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Phytophthora control in Australia

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SYNOPSIS
Control of Phytophthora root rot is based on several cultural procedures including clean nursery stock, improved drainage and an intensive cover cropping and mulching system. Fungicide applications are integrated with these cultural treatments. Phosphorous acid trunk injections have proved to be successful and registration of this chemical has been achieved in Queensland.

INTRODUCTION

Phytophthora cinnamomi Rands is widely distributed in Australia (Newhook & Podger, 1972) and very destructive in many of the indigenous communities (Brown, 1975; Weste, 1974; Shea, 1975). It causes its greatest devastation in the jarrah forests *(Eucalyptus marginata* Donn ex Sm) of south-western Western Australia, where it not only destroys jarrah, but also most of the plants which form the shrub and understorey layers of the forest. It is also a devastating pathogen in Australia in horticultural crops such as avocado and pineapple (Allen *et al,* 1980).

Although avocados are grown in all mainland Australian states, the major producing areas are in eastern Australia. In northern New South Wales and the elevated plateau areas of Queensland (Tamborine Mountain, Blackall Range and Atherton Tableland) they are grown on deep red basaltic soils which previously carried dense tropical or subtropical rain-forest, or wet sclerophyll forest. In coastal south-east Queensland, the Murray Valley, the Riverland district of South Australia and in the south-west of Western Australia, relatively free-draining sandy soils are utilised for avocado production. *P. cinnamomi* is present in most areas, and root rot is the disease most feared by Australian avocado growers. A number of strategies are employed by these growers to lessen the impact of this most destructive pathogen.

CULTURAL ASPECTS OF CONTROL

A number of cultural techniques are employed to reduce the severity of root rot.

Nursery stock

The exclusion of *P. cinnamomi by* planting clean nursery stock into clean areas, is considered to be the most important short-term control measure which can be taken. An

Avocado Nursery Voluntary Accreditation Scheme (ANVAS), which is administered by the Australian Avocado Growers' Federation (AAGF) with technical assistance provided by State Departments of Agriculture, has been operating successfully since 1978. This scheme ensures that the buyer of nursery stock receives plants free of *P. cinnamomi,* thus reducing the risk of introducing the fungus into new areas. Even in areas where the fungus is already present, the planting of clean nursery stock makes *Phytophthora* management much easier and more likely to be successful in the long term.

Site selection

As in other countries where *P. cinnamomi* is present, careful site selection to avoid areas of impeded drainage is fundamental to success. In Australian orchards the soil is often ridged in the tree rows to improve drainage and thus lessen disease.

Companion cropping

Companion cropping with bananas is used to reduce root rot in the Coffs Harbour district of New South Wales. These crops are planted on heavy textured soils on steep hillsides. The bananas contribute much organic matter and 'pump out' out excessive soil moisture following torrential rain. This is an extremely competitive environment where the avocado trees compete for both light and space. However, the eventual removal of banana plants to reduce competition, results in the development of severe *Phytophthora* decline symptoms in the avocado trees.

The role of organic matter

In the red basaltic soils which previously supported rain-forest, growers' use an ecological method to control root rot. An intensive cover cropping and mulching system is used in an attempt to build up the organic matter content of orchards to reach those levels found in the surrounding undisturbed rain-forest (Pegg *et al,* 1982). In the rain-forest, the vegetative cover and organic matter help maintain a self-regulatory system which locks in nutrients to the growth and decay cycle. When the rain-forest is cleared, the soils are exposed to rainfall and sunlight and the organic matter content is reduced from 18 per cent to 3-5 per cent under grass sward.

Before planting avocado trees and also while the trees are young, extensive cover cropping is practised, using forage sorghum or maize and *Dolichos lablab* in summer, followed by New Zealand blue lupin *(Lupinus angustifolius* L*)* and oats (*Avena sativa* L) in winter. When tree canopies touch, mulches with a high ratio of carbon to nitrogen, eg barley straw or sorghum stubble, are added. The timing of the application of mulches is important; mulches should be partly decomposed before the summer rains, otherwise too much soil moisture will be retained.

Broadbent & Baker (1974) demonstrated that soils in these natural communities, as well as in avocado orchards with intensive cover cropping and mulching, were suppressive to root rot. If the organic matter content was depleted in these soils, it was found that it became conducive to root rot development. Suppression of the pathogen was associated with the humus layer of the soil profile, which showed intense microbial activity. Microbial factors operating towards suppression were destroyed when soil was treated at 100°C for 30 minutes, but were not removed by steam-air treatment at 49°C or 60°C for 30 minutes. A diverse population of soil micro-organisms probably work together to suppress the pathogen.

A good example of the natural suppressive ability of these red basaltic soils is provided in north Queensland, where Brown (1976) studied 'patch death' in virgin rain-forest. 'Patch death', which he attributed to *P. cinnamomi,* was restricted to soils derived from granite-diorite-granodiorite parent material, where it was often associated with feral pig wallows. The same vegetation growing in adjacent areas on red basaltic soils was not affected even though climatic conditions were the same.

Besides providing a complex microflora and fauna, which affect *Phytophthora* activity and its ability to cause disease, cover cropping, and mulching and leaf litter from the tree itself, also increase soil porosity, as well as the moisture and nutrient-holding capacity. This provides an ideal environment for feeder root growth. Although rootstocks used in Australia do not possess genuine physiological resistance to *P. cinnamomi,* many of these have good root replacement ability (eg Velvick Guatemalan seedlings). These plateau areas also have a cool, humid, high rainfall environment which is extremely favourable for plant growth. All these factors, together with biological suppression, are interacting in a very complex way to suppress root rot.

Provided the fungus has not caused too much damage, trees growing in rain-forest soils can recover from the effects of *Phytophthora* root pruning by the addition of organic mulches alone. Once root rot has had a marked effect on above-ground tree health, organic matter alone will not produce a significant response in tree health, unless a fungicide is also used to protect the new roots. The organic matter will then influence the speed of recovery.

Nutrition

A balanced nutritional programme is used to assist in maintaining health by increasing the capacity of the tree to regenerate replacement roots where *Phytophthora* has caused losses. Particular attention is given to phosphorus, calcium and boron nutrition, which are particularly important for healthy root growth (Wolstenholme, .1981). The relationship between calcium and root rot has been investigated by a number of researchers, of whom several have indicated that a favourable soil calcium level will reduce Phytophthora root rot in avocado (Snyman & Darvas, 1982; Lee & Zentmyer, 1982; Falcon *et al,* 1984). A high calcium content is one of the characteristics of *P. cinnamomi* suppressive rain-forest soils in Queensland and New South Wales (Broadbent & Baker, 1974). In a root rot management trial in New South Wales (Trochoulias, 1986), it was found that calcium amendments gave the trees a higher health rating (greener leaves) than those trees which did not receive calcium. These results justify the high soil calcium (3 000-5 000 mg kg^{-1}) levels which are maintained in Australian orchards for disease suppression.

Most of the visible symptoms of Phytophthora root rot are associated with water stress (Sterne *et al,* 1978; Whiley *et al*, 1986) or interference with mineral uptake and distribution of nutrients in plant tissues. If *Phythophthora-affected* trees are to recover quickly, any nutrient deficiency or toxicity induced by the disease must be corrected. Phytophthora root rot-affected trees in Queensland have been found to have lower leaf concentrations of nitrogen, phosphorus, sulphur, zinc and boron than healthy trees (Whiley *et al,* 1987). Soil applications of nitrogen, phosphorus and sulphur are adequate means of increasing leaf concentrations of these nutrients when applied with effective fungicides. However, it has been found to be much more difficult to supply zinc and boron to trees during the recovery phase. Preliminary results (Whiley & Pegg, 1987) suggest that trunk injections of zinc nitrate will increase leaf concentrations of zinc.

Root damage as a result of *Phytophthora* infection can also result in chloride accumulation in leaves (Whiley et al, 1987), particularly if irrigation water is high in chloride or if potassium chloride is used as a source of potassium. Potassium sulphate is recommended in preference to potassium chloride as a source of potassium in *Phytophthora*-infested soil.

CHEMICAL CONTROL

Cultural procedures rarely give complete root rot control and chemicals may be required to reduce disease severity. In February 1987, phosphorous acid was registered as a fungicide to be used by the Queensland avocado industry. Registration is pending in all other states. Phosphorous acid is commercially available in Australia as a buffered solution (monohydrogen dipotassium phosphite) to reduce the likelihood of phytotoxicity. The discovery of the trunk injection technique for root rot control (Darvas *et al,* 1984) and the registration of this inexpensive chemical, have added a new dimension to root rot control. For the first time an economically-proven procedure is available in Australia for the control of root rot in mature bearing avocado trees.

Phosphorous acid has been evaluated in Australia as a soil drench, a foliar spray and for use in trunk injections (Pegg *et al,* 1987). During initial experiments soil drenches and foliar sprays of phosphorous acid, partially neutralised with potassium hydroxide, were investigated on *Persea indica* seedlings growing in pots in a glasshouse (Table 1).

Both foliar and soil treatments were very effective in controlling Phytophthora root rot. Phosphorous acid soil drenches were also evaluated in the field at Tamborine Mountain. These drenches gave only short-term (11 weeks) feeder root protection in a red basaltic soil which had intense biological activity due to a high organic matter content. Foliar applications of phosphorous acid are effective for root rot control, but limited experience has shown that foliar sprays may cause marginal leaf burn and basal burn on fruit if residues of copper fungicides, which are used for anthracnose control *(Colletotrichum gloeosporioides* Penz var *minor* Simmonds), are present when the acid is applied. Furthermore, if applied within seven days of applying dimethoate for the control of Queensland fruit fly (*Dacus tryoni* Froggott), it may cause severe leaf burn and premature abscission. The reduced leaf area in diseased trees will also not absorb sufficient phosphorous acid for any significant curative effect.

A 20 per cent solution of partially neutralised phosphorous acid injected into trunks of trees severely affected by Phytophthora root rot, was found to give rapid remission of disease symptoms (Table 2).

After tree injections, residues of phosphorous acid occur in fruit (October plus December injection with a 10 per cent solution gave from 33-51 mg kg^{-1} fresh weight phosphorous acid in Fuerte fruit at maturity, while with a 20 per cent solution, a residue from 76-83 mg kg^{-1} fresh weight of phosphorous acid was found). The Australian registration authorities have set the maximum residue level for phosphorous acid permitted to be present in the flesh of the avocado, at 100 mg kg^{-1} fresh weight. Injections of phosphorous acid administered as directed give residual levels below this limit.

Prior to the registration of phosphorous acid, metalaxyl was widely used for root rot control. When first used, metalaxyl gave significant rehabilitation of root rot affected trees. However, in field experiments there has been a dramatic deterioration in tree health following three years of exclusive and continuous use (Table 3).

Apparently this is due to the accelerated biodegradation of metalaxyl. At present metalaxyl has a very short half life (seven days) in some sandy soils used for avocado production in southeast Queensland. Besides this vulnerability to biodegradation, metalaxyl is so expensive that it cannot be used economically for root rot control in mature bearing avocado trees.

With the development in nature of a strain of *P. cinnamomi* with resistance to phosphorous acid (Vegh *et al,* 1985), anti-resistance strategies have been suggested to prolong its usage in Australian avocado plantations. Fortunately, due to its strong curative activity, it is well adapted for use in integrated control strategies. In the relatively cool, humid and high rainfall districts where soils previously supported dense rain-forests, phosphorous acid injections are combined with ecological and biological control procedures. Once trees are restored to full productivity, ecological and biological techniques are relied upon to maintain health. With good management this should be possible for several years. If decline symptoms should reappear, the curative potential of phosphorous acid can once again be used. In hotter and more stressful environments where orchards are often planted in poorly structured soils, the root rot hazard is much greater and a fungicide may be needed every year. Before trees growing in these soils are injected with phosphorous acid, it has been suggested that the population of *P. cinnamomi* be lowered using metalaxyl, which is the most effective substitute for phosphorous acid in root rot control. It may then be advisable to continue the use of metalaxyl in alternate years, or every three years. These strategies will help to overcome the problems of resistance and accelerated biodegradation, both of which are irreversible processes, and also help to minimise chemical residue accumulation in fruit.

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TABLE 1 Control of Phytophthora root rot of *Persea indica* seedlings in a glasshouse.				
Treatment	Per cent healthy roots	Root dry weight (g)	Shoot dry weight (g)	Shoot growth (cm)
Dolomite incorporated (5 t ha^{-1})	23,92	0 81	2,08	5,80
Gypsum incorporated (5 t ha^{-1})	50,00	1 08	3,28	8,50
Gypsum incorporated (10 t ha^{-1})	30,83	087	3,05	6,70
Diammonium phosphate surface application (8 g 4 L pot)	20,42	0 49	2,34	5,00
Phosphorous acid drench (1 g L^{-1})	82,92	224	5,95	35,00
Phosphoric acid drench (1,2 g L^{-1})	11,67	035	1,64	2,70
Phosetyl-Al drench (1,5 g ai L^{-1})	89,58	222	5,55	44,80
Phosphorous acid spray (1 g L^{-1})	91,67	233	5,20	42,70
Phosphoric acid spray (1,2 g L^{-1})	9,58	040	1,76	1,00
Phosetyl-Al spray (1,5 g ai L^{-1})	78,33	1 77	4,59	38,00
Untreated control	19,58	0 58	1,83	3,80
LSD P = 0,05	22,75	053	1,19	8,13
LSD P = 0,001	39,66	0 92	2,08	14,20
Source: Pegg *et al,* 1985.				

TABLE 2 Growth and vigour of branch terminals of avocado trees treated with various fungicides (values are means from five trees).		
Fungicide treatment	Total length of summer flush on two branch terminals (cm)	Flush rating (0 = no terminal flush; 10 = 100% flush of terminals)
Untreated control	618,9	2,0
Metalaxyl under canopy	1155,8	3,1
Phosetyl-Al trunk injection	911,5	3,8
Phosetyl-Al and zinc sulphate 10% trunk injection	975,0	4,4
Phosphorous acid 10% trunk injection	817,6	4,2
Phosphorous acid 10% and zinc sulphate 10% trunk injection	1133,6	5,1
Phosphorous acid 20% trunk injection	2146,2	7,5
LSD (P = 0,05)	598,7	1,8
LSD (P = 0,01)		
Source: Whitey *et al,* 1987	811,4	2,4

TABLE 3 Health ratings and fruit yields in avocado trees (cv Fuerte) treated with various fungicides (values are means from five trees)

Fungicide treatment	Health rating (0 = healthy; 10 = dead)		Fruit weight (kg/tree)
	After 2 years	After 3 years	
Untreated control	4,1	7,2	4,3
Metalaxyl under canopy area	2,0	4,0	12,9
Phosetyl-Al trunk injection	1,5	0,6	53,7
Phosetyl-Al and zinc sulphate 10% trunk injection	1,4	1,6	48,8
Phosphorous acid 10% trunk injection	1,2	0,4	55,4
Phosphorous acid 10% and zinc sulphate 10% trunk injection	0,6	0,2	47,9
Phosphorous acid 20% trunk injection	0,2	0,4	67,5
LSD (P = 0,05)	1,7	1,7	19,8
LSD (P = 0,01)	2,3	2,4	26,8