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An Integrated Approach to the Control of Avocado Root Rot

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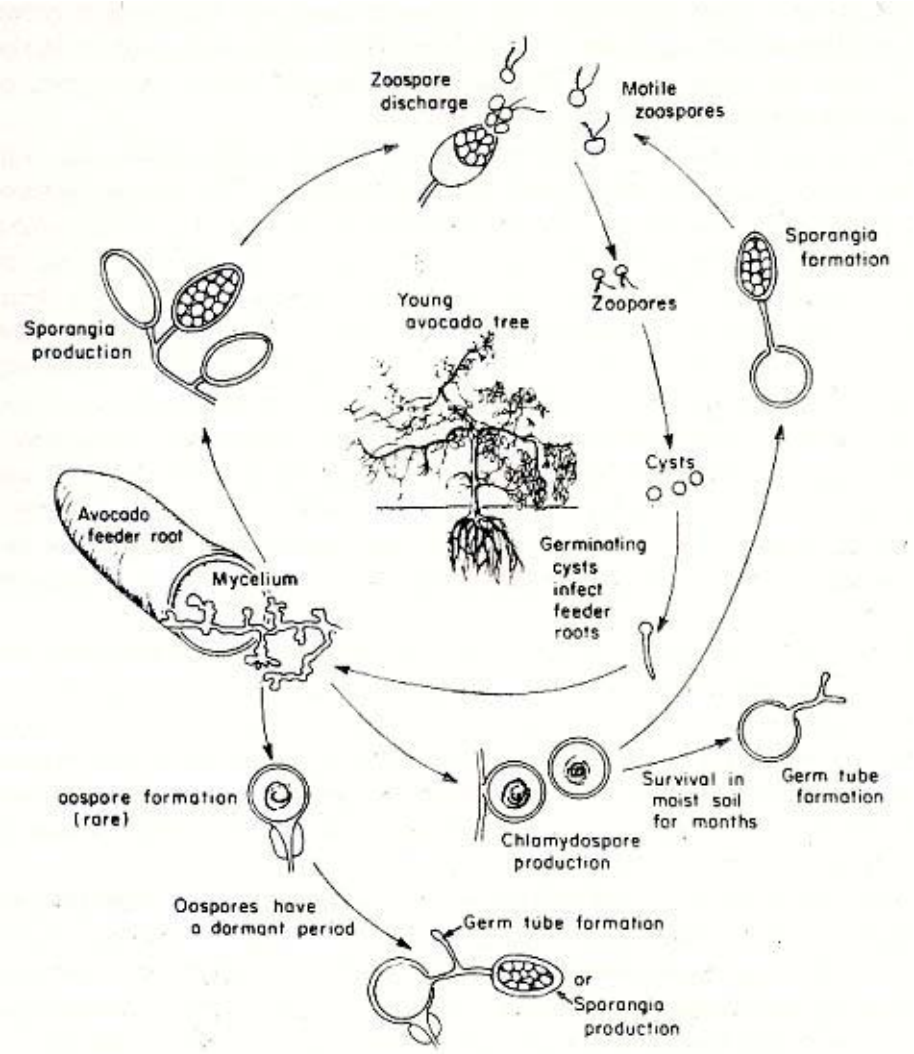
Life-cycle of Avocado Root Rot

Phytophthora cinnamomi Rands is the cause of this disease of the feeder roots of avocados. Zoospores, small motile spores with two flagella, are attracted to the actively growing feeder roots. They become attached to the root surface, round-up by forming a wall, and penetrate into the root tissue. Within about 6 hours the feeder root tissue is dead, and the fungus grows within this necrotic tissue for several days. When the food reserves of the root tissue are used up, the Phytophthora fungus forms two types of spores: sporangia and chlamydospores.

Sporangia can survive for days or even weeks under moist soil conditions. They can also liberate more motile zoospores. The zoospores have limited mobility (less than a centimeter), but this can obviously allow significant disease development within the feeder root system of an infected avocado tree. Under moist, warm soil conditions there is a rapid proliferation of zoospores within a tree root system. The main effect of the pathogen is on the feeder root system, which through its rapid destruction, destroys the ability of the avocado tree to take up water and nutrients. Under the harsh semi-arid conditions found in California, this results in a rapid decline of the trees. Symptoms include die-back of the tree's branches, wilting and yellowing of the leaves, and ultimately complete defoliation. Frequently it is not realized that once foliar symptoms are expressed, this indicates that much of the feeder root system is already destroyed.

Chlamydospores have a similar wall thickness to sporangia and serve the purpose of maintaining the pathogen apart from its host. They can survive years under moist soil conditions. However, they are very sensitive to freezing temperatures and dry conditions within the soil. These spores germinate under warm, moist conditions in response to an increase in root exudates. In the soil they usually germinate to form sporangia, which in turn liberate motile zoospores.

Oospores are only rarely found in avocado roots. They are not believed to be important in the infection cycle. However, these spores are very thick-walled and much more resistant to cold and dry conditions than are chlamydospores. Thus, they may serve as an ultimate reservoir of survival under cultural conditions such as fumigation and drying used to reduce the level of *P. cinnamomi* in the soil.



Disease cycle of avocado root rot caused by Phytophthora cinnamomi

Spread of the pathogen

Under wet conditions, motile zoospores of the pathogen can be moved passively in run-off and irrigation water. As these spores can remain motile for over 24 hours, such a passive movement of the pathogen can cause significant spread of the disease within an avocado grove. In addition, soil already contaminated with *P. cinnamomi* contains decaying roots which hold mycelium and chlamydospores, and these structures are highly infective. Physical movement of wet soil is a common method of spread of the disease, both within a grove and from property to property.

Ornamentals

P. cinnamomi is known to be parasitic on over 1000 different host plants, including many ornamentals. It is a cause of root rot on fruit trees such as peach, plum, and, almond and on ornamentals like azaleas, firs, pines, and eucalyptus. The fact that a particular plant is not a known host of *P. cinnamomi* is certainly not a safeguard against introduction of the disease. *P. cinnamomi* will cause limited infection of plant species which are not normally considered hosts. Since *P. cinnamomi* is widespread (endemic) in most countries where avocados are grown, and as it can survive in soil apart from a host, there is no ornamental planting which does not pose a threat to avocado production.

Integrated disease control

There are five principal factors to consider:

1. Nursery practice
2. Cultural practice
3. Clonal rootstocks
4. Biological control
5. Chemical control

1. Nursery practice. It is extremely important to raise avocado trees in an environment free from *Phytophthora.* In California, the avocado certified program lays down the conditions necessary to minimize the possibility of infection of nursery trees by *P. cinnamomi.* It does not cover other Phytophthora species such as *P. citricola* which may also attack avocado.

Unfortunately, the planting of trees obtained from nursery operations which have not guarded against infestation by *P. cinnamomi* has been a major factor in the spread of the disease in many avocado-producing areas.

It should be stressed that the certified program lays down guidelines to minimize the possibility that the trees have root rot. There is unfortunately no absolute guarantee of not introducing root rot.

Nursery practice should include:

(a) The use of well-drained steamed or fumigated soil mixes.

(b) The propagation of all trees on benches (a practice not yet widely adopted in California).

(c) The provision of adequate drainage within the nursery to minimize the risks of

spread of *P. cinnamomi* from outside the nursery during periods of high rainfall.

(d) The periodic sampling of the tree roots for *P. cinnamomi* during the 2-year production period.

(e) The minimal use of fungicides in nursery practice. Fungicides, and especially the systemic fungicides such as Ridomil® and Aliette®, should not be used for nursery practice, since they would actively suppress *P. cinnamomi*, making its early detection difficult.

(f) The provision of adequate barrier fences around the nursery to prevent illicit entry, and the use of copper-based fungicide dips for feet at the entrances to the nursery.

(g) The avoidance of use of natural composts which have not been fumigated. In view of the widespread distribution of *P. cinnamomi* and other *Phytophthora* spp. potentially infectious to avocado, organic materials should never be used without adequate steaming or fumigation.

2. Cultural practice. Cultural practices are critical to proper disease management. Since *P. cinnamomi* is favored by wet conditions, irrigation and cultural practices should aim to minimize the effects of excessive watering. These practices should include:

(a) Provision of a well-drained, deep soil. Incorporation of adequate organic matter, such as chicken manure and straw, should be made at the time of planting in an attempt to improve the drainage and nutrient status of the soil. On heavier soils, the use of mounds (about 1 foot high by 3 feet diameter), or ridges, may prove effective in allowing more rapid growth and establishment of nursery trees.

(b) Provisions of adequate irrigation. The correct use of drip-irrigation or mini-sprinklers facilitates the maintenance of proper moisture conditions around the roots and avoids the periods of either severe water stress or excessive water-logging frequently associated with other types of irrigation. Irrigation should be critically controlled to allow maximal growth of the avocado.

(c) The use of drip irrigation also provides the opportunity to provide frequent low levels of macronutrients (N, P and K). In addition, drip irrigation can be used to attempt a correction of micronutrient deficiencies (Fe and Zn), and provide the trees with fungicides such as metalaxyl.

(d) The addition of a straw mulch to provide a suitable environment for development of the feeder roots is to be encouraged. In California this practice is not widespread, but in Queensland, Australia (a high rainfall area) it has proved extremely useful both in the establishment of avocado groves and in maintenance of a healthy feeder root system with mature trees.

(e) Adequate drainage channels and barriers should be constructed to reduce the possibility of flooding introducing *P. cinnamomi.*

3. Clonal rootstocks. The development of the clonal rootstocks Duke 7 and G6 has revolutionized our concepts about avocado planting. These rootstocks have moderate

field tolerance to *P. cinnamomi*. Providing they are planted in adequately drained, reasonably deep (3 feet or more) soils they have been established in the presence of *P. cinnamomi.* Ideally they should be established in the absence of root rot, since their field tolerance to root rot appears to improve with increasing age of the tree.

Any young avocado tree, but particularly a clonal rootstock, requires proper planting conditions. Irrigation practice is critical in an environment such as southern California where temperatures may reach 100° to 105° F literally within days of planting. Excessive dryness or excessive wetness can be more damaging than root rot to the root systems of newly planted avocado trees and are very common causes of failure. The use of potentiometers placed to measure soil moisture conditions in the rootball is strongly recommended. We are in the process of evaluating several new clonal selections:

G 755 A	Persea schiedeana
G 755 B	P. schiedeana
G 755 C	P. schiedeana
G 1033	P. americana
G 1038	P. americana
G 1077	P. americana
Thomas	P. americana
Toro Canyon	P. americana
D9	P. americana
Barr Duke	P. americana

The G755 selections have now been released by the University of California and are commercially available in limited quantities.

4. Biological control. A range of soil microbes including fungi, bacteria, actinomycetes, and even zoospore-engulfing amoebae and paramecia have been studied for their ability to suppress *P. cinnamomi*. No single culprit has emerged. Indeed some scientists believe the main effect is cultural, by providing a good physical and chemical environment for root growth, and a generally suppressive biological soil environment for *P. cinnamomi.*

The selection and use of specific antagonistic microbes to reduce the effects of root rot during the first few years of establishing a clonal root-stock in a manner similar to that used for fungicides is an exciting possibility for the near future. In particular, it may be possible to select bacteria that will inhabit the root zone, stimulate growth, and antagonize *P. cinnamomi*. They would probably be used in conjunction with a fungicide such as Ridomil®.

At Mt. Tamborine in eastern Queensland, Australia, the adoption of the Ashburner system, in which the high organic matter content, nutrient status, and good drainage of the tropical rain forest soil is partially restored, has allowed production of avocados in areas where *P. cinnamomi* is endemic. The process involves the addition of large amounts of organic matter (chicken manure and straw mulch) and dolomitic limestone, as well as intercropping with various legumes. A critical measure is the creation of a soil environment which encourages very active growth of the feeder roots through a mulching practice. However, these soils are extremely deep (20 feet or more), the area has a very high rainfall, and in the past the high cost of organic farming has been aided by a relatively small avocado acreage and a high demand for the limited supply of avocados (i.e., the growers get high prices). Even under ideal conditions, this system is not without its problems. Without critical management of the organic mulching process, it is possible to create conditions where a relatively impervious layer of organic matter traps excessive moisture leading to rapid death of the avocado feeder roots. The very good growth conditions created for the avocado favor very rapid growth and establishment. This is initially desirable since it brings early and consistent fruit production. However, by about the tenth year the trees are typically so large that picking costs become very prohibitive.

In California, where the majority of suitable soils are generally much shallower and where current fruit prices are low, the possibilities for such a system working are poor. However, adoption of suitable mulching practices to favor good feeder root development does seem worthwhile, and more research is needed into the suitability of this cultural practice in the semi-arid or arid cultivation of avocados.

5. Chemical control. Fumigation using methyl bromide or soil biocides such as Vapam® and Mylone® has been a recommended practice where avocados are planted. Soil biocides are broad spectrum in activity and may partially suppress populations of nematodes and pathogenic fungi. They also suppress beneficial and mycorrhizal fungi. There is no good evidence with avocados that fumigation is necessary. With the development of chemicals which are highly active specifically against P. cinnamomi, new possibilities of disease control have recently emerged.

Ridomil® is a systemic fungicide produced by Ciba-Geigy registered for use on avocados. It is formulated either as an emulsifiable concentrate (2 Ibs. active per gallon) or as a granule (5% active). Ridomil® is one of the most active fungicides ever developed. As little as one-tenth of a part per million will inhibit fungal activity. Ridomil® is not fungicidal, but fungistatic, at the concentrations generally used for disease control. High concentrations of about 300 parts per million can be phytotoxic. Ridomil ® is highly water soluble (7000 parts per million) and this property aids its movement in the soil and in the plant. Ridomil® has proven to be an extremely effective fungicide against *P. cinnamomi* especially with nursery trees where it is applied prior to planting. SAN 371 F (oxadixyl) is another fungicide in the same family as Ridomil®. It is produced by Sandoz (Zoecon) and appears to have similar activity to Ridomil® against root rot in field trials with nursery avocados.

Aliette® is a fungicide produced by Rhone-Poulenc. It is not registered for use on

avocados. It is systemic in plants in both an acropetal (root to shoot) and basipetal (shoot to root) direction. Consequently, in addition to use as a soil application it can be put on as a foliar spray. There is also the possibility of injecting it into the trunk of mature trees. The relative effectiveness of these different methods is being actively investigated here in California, in South Africa, and in Australia.

Research with fungicides should be directed more toward obtaining improved control of P. cinnamomi on avocados, especially young nursery trees, through more intelligent use of Ridomil® and Aliette®. In experimental trials the use of a preventive treatment of Ridomil ® (100 to 150 parts per million) or Aliette® (1500 parts per million) has proved highly effective in allowing the establishment of Duke 7 nursery trees in soil infested with *P. cinnamomi*.

Postplant fungicide treatments should not rely too heavily on control with a single site-specific fungicide such as Aliette® or Ridomil®. Our current research is aimed at producing more stable disease control utilizing either alternative applications or various mixtures of Aliette® and Ridomil ®. For a perennial crop such as an avocado, the objective should be effective disease control for the life of the crop.

Summary of disease control. The critical factors for adequate control of avocado root rot are the planting of a good clonal rootstock, careful cultural practice, and intelligent use of fungicides. This is an integrated control approach and does not rely excessively on any single method for reducing the impact of root rot.