South African Avocado Growers' Association Yearbook 1987. 10:103-105
Proceedings of the First World Avocado Congress

Leaf mineral nutrient concentrations and yield in Phytophthora root rot affected avocado trees treated with phosphite-phosphorus compounds

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SYNOPSIS
Phytophthora root rot reduced leaf concentrations of N, P, S, Zn and B to below critical values for optimum growth and increased leaf chloride levels to the phytotoxic range. For the most part nutrient levels recovered rapidly when trees were injected with phosphite-phosphorus compounds and treated with soil-applied fertiliser programmes. Two injections of zinc nitrate increased zinc leaf levels. Significant yield increases ocurrred 30 months after the first fungicidal treatments were given.

INTRODUCTION

Phytophthora cinnamomi Rands attacks the unsuberised roots of avocados causing severe loss of the primary organs of water and mineral nutrient uptake. Root decay soon leads to water stress in the tree (Sterne *et al,* 1978; Whiley *et al*, 1986) and this is followed by nutrient depletion through reduced absorption surfaces and failure of tree water-transport systems.

Effective chemical treatments have been developed to control Phytophthora root rot in avocados (Allen *et al,* 1980; Darvas *et al,* 1984; Pegg *et al,* 1985; Whiley *et al,* 1986) but initial growth response from severely affected trees is variable. The efficacy of the fungicide, the genetic capacity of rootstocks to regenerate and the base nutritional status of diseased trees are probably all critical factors in determining the rate of recovery to economic productivity levels.

This paper examines leaf nutrient concentrations, methods of applying mineral nutrients and the fruit yield from avocado trees affected by Phytophthora root rot which were being rehabilitated *by* treatment with phosphate-phosphorus compounds.

MATERIALS AND METHODS

This study is based on two separate experiments using avocado trees growing in commercial orchards in southeastern Queensland (latitude 27°S), Australia.

Prior to treatments, trees on both sites showed advanced aerial symptoms of root rot decline. *P. cinnamomi* was detected in the rhizosphere and roots using a wet sieving technique (McCain *et al,* 1967) and selective agar (Tsao& Guy, 1971).

Experiment 1

In the first experiment seven-year-old avocado trees (Fuerte) which were being treated with phosetyl-Al (EF 2008) and phosphorous acid trunk injections (Pegg *et al,* 1985) were used for leaf nutrient and fruit yield evaluations. The trees were growing in a shallow sandy loam which was ridged in the row to increase the effective root zone and improve drainage.

Five fungicidal treatments and an untreated control were used, and each treatment was replicated five times in a completely randomised design with single tree plots. Data was analysed using one-way analysis of variance.

Fungicides used were phosetyl-Al (EF 2008), phosetyl-Al (EF 2008) plus zinc sulphate (10 percent), phosphorous acid (10 per cent), phosphorous acid (10 per cent) plus zinc sulphate (10 per cent) and phosphorous acid (20 per cent). All phosphorous acid formulations had the pH adjusted to 5,8 with potassium hydroxide. Phosetyl-Al (EF 2008) is registered as Aliette Ca (Maybaker) in South Africa and degrades via ethyl phosphonate to the efficacious phosphite ion which is also the active constituent of phosphorous acid. The fungicides were injected into the tree trunk in the manner described by Buitendag & Bronkhorst (1980) at 15 ml m^{-1} of canopy diameter. Trees were injected with these phosphite-phosphorus compounds on November 3, 1983 and on January 19, September 6 and December 11, 1984. Since zinc sulphate was incompatible with the fungicide formulations, it was injected in separate holes in the trunks on November 3, 1983 and again on September 6, 1984.

Twelve months after the first fungicidal applications all trees were mulched with soybean straw, 50 mm deep, from the trunk to the drip line and fertilised under the canopy in November 1984 with superphosphate at 25 g m^{-2}, muriate of potash at 60 g m^{-2} and gypsum at 30 g m^{-2}. These fertilisers were repeated at the same rates in January 1985 with the addition of urea at 12,5 g m^{-2}, and again in March 1985 with the addition of solubor at 1,25 g m^{-2}. The analyses of the fertilisers used were superphosphate 9 per cent P, 10 per cent S, 20 per cent Ca; muriate of potash 50 per cent K, 45 per cent Cl; gypsum 18,5 per cent Ca, 14,5 per cent S; urea 46 per cent N; solubor 22 per cent B.

Fruit yields were recorded from each tree at maturity in 1985 and 1986.

Experiment 2

The second experiment used five- to nine-year-old Hass trees growing on a deep, well-drained, red basaltic soil. Minimal management inputs had resulted in severe tree decline in this orchard.

All trees in this experiment received biannual injections of 20 per cent phosphorous acid as described by Pegg *et al* (1985). In addition six nutrient regimes were applied, and each was replicated five times in a completely randomised design with single tree plots. Data was analysed using oneway analysis of variance.

All treatments received a base rate of a P, K, Ca formulation (ratio of one superphosphate: 2, 6 muriate of potash: 1,2 gypsum - analyses of fertilisers as per experiment one) at 0,8 kg m^{-1} diameter of tree canopy. These were the only nutrients received by control trees. Other treatments were zinc sulphate (10 per cent), zinc nitrate (10 per cent), boric acid (two per cent), urea (10 per cent) and zinc nitrate, boric acid plus urea. Each of these treatments was trunk injected at the rate of 15 ml m^{-1} diameter of canopy for zinc and boron and 22 ml m^{-1} diameter for urea. In addition there was a soil-applied treatment of $ZnSO_4$ (25 g m^{-2} canopy), solubor (1 g m^{-2} canopy) and urea (0,1 kg m^{-1} canopy diameter).

Trunk injections of phosphorous acid 20 per cent were given on October 15 and December 3, 1985 while the fertiliser treatments were applied on December 5, urea and boron injections only on February 5, 1986 and all treatments again on April 2, 1986.

In both experiments mature summer flush leaves, approximately four months old were harvested and analysed for nutrient content in a manner described by Whiley *et al* (1987). Visual assessments of tree health were taken periodically using the scale of 0 (healthy) to 10 (dead) described by Darvas et al (1984).

RESULTS

Experiment 1

Phosetyl-Al (EF 2008) and phosphorous acid trunk injections significantly ($P<0,05$) improved tree health (Table 1). Trees treated with 20 per cent phosphorous acid returned to almost full health 16 months following the first treatment.

The concentrations of nitrogen, phosphorus and sulphur were lower ($P<0,05$) in leaves of the untreated controls than in leaves from trees that had been treated with fungicides (Table 1).

Boron leaf levels were higher ($P<0,05$) in trees treated with fungicides than in leaves from untreated controls, with the exception of those trees treated with 10 per cent phosphorous acid plus 10 per cent zinc sulphate.

With the exception of those trees treated with 10 per cent phosphorous acid, all other fungicide treatments increased leaf zinc concentrations ($P<0,05$) over untreated control trees (Table 1). However, there was no significant increase in zinc leaf concentrations in those treatments receiving 10 per cent zinc sulphate injections in spring.

Leaf chloride concentrations went against the general trend and were significantly higher ($P<0,01$) in the untreated controls when compared with trees receiving fungicides (Table 1).

Leaf concentration data of other nutrients is not presented, but there was no significant difference between any of the treatments of potassium, calcium, magnesium, sodium, manganese arid iron (Whiley *et al*, 1987). Spraying with copper fungicides for fruit disease control contaminated copper data.

There was no significant difference in fruit yield (Pegg *et al*, 1987) 17 months after the first fungicide treatment. However, all phosphite-phosphorus treatments had increased (P<0,01) fruit yield 30 months after the experiment began (Table 1).

TABLE 1 Health ratings (03/85), fruit yield (04/86) and nutrient concentration (05/86) in four-month-old Fuerte leaves from avocado trees treated with phosetyl-Al and phosphorous acid. Values are means from five trees. The data is sourced from Pegg *et al* (1987) and Whitey *et al* (1987).

Fungicide treatment	Health rating (0 10)	Fruit weight (kg tree^{-1})	N	P	S	Cl	Zn	B
				(% w/w DM)			(mg kg^{-1} DM)	
Untreated control	4,1	4,3	2,59	0,16	0,24	0,35	24,4	8,1
Phosetyl-Al	1,5	53,7	2,97	0,19	0,27	0,19	30,4	13,4
Phosetyl-Al and zinc sulphate 10%	1,4	48,8	2,92	0,17	0,26	0,20	33,2	16,2
Phosphorous acid 10%	1,2	55,4	2,95	0,18	0,26	0,27	26,2	14,5
Phosphorous acid 10% and zinc sulphate 10%	0,6	47.9	3,04	0,19	0,27	0,21	28,8	12,7
Phosphorous acid 20%	0,2	67,5	3,02	0,19	0,28	0,13	33,2	17,7
LSD (P = 0,05)	1,7	21,2	0,17	0,10	0,02	0,10	5,5	4,8
LSD (P = 0.01)	2,3	28,9	0,23	0,20		0,14	7,5	6,5

Experiment 2

All treatments recorded a substantial improvement in tree health (Table 2) as a direct response to 20 per cent phosphorous acid injections (Pegg *et al*, 1985). However, there was no significant increase in leaf nitrogen or boron levels between any of the treatments including the control.

Zinc leaf concentrations in trees injected with 10 per cent zinc nitrate were significantly higher than the other treatments (Table 2).

TABLE 2 Health improvement (03/86) and nutrient concentrations (05/86) in four-month-old Hass leaves from avocado trees affected by Phytophthora root rot and treated with trunk injected and soil applications of zinc, boron and urea. All trees were treated with 20% phosphorous acid injections. Data are means from five trees.

Nutrient treatment	Health improvement %	N (% w/w DM)	Zn	B
			(mg kg^{1} DM)	
Untreated control	69,4	2,8	29,4	17,9
Zinc sulphate 10% trunk injected	70,9	2,7	45,1	14,9
Zinc nitrate 10% trunk injected	66,7	2.7	68,0	18,0
Boric acid 2% trunk injected	63,2	2,7	30,2	17,3
Urea 10% trunk injected	69,2	2,7	34,8	14,5
Zinc nitrate 10%, boric acid 10%, urea 10% trunk injected	59,0	2,6	55,5	30,4
Zinc sulphate, boron and urea soil applied	80,5	3,0	31,2	13,3
LSD (P = 0,05)	n s	n s	23,0	n s
LSD (P = 0,01)			31,2	

DISCUSSION

Our experiments have shown that avocado trees affected by Phytophthora root rot have depleted leaf nutrient levels. Leaf concentrations of specifically nitrogen, phosphorus, sulphur, zinc and boron, were shown to be lower in diseased trees than in trees that were returning to full health through treatment with phosphite-phosphorus compounds.

In our first experiment (Table 1) all leaf levels reached the adequate range (Embleton & Jones 1964) except for boron and in some treatments zinc. The soil was deficient in both of these elements and soil applications of boron with fertiliser two months before leaf analyses, may not have had time to affect leaf concentrations.

Also in this experiment chloride levels increased substantially in leaves of the untreated controls, reaching phytotoxic levels (Embleton & Jones, 1964). Many factors affect ion uptake in plants, however in this case increased chloride concentration could be due to the impact of *P. cinnamomi* on some basic exclusion process in the roots.

Increased leaf chloride levels following root damage by pathogens have been reported for other crops. Willers & Holmden (1980) found that nematode infestation of citrus roots increased leaf chloride levels by 300-400 per cent, raising them into a phytotoxic range causing severe defoliation.

In this experiment muriate of potash (KCl) was used as a potassium source and it has also been identified as the chloride source in our trees (irrigation water 56 mg kg^{-1} and soil 5 mg kg^{-1} chloride had very low endemic concentrations of this anion). The cheaper source of potassium is used in most Australian formulated fertilisers. In the light of these results potassium sulphate or formulations using this source, should be preferred to potassium chloride as a source of potassium for Phytophthora-infected trees.

Our study failed to show any significant difference in the rate of improvement of tree health by rapid correction of key nutrients (Table 2). Injected nitrogen or boron at the rates chosen, did not increase leaf concentrations of these nutrients above the soil-applied treatment, or indeed where these nutrients were not given at all.

The spring and summer injections of 10 per cent zinc nitrate significantly increased leaf zinc concentrations (Table 2). However, unlike Darvas (1984) we were not able to show any faster remission of Phytophthora root rot symptoms when phosphite-phosphorus fungicides and zinc injections were used simultaneously. The failure to lift boron leaf concentrations above the critical deficiency threshold (50 mg kg-1 DM, Embleton & Jones, 1964) in all treatments, may have obscured any potential zinc response.

This study has also shown that trees affected by root rot can make a significant return to economic production within 30 months from treatment with phosphite-phosphorus fungicides (Table 1). Although canopy health of these trees treated with phosetyl-Al (EF 2008) and phosphorous acid had substantially improved by spring 1984 (Pegg et al, 1985) this was not reflected in 1985 fruit yields. It is likely that available photosynthates during the first 12 months of tree recovery are largely diverted into shoot and root sinks rather than increased yields.

ACKNOWLEDGEMENTS

The authors thank Messrs Greenaway and Byrne for the use of trees on their properties. The experiments were funded by the Other Fruits Sectional Group Committee of the Committee of Direction of Fruit Marketing while Consolidated Fertilizers Ltd, Brisbane, assisted with leaf tissue analysis.

REFERENCES

1 Allen, RN, Pegg, KG, Forsberg, LI & Firth, DJ, 1980. Fungicidal control in pineapple and avocado of diseases caused by *Phytophthora cinnamomi. Australian Journal of Experimental Agricultural and Animal Husbandry*, **20**, 119-24.

2 Buitendag, CH & Bronkhorst, CJ, 1980. Injection of insecticides into tree trunks - a possible new method for the control of citrus pests. *Citrus and Subtropical Fruit Journal*, No **556**, 5-7.

3 Darvas, JM, 1984. Zinc supplementation to avocado trees in conjunction with root rot injections, *S Afr Avocado Growers' Assoc Yrb*, **7**, 79,

4 Darvas, JM, Toerien, JC & Milne, DL, 1984. Control of avocado root rot by trunk injections with phosethyl-AI. *Plant Disease*, **68**, 691-3.

5 Embleton, TW & Jones, WW, 1964. Avocado nutrition in California. *Proceedings Florida State Horticultural Society*, **77**, 401-5.

6 McCain, AH, Holtzmann, OV & Trujillo, EE, 1967. Concentrations of *Phytophthora cinnamomi* chlamydospores by soil sieving. *Phytopathology*, **57**. 1134-5.

7 Pegg, KG, Whitey, AW, Langdon, PW & Saranah, JB, 1987. Comparison of phosetyl-AI, phosphorous acid and metalaxyl for the long-term control of Phytophthora root rot of avocado. *Australian Journal of Experimental Agriculture*. In press.

8 Pegg, KG, Whitey, AW, Saranah, JB & Glass, RJ, 1985. Avocado root rot control with phosphorous acid. *Australasian Plant Pathology*, **14**, 25-9.

9 Sterne, RE, Kaufmann, MR & Zentmyer, GA, 1978. Effect of Phytophthora root rot on water relations of avocado interpretation with a water transport model. *Phytopathology*, **68**, 595-602

10 Tsao, PH & Guy, SO, 1977. Inhibition of *Mortierella* and *Pythium* on a *Phytophthora* isolation medium containing hymexazol. *Phytopathology*, **67**, 796-801.

11 Whitey, AW, Pegg, KG, Saranah, JB & Forsberg, LJ, 1986. The control of Phytophthora root rot of avocado with fungicides and the effect of this disease on water relations, yield and ring neck. *Australian Journal of Experimental Agriculture,* **26**, 249-53.

12 Whitey, AW, Pegg, KG, Saranah, JB & Langdon, PW. 1987. Influence of Phytophthora root rot on mineral nutrient concentrations in avocado leaves. *Australian Journal of Experimental Agriculture*. In Press.

13 Wipers, P& Holmden, E, 1980. The influence of citrus nematode, *Tylenchulus semipentrans*, on the performance of trees growing under saline conditions. *Citrus and Subtropical Fruit Research Institute Information Bulletin*, **1(11),** 13-16.