initial tree condition □, conditon after five years ■

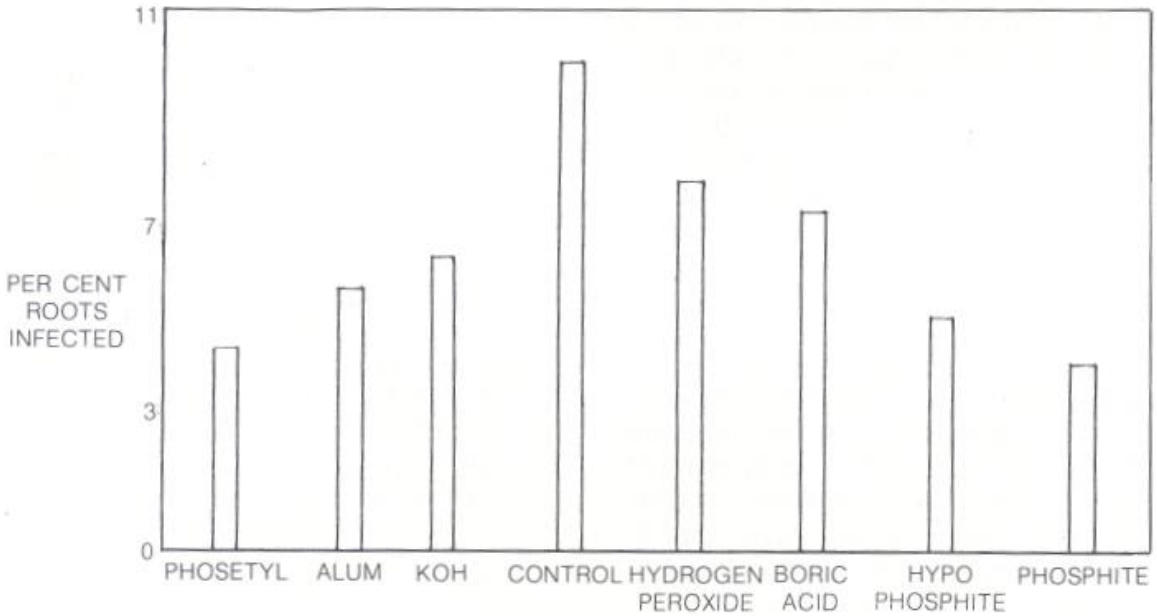


**Fig 5** Percentage of avocado root tips infected by *P. cinnamomi* after injections of different compounds in an 18-month trial.

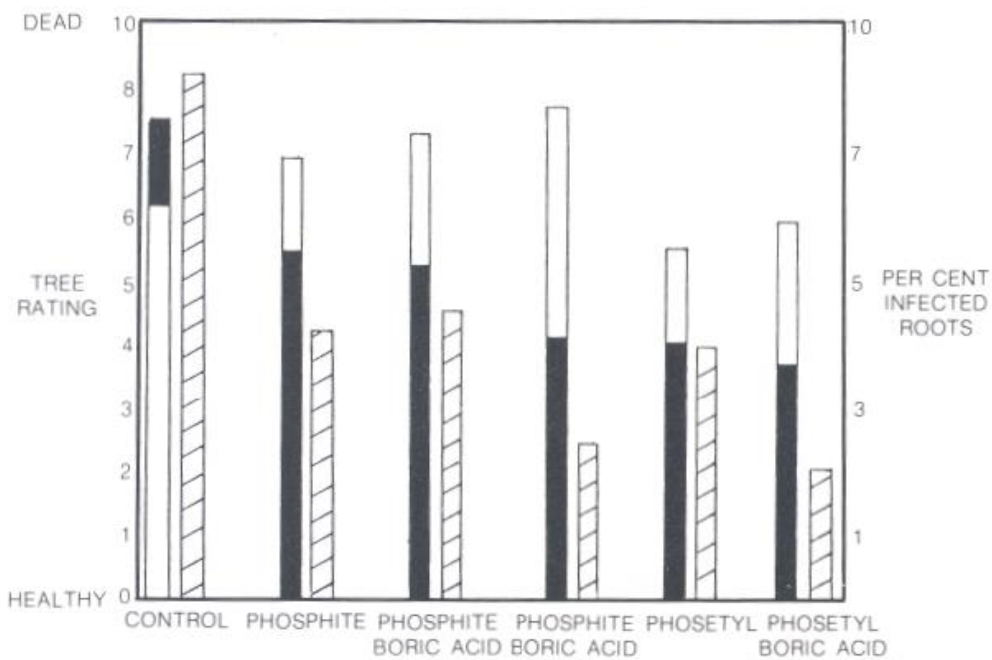


**Fig 6** Changes in tree condition after injecting phosphite compounds supplemented with boric acid and zinc. Initial tree condition □, tree conditon after 18 months ■, percentage roots infected with *P. cinnamomi* ▨.