Book 2

Chapter 4

Strategies for Control of Avocado Root Rot

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Summary

Integrated management of avocado root rot includes planting clean avocado nursery stock, selecting low hazard sites, planting on mounds in more hazardous sites, preventing the introduction of *Phytophthora cinnamomi,* using resistant rootstocks, preventing over- or under-irrigation, applying systemic chemicals, treating with gypsum and adding organic mulches. It appears that avocados can survive and grow in the presence of *P. cinnamomi* if this management scheme is practiced.

Introduction

P. cinnamomi, the casual agent of avocado root rot, is the limiting factor in avocado production in most avocado-producing countries. It attacks all varieties of avocado by rotting the feeder roots, which can result in death of the tree. In California it has been estimated to affect between 60% and 75% of the orchards and it caused an annual loss of approximately $44 million in 1989 (Coffey, 1992). Although the disease has been studied for more than 60 years, definitive control measures have not been found and losses continue to mount. However, many control strategies have been discovered that will reduce the impact of avocado root rot. When all of these control measures are packaged into a single strategy called the "integrated management of avocado root rot", they allow the continued economical production of avocados in the presence of *P. cinnamomi* (Coffey, 1987). The following is an attempt to enumerate the various components of the "integrated management of avocado root rot".

Clean Nursery Practices

The best control for avocado root rot is to prevent introduction of the fungus into the orchard. Diseased nursery stock has undoubtedly been mainly responsible for the wide distribution of avocado root rot throughout the avocado producing areas of the world. The fungus can be readily transmitted in balled or container grown trees.

It can also be spread via infected seed that has been gathered from the ground. Clean nursery practices which will prevent avocado root rot from infesting nursery stock include heat treatment of seeds, fumigation or heat treatment of soil used to grow the avocados, use of clean water and good sanitation (Zentmyer and Ohr, 1978). A certification program run by the local government or growers to make sure that nurseries are producing clean stock is a safeguard against importing pests into clean orchards via nursery stock.

Clean Seed. Because *P. cinnamomi* can infect avocado seed through fruit which has dropped on the ground, seed used to propagate avocados should be picked from the tree or treated with hot water to kill *P. cinnamomi*. Seed, which is immersed in water at 49° to 50° C for 30 min. and then quickly cooled, will be free of *P. cinnamomi* (Zentmyer and Ohr, 1978). Care must be taken because treatment at 52° C will damage the seed.

Disinfested Soil. Soil or soil mixes used to propagate avocado should be disinfested to make sure they are not contaminated with *P. cinnamomi*. Fumigating with methyl bromide at 2 lbs/11 cu. M of soil for 24 hr. will free the soil of *P. cinnamomi* (Zentmyer and Ohr, 1978). Heat treatment with steam at 100° C for 30 min. or with aerated steam at 60° C for 30 min. is also effective at disinfesting soil or soil mix with *P. cinnamomi* (Coffey, 1992).

Clean Water. Water should come from deep wells which are devoid of *P. cinnamomi* propagules. Surface water from rivers, canals and reservoirs are often contaminated with *P. cinnamomi* and should not be used to irrigate nurseries. This water could be disinfested by treating with 20 ppm copper sulfate or 0.5 ppm chlorine (Coffey, 1992).

Sanitation. Sanitation is the single most important tool for preventing avocado root rot in the nursery. Nurseries should be fenced and protected from excessive human and animal traffic. Phytophthora is frequently tracked into the nurseries in soil or mud. Many nurseries place boxes of copper sulfate at their entrance and ask all workers and visitors to dust their shoes with this material before entering. Vehicles must pass through a shallow, chlorinated or copper sulfate-treated water bath before entering the premises. Vehicles should be washed and disinfested as necessary, especially if they have been in Phytophthora-infested avocado groves. These precautions not only serve to protect the nursery from unwanted Phytophthora introduction, but they also create a psychological mindset among workers that bringing avocado soil into the nursery is unacceptable. Benches in greenhouses should be at least 45 cm above the ground to prevent soil from splashing into pots and to provide air circulation under benches. In container nurseries, containers should always be placed on blocks or kept from contact with the ground. Containers should never be placed on tarps or cement slabs, which are impenetrable to water, since Phytophthora spreads rapidly in the water film on these surfaces after irrigation or rain. Potting media and fertilizer should never be stored on the ground, but on benches or a dry concrete pad. All pots and liners should be sterilized before use. Vigorous monitoring for Phytophthora in seedbeds or nurseries should be practiced. Avocados contaminated with Phytophthora the seedbed, nursery or containers must be destroyed, since Phytophthora often spreads rapidly through a nursery if left unchecked. Although fungicides, which are effective in the control of avocado root rot, are available, neither phosphorous acid nor metalaxyl will kill 100% of the Phytophthora propagules. Some Phytophthora will survive these fungicide treatments and will be spread from the nursery to a grower's field. Because many nurserymen repeatedly treat nursery stock with fungicides, resistant Phytophthora isolates may appear. The spread of resistant isolates of *P. cinnamomi* would be disastrous to the avocado industry. If sanitation is practiced correctly, the use of fungicides in avocado nurseries should be unnecessary.

Site Selection and Preparation

Soil with poor drainage, high clay content, high water tables, hard pans, and clay pans or where water pools after irrigation or rainfall have historically been associated with sites where avocado root rot is severe (Zentmyer and Ohr, 1978; Zentmyer, 1980). Soils in California were classified by Zentmyer and Ohr, 1978 according to their hazard to root rot. Severe hazard soils have a slow to very slow subsoil permeability, are poorly to very poorly drained, are less than 91 cm deep and have clay textures. Moderate hazard soils are those with a moderately slow permeability, are somewhat poorly drained, are 91 to 152 cm deep and have clay loam textures. Soils with only a slight hazard for root rot development have a rapid to moderate subsoil permeability, are well drained, are over 152 cm deep and have sand to loam textures. Soil with a high hazard for avocado root rot or soils which already have *P. cinnamomi* present, should be avoided when planting an avocado orchard. Soils with high salinity levels should also be avoided since, not only does salinity weaken avocado grow and yields, but salinity severely exacerbates avocado root rot (Borst, 1970). Alternative crops such as citrus would be a better choice for planting under these conditions. For soils with moderate hazard, soil preparation prior to planting may pay huge dividends in the future. Soils with impervious subsoil layers may be improved by deep ripping and inserting subsurface tile drains. On sloped land, the construction of interception and diversion drainage canals or water-tight drain pipes which drain rain water away from the orchard may prevent the introduction of *P. cinnamomi*. In heavy clay soils, planting trees on soil mounds (1-1.5 M in diameter and 0.5 to 1 M high) or ridges has been shown to increase survival and improve growth of avocado in California by as much as 1800% during the first three years in *P. cinnamomi*-infested soil. Mounding breaks up the soil and provides a well-drained soil for young trees to become established in before they encounter the more hazardous surrounding soil. Soil solarization, which consists of heating the soil to above 45° C with clear polyethylene sheets that have been placed on the soil surface to trap the sun's radiant energy, has been found to be effective for reducing Phytophthora inoculum following tree removal in infested soil in Israel (Erwin and Ribeiro, 1996). This method is particularly effective where summers are hot and most days are cloudless. Fumigation of infested soil and replanting is not recommended because complete eradication of *P. cinnamomi* from soil once it has been infested is extremely difficult. Often *P. cinnamomi* re-invades fumigated soil and the avocado root rot becomes worse than during the initial infestation because the soil microbial community and competing microorganisms have been reduced by the fumigation.

Grove Sanitation

Excluding *P. cinnamomi* from a clean avocado grove is the most economical method of controlling the disease. Groves should be fenced to protect them from human and animal traffic. All soil or water should be prevented from movement into diseased groves from healthy ones. The fungus is readily moved from grove to grove in moist soil on cultivation equipment, trucks, cars, shovels, soil augers, picking boxes, shoes, etc. Boxes of copper sulfate may be placed at the property entrance and all workers and visitors are asked to dust their shoes with this material before entering. Shallow, chlorinated or copper sulfate-treated water baths may also be placed at the entrance to the property for vehicles to drive through before entering the premises. Small pieces of equipment such as shovels, augers and towels should be washed and dipped in 70% ethanol or rubbing alcohol. Always use equipment in the healthy groves before using it in a diseased grove. Thoroughly wash and dry equipment after using it in a diseased grove. Remember that *P. cinnamomi* has an extremely wide host range and can attack many other woody plants. Use care when planting ornamental plants into an avocado orchard, since they could be infected with *P. cinnamomi*. If diseased trees exist near healthy trees, a dry barrier of at least two rows of trees should be established between the diseased and healthy trees. Diversion furrows should be dug to divert rainwater, which passes through the diseased grove, away from the healthy grove and also to isolate healthy groves from diseased ones. Fences should be erected separating diseased and healthy trees. Once isolated, the diseased trees should be removed and the soil fumigated to reduce the chance of spread from inoculum in the diseased area. Methyl bromide, VorlexR, or VapamR are fumigants which can be used to reduce *P. cinnamomi* inoculum in infested soil (Zentmyer and Ohr, 1978). Irrigation water must be kept free of *P. cinnamomi* inoculum. Water from deep wells is preferred. Water from canals and reservoirs should be treated with chlorine or copper sulfate to eliminate Phytophthora inoculum.

Resistant Rootstocks

Resistant rootstocks have the greatest possibility of successfully controlling avocado root rot in the long run. Several breeding and selection programs around the world have identified rootstocks with a high degree of tolerance to *P. cinnamomi*. In order to use resistant rootstocks, they must be clonally propagated so that they all contain the same genetic identity, which results in resistance to *P. cinnamomi*. Heritability of resistance traits in avocado is generally low, less than 1%. Therefore seedlings produced from seeds gathered from resistant trees usually show little resistance. In most cases the mechanisms for the resistance are not yet fully understood, although several resistant rootstocks appear to simply produce new roots faster than susceptible rootstocks in the presence of *P. cinnamomi*. None of the rootstocks identified so far is able to withstand infections by *P. cinnamomi* under hazardous disease conditions. That is why several other methods of control must be used in conjunction with resistant rootstocks in order to control the disease. Duke 7 was discovered by Zentmyer and in 1975 it became the first commercial rootstock which was resistant to *P. cinnamomi*. It was highly successful, and it is now being used worldwide to combat avocado root rot (Zentmyer, 1980). Several newer varieties are now available which are even more resistant to avocado root rot than Duke 7. These include

Dusa Thomas, D9, Barr Duke and Evstro. These rootstocks may not perform well under all avocado growing conditions, and some like Thomas may not yield as well as other rootstocks when Phytophthora is not present (Menge et al.1992). However, it appears that when these rootstocks are used in conjunction with other control methods, the trees will survive and even thrive in the presence of *P. cinnamomi*. However, with older, highly susceptible seedling rootstocks such as Topa Topa, spending money on other control measures only postpones the inevitable death of the trees. Newer, even more resistant rootstocks are currently being tested and provide hope that one day avocado root rot will be fully controlled.

Irrigation Management

It is difficult to manage irrigation of avocado to benefit the avocado and not *P. cinnamomi* because avocado roots are very shallow and sensitive to drying. Tensiometers should be installed at depths of 15 and 30 cm near the dripline of one or two representative trees. These should be used as a guide to identify when trees are receiving too much or too little water. Trees must not be over watered (several days at 0 to -10 cb) or under-watered (several days at -50 to -70 cb). As little as three days under saturated conditions can predispose roots to attack by *P. cinnamomi*. Over-watering or drought conditions apparently injure the roots so that root exudates are produced, which attract more zoospores of *P. cinnamomi* (Erwin and Ribeiro, 1996). For correct irrigation growers should vary water applications depending on the local evapotranspiration demands. In hot, summer weather more water should be scheduled; while in cooler, winter conditions less water should be scheduled. Constant monitoring of the tensiometers will alert growers to any over- or under-watering. In saline soils periodic leaching irrigations should be scheduled, which will force salt below the root zone, thus ameliorating the predisposing effect of salt on avocado root rot. Remember that root rot itself results in fewer roots and thus less water uptake. Adding more water to wilting, root-rotted trees will only exacerbate the situation. Use the tensiometers to maintain adequate soil moisture under root-rotted trees, but use care not to over-water.

Systemic Fungicides

Two fungicides have been very successful at reducing avocado root rot in many areas of the world (Coffey, 1987, 1992; Erwin and Ribeiro, 1996). Metalaxyl (Ridomil) is highly soluble, moves readily in soil and is absorbed readily by avocado roots. It may be applied as a granular, a drench or injected into the irrigation water. A single application of metalaxyl will provide 3 months of control. Some resistance to metalaxyl has been found in some Phytophthora spp. and rapid soil degradation may occur in some soils, although uptake of the material by roots should occur well before degradation begins. Metalaxyl will kill active Phytophthora in the soil, but it is not capable of destroying all the Phytophthora inoculum. The other fungicide is fosetyl-AL (Aliette) or potassium phosphonate which breaks down into the active ingredient phosphorous acid. They appear to be superior to metalaxyl when applied to mature trees in California (Coffey, 1992). This fungicide is translocated both upward and downward in the plant, although the upward movement is much stronger. Fosetyl-AL or potassium phosphonate can be applied as soil drenches, foliar sprays, trunk paints, trunk injections or injected into the irrigation water. All methods are effective if used properly, but local preferences indicate some methods work better than others under certain growing conditions. Foliar sprays require more chemical be applied and this method may not be practical on steep slopes. Soil applications require that roots be available for uptake of the material, so trees in advanced stages of root rot are difficult to rejuvenate using soil applications. Heavy clay soils may also impede the uptake of this material from soil. Trunk paints are more effective for treating trunk lesions, and it is often difficult for enough fungicide to be absorbed through the bark to effectively rejuvenate the roots. Injections are often the best way to rejuvenate root-rotted trees, but there is concern in many countries that wood decay organisms may invade the injection holes; or that the intense, brown stain in the avocado wood surrounding injection holes may damage the trees. There is little evidence to support either of these concerns. Fosetyl-AL should be buffered with potassium hydroxide before it is injected into trees. The correct timing for treatment is during active root growth since the material moves toward areas in the tree with active growth. Since root flushes generally follow foliage flushes, these fungicides should be added when the foliage flush is three-quarters complete. There are generally two root flushes per year—one in the spring and the other in the late summer or fall. Fosetyl-AL has little direct effect on soil populations of Phytophthora, but rather it seems to function mainly by increasing the resistance of avocado roots to infection, which indirectly lowers the soil populations of *P. cinnamomi*. A single application of Fosetyl-AL or potassium phosphonate will provide 3 - 4 months of control. For both fungicides, growers should heed label directions because rates, products, and methods of application may vary for each country in which avocados are grown.

Cultural Practices

To best combat avocado root rot, fertilizer nutrients should be applied so that trees are vigorous and healthy. Use leaf analysis to determine if deficiencies exist. Ammonium nitrogen fertilizers are thought to be less conducive to avocado root rot than nitrate fertilizers (Pegg, et al. 1982). Calcium is a particularly important nutrient that may be utilized in the control of avocado root rot. Applications of calcium as calcium carbonate, calcium nitrate and calcium sulfate have also been shown repeatedly to reduce avocado root rot (Broadbent and Baker, 1974; Messenger-Routh, 1996; Pegg et al. 1982). Calcium may reduce avocado root rot by:

1) Stimulating avocado root growth;
2) Increasing disease resistance in avocado roots;
3) Impairing activity of *P. cinnamomi* by reducing sporangial formation;
4) Interfering with zoospore motility or inducing premature encystment;
5) Improving soil drainage; and
6) Stimulating antagonistic microorganisms.

Messenger-Routh (1996) studied all of these mechanisms in California soils and determined that calcium primarily acted as a weak fungicide by reducing the size and number of sporangia produced by *P. cinnamomi*. It is recommended that applications of between 1500 and 3000 kg/ha of gypsum be made under the tree canopies, depending on the size of the trees. Animal manures are known to reduce populations of *P. cinnamomi*, probably because they frequently release ammonia which is very toxic to *P. cinnamomi* (Tsao and Oster, 1981). However, avocado roots are also very sensitive to ammonia and the damaged roots may even be more susceptible to avocado root rot. Therefore, animal manures should be broadcast sparingly and not used as mulch directly on top of avocado roots. If animal mulches are used, they could be spread over other organic mulches with a high C:N ratio (Pegg, et al. 1982). Soil pH should be maintained above 6.0, ostensibly to maintain high populations of antagonistic bacteria, which may reduce populations of *P. cinnamomi* (Broadbent and Baker, 1974).

Mulches

The use of mulches to control avocado root rot originated with Broadbent and Baker (1974) in Australia. They found that certain Queensland rainforest soils were often free of *P. cinnamomi*. They attributed this effect to the high microbial populations, high levels of organic matter (>7%), and high exchangeable magnesium, calcium and nitrogen. They labeled these soils suppressive to *P. cinnamomi*. They found that a complex scheme called the Ashburner method using bulky, organic mulches such as wheat straw, barley straw, or sorghum stubble together with fowl manure and dolomite to encourage breakdown of the mulch simulated the natural suppressiveness of soils. Today the practice has been modified to add only the key ingredients which are organic mulches and gypsum. High populations of bacteria and actinomycetes, according to Broadbent and Baker (1974); or cellulose and lignin-degrading microorganisms, according to Downer (1998); are naturally stimulated to create the suppressive soils. Organic material in soil can reduce avocado root rot by:

1) Increasing the activity of the indigenous microflora resulting in suppression of the pathogen population through competition or specific inhibition;
2) Releasing degradation compounds such as carbon dioxide, ammonia, nitrites, saponins or enzymes which are generally toxic to *P. cinnamomi*;
3) Acting as a trap, since Phytophthora will be attracted and encyst on organic matter; 4) inducing plant defense mechanisms;
5) Improving soil drainage; and
6) creating an environment that stimulates root development but physically inhibits Phytophthora (Turney and Menge, 1994).

Downer (1998) has shown that enzymes such as cellulase or glucanase are extremely disruptive to the life cycle of *P. cinnamomi* because its cell wall, unlike that of most other fungi, is composed of cellulose and glucans. He found that cellulases and gluconases are prevalent at high concentrations in organic matter as a result of the breakdown of cellulose and lignin compounds by microorganisms. It is recommended to layer organic matter in the form of yard trimmings, avocado trimmings, corn stubble, sorghum stubble, wheat straw, alfalfa straw, and pine bark with a C:N ratio between 25:1 and 100:1 under the canopy at the base of trees in layers 15-30 cm thick. It is important to keep the mulch away from the trunk because animals, which frequent the mulch, may occasionally damage the trunk. Tensiometers should be used to carefully monitor soil moisture under the mulch. Since the mulch reduces water loss, it is easy to over-water mulched trees and thus eliminate much of the beneficial effects that the mulch produces. Avocado roots that proliferate abundantly in the mulch and at the mulch/soil interface are relatively free of *P. cinnamomi*. Unfortunately the beneficial effects of mulch do not extend very far into the soil, probably because enzymes detrimental to *P. cinnamomi* that are produced in the mulch are adsorbed and inactivated on soil particles. Therefore roots in the soil below the much are often rotted; however, mulches have provided substantial growth stimulation of up to 43% in some California soils infested with *P. cinnamomi*.

Biological Control

Broadbent and Baker (1974) maintain that high levels of active microorganisms can reduce avocado root rot. Since then many soil-borne microorganisms such as *Myrothecium roridum, Trichoderma harzianum, Epiccocum purpurascens, Catenaria anguillae, Humicola fuscoatra, Anguillospora pseudolongissma, Hypochytrium catenoides, Myrothecium verrucaria, Streptomyces griseoalbus, Micromonospora carbonacea, Streptomyces violascens* and *Ceraceomyces tessulatus* have been shown to be inhibitory to *P. cinnamomi* via competition, antibiosis or parasitism (Downer, 1998; Erwin and Ribeiro, 1996). Today there are several commercial biocontrol products available with Trichoderma or Gliocladium as the active biocontrol agent. However, these products are mostly experimental at this time. Evidence indicates these biocontrol microorganisms do not always survive when used in avocado groves. It may be that biocontrol microorganisms, such as these, may add little benefit if mulches with large populations of antagonistic microorganisms are already present. Research is continuing in the search for specific biocontrol microorganisms which target and kill *P. cinnamomi*. Another interesting biocontrol approach is the field production of antagonistic bacteria in field fermentors and their continuous application in irrigation water.

LITERATURE CITED

Borst, G. 1970. Selection and Management of Avocado Soils. Calif. Citrograph 55:263-265.

Broadbent, P. and K. F. Baker. 1974. Behavior of Phytophthora Cinnamomi in Soils Suppressive and Conducive to Root Rot. Aust. J. Agric. Res. 25:121-137.

Broadly, R. H. 1992. Protect Your Avocados. Information Series Q191031, Dept. Primary Indust. Queensland, Brisbane.140p.

Coffey, M. D. 1992. Phytophthora Root Rot of Avocado.pp. 423-444. In Plant Diseases of International Importance, Volume III. Diseases of Fruit Crops. J. Kumar, H. S. Chaube, U. S. Singh and A. N. Mukhopadhyay (eds.) Prentice Hall, Englewood Cliffs.

Coffey, M. D. 1987. Phytophthora Root Rot of Avocado: An Integrated Approach to Control in California. Plant Dis. 71:1046-1052.

Downer, A. J. 1998. Control of Avocado Root Rot and *Phytophthora Cinnamomi* Rands in Mulched Soils. Ph. D. Dissertation., University of California, Riverside. 210p.

Erwin, D. C. and O. K. Ribeiro. 1996. Phytophthora Diseases Worldwide. APS Press, St Paul. 562p.

Menge, J. A., F. B. Guillemet, S. Campbell, E. Johnson, and E. Pond. 1992 The Performance of Rootstocks Tolerant to Root Rot Caused by *Phytophthora Cinnamomi* under Field Conditions in Southern California. Proc. 2nd World Avocado Congress, Pp. 53-59.

Messenger-Routh, B. J. 1996. The Effects of Gypsum Soil Amendments on Phytophthora Root Rot of avocado. Ph. D. Dissertation, University of California, Riverside, 106p.

Pegg, K. G., L. I. Forsberg, and A. W. Whiley. 1982. Avocado Root Rot. Queensland Agric. J. 108: 162-168.

Turney, J. and J. Menge. 1994. Root Health--Mulching to Control Root Disease in Avocado and Citrus. The California Avocado Society. Circ. No. CAS-94/2.

Tsao, P. H. and J. J. Oster. 1981. Relation of Ammonia and Nitrous Acid to Suppression of Phytophthora in Soils Amended with Nitrogenous Substances. Phytopathology 71:53-59.

Zentmyer, G. A. 1980. *Phytophthora Cinnamomi* and The Diseases It Causes. Monograph # 10, Amer. Phytopath. Soc., St Paul. 96p.

Zentmyer, G. A., and H. D. Ohr. 1978. Avocado Root Rot. Div. Agric. Serv., University of California, Leaflet # 2440.