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PHYTOPHTHORA ROOT ROT

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Phytophthora root rot (PRR) is considered the most important and most widely distributed disease of avocados in countries where avocados are produced. From a production point of view PRR is the single most important disease of avocado. In California alone it has been estimated to affect between 60-75% of the orchards and causes a loss in excess of $40 million annually (Coffey 1992). The causal fungus, *Phytophthora cinnamomi* Rands, was first isolated from cinnamon trees in Sumatra in 1922 and has since been reported from over 70 countries. It has an extremely wide host range including 1000 varieties and species of plants. Major hosts include avocado, pineapple, chestnut, eucalyptus, several species of pine, sycamore, peach, pear, many ornamentals (including azalea, camellia and rhododendron) and many indigenous Australian and South African plants. The first published report on PRR was from Puerto Rico in 1927. A PRR-like decline was reported in California during 1920-1930, but it was only in 1942 that *P. cinnamomi* was isolated from avocado (Zentmyer 1980, Zentmyer et al. 1998).

Symptoms

The first signs of the disease are manifested in the tree canopy. The leaves are small, pale green, often wilted with brown tips, and drop readily. In contrast to Phytophthora stem canker, new growth is usually absent. Shoots die back from the tips, and eventually the tree is reduced to a bare framework of dying branches. Tree death may take

A. Healthy feeder roots growing near the soil surface are often cream colored.

B. The roots on the left have been attached by root rot fungus while those on the right may succumb to the disease soon. Note the difference in root color (dark brown) of the damaged roots.

from a few months to several years, depending on soil characteristics, cultural practices and environmental conditions. When declining trees flower, the trees may defoliate completely and may set a heavy crop of small fruit.

The small feeder roots on diseased trees may be absent in the advanced stages of decline. When present, they are usually black, brittle and decayed, in contrast to healthy trees which have an abundance of creamy-white feeder roots. Pencil sized and larger roots are seldom attacked by the fungus. (Faber and Ohr 1999, Manicom 2001, Pegg 1991, Zentmyer 1980 and 1984).

Causal Organism and Epidemiology

P. cinnamomi forms several different spore stages that are involved in infection, disease development and survival of the fungus; these include zoospores, chlamydospores and oospores. Fruiting structures on the fungus called sporangia give rise to motile (swimming) zoospores which are disseminated by flowing water on the surface of the soil or in films of water within the soil pores. The zoospores are attracted to the roots by root exudates. Zoospores then penetrate, germinate and infect tender root tissue. Root lesions appear within 24 hrs and mycelium (fungus tissue) can be found throughout the small absorbing roots within 72 hrs.

C. Root rot infected trees often produce an abundance of fruit while leaves on the tree are often pale, small and sparse.

D. Typical above-ground tree symptoms of root rot infection (foreground). Note the dead upper branches, sparse leaf cover and pale leaves.

Photos: G. Witney

Under dry soil conditions the fungus may produce chlamydospores which are survival structures that can survive for several years. These spores are formed within the roots and are released into the soil when the roots decay. Under low soil temperatures oospores, another type of survival spore, are produced by *P. cinnamomi*. Both chlamydospores and oospores can live for several years in orchard soils. When suitable moisture and temperature conditions arise, both can give rise to sporangia which produce infectious zoospores.

Soil moisture is the primary environmental factor influencing PRR development. High soil moisture stimulates the development of sporangia and improves conditions for zoospore release and movement in the soil. However, stress from low moisture and excess salt can also injure roots causing them to exude substances which attract zoospores and incite infection.

Where *P. cinnamomi* is not native to an area, the primary method of introduction of the disease into orchards is by infected nursery trees. Once in the orchard, PRR can be spread by infected soil on shoes, tools, vehicles, picking boxes, ladders and storm water (Faber and Ohr 1999, Manicom 2001, Menge and Marais 2000a, Zentmyer et al. 1965, Pegg 1991, Zentmyer 1980 and 1984, Zentmyer et al. 1998).

Disease Management

Since no definitive measures have yet been found to control PRR, an integrated approach to managing the disease has been found to be most effective. This approach includes prevention, cultural practices and chemical treatment. These aspects are discussed below:

Site selection and soil preparation: Planting an avocado orchard is a long-term investment and requires a high capital outlay in the initial stages. Soil should be prepared well in advance of planting. Severe PRR is associated with soils that have poor internal drainage, are less than 3 feet deep, have hard pans, clay pans and high clay content. These soils are conducive to inoculum build-up and infection of roots, and should be avoided. Less hazardous soils with a clay-loam texture and depth of 3-5 feet should be deep ripped and provision made for drainage. Saline soils and soils with high salinity potential should also be avoided since not only does salinity retard growth and reduce yield but it exacerbates avocado root rot (Borst 1970, Menge and Marais 2000a, Zentmyer and Ohr 1978).

On sloped land, the construction of interception and diversion drainage ditches, or provision of water tight drain pipes which drain rain water away from the orchard, will help prevent the introduction of *P. cinnamomi* into lower lying orchards. In heavy clay soils, trees can be planted on mounds or ridges. This practice has been found to increase the survival rate of young trees by as much as 180% because of improved drainage. Ridges and mounds improve top soil depth in poor or limiting soils since surrounding top soil is gathered and incorporated into the mounds and ridges.

Soil solarization, a practice of using clear polyethylene sheets on the soil surface to trap solar radiation and heat the soil, has been found to be effective in reducing Phytophthora inoculum following tree removal in infested soil in Israel (Erwin and Ribeiro 1996).

Soil amendments: Most soils in native habitats of avocados are high in organic matter, and the trees do best in soils with 8% or greater organic matter content. The application of amendments such as organic mulches and gypsum contribute to improving soil structure, thereby improving drainage, helping to remove salts from the soil, and have the added benefit of increasing the soil's suppressiveness to *P. cinnamomi*. The suppressive effect of calcium and organic matter was first discovered in Australia (Broadbent and Baker 1974). The beneficial effects of organic mulch are thought to be due to the development of high populations of micro-organisms in the soil which are antagonistic to *P. cinnamomi*. Also, avocado roots do best in soils with oxygen content greater than 25% and porous mulches contain high levels of oxygen. Mulches placed in layers 4 - 6 inches thick under the canopies of the trees has been shown to suppress PRR and be beneficial to avocado trees in California (Menge and Marais 2000a,b).

A study of the effects of calcium on PRR was conducted in California soils by Messenger-Routh (1996) who concluded that calcium primarily acted as a weak fungicide by reducing the size and number of sporangia produced by *P. cinnamomi*. Applications of 1500-3000 lbs/acre gypsum under the tree canopies, depending on the size of the trees, may be helpful in the prevention of the spread of PRR.

Disease-free nursery trees: Historically, diseased nursery stock was the major source of spread of PRR in California. Now, commercial nurseries have certification programs which ensure that growers can purchase PRR-free trees.

Irrigation and irrigation water: The avocado tree is extremely sensitive to water-logging due to the high oxygen requirement of its roots. Under such conditions, root growth ceases and the stage is set for large-scale destruction of feeder roots. The use of tensiometers or other tools to schedule irrigation is advised. Water from deep wells is unlikely to be contaminated with *P. cinnamomi*, while water from reservoirs and canals can be a source of infection and should be treated with chlorine to eliminate inoculum.

When an infection area is identified in an orchard, the diseased trees and the trees at the margins of the diseased area should be irrigated with caution, avoiding over-irrigation. Careful irrigation can retard the spread of the disease and often prolong the life of affected trees (Faber and Ohr 1999, Menge and Marais 2000a,b).

Orchard sanitation: Excluding *P. cinnamomi* from a clean avocado orchard is the most economical method of controlling the disease. Movement of soil and water from diseased orchards into healthy ones should be avoided at all costs. The fungus readily moves from orchard to orchard in moist soil on tools, vehicles, bins, ladders, shoes, domestic and wild animals, etc. Barriers in the form of fences and warning signs should be placed between uninfected and infected orchards. Boxes containing copper sulfate should be placed at the property entrance and all foot traffic should dust shoes before entering the grove. Shallow, chlorinated or copper sulfate-treated water baths may also be placed at the entrance to the property for vehicles to drive through when entering the premises. Shovels, soil augers and trowels should be dipped in 70% ethanol or rubbing alcohol before reuse. Always use disinfected equipment in healthy orchards after use in a diseased orchard. Severely affected trees should be removed (Menge and Marais 2000b, Faber and Ohr 1999, Zentmyer and Ohr, 1978).

Resistant rootstocks: A great deal of research has been conducted on detecting and developing resistant rootstocks, particularly in California, South Africa and Israel. Rootstocks such as Duke 7, Thomas, Barr Duke, Toro Canyon, and Merensky 2, exhibit a greater degree of tolerance to PRR than traditional Topa Topa seedling rootstocks. Not all of these rootstocks yield as well as the traditional PRR sensitive ones in non-infected groves. Trees on resistant rootstocks will survive under disease pressure when used in conjunction with the control measures mentioned above (Bijzet and Sippel 2001, Menge 2001, Menge et al. 1992, Menge and Marais 2000b). While disease-free clonal rootstocks have different levels of tolerance/resistance to PRR and may be expensive to purchase, they can provide a degree of insurance against devastation by PRR.

Crop replacement: When disease pressure and contributing environmental factors result in economic loss, it may be necessary to remove avocado trees. All varieties of citrus, many deciduous fruit tree crops, macadamia, persimmon, berries, all types of vegetables, and most annual flower crops are not susceptible to PRR and can be planted in old avocado orchard soils (Ohr et al. 1994, Faber and Ohr 1999).

Chemical control: In the 1970s and 1980s, systemic fungicides with specific activity against species of Phytophthora and related fungi revolutionized control of diseases such as PRR. The first of these compounds were metalaxyl (Ridomil®) and fosetyl Al (Aliette®) (Coffey 1987 and 1992, Erwin and Ribeiro 1996, Menge and Marais 2000b).

The phosphonates, including fosetyl Al and its active breakdown product phosphorous acid and potassium phosphite, have been effective when applied as foliar sprays, trunk paints, trunk injection, or soil application.

Trunk injection, first developed in South Africa, has given good results in several avocado producing countries (Darvas et al. 1984). In South Africa and Australia salts of phosphonic (phosphorous) acid, particularly potassium phosphonate (potassium phosphite) have been registered for foliar and trunk injection. A similar product has been registered for use in Israel. In most countries, trunk injection of these chemicals is the preferred method of application and is the best way to rejuvenate trees severely affected by PRR. Fosetyl Al injected into severely affected trees has resulted in complete recovery.

In South Africa 1 ml of a 50% neutralized (buffered) phosphonic acid (neutralized with potassium hydroxide) is injected per meter square (10 feet square) of tree drip area; this equates to 0.5 g (0.02 oz) active ingredient per meter square of tree drip area. Injections are applied twice annually, once following the hardening off of the spring flush, which occurs during and after flowering, and the second application following the hardening off of the summer flush. These two applications coincide with peak root flushes (Menge and Marais 2000b).

Metalaxyl (Ridomil®) has been applied as a granular, a drench, or injected into the irrigation water and has been found to be effective in some cases. However, Aliette® has been found to be more effective than metalaxyl in mature orchards in California (Coffey 1992).

Foliar and soil applications of Aliette® or phosphorous acid are made under certain conditions. The current recommended treatment for healthy and lightly infected trees in South Africa, New Zealand and Australia, is a foliar application of 0.8-1% buffered phosphorous acid 4-6 times annually.

Field trials continue in California, to test different chemicals and modes of application, for their efficacy in controlling PRR (Marais et al. 2001).

LITERATURE CITED

1. Bijzet, Z. and Sippel, A.D. 2001. Rootstocks. In: The Cultivation of Avocado (ed. E.A.de Villiers). Institute for Tropical and Subtropical Crops, Nelspruit, South Africa, pp.85-90.
2. Borst, G. 1970. Selection and management of avocado soils. Calif. Citrograph 55:263-265.
3. Broadbent, P. and Baker, K.F. 1974. Behaviour of *Phytophthora cinnamomi* in soils suppressive and conducive to root rot. Aust. J. Agric. Res. 25:121-137.
4. Coffey, M.D. 1987. Phytphthora root rot of Avocado: An integrated approach to control in California. Plant Dis. 71: 1046-1052.
5. Coffey, M.D. 1992. Phytophthora root rot of avocado. In: Plant Diseases of International Importance. Volume III. Diseases of Fruit Crops (eds. J. Kumar, H.S. Chaub, U.S. Singh and A.N. Mukhopadhyay). Prentice Hall, Englewood Cliffs.
6. Darvas, J.M., Toerien, J.C. and Milne, D.L. 1984. Control of avocado root rot by trunk injection with fosetyl-Al. Plant Dis. 68:691-693
7. Erwin, D.C. and Ribeiro, O.K. 1996. Phytophthora diseases worldwide. APS Press, St. Paul, MN., USA. 562p.
8. Faber, B.A. and Ohr, H.D. 1999. UC Pest Management Guidelines: Avocado. Univ. California Davis, Davis, CA, USA.
9. Manicom, B.Q. 2001. Diseases. In: The Cultivation of Avocado (ed. E.A. deVilliers), Institute for Tropical and Subtropical Crops, Nelspruit, South Africa, pp. 214-230.
10. Marais, L.J., Menge, J.A., Pond, E. and Campbell, S. 2001. Chemical control of avocado root rot and stem canker. In: Proc. Avocado Research Symposium, Riverside, CA. pp. 33-35.
11. Menge, J.A. 2001. Screening and evaluation of new rootstocks with resistance to *Phytophthora cinnamomi*. In: Proc. California Avocado Research Symposium, Riverside, CA. pp. 49-53
12. Menge, J.A., Guillemet, S., Campbell, S., Johnson, E. and Pond, E. 1992. The performance of rootstocks tolerant to root rot caused by *Phytophthora cinnamomi* under field conditions in Southern California. In: Proc. 2nd World Avocado Congress, pp. 53-59.
13. Menge, J.A. and Marais, L. J. 2000a. Soil Environmental Factors and their Relationship to Avocado Root Rot. Subtropical Fruit News 8(1-2):11-14.
14. Menge, J.A. and Marais, L.J. 2000b. Strategies to control *Phytophthora cinnamomi* root rot of avocado. Subtropical Fruit News, Univ. of California (In Press).
15. Messenger-Routh, B.J. 1996. The effects of gypsum soil amendments on Phytophthora root rot of avocado. Ph.D. Dissertation, Univ. of Calif. Riverside.
16. Ohr, H.D., Faber, B.A. and Grech, N. 1994. Avocado diseases. Circular No. CAS-94/1. The California Avocado Society Inc., and The California Avocado Commisssion.
17. Pegg, K.G. 1991. Causes of disease. In: Avocado Pests and Disorders (ed.. R.H. Broadley), Queensland Dept. of Primary Industries, Brisbane, Australia, pp.1-7.
18. Zentmyer, G.A., Paulus, A.O., Gustafson, C.D., Wallace, J.M., and Burns, R.M. 1965. Avocado diseases. Univ. Calif., Div. Agric. Sci., Calif. Agric. Exp. Stn. Ext. Serv. Circ. 534.
19. Zentmyer, G.A. 1980. *Phytophthora cinnamomi* and the Diseases It Causes. Monogr. 10. APS Press, St. Paul, Minnesota, USA.
20. Zentmyer, G.A. 1984. Avocado diseases. Trop. Pest Manage. 30:388-400.
21. Zentmyer, G.A. 1998. Avocado. In: Compendium of Tropical Fruit Diseases (eds. R.C.Ploetz, G.A. Zentmyer, W.T. Nishijima, K.G. Rohrbach and H.D. Ohr), APS Press, St. Paul, MN., USA, pp.71-72.
22. Zentmyer G. A. and Ohr, H.D. 1978. Avocado root rot. Div. Agric. Ext. Serv., Univ. of Calif., Leaflet # 2440.
23. Zentmyer, G.A., Menge, J.A. and Ohr, H.D. 1998. Phytophthora Root Rot. In: Compendium of Tropical Fruit Diseases (eds. R.C.Ploetz, G.A. Zentmyer, W.T. Nishijima, K.G. Rohrbach and H.D. Ohr), APS Press, St. Paul, MN., USA, pp.77-79.