

# Control of Avocado Root Rot by Trunk Injection with Phosethyl-Al

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## ABSTRACT

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Excellent control of *Phytophthora* root rot was achieved on fully grown avocado trees by injecting phosethyl-Al twice a year at a rate of 0.4 g a.i./m<sup>2</sup> of canopy area. The treatment resulted in a significant reduction of *Phytophthora cinnamomi* incidence in the feeder roots. An increase in the aluminum content of the treated trees was observed. A negligible amount of phytotoxicity occurred on the foliage of some phosethyl-Al-injected trees. Metalaxyl injected at 0.028 g a.i. and pyroxyfur at 0.4 g a.i./m<sup>2</sup> of canopy area failed to control the disease.

Additional key words: *Persea americana*

Chemical control of the serious root rot disease of avocados (*Persea americana* Mill.) caused by *Phytophthora cinnamomi* Rands has received considerable attention in the past. Zentmyer (12) developed a laboratory method for screening fungicides against *P. cinnamomi* and later reported on the controlling effect of *p*-dimethylaminobenzenediazo sodium sulfonate (Dexon) (13). Significant progress in control of root rot was made with some recently developed fungicides such as metalaxyl, phosethyl-Al, ethazol, and pyroxyfur (Dowco 444) (4,10,14).

The initial success in controlling root rot with metalaxyl was followed by a sharp decline in the efficacy of the chemical (4), partly caused by the development of resistance in the fungus to metalaxyl (7). Six foliar applications of phosethyl-Al at monthly intervals in a growing season gave a very slow reaction, and trees in this expensive treatment showed first signs of improvement years after commencement of the experiment (4). Thus, it became necessary to search for more effective, low-cost chemical control measures. In the first part of this program, three systemic fungicides were tested in the form of a trunk paint application and phosethyl-Al gave some control against root rot on bearing avocado trees (5). Similar trunk treatments were tested on seedlings and established trees (10,11).

This report gives the results from an experiment in which systemic fungicides were injected into the trunks of established avocado trees for control of *Phytophthora* root rot.

## MATERIALS AND METHODS

Ten-year-old Fuerte avocado trees on *Phytophthora* root rot-susceptible Guatemalan rootstocks were used for the experiment in block 14 of the Westfalia Section of Westfalia Estate in Northern Transvaal, South Africa. The experiment began in 1980 and continued for 3 yr.

Trees were injected with the fungicides in the main trunk by using a slightly modified form of the technique of Buitendag and Bronkhorst (3). The method consisted of drilling holes 5 mm in diameter and 40 mm deep at a slight downward angle into the trunk of the tree. A small pressure seal was tapped into the hole. The pressure seal is identical to the plastic needlehead of the Luer-type (Daiwa) disposable needles, size 18G × 1.5 in. A 60-ml disposable eccentric-tip plastic syringe (Brunswick type) was then filled with 20 ml of solution and drawn to the full 60-ml mark with air. The syringe was coupled to the pressure seal in the tree and the plunger was inserted to the 30-ml mark and fixed at this position so the solution would remain under pressure. The required amount of material and the number of syringes per tree were based on the size of the tree as measured by the canopy area.

The injection holes were spaced evenly around the trunk at about 0.5 m above ground level. In general, it took from a few hours to a few days for the liquid to penetrate, depending on various factors. After the syringe and the pressure seal were removed, the hole was covered with tree sealant. To prevent the possibility of transmitting diseases from one tree to another, the drill was dipped in a 1% calcium hypochlorite solution after each tree was treated.

There were 10 single-tree replicates of each treatment. The treatments used in the experiment were as follows: Phosethyl-Al was injected twice a year, first in August and again in October at a

rate of 0.4 g a.i./m<sup>2</sup> of canopy area by using a 10% aqueous solution made from an 80% a.i. WP formulation. The material was dissolved in tap water at ambient temperature by vigorous agitation for 0.5 hr and was then left to settle for 7 days. Metalaxyl was injected at a rate of 0.028 g a.i./m<sup>2</sup> of canopy area in August and again in October, using an aqueous solution of 0.7% metalaxyl made from a 25% a.i. WP formulation. The material was dissolved in water as for phosethyl-Al. Pyroxyfur was injected at a rate of 0.4 g a.i./m<sup>2</sup> of canopy area in August and again in October, using an 80% a.i. EC formulation.

The assessment of results was based on rating trees according to a disease index of 0 (healthy) to 10 (dead) during the winter months each year. The root rot severity rating entailed the objective visual rating of trees, taking into consideration growth vigor, color of leaves, and degree of defoliation and wilting. A useful guide illustrated with color photographs for the root rot severity index scale of 0-10 has been released to avocado farmers by Ciba-Geigy in South Africa.

Root samples were collected 12 times from under four trees in each treatment at monthly intervals during the first year (1980-1981) of the experiment. Each time, 16 freshly killed feeder roots were removed from each treatment and surface-sterilized in 0.1% HgCl<sub>2</sub> solution for 5 sec, then rinsed in sterile water. Five 2-mm segments were cut from each feeder root and placed onto potato-dextrose agar in petri dishes. Freshly killed feeder roots were brown and still intact, before the onset of the usually darker colored decomposition stage. Isolated fungi were identified and the mean frequency of the following organisms was calculated for each treatment: *Phytophthora cinnamomi* Rands, *Pythium* spp., *Cylindrocladium scoparium* Morgan, *Rhizoctonia solani* Kühn, *Macrophomina phaseolina* (Tassi) Goid., *Fusarium oxysporum* Schlecht., and *Cylindrocarpon destructans* (Zins.) Scholten.

The aluminum content in the trunk wood at and above the point of injection as well as in leaves and fruits of phosethyl-Al-injected trees was analyzed. Zinc content was also determined in the leaves of some of the phosethyl-Al-injected trees. All chemical analyses for these elements were carried out by the Chemistry Laboratory of the Northern Transvaal Cooperative in Potgietersrus, using standard procedures (2,9).

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To determine optimum dose rate, 2,115 randomly selected avocado trees, including Fuerte, Hass, Edranol, and Ryan cultivars varying between 1- and 17-m drip-line diameter were injected in commercial orchards with phosethyl-Al doses of between 0.1 and 2.5 g a.i./m<sup>2</sup> of canopy area. Disease ratings of the trees ranged from 0 to 8 on the root rot severity index scale of 0 (healthy) to 10 (dead).

Trees were injected in July 1981 and the reaction was assessed in July 1982. Disease rating differences that occurred during this period were correlated with the dose rates used and the initial disease condition of the trees; a multiple linear regression model was then constructed to forecast the first year's reaction.

Yield data and root rot severity ratings for the whole orchard were recorded from

the 10.8-ha block 11A of Westfalia Section planted in 1968 with Fuerte on Guatemalan rootstocks. Because of the severe Phytophthora root rot infection, metalaxyl had been used at 2.5 g a.i./m<sup>2</sup> twice a year for the period between 1978 and 1980. Since 1981, all trees in this orchard had received phosethyl-Al injections at 0.4 g a.i./m<sup>2</sup> of canopy area twice a year.

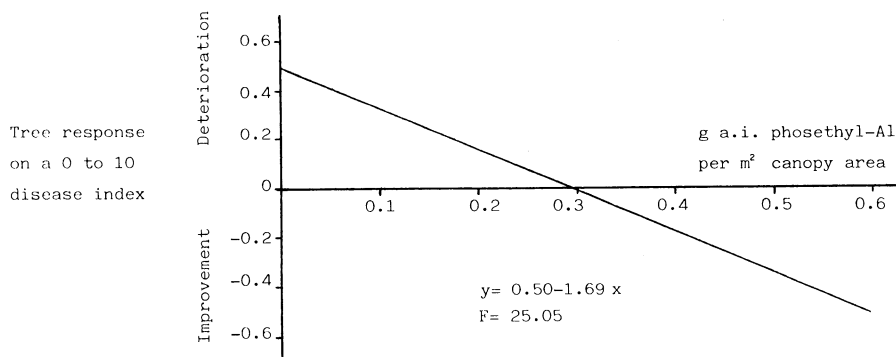


Fig. 1. Correlation between phosethyl-Al dose rates by trunk injection and tree response in the first year of treatment.

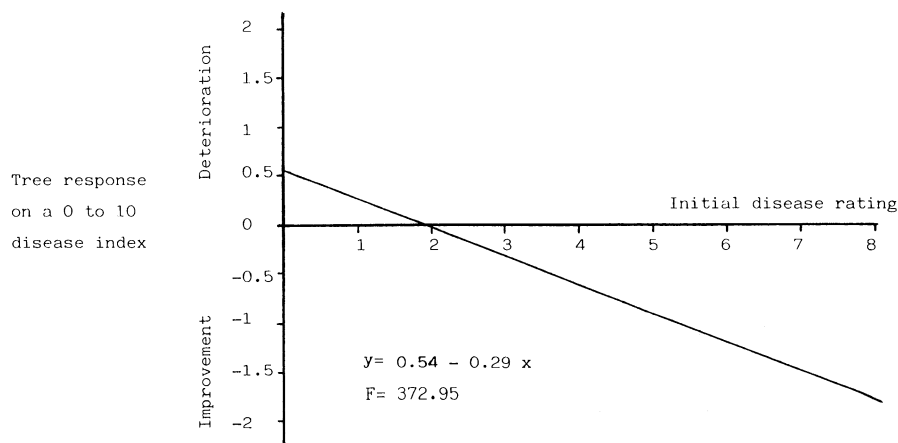


Fig. 2. Correlation between initial disease rating of trees and tree response in the first year of phosethyl-Al trunk injection.

Table 1. Control of Phytophthora root rot by injecting fungicides into the trunks of established Fuerte avocado trees

Treatment	Mean disease rating <sup>a</sup>			
	1980	1981	1982	1983
Phosethyl-Al (0.4 g a.i./m <sup>2</sup> )	5.3	5.0	1.0	0
Metalaxyl (0.028 g a.i./m <sup>2</sup> )	4.1	4.6	5.8	6.1
Pyroxyfur (0.4 g a.i./m <sup>2</sup> )	4.1	5.0	5.6	6.8
Control	5.0	4.8	6.4	7.1

<sup>a</sup> Average rating from 10 trees per treatment. Disease rating on a scale of 0-10, where 0 = healthy and 10 = dead.

Table 2. Incidence of common root pathogens in dead feeder roots of avocado trees injected with fungicides

Treatment	Mean frequency in roots <sup>1</sup>						
	<i>Phytophthora cinnamomi</i>	<i>Pythium</i> spp.	<i>Cylindrocladium scoparium</i>	<i>Rhizoctonia solani</i>	<i>Macrophomina phaseolina</i>	<i>Fusarium oxysporum</i>	<i>Cylindrocarpum destructans</i>
Phosethyl-Al	2.2 b <sup>2</sup>	0.50 a	0.8 a	2.2 a	5.7 a	21.8 a	25.8 a
Metalaxyl	7.1 ab	0.10 a	0.4 a	1.0 a	6.8 a	12.7 a	30.1 a
Pyroxyfur	6.3 ab	0.07 a	0.7 a	1.0 a	6.6 a	19.8 a	22.2 a
Control	14.1 a	0.70 a	2.7 a	1.2 a	3.6 a	21.2 a	23.2 a

<sup>1</sup> A total of 3,840 root sections were assayed.

<sup>2</sup> Means followed by the same letter do not differ significantly at  $P = 0.05$  according to Duncan's multiple range test.

## RESULTS

As illustrated in Table 1, the best root rot control was obtained with phosethyl-Al injections. This treatment showed little effect in the first year but dramatically improved the condition of the trees in the second year, with all trees regaining full health after 3 yr of continued treatment. Poor control was obtained by injection of metalaxyl and pyroxyfur at the rates used.

All three fungicides tended to reduce the incidence of *P. cinnamomi* in the roots, but only in the case of phosethyl-Al injection was this reduction statistically significant. None of the treatments significantly influenced the occurrence of the other pathogens recorded in this survey (Table 2).

Trees injected with phosethyl-Al showed a slight increase in the aluminum content of the trunk, leaves, and fruit (Table 3). The buildup of aluminum in the trees is progressively higher with prolonged treatments. There was also a higher concentration of zinc in the leaves of the phosethyl-Al-injected trees than in the control trees.

A highly significant correlation was found between the amount of phosethyl-Al injected into avocado trees and tree response (Fig. 1). This showed that dose rates below 0.3 g a.i./m<sup>2</sup> of canopy area were ineffective, whereas the 0.4-g a.i. rate injected twice a year fell in the effective dose rate regimes.

A similar, highly significant correlation was shown between the initial disease condition of avocado trees and tree response (Fig. 2). This showed that trees with full foliage require more phosethyl-Al than similar sized but partially defoliated trees in order to produce equivalent responses.

It is possible to compute a forecasted tree response with the following multiple linear regression equation:  $Z = 0.85 - 1.17x - 0.29y$ , where  $Z$  = the forecasted tree response on a disease index of 0-10,  $x$  =

**Table 3.** Aluminum and zinc content of avocado trees injected with phosethyl-Al

Treatment	Part of plant	Al content (mg/kg)	Zn content (mg/kg)
Phosethyl-Al injected 3 yr	Wood next to hole	5	...
	Wood 20 cm above hole	4	...
	Wood 50 cm above hole	3	...
	Leaves	5	34
	Fruits	8	...
Phosethyl-Al injected 2 yr	Wood next to hole	4	...
	Wood 20 cm above hole	3	...
	Wood 50 cm above hole	2	...
	Leaves	4	34
	Fruits	5	...
Control	Wood	2	...
	Leaves	3	23
	Fruits	3	...

phosethyl-Al dose rate (in g a.i./m<sup>2</sup> of canopy area), and  $y$  = initial disease rating on a disease index of 0–10 ( $F$  for  $Z$  = 198.26,  $F$  for  $x$  = 20.18, and  $F$  for  $y$  = 378.20).

In spite of the Fuerte cultivar's alternate bearing habit, there is an obvious correlation between disease condition of trees and yield of a commercial orchard as presented in Table 4. The improvement resulting from metalaxyl treatments continued with the phosethyl-Al injections. It is important to note that good yields were maintained with the phosethyl-Al injection treatments.

A few of the sparsely foliated trees in advanced stages of root rot showed symptoms of phytotoxicity after injections with phosethyl-Al, but these symptoms disappeared in the second year of treatment. Some of the pyroxyfur-injected trees developed severe phytotoxic symptoms, with damage more serious on trees with less foliage.

## DISCUSSION

Outstanding root rot control and significant reductions of *P. cinnamomi* incidence in feeder roots were achieved on established avocado trees by injecting small quantities of phosethyl-Al into the trunks of the trees. This treatment greatly outperformed all chemical treatments tested at Westfalia Estate, including the foliar spray of the same product six times a year as recommended for corrective treatment (4). It is also considerably cheaper than any chemical treatment presently available for control of root rot.

It was found that phosethyl-Al must be injected at dose rates higher than 0.3 g a.i./m<sup>2</sup> of canopy area to be effective and that infected but healthier-looking trees require more of the material than sick trees in order to improve or maintain their condition.

It is believed that phosethyl-Al injected into the trunk is gradually broken down, releasing phosphorous acid. Phosethyl-Al and its breakdown product, phosphorous acid, has been experimentally proven to give protection against *Phytophthora* diseases by inducing a number of physiological changes in the

plant (1,8).

Phosethyl-Al injection treatments have been tested with good results on Fuerte, Hass, Edranol, and Ryan cultivars. Investigation of the woody parts of the trunk after phosethyl-Al injections showed that a certain amount of discoloration occurs in the xylem tissues above and below the point of injection, but this decreases with time and causes no serious damage to the transporting elements in the trunk. Holes drilled in the trunk callused rapidly after injection and no secondary infections occurred.

It is not known what long-term side-effects the aluminum accumulation may have on trees injected with phosethyl-Al. In some trees, aluminum concentrations were artificially built up to levels as high as 10 mg/kg with KAl(SO<sub>4</sub>)<sub>2</sub> injections without any phytotoxic symptoms to date.

It is interesting to observe the favorable increase of zinc content in the leaves of phosethyl-Al-injected trees; this may be attributed to a better uptake of nutrients from the soil by a healthier root system.

It has been found that avocado trees can be supplemented easily with zinc in the form of ZnSO<sub>4</sub> in mixtures with phosethyl-Al solution (6). Trees injected with these mixtures kept satisfactorily high zinc levels and recovered more rapidly in the first year of the experiment than trees injected with phosethyl-Al alone.

Phosethyl-Al is now used experimentally on a large scale at Westfalia Estate, and the improvement in tree conditions and yield records in this severe root rot-affected area indicate that the trunk injection method with phosethyl-Al is biologically and commercially a most effective treatment for combatting this serious disease.

Metalaxyl was extracted from a wettable powder formulation, and because of its lower water solubility, a low concentration of 0.028 g a.i./m<sup>2</sup> of canopy area was administered to the trees, and this rate failed to control the disease. It is possible, however, that more effective control would be obtained at higher rates. Pyroxyfur at a rate of 0.4

**Table 4.** Disease ratings, yield records, and root rot treatments for a commercial Fuerte orchard at Westfalia Estate planted in 1968

Year	Root rot treatment	Disease rating <sup>a</sup>	Yield (kg/ha)
1975	None	2	9,094
1976	None	3	7,907
1977	None	5	6,456
1978	Metalaxyl	7	6,927
1979	Metalaxyl	5	3,560
1980	Metalaxyl	3	10,274
1981	Phosethyl-Al injection	2	5,780
1982	Phosethyl-Al injection	1	11,535
1983	Phosethyl-Al injection	1	12,761

<sup>a</sup> Disease rating on a scale of 0–10, where 0 = healthy and 10 = dead.

a.i./m<sup>2</sup> of canopy area was also ineffective against root rot.

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