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Control of Phytophthora root rot of avocados by trunk injection

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SYNOPSIS
The most important avocado disease, Phytophthora root rot was brought under control with a trunk injection technique which has been developed at Westfalia Estate in South Africa. The technique proved to be biologically the most effective and at the same time the least expensive method of controlling the disease. Initially, the wettable powder form of phosetyl-Ca and phosetyl-Al have been used in experiments with good results and later phosphorous acid was tested with even more impressive effect. As additives to root rot injection, trace elements were also tested and compatible forms of zinc formulations were found to be beneficial to the trees and they appeared to enhance tree recovery. Zinc sulphate was compatible with phosetyl-Al solutions obtained by dissolving the wettable powder form and injections with this mixture ncreased the zinc content of the trees. Zinc sulphate alone had no effect on tree health and was phytotoxic at high rates. Effective dose rates of phosetyl-Al are over 0,3g at per m^2 *canopy area and to improve the condition of badly diseased trees needed less material than of slightly affected trees. The aluminium content of trees regularly treated with phosetyl-Al increased without side effects. No decline in efficacy or resistance problem can be seen on producing trees treated with phosetyl-Al for the past 10 years at Westfalia Estate.*

The biological control of Phytophthora root rot appeared to be possible with the injection of cell suspensions of various antagonistic bacteria. Isolates of different Bacillus *species occurring naturally in the root zone of avocados were selected for the purpose on the basis of their* in vitro *activity against* Phytophthora cinnamomi.

INTRODUCTION

The root rot disease of avocados *(Persea americana* Mill) caused by *Phytophthora cinnamomi* Rands is the most serious problem threatening the cultivation of this crop in all major growing centres of the world.

This article is a review of works done on the chemical control of Phytophthora root rot in South Africa and elsewhere, with particular reference to the trunk injection method. Most of the results discussed here have been published previously, but a few findings are made public for the first time. This is also the first preliminary report on the use of cell suspensions of antagonistic bacteria in trunk injection form for the biological control of avocado root rot.

Controlling the disease with chemicals has been attempted in the past, but limited success was achieved (Zentmyer, 1955; Zentmyer, 1973; Snyman, 1982; Darvas, 1983a). In field trials, the significant control achieved by metalaxyl in the first two years of its application was followed by a disappointing inefficacy thereafter, with different reasons given for the failure. Darvas& Becker (1984) found resistance to metalaxyl *by P. cinnamomi* at Westfalia Estate, but McKenzie & Margot (1982) and McKenzie (1984) proposed that a rapid biodegradation in soils treated with metalaxyl for prolonged periods was the cause of the problem. Pegg, Whiley, Langdon & Saranah (1987) also suggested degradation (biological or chemical) of metalaxyl in the soil.

Another alternative fungicidal treatment commercially available at the time was phosetyl-Al wettable powder for foliar spray with an unaffordably expensive six-times-a-year application. The spraying of the trees with a fixed-wing aeroplane gave approximately the same reaction as foliar spray with ground sprayers, but was also very expensive (unpublished).

A series of research projects were commenced in 1980 in South Africa, with most of the field work undertaken at Westfalia Estate and some glasshouse tests at the University of Pretoria. The aim of these projects was to develop new application methods with known chemicals or compounds novel to the avocado disease management which is inexpensive and biologically more effective than commercially available methods. Results soon showed that at least two methods perform well. These were trunk paint (Snyman & Kotze, 1983; Darvas, 1983b) and trunk injection (Darvas, Toerien & Milne, 1984). The product that gave best results in the trunk injection tests was phosetyl-Al. The recovery rate of diseased trees and the zinc content of trees could be improved by the addition of zinc sulphate to the phosetyl-Al mixture (Darvas, 1984). In experiments at Westfalia Estate, phosphorous acid, the breakdown product of phosetyl-Al, was found even more effective (Darvas, 1983c; Darvas, 1983d).

One of the new formulations tested successfully against root rot in trunk injection form is potassium phosphite (Pegg & Whiley, 1986).

MATERIALS FOR TRUNK INJECTION

Phosetyl-Al and phosetyl-Ca

In experiments at Westfalia Estate both phosetyl-Al (Darvas *et al,* 1984) and phosetyl-Ca (unpublished) gave an outstanding root rot control if injected into the trunk of the trees. Since manufacturers favoured the industrial production of aluminium salt, all subsequent work was done with the aqueous solution of phosetyl-Al wettable powder or the later released liquid phosetyl-Al form (stabilised with Ca-acetate). It was established that effective dose rates of phosetyl-Al on bearing avocado trees are over 0,3g ai/m^2 canopy area (Darvas, etal, 1984) (Figure 1).

It was found that very sick trees with sparse foliage required less phosetyl-Al than a similar size but healthier tree with a denser foliage to produce equivalent responses (Darvas *et al,* 1984) (Figure 2).

Due to the high water solubility of phosetyl-Ca, it was a more convenient product to dissolve in water for trunk injection than the phosetyl-Al wettable powder. This problem has been overcome with the liquid formulation of phosetyl-Al formulated specifically for injection. It is also a much faster penetrating solution than the solution made up from the wettable powder formulation.

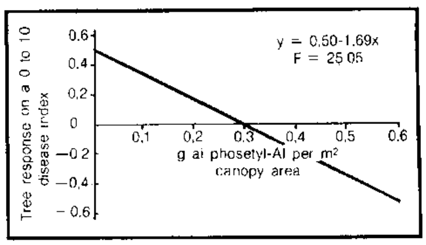

Fig 1 Correlation between initial disease rating and tree response in the first year of trunk injection with phosetyl-Al.

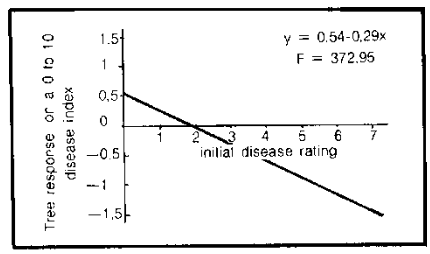

Fig 2 Correlation between initial disease rating o trees and tree response in the first year o phosteyl-Al injection.

Phosphorous acid

Phosphorous acid is the active ingredient which controls root rot (Bompeix, Ravise, Raynal, Fettouche & Durand, 1980; Durand & Salle, 1981). It was first tested in injection form at Westfalia Estate from 1981 and results released at the 1983 Avocado Research Symposium (Darvas, 1983c; Darvas, 1983d). The results were simultaneously submitted for publication, but it had to be withdrawn due to objections by the manufacturers of phosetyl-Al based on patent regulations. The testing of the product has been carried on by others and Fenn & Coffey (1984) reported on laboratory and Pegg *et al* (1985) on field results. It was more effective in our experiments than phosetyl-Al and similar observations were made by Pegg *et al* (1985) in Australia.

Potassium phosphite

It has been proved in field experiments by Pegg & Whiley (1986) in Australia that potassium phosphite injected into the trunk is effectively curing avocado trees affected by root rot.

Cell suspension of antagonistic bacteria

The possibility of controlling Phytophthora root rot with antagonistic organisms was investigated by several workers. Suppressive soils are believed to have the suppressive property against *Phytophthora cinnamomi* due to high bacterial and actinomycete counts (Broadbent & Baker, 1974). An interesting protection against *Phytophthora citricola* and *Phytophthora cinnamomi* on avocado trees was demonstrated with prior inoculation of a *Phytophthora parasitica* isolate by Dolan, Cohen & Coffey (1986). The idea of injecting cell suspensions of antagonistic bacteria against tree diseases caused by fungi has been tested before (Strobel & Myers, 1981).

In our work a number of bacteria were selected from the soil of avocado orchards and they were tested for their *in vitro* inhibition of *Phytophthora cinnamomi.* The best performing 11 isolates were preserved in freeze-dried cultures and used in further experiments. These are *Bacillus* species and their identification is still in progress.

Unfiltered liquid cultures of these bacteria were injected into producing avocado trees and a marked improvement in disease condition followed. The recovery was not as spectacular as with phosetyl-Al. It may be possible to enhance control by further selection of more active isolates and better culture techniques (unpublished).

Additives with root rot injection

Avocado trees frequently develop problems as a result of micro-nutrient deficiency in the trees. Kadman & Lahav (1971) described a trunk injection method in Israel for the correction of iron deficiency in avocado trees with iron chelates.

One of the most common micronutrient deficiencies in South African avocados is zinc shortage and the zinc content of trees was sufficiently increased by the injection of zinc sulphate with the phosetyl-Al solution made up from the wettable powder at Westfalia Estate (Darvas, 1984). It was reported from Australia that no zinc increase occurred in trees injected with the mixture of phosetyl-Al (liquid formulation with Ca-acetate) and phosphorous acid plus zinc sulphate (Pegg *et al,* 1985). It would be useful to establish the reason for the difference in compatibility of the two phosetyl-Al sources with the zinc sulphate. A serious incompatibility was experienced at Westfalia Estate too with the injected mixture of phosphorous acid and zinc sulphate resulting in a lessened root rot control. Phosphorous acid was, however, compatible with zinc chelate formulations (Bezuidenhout, Darvas & Toerien, 1987).

Another micro-element, boron, was successfully supplied to bearing avocado trees in the form of boric acid in mixtures with phosetyl-Al solution from the wettable powder form (Bezuidenhout *et al,* 1987).

The use of fertiliser mixtures such as Multifeed P and Wuxal alone or in conjunction with phosetyl-Al failed to provide extra benefit in tree response. Likewise, root rot was not controlled by the injection of phosphoric acid (unpublished) and hypophosphorous acid (Bezuidenhout *et al,* 1987).

Some of the fungicides reduced the incidence of *Phytophthora cinnamomi* on feeder roots of injected trees without improving tree condition. They were metalaxyl, pyroxyfur (Darvas *et al,* 1984) and triadimefon (unpublished). Although not claimed officially by the manufacturers, Ca-acetate is said to be useful in trees injected with the liquid formulation of phosetyl-Al in reducing post-harvest physiological fruit disorders caused by calcium deficiency, but this theory was not put to the test. It would be interesting to compare the two formulations which contain calcium (phosetyl-Ca and phosetyl-Al liquid with Ca-acetate) to select the more effective supplier of this important element to deficient trees. Trunk injection with water soluble calcium compounds such as Ca-chloride, Ca-nitrate, Ca-formate and Ca-lactate have all proved to be ineffective in increasing calcium levels when applied alone or in mixtures with phosetyl-AI from the powder form in Fuerte fruit (unpublished).

SIDE EFFECTS OF TRUNK INJECTION

Phytotoxicity

Phosetyl-Al, phosetyl-Ca and phosphorous acid all produce very similar phytotoxic symptoms on the foliage in the form of intervenal necrotic areas. The dead tissues of the leaf blade are shed, leaving large holes behind. It is noteworthy that these damaged leaves do not normally drop from the trees. Leaf damage is usually more serious on much defoliated trees and it becomes less apparent from the second year of the treatment, when denser foliage develops. A dark-brown wood discolouration is visible inside the trunk below and above the point of injection with phosetyl-Al from the powder, but it seems to have no adverse effect on tree growth.

The aluminium content of phosetyl-Al injected trees is progressively increasing with the continued injection treatments, but it shows no disadvantageous effect on tree health (Darvas *et al*, 1984). No phytotoxicity was seen on trees receiving potassium aluminium sulphate to increase the aluminium content of the tree to an abnormally high level (Darvas *et al,* 1984). Instead, the tree receiving this treatment has in fact improved (Bezuidenhout *et al,* 1987).

Fuerte fruit of phosetyl-Al injected trees did not differ in their susceptibility to the physiological flesh discolouration (pulp spot) from fruit of untreated trees. Fruit from the injected trees had 14 per cent less stem-end rot and the reduction occurred mainly in the incidence of *Colletotrichum gloeosporioi*des and *Thyronectria pseudotrichia.* They were also less damaged by anthracnose, but at the same time Cercospora spot increased on them (unpublished).

Plant nutrition

Differences were noted in the concentration of some elements in the leaves of phosetyl-AI injected versus untreated avocado trees (Darvas *et al,* 1984). An increase in the leaf concentration of various elements after treatments which improved tree health was reported by Whiley, Pegg, Saranah & Langdon (1987).

The phosphorus content in the leaves of trees injected with phosphorous and phosphoric acid has considerably increased (Toerien & Slabbert, 1984) and this is a good indication that root rot control injections may have an influence on the tree-nutrition aspect. It is a future challenge to interphase root rot control with plant nutrition by adding compatible forms of the important elements to the mixtures. This may not only improve tree response, but could also cut on fertiliser costs.

Resistance

Development of resistance to phosetyl-Al by the pathogen is a constantly present danger. Resistant isolates were already found in a nursery where frequent drenching with the chemical is practised (Vegh, Leroux, Le Berre & Lanen, 1985). Pegg *et al* (1987) have suggested the rotation of fungicides to avoid the development of resistance. In our field experiments, producing trees receiving phosetyl-Al sprays six times a year for five years and phosetyl-Al trunk injections three times a year for another five years are still looking vigorous and show no relapse in their condition.

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