Avocado Diseases in the Americas

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Relatively little has been known regarding diseases affecting the avocado tree *(Persea americana)* until the past fifteen to twenty years. A native tree to various sections of Latin America, the avocado is a relative newcomer to cultivation on a large scale. In the cultivation of this crop in the United States and in Latin America, a number of diseases are now recognized.

In California the following major diseases have been found (17, 34, 41):

Disease	Causal Agent
Phytophthora root rot	*Phytophthora cinnamomi*
Verticillium wilt	*Verticillium albo-atrum*
Armillaria root rot	*Armillaria mellea*
Dothiorella fruit rot	*Botryosphaeria ribis (Dothiorella gregaria)*
Sun-blotch	Virus
Trunk and branch cankers	*Phytophthora* spp. and *Botryosphaeria ribis*

Phytophthora root rot is by far the most important of these problems in California. The other diseases are more sporadic in occurrence and generally less severe in their effects. In addition to these diseases found in the field, it has been shown by inoculations in the greenhouse that avocado is very susceptible to the soil fungus *Rosellinia necatrix (Dematophora necatrix)* (23).

In Florida the major diseases are fruit rots or leaf spots (24) instead of root rots as in California, although Phytophthora root rot occurs to some extent in southern Florida. These include the following:

Disease	Causal Agent
Scab of fruit and foliage	*Sphaceloma perseae*
Cercospora spot or blotch of fruit	*Cercospora purpurea*
Anthracnose of fruit	*Colletotrichum gloeoporioides*

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Powdery mildew is occasionally found in Florida on foliage in nurseries or on young trees growing in shaded, damp locations. Phytophthora seedling blight, caused by the fungus *Phytophthora palmivora*, has been described from Florida by Conover (9) and from Honduras by Zentmyer and Muller (44).

In Latin America there have been relatively few publications dealing with avocado diseases. Occasional reports have appeared on Phytophthora root rot in Argentina, Brazil, Perú, Puerto Rico, and Venezuela (14, 29, 10, 13, 2, 28, 20). The following other diseases, principally of foliage and fruit, have been reported from various locations in Latin America:

Cercospora spot or blotch (causal fungus, *Cercospora purpurea):* Brazil, Perú, Venezuela (29, 25).
Anthracnose *(Colletotrichum gloeosporioides):* Brazil, Dominican Republic, Peru, Puerto Rico, Venezuela (4, 8, 29, 25).
Leaf spot *(Mycosphaerella perseae): Puerto Rico* (21).
Tar spot *(Phyllachora gratissima):* Bolivia, Colombia, Ecuador, Puerto Rico, Venezuela (25, 27, 29).
Scab *(Sphaceloma perseae):* Brazil, Cuba, Haiti, Mexico, Peru, Puerto Rico (4, 19).

In addition to the above diseases that have been reported commonly in several different parts of Latin America as a rule, the following pathogenic fungi or diseases have been listed only rarely or are of restricted occurrence geographically:

Botryosphaeria ribis: Trinidad and Brazil (29).
Diaporthe citri: Trinidad (29).
Diplodia natalensis: Brazil (29).
Phomopsis sp.: Brazil (29).
Rosellinia bunodes: Peru (29).
Rosellinia sp.: Grenada, W. I. (1).
Gummosis — *Phytophthora cactorum?:* Brazil (5).
Pestalozzia canker: Brazil (5).
Algal leaf spot: Brazil (5).
Carapace spot: Brazil (4).
Eruptive pustule: Brazil (6).
Phyllosticta perseae leaf spot: Dominican Republic (8).

As a result of observations and cultures made on several trips to Latin America by the author during the past few years in search of root rot resistant avocado rootstocks, the following specific disease records have been obtained on avocado (37):

PHYTOPHTHORA ROOT ROT (Causal fungus: *Phytophthora cinnamomi)*
Mexico: Ciudad Victoria (Tamps.); Atlixco (Puebla); Jungapeo (Michoacan); Tapachula (Chiapas); Huatusco (Veracruz).
Guatemala: San Pedro Carcha (Alta Vera Paz) (isolation from *Persea schiedeana).*

Honduras: Zamorano (Escuela Agricola Panamericana).
Costa Rica: San Mateo, Orotina.
Chile: La Cruz, San Fernando, Malloa.
Peru: Chanchamayo Valley.
Brazil: Campinas (Sao Paulo).
Trinidad: Port of Spain.
Cuba: Santiago de las Vegas.
Puerto Rico: Isabela, Jajuja, Mayaguez, Ponce.

PHYTOPHTHORA TRUNK CANKER (causal fungus: *Phytophthora cinnamomi)*
Brazil: Piricaba (Sao Paulo).

PHYTOPHTHORA BRANCH CANKER (causal fungus: *Phytophthora palmivora?)*
Honduras: Mt. Uyuca

PHYTOPHTHORA SEEDLING BLIGHT (causal fungus: *Phytophthora palmivora?)*
Honduras: Zamorano (Escuela Agricola Panamericana)

VERTICILLIUM WILT (causal fungus: *Verticillium albo-atrum)*
Chile: La Cruz
Ecuador: Guiallabamba Valley

ARMILLARIA ROOT ROT (causal fungus: *Armillaria mellea)*
Ecuador: Guiallabamba Valley

SUN-BLOTCH (virus)

POWDERY MILDEW
Peru: Chanchamayo Valley
Brazil: Campinas

SCAB (causal fungus: *Sphaceloma perseae)*
Brazil: Sao Paulo State
Peru: Chanchamayo Valley
Puerto Rico: Isabela

PHYSALOSPORA CANKER (causal fungus: *Physalospora perseae)*
Peru: La Molina

BOTRYOSPHAERIA OR DOTHIORELLA CANKER (causal fungus: *Botryosphaeria ribis)*
Chile: La Cruz

MISTLETOE *(Phoradendron* sp.)
Mexico: Atlixco (Puebla)

LEAF SPOT (causal fungus: *Mycosphaerella perseae)*
Mexico: Teziutlan (Puebla)

Cultures were made in the course of these trips to confirm diagnosis of Phytophthora root rot and canker, Armillaria root rot, and Botryosphaeria canker. Cornmeal agar or 3 P antibiotic agar (12) was used for isolation of *Phytophthora* spp.

A brief description of the most important of the avocado diseases, with present control measures, follows.

Phytophthora Root Rot

Phytophthora root rot of avocado *(Persea americana* Mill.), caused by the soil fungus *Phytophthora cinnamomi* Rands, is the most serious problem in avocado culture in California. The same disease has also been reported from Mexico, Honduras, El Salvador, Costa Rica, Peru, Chile, Argentina, Brazil, Venezuela, Trinidad, Puerto Rico, Cuba, South Africa, Hawaii, and Australia, and occurs to a limited extent in Florida and Texas.

The soil fungus *Phytophthora cinnamomi* was first described by R. D. Rands as causing a stripe canker of cinnamon trees in Sumatra in 1922. The first report of the fungus on avocado was in 1929 when C. M. Tucker isolated the fungus from diseased avocado trees in Puerto Rico. *P. cinnamomi* was first recorded in the United States on rhododendron plants in New Jersey in 1930, and was isolated from avocado roots in California in 1940 (30).

Two factors are necessary for disease development: the fungus *P. cinnamomi,* and excess soil moisture. Water is important because the fungus needs water to form its principal spore stage (the zoospore), and to permit these spores to swim about, germinate on, and infect avocado roots. Excess water is more important because of its effect on the fungus than because of any harmful effect on the host. Experiments on growing seedlings under waterlogged soil conditions and in solutions with reduced oxygen content indicate that without the fungus *P. cinnamomi* there would be little or no damage to avocado trees growing under conditions of impaired drainage. Most of the early statements on sensitivity of avocado to poor drainage may really be reflections of the susceptibility of the avocado tree to attack by this fungus.

Disease Symptoms.—Leaves of infected trees are smaller than normal, usually pale green or yellow green instead of dark green, often wilted, and tend to drop, giving the tree a sparse appearance. New growth is often absent; if new leaves are formed, they do not develop normally and are of pale green color. Branches tend to die back in advanced stages of disease. Fruit does not reach normal size. Frequently an abnormally heavy set of fruit occurs soon after symptoms of the disease first appear; evidently this is a reflection of the fact that much of the root system is rotted and food material has accumulated in the top.

Many of the small feeder roots on diseased trees are blackened, brittle, and dead. In advanced stages of disease it is difficult to find feeder roots when digging under affected trees. The soil under diseased trees tends to stay wet, as small absorbing roots are not removing water from the soil. The gradual decline in vigor and productivity of the tree usually goes on for several years, although occasionally the deterioration is more rapid. *P. cinnamomi* rarely invades roots larger than $\frac{1}{8}$ to $\frac{1}{4}$ inch in diameter; very occasionally lesions are found on larger roots and on the rootstock.

The fungus can also cause cankers of the trunk; canker formation is not common under California conditions, but occurs to a greater

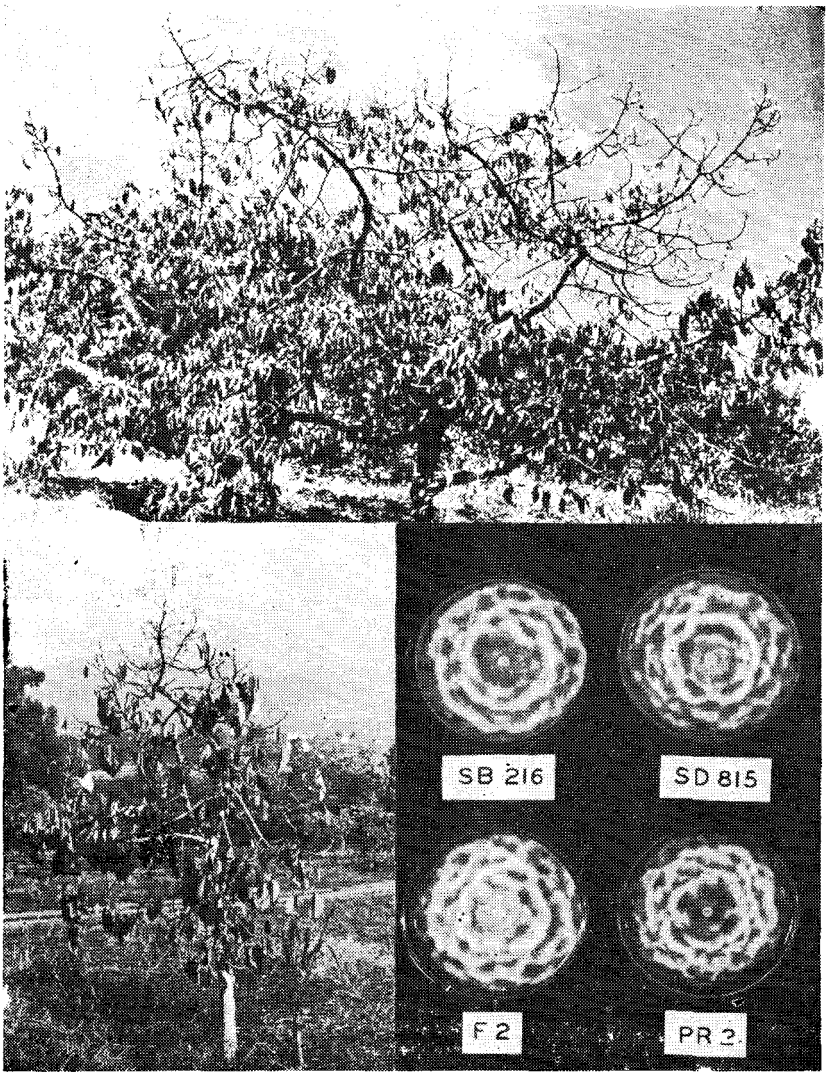

Fig. 1.—(Top) Twelve-year old Fuerte avocado tree in advanced stage of Phytophthora root rot.

Fig. 2.—(Lower left) Young avocado tree showing severe symptoms of Phytophthora root rot two years after planting.

Fig. 3.—(Lower right) Cultures of Phytophthora cinnamomi, **causal fungus of Phytophthora rrot rot of avocado, op potato dextrose agar. Uupper two cultures are isolates from California, F2 is from Florida, PR 2 from Puerto Rico.**

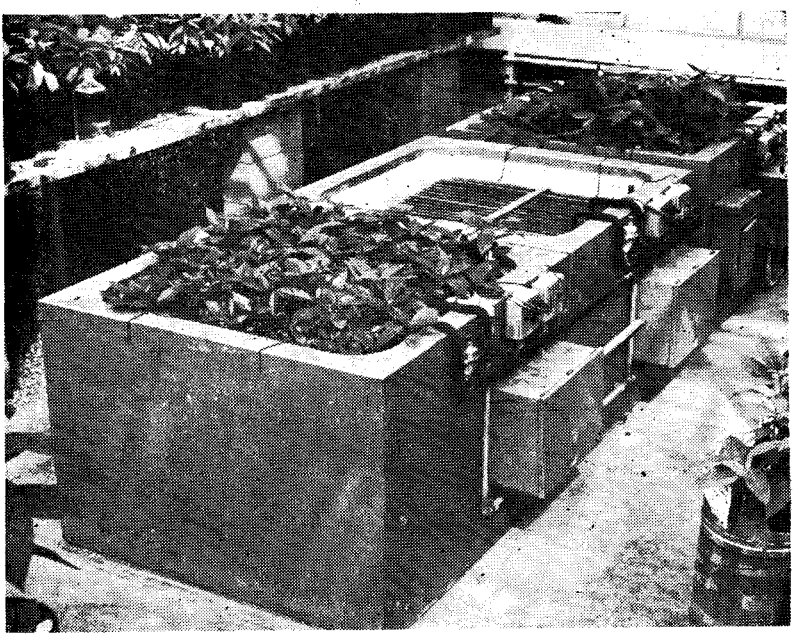

Fig. 4.—(Top) Temperature-controlled tanks for testing resistance to Phytophthora root rot of avocado. Seedlings are grown in aerated nutrient solution at 24°C., at pH 6.5, then inoculum of the fungus is added to the tanks.

extent in some tropical areas. In this case the tree may look somewhat like a tree affected with root rot, although occasionally sudden collapse of the top occurs. Examination of the trunk usually reveals a darkening of the bark and an exudation of powdery white material (hepitol, a 7-carbon sugar alcohol) from the affected bark. When the bark of the cankered area is cut into, it is found to be brown in color; the brown discoloration often extends into the wood as well. On many trees the trunk is not completely girdled, but the canker may extend up the trunk several feet from the ground.

The Causal Fungus.—Phytophthora cinnamomi is in the Phycomycete group of fungi, and is known as one of the "water molds". It forms three types of spores: zoospores (swimming spores formed in sporangia), oospores (resistant spores) and chlamydospores. Sporangia are formed most abundantly between the temperatures of 24° and 27° C, although some of these spore-bearing structures are produced over a wide range of temperatures. The zoospores when liberated in water, swim about rapidly, are attracted to small avocado roots, germinate on the root surface and penetrate the root to cause an infection within 24 hours after germination. If spores do not find an avocado root or other suitable subtrate, they can swim for many hours. It has recently been found that actively growing small roots of susceptible avocado varieties exude some material that attracts zoospores of *P. cinnamomi;* this is a striking chemotactic phenomenon (38).

Information is lacking on the role that the thick-walled oospores play in disease development, although they are probably spores that permit the fungus to survive unfavorable temperature or other unfavorable environmental conditions. The mycelial or vegetative stage of the fungus makes its maximum growth at 24° to 27° C (75° to 80° F) and does not grow above 33° C (92° F) or below 10° C (50° F).

Hosts of the Fungus.—In addition to the avocado, *P. cinnamomi* attacks a wide variety of plants; it has been described from over 115 species of plants in various parts of the world. Some of the more commonly affected plants are: azalea, camellia, chestnut, cinnamon, cinchona, heather, Lawson cypress, Douglas fir, oak (several species), papaya, pineapple, pine (several species), plane tree, rhododendron, and yew (26, 45).

Control of the Disease.—In control of Phytophthora root rot, a number of aspects are under investigation in our laboratory at Riverside, California: resistant rootstocks (primary emphasis on this phase), soil fungicides and fumigants, chemotherapy, exclusion of the fungus (certified nursery stock), nutritional factors, biological control, and cultural factors, including irrigation.

Resistant Rootstocks.—The resistance phase of the research on this disease has emphasized three approaches: the search for resistance in the native habitat of the avocado in Mexico, Central and South America, and the West Indies; the search for resistance among the miscellaneous seedlings and varieties of avocado present in California; and the search for resistance in areas in California and in Latin America where the disease has been present for many years.

In the course of several trips to Latin America, collections have been made of seeds and budwood of nearly 300 different avocado types and of seed of seven other species of *Persea; P. Skutchii* from Honduras and Costa Rica; *P. caerulea* from Venezuela; *P. chrysophylla* from Colombia; *P. Donnel Smithii* from Honduras and Guatemala; *P. schiedeana* from Mexico, Guatemala, and Costa Rica; *P. durifolia* from Peru; *P. lingue* from Chile; and *P. alba* from Brazil. In addition to these species, several collections have been made of trees in other genera in the family Lauraceae, of which the avocado is a member. These include species of the genus *Phoebe, Nectandra, Ocotea, Beilschmedia,* and *Umbellularia.*

Collections have been made in Mexico, Guatemala, El Salvador, Honduras, Costa Rica, Colombia, Ecuador, Chile, Peru, Argentina, Brazil, Venezuela, Trinidad, Puerto Rico, St. Croix, Haití, Jamaica, and Cuba (33, 36).

For the rootstock resistance tests, seeds are germinated in flats of steam-sterilized sand in the greenhouse; when the seedlings are from 3 to 6 inches in height, they are transplanted to tanks of aerated nutrient solution. The temperature of the solution is maintained at 24° C, the optimum temperature for disease development, and the pH is maintained at 6.5. From 400 to 450 seedlings can be tested in a tank; three tanks are available for this testing program.

The seedlings to be tested for resistance are then grown in the nutrient solution for 7 to 10 days until abundant new root growth occurs. Inoculum of the pathogen *Phytophthora cinnamomi* is then placed in the tanks in the form of sections cut from potato dextrose agar cultures of the fungus. The fungus inoculum is suspended in the nutrient solution in cheesecloth bags. Under these conditions the fungus forms millions of swimming zoospores which attack the susceptible avocado roots and produce visible lesions within 2 to 3 days. Within a period of 10 days, 95 to 100 percent of the root systems of susceptible plants are completely rotted by the fungus, and resistant types can be determined.

Using this method, high resistance to Phytophthora root rot has been found in *Persea Skutchii, P. caerulea, P. chrysophylla,* and *P. Donnell-Smithii,* all of which are small-fruited species of *Persea* (47). In addition, *P. borbonia,* a member of this genus native to swampy areas in the southeastern United States, also has high resistance. Unfortunately propagation tests, primarily conducted at the University of California at Los Angeles by E. F. Frolich, show that none of the above resistant species is graft-compatible with the avocado; thus these types cannot be used directly as rootstocks (15). Attempts are being made by B. O. Bergh at the University of California, Riverside, to hybridize the resistant species with *P. americana.* Seedlings of several other non-graft-compatible plants in the Lauraceae also have high resistance, including species of *Ocotea?* and *Alseodaphne* and (provided by R. A. Hamilton, etc.)

In addition to this high resistance in the non-compatible species, slight to moderate resistance has been found in several avocado seedling varieties, notably in the Duke variety (48). The Duke is a Mexican

Fig. 5.—(Bottom) Verticillium wilt of young avocado tree. Leaves wilt suddenly, turn brown, and remain hanging for a considerable period.

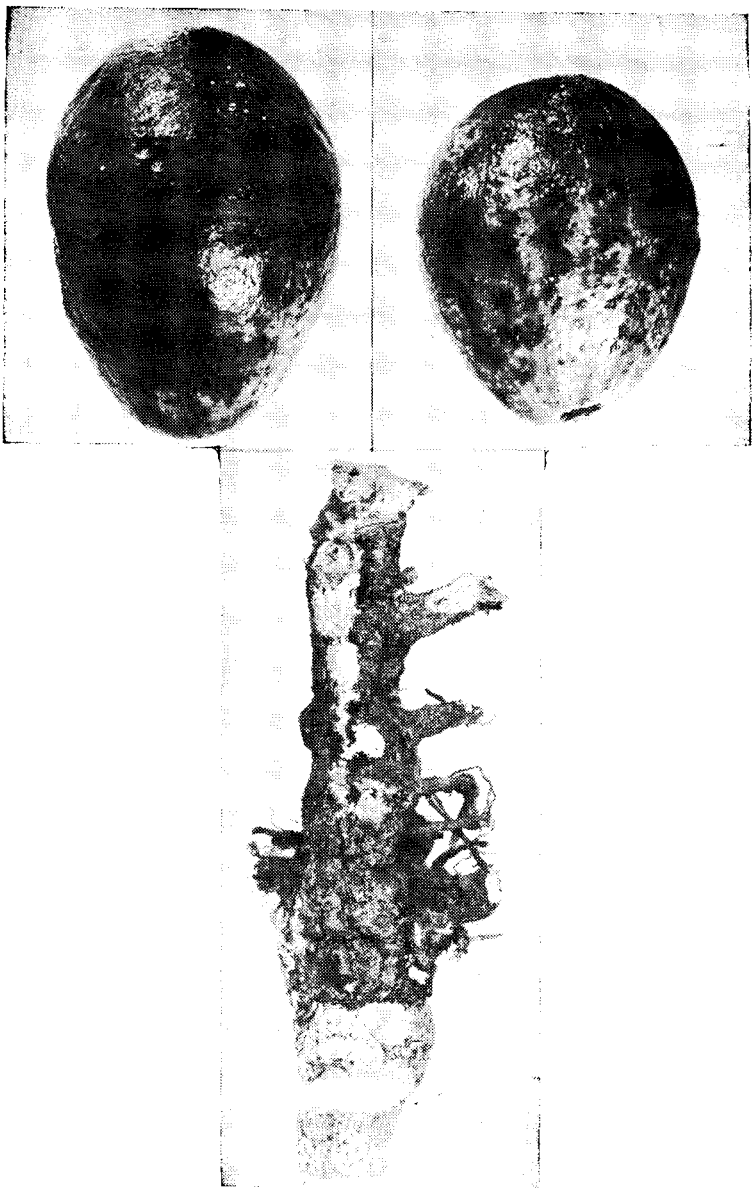

Fig. 6.—(Top) Rootstock of young avocado tree affected with Armillaria root rot, with white mycelial fans of the fungus under the bark.
Fig. 7.—(Bottom) Dothiorella rot of Fuerte avocado fruit.

type avocado variety that has been in California for nearly 40 years, and has been planted to some extent as an early fall fruit of fair quality. Further tests are being conducted with cuttings from selected Duke seedlings with some resistance and with cuttings from the Duke clone. These show some initial promise in field trials, and in all tests are more resistant that the standard rootstock types used in California, such as the Mexican varieties Topa Topa and Mexicola. Several other collections, including *P. americana* types from Mexico, Guatemala, Puerto Rico, Costa Rica, and Florida (U. S. Plant Introduction Garden, Miami), have shown slight to moderate resistance.

Soil Fungicides and Fumigants.—Various types of chemical treatment have been evaluated for control of this disease, and considerable information has been obtained which is of use under special conditions. *P. cinnamomi* can be killed by any one of several fumigants or fungicides: D-D (dichloropropane-dichloropropene mixture), Telone (principally dichloropropenes), methyl bromide, and Vapam (sodium N-methyl dithiocarbamate). Any of these materials are useful in attempting to eradicate small spots of infection, but are impractical for treating large infections. Methyl bromide is used extensively by commercial nurserymen for treating nursery potting soil, and is equally useful in avocado nurseries.

Experiments are being conducted with several of the above materials as barriers for preventing the spread of *P. cinnamomi* through the soil and along roots; current results appear promising.

The fungicide testing program has recently been directed primarily toward developing chemicals that can be applied to living trees in the irrigation water and that will reduce the population of *P. cinnamomi* without damage to the tree roots. Two organic fungicides have recently shown promise in this regard: Chemagro Chemical Co.'s Dexon (p-dimethylaminobenzenediazo sodium sulfonate), and Shell Development Co.'s SD 4741 (0,0,0-trimethyl phosphorothioate) (41). In greenhouse tests, these materials, when applied as a drench to the soil in which avocado seedlings are growing, have given excellent prevention of the disease at dosages of 10, 20 and 40 ppm of Dexon in soil, and 50, 100 and 200 ppm of SD 4741 in soil. The chemicals have also shown promise in arresting incipient cases of root infection and permitting seedlings to resume normal growth. Field trials are underway to determine if these materials will be useful in control of the disease on large trees when the chemical is applied in the irrigation water.

Chemotherapy.—A new phase of the investigation of this disease problem concerns chemotherapy, or the treatment of disease by chemicals that are translocated in the plant. Screening tests are being developed to detect translocation of chemicals in a downward direction when applied to the leaves, and in an upward direction when applied to the roots. In tests with a number of organic fungicides and antibiotics, one chemical has shown promising indications of translocation. An ideal chemical for control of a root disease would of

course be one that is translocated downward when sprayed on the leaves and prevents or controls fungus infection in the roots.

Exclusion of the Fungus.—New infections caused by spread of this fungus can be prevented by use of clean seed and clean planting stock, and by careful sanitary measures so that the fungus is not transported in soil or water from infested areas. A certified avocado nursery stock program has been adopted recently by the State Department of Agriculture in California, based on research in this Department and aimed at preventing the spread of the fungus by means of infected nursery stock. This program involves hot water treatment of the seed at 49°-50°C (120°-122°F) for 30 minutes to kill any possible fungus present in the seed, treatment of nursery soil for use in containers with 3 lbs. of methyl bromide per 100 cu. ft. or with steam at 82°C (180°F) for 30 minutes, and growing nursery stock in containers above the ground so that possible contamination with *P. cinnamomi* is avoided.

Diseased nursery stock has undoubtedly been the primary means by which this fungus has been so widely distributed over the avocado-producing areas of California as well as in many other countries where the disease is a problem. A soil fungus of this type can be readily transported with balled or container-grown plants of many types, and can also, of course, be spread by moving infested soil or in water draining from infested to non-infested soils.

Nutritional Factors.—A number of experiments have been conducted to study the effect of various nutritional factors on the fungus and on disease development. These include investigation of the effects of varying levels of nitrogen, phosphorus and potassium; the effect of various pH levels; the effect of nitrites; and the effect of varying levels of oxygen. These studies show little effect of nitrogen, phosphorus, and potassium on disease development; the pathogen is able to attack avocado roots over an extremely wide range of concentrations of these elements.

The only pH level at which the disease is strikingly controlled is the extremely acid level of pH 3. Above pH 3, disease development increases to the most rapid progress at pH 6, then decreases slightly at pH 8 (3). Studies of the effect of nitrites on root infection and on the fungus show that the fungus is more sensitive to the presence of small amounts of nitrite than is the avocado plant (40). The disease has been found to occur over a wide range of oxygen levels in solution, with reduction in fungus attack but increase in plant root injury at extremely low levels of oxygen.

Biological Control.—Studies have been conducted of the effect of various organic amendments on the development of Phytophthora root rot. In these tests it was found that alfalfa meal (ground stems and leaves) has the property of retarding the activity of *P. cinnamomi* in some soils (34). Control of the disease under greenhouse conditions has been striking in many cases with additions of from 3 to 5 percent alfalfa meal to the infested soil. In some cases in the field, applications of 100 to 150 pounds of alfalfa meal per tree

have resulted in beneficial effects, but field results have been inconsistent. Alfalfa straw has not been effective in tests to date, nor have several other types of organic matter, including bean straw, manure, sawdust, soybean and cottonseed meals.

It is probable that the effect of alfalfa meal is one of biological control in that beneficial microorganisms are increased in the soil and some of these may be antagonistic to *P. cinnamomi.*

Cultural Factors.—The history of infection with this type of disease has been that it is most severe in soils from which water drains slowly. Recent surveys in California have substantiated this (7). As pointed out above, there is a very close connection between activity of the fungus and free water in the soil. There has been little disease on well-drained soils, with the possible exception of some tropical areas where rainfall is so heavy that what are normally considered as well-drained soils hold sufficient water for a long enough time to permit the fungus to attack roots.

In view of this requirement of the fungus for water in order to produce its spores and to cause infection, any practice that tends to reduce the period that free water may remain in the soil will reduce the severity of disease even though it does not eliminate it. Examples of such practices include selection of a site with good drainage, careful irrigation to prevent watering soil that is already wet (in locations where irrigation is necessary) (46), and establishing drainage to take care of runoff of rainfall.

Resistance of Other Crops.—One means of dealing with an infection caused by the fungus *P. cinnamomi* is to replant the infested soil to resistant plants. The fungus has an extremely wide host range, but there are a number of plants that are not susceptible and can be used to replant such areas. These include all types of citrus, cherimoya, persimmon, all types of vegetables, and most annual flower crops. The macadamia nut also has high resistance to the root rot phase of this disease, although it has been found recently that the trunks of macadamia trees, when wounded, are susceptible to cankers caused by *P. cinnamomi* (39).

Phytophthora Seedling Blight

Under tropical or subtropical conditions another species of *Phytophthora, P. palmivora,* can cause a severe blight of avocado seedlings. The fungus invades the stems of young seedlings, causes cankers which girdle the stems, with subsequent wilting and death of the seedlings. This disease has been described from Florida by Conover (9), and from Honduras by Zentmyer and Muller (44). This type of disease would be expected to occur primarily in regions of high rainfall; it has not been found in California and probably would not be a problem under California conditions.

Cankers

Cankers of roots, trunks, or branches of avocado trees may be caused by several fungi. *Phytophthora cactorum* and *P. cinnamomi* are the two fungi most commonly involved in California in cankers of the lower trunk and rootstock. *P. cinnamomi* and *P. palmivora* have been found in Latin America. Artificial inoculations show that *Phytophthora citrophthora,* the fungus that causes brown rot of lemon fruits and brown rot gummosis of citrus trees, also is capable of invading avocado trunks. This fungus has not been found on avocado in the field, however.

The fungus *Botryosphaeria ribis* (imperfect stage: *Dothiorella gregaria)* also causes cankers of avocado trunks and branches. The cankers caused by this fungus are usually not as serious as those caused by the species of *Phytophthora.* Guatemalan varieties are particularly susceptible to this fungus (16).

Symptoms of the canker diseases in general vary from gradual loss of vigor and chlorosis of leaves to sudden death of the entire tree. Trees affected with Dothiorella cankers may show no symptoms in the top of the tree. Examination of the trunk usually reveals a darkening of the bark and an exudation of powdery white material from the affected bark. When the bark of the cankered area is cut into, it is found to be brown in color. Phytophthora cankers usually have a noticeably sour odor, and often extend into the wood. Dothiorella cankers are usually more superficial, often involving only the outer bark; margins of these cankers are very irregular. In many cases of Dothiorella canker, new bark forms beneath the affected tissue, and the cankered area is sloughed off.

If detected in a sufficiently early stage, Phytophthora cankers can be controlled by cutting out infected tissue and painting the treated area with a fungicidal paint such as bordeaux paste. Similar treatment may be given to Dothiorella cankers, though often if a tree is vigorous it will outgrow these infections. The Guatemalan varieties of avocado appear to be more susceptible to both Phytophthora and Dothiorella cankers. In an attempt to avoid Phytophthora cankers, therefore, it is desirable to bud Guatemalan varieties high and avoid covering the bud union with soil in low-budded trees.

An unusual branch canker of Mexican avocado trees growing in the experimental planting of the Escuela Agricola Panamericana on Mt. Uyuca, Honduras, was observed in 1956 (44). Brownish-black cankers were found ten to twelve feet from the ground, with dieback of branches resulting from these lesions in many cases. A species of *Phytophthora,* probably *P. palmivora,* was isolated from the cankers. Wind-blown rain and high humidity under the essentially rain-forest conditions in that area undoubtedly favor the dispersal of sporangia and consequent aerial infection.

Verticillium Wilt

Verticillium wilt of avocado trees has been recognized as such since 1948 when isolation of the soil fungus *Verticillium albo-atrum* from affected trees and proof of its pathogenicity to avocado trees were reported by Zentmyer (32). Occasional reports during the previous 15 or 20 years in California and Florida had described sudden wilting and collapse of isolated trees in well-drained soils. In California the trouble was termed collapse, asphyxiation, or apoplexy and was thought to be the result of exclusion of oxygen from the soil, brought about by sudden saturation of the soil with water. Occasionally young trees may "collapse" when the soil in which they are growing has been waterlogged for a considerable period, but this is not common, does not occur on well-drained soils, and can be readily distinguished from Verticillium wilt. The disease has been observed in Ecuador and Chile (37).

Avocado trees affected with Verticillium wilt show symptoms similar to those that develop on other woody hosts. The symptoms include a sudden wilting of all the leaves on a part of a tree, or on the entire tree, and the rapid death of the leaves. The leaves turn brown and remain attached to the branches for a long time. Typical brown streaks may be seen in the wood when the bark is peeled from branches or roots of affected trees. Within a few months after the initial collapse of the tree, vigorous new shoots may appear, and within 1 to 2 years the trees may recover completely. Occasionally trees die from the disease and occasionally the disease may recur in a given tree. Most affected trees recover completely and show no further symptoms.

Observations on rootstock plots and inoculation tests have shown that the Guatemalan varieties of avocado are much more susceptible to Verticillium wilt than are the Mexican varieties (42).

Several suggestions as to control of this disease can be made. Use of land that has been planted to a susceptible crop should be avoided, and susceptible crops should not be interplanted after the land has been planted to avocados. Other common plants affected by the fungus include tomato, pepper, eggplant, berries, apricot, potato, and a number of flower crops. Guatemalan varieties should be avoided as rootstocks because of their susceptibility to Verticillium wilt. Avocado trees that are, or have been affected with this disease should not be used as sources of budwood, as it is possible that the disease may be transmitted in budwood, as is the case with Verticillium wilt of rose.

Armillaria Root Rot

The fungus *Armillaria mellea* (oak root fungus) has been found in recent years on avocado trees in California and also in Ecuador (11, 37). The fungus is capable of causing a severe root rot of avocado, similar to its attack on citrus and many other hosts. Affected trees commonly wilt when much of the root system has been invaded, and may then die suddenly. The most characteristic symptom of this

disease is the white mycelial fans of the fungus, which are seen on peeling the bark from roots of the diseased tree. These fans occur on roots of all sizes, from those $\frac{1}{4}$ inch in diameter to the main roots of the tree, and the rootstock. Sometimes the black rhizomorphs ("shoestrings") of the fungus occur on the surface of diseased roots.

Little is known of the action of Armillaria on avocado, other than the fact that some trees are extremely susceptible. Tests to determine susceptibility of various rootstocks are being conducted at Riverside in cooperation with E. F. Darley.

Control measures similar to those used for citrus trees are suggested; these involve removal of diseased trees and the larger roots, and fumigation of the soil with carbon disulfide, 2 ounces per injection hole, at 18 inch intervals.

Rhizoctonia Seed and Root Rot

Mircetich and Zentmyer (22) have recently reported the pathogenicity of the soil fungus *Rhizoctonia solani* to avocado seeds and seedlings. The fungus invades the cotyledons and kills the embryo in some cases, causing a brown rot. If the embryo is not killed and germination occurs, sometimes the young root is rotted and the young shoot begins to grow but may be attacked before it emerges from the cotyledons. Occasionally the young shoots escape infection and grow even though the radicle or young root is completely rotted. Under this situation, secondary roots may be formed which continue to grow and eventually produce a new root system.

If infection occurs after the primary root has grown several inches, the fungus usually attacks the youngest part of the root, causing girdling brown lesions and spreading in some cases until the root is destroyed. Lesions may also occur at various places along roots of seedlings, as at the point of attachment of small roots with larger roots. The rot is soft, not firm and brittle as in the case of root rot caused by *Phytophthora cinnamomi.*

This disease has been found primarily in seed flats in the greenhouse or in seed beds in the field. It occurs occasionally on young seedlings or on roots of older trees in the field. In such cases it is not nearly as severe a pathogen as *Phytophthora cinnamomi. Rhizoctonia solani* attacks only occasional small roots on large trees, and regeneration of roots usually occurs.

Since the principal damage is in seed beds, the fungus can be controlled under greenhouse or nursery conditions by steaming the sand or soil used for the seed flats or for the container-grown stock, for 45 minutes to one hour at 82°C (180°F). Seeds used for planting should be taken from fruit picked from the tree to avoid the possibility of contamination by Rhizoctonia of seed taken from the ground. This is a common fungus in many soils and can invade fruit and seed if fruit contacts the ground. Sanitary measures should also be used in the nursery operation to prevent the seed plants or containers from coming in contact with untreated and possibly contaminated soil.

This disease has not been observed in Latin America, but with the cosmopolitan nature of the causal fungus, it could become a problem under tropical seed bed conditions.

Sun-Blotch

Sun-blotch, the only known virus disease of avocado, was first described in California in 1928. Its virus nature was established by Horne and Parker in 1931 (18). It is of common occurrence in California, but has been observed only a few times in Florida and rarely in Latin America. It has been reported from the Chanchamayo Valley in Peru (37).

Typical symptoms are a yellow streaking of the green stems and branches and a yellow-to-red streak on the fruit. On fruit that remains green at maturity, the streak is yellow. On fruit that turns black or purple at maturity, the streak is usually red. A slight deformation and pronounced mosaic pattern may occur in the leaves, but the stem and fruit symptoms are the most common. Some affected trees tend to have a decumbent, willowy type of growth, and may be stunted. A checking of bark on mature branches and trunks is often associated with the disease, but it has not been definitely established that this is a symptom of the disease. In addition to the loss from decreased production that may be associated with sun-blotch, in many cases the fruit are severely damaged by the sunken streaks and are down-graded into cull grades.

Sun-blotch is readily transmitted through budwood or graftwood. Wallace and Drake (31) have also demonstrated that the disease can be transmitted through the seed; in some cases a high percentage of seed from a given tree will transmit sun-blotch. Some trees are symptomless carriers of the disease, so a tree cannot be considered free of sun-blotch merely because it shows no symptoms. Seedlings from symptomless carrier trees do not show sun-blotch symptoms even though they are carrying the virus, but when they are used as rootstocks, the disease will appear in the scion. There is no evidence of insect transmission

The primary control measure for this disease involves careful selection of disease-free scion and seed sources.

Fruit Rots

Several types of fungi attack avocado fruit prior to harvest and cause significant damage. In California the only important fruit rot is that caused by the fungus *Botryosphaeria ribis* (imperfect stage: *Dothiorella gregaria).* In Florida and in some of the more tropical avocado-growing areas in Latin America, several other types of fruit rots are often of importance. These include scab, caused by the fungus *Sphaceloma perseae;* Cercospora spot or blotch, caused by the fungus *Cercospora purpurea;* and anthracnose, caused by the fungus *Colletotrichum gloeosporioides.**

Dothiorella rot.—This disease is occasionally of importance on the Fuerte variety in plantings near the coast in southern California. In inland areas it is of relatively little importance. The fungus is commonly present on dead wood, dead leaf tips, and debris. It enters the fruit sometime before harvesting. After entering the fruit, the fungus lies dormant, and rot does not develop until the fruit begins to soften, by which time it has reached the consumer. The fact that there is no method of detecting fruit that will develop this rot and culling it out in the packing house creates a difficult marketing problem.

This rot commonly appears first as small, brown, or purplish-brown spots on the green fruit surface. The spots gradually enlarge until much of the surface may be involved. In early stages there is little involvement of the flesh. As the disease progresses, however, the fungus invades the flesh and causes a brown discoloration and an offensive odor. Occasionally the fungus induces a stem-end rot. It may also invade fruit pedicels, causing the fruit to drop. In Florida the fungi *Diplodia* and *Phomopsis* are also involved in stem-end rot of fruit.

The following control measures are effective in reducing or eliminating this fruit rot: Removal of dead wood and dead leaf tissue from trees to reduce sources of fungus inoculum; use of all possible measures to reduce tipburn of leaves; use of low rather than overhead sprinklers; picking fruit before it reaches the peak of maturity, as it is not so severely affected in early season; and spraying trees with bordeaux 6-6-100, Cuprocide (2 pounds to 100 gallons), or zineb (2 pounds to 100 gallons). If rainfall is relatively light, two sprays give good control in California, the first in mid-September and the second in early November.

Cercospora spot or blotch. This is the most important disease of avocado in Florida, and occurs in several areas in Latin America. Lesions on fruit appear as small, scattered, brown, slightly sunken spots that have a definite outline but irregular shape. Grayish spore-bearing structures of the fungus appear on the spots in humid weather. These fruit spots, which are one-eighth to one-fourth inch in diameter, later develop cracks or fissures, which permit the entry of other fungi that cause fruit decay. The *Cercospora* fungus also causes small angular spots on leaves.

Research in Florida has demonstrated that the disease can be controlled by two or three copper sprays, the first between May 1 and May 15, the second not more than a month later, and the third a month after the second. The third is usually necessary only for varieties that mature in winter or early spring. G. D. Ruehle has shown that 6-6-100 bordeaux or 4-4-100 bordeaux (the latter where annual

* **Information on avocado fruit rots in Florida obtained from publications of and correspondence with Dr. George D. Ruehle, Vice-Director in Charge, Sub-tropical Experiment Station of the University of Florida, Homestead, Florida.**

spraying is practiced), or wettable cuprous oxide (1.5 pounds to 100 gallons), or copper A (4 pounds to 100 gallons), or basic copper sulfate (3 pounds to 100 gallons) are equally satisfactory.

Scab.—This is also an important disease in Florida and in several countries in Latin America where avocados are grown commercially. This disease has been described by Jenkins from Brazil, Peru, Cuba, Puerto Rico, Haití, and Mexico (19) and by Zentmyer from Chanchamayo Valley, Peru (37). The causal fungus attacks both foliage and fruit. This fungus causes corky, raised, brownish, oval-shaped spots on the fruit. As the spots become older they may coalesce and give the fruit a russetted appearance. They may develop cracks that permit entry of other fruit-rotting organisms. Scabby, deforming lesions are also formed on leaves, leaf petioles, and twigs. There is considerable variation in susceptibility of the different varieties of avocado to this disease. Lula is listed as very susceptible; Hall, Taylor, Nabal, and Booth 7 and 8 moderately susceptible; and Fuchsia, Pollock, Booth 1, Waldin, Itzamna, Linda, and Collinson quite resistant.

On resistant varieties, and in solid block plantings of moderately susceptible varieties, scab can be controlled by spraying with 6-6-100 bordeaux or 1.5-100 wettable cuprous oxide, using the same schedule as the one for blotch. On the highly susceptible Lula variety, on susceptible seedlings and on moderately susceptible varieties interplanted to Lulas, it is necessary to apply the first copper spray as the bloom buds begin to open, to repeat in the last of the bloom and again 3-4 weeks later in addition to the sprays applied for control of cercospora blotch.

Anthracnose.—This disease causes less damage than scab or blotch in Florida and has been occasionally observed in Latin America. Principal symptoms are sunken black spots on the fruit, the spots being nearly circular in outline and one-fourth to one-half inch in diameter. As the fruit ripens, the fungus invades the flesh to a greater degree until most of the fruit is rotted. The fungus is unable to enter unwounded fruit. It usually becomes established in lesions caused by *Cercospora* or *Sphaceloma.* Where spray applications are made to control cercospora blotch or scab, no additional sprays are necessary to control anthracnose.

Other Minor Diseases

Powdery mildew occasionally has been reported from Florida, and also from Brazil and Honduras. It usually occurs on foliage of nursery trees or on young trees growing in shaded, damp locations. When young trees are affected, tender tips of shoots may be killed back. Dark green discolorations may appear on the leaves, which show the characteristic white, powdery mildew growth on the lower side. Control may be obtained with copper fungicides if the problem becomes acute in non-bearing trees or in nurseries. The spray program for control of cercospora blotch and scab is usually adequate for control of powdery mildew on bearing trees.

The avocado fruit occasionally is subject to several types of post-harvest decay, although this is usually not an important problem. Some decays which appear after harvest are actually the result of fungus invasion some time prior to harvest, as in the case of Dothiorella rot described earlier. Other fungi causing post-harvest rots include *Colletotrichum gloeosporioides, Cephalothecium roseum, Diplodia natalensis, Diaporthe citri,* and *Rhizopus nigricans* (17, 24). Colletotrichum may also invade fruit prior to harvest.

Resumen [1]

Las principales enfermedades del aguacate que se encuentran en los Estados Unidos y en muchas de las principales áreas de cultivo del aguacate en Méjico, América Central, América del Sur y el Caribe son aquí descritas. Se presentan descripciones de los síntomas, de las investigaciones llevadas a cabo en la Universidad de California, Riverside; y se sugieren medidas de control para cada una de las siguientes enfermedades.

Podredumbre (de Phytophtora) de la Raíz (hongo causal: Phytophtora cinnamomi).
Tizón de la Plantita (hongo causal: P. palmivora).
Cáncer de Phytophtora (hongo causal: P. cactorum, P. cinamomi).
Cáncer de Dothiorella (hongo causal: Botryosphaeria ribis. Dothiorella gregaria).
Marchitez de Verticilium (hongo causal: Verticilium albo-atrum).
Podredumbre (de Armillaria) de la Raíz (hongo causal: Armillaria mellea).
Podredumbre (de Rhizotocnia) de la Semilla y la Raíz (hongo causal: Rhizotocnia solani).
Mancha de Sol (agente causal: virus).
Podredumbres de la fruta:
Podredumbre de Dothiorella (hongo causal: Botryosphaeria ribis).
Sarna (hongo causal: Sphaceloma perseae).
Mancha de Cercospora (hongo causal: Cercospora purpúrea).
Antracnosis (hongo causal: Colletotrichum gleosporiodes).

Además de las enfermedades mayores citadas arriba, varios problemas menores son citados junto con el lugar donde fueron descritas. Como resultado de las observaciones y cultivos hechos en varios viajes de los autores a Latinoamérica durante los últimos años en busca de patrones de aguacate resistentes a la Podredumbre de la Raíz, se han obtenido records específicos sobre varias enfermedades del aguacate. Estas incluyen: Podredumbre de Phytophtora en Méjico (cuatro estados) Guatemala, Honduras, Costa Rica, Chile, Perú, Brasil, Trinidad, Cuba y Puerto Rico; Cáncer de Phytophtora en el tronco en Brasil; Cáncer de Phytophtora en las ramas (P. palmívora?) **en Honduras; Tizón (de Phytophtora) de la plantita** (P. palmívora?) **en Honduras; Marchitez de Verticilium en Chile y Ecuador; Podredumbre (de Armillaria) de la raíz en Ecuador; Mancha de Sol en Perú; Tizón polvoriento en Brasil; Sarna en Brasil, Perú y Puerto Rico; Cáncer de Physalospora en Perú; Cáncer de Dothiorella en Chile; Muér-**

(1) Por FERNANDO FERNANDEZ DE CORDOBA

dago (Phoradendron Sp.) en Méjico y Mancha de la Hoja (de Mycosphaerella) (Mycosphaerella perseae) en Méjico.

La enfermedad más seria en California y en la mayoría de las áreas donde se cultivan aguacates es la Podredumbre de la Raíz (Phytophtora). Se describe el progreso de investigaciones sobre: el hongo causal y sus tres etapas de espora, la relación de la temperatura a su formación y al crecimiento del hongo, y quimotaxis de los zoosporos hacia exudados de las raíces; huéspedes del hongo y varias fases de control incluyendo patrones resistentes, fungicidas y fumigantes para el suelo, quimoterapia, exclusión del hongo (patrones y material de vivero certificado), factores nutricionales, control biológico, y factores culturales incluyendo irrigación.

En la búsqueda de un patrón resistente, se han hecho colecciones en: Méjico, Guatemala, El Salvador, Honduras, Costa Rica, Colombia; Ecuador; Perú; Chile; Argentina; Brasil, Venezuela, Trinidad, Puerto Rico, Santa Cruz; Haití; Jamaica y Cuba. Esto incluye semillas y yemas de cerca de 300 diferentes tipos de aguacate y de otras siete especies de Persea. Un método rápido y severo de prueba con solución nutritiva se usa para determinar resistencia con temperatura mantenida a 24 grados C. y pH a 6.5. Dentro de 10 días después de la inoculación 95-100 por ciento de los sistemas radiculares de las plantas susceptibles son afectadas por el hongo, y los tipos resistentes se pueden determinar.

Usando este método de prueba se ha encontrado alta resistencia a la Podredumbre de Phytophtora en: Persea caereulea, P. chrysophyla, P. Donnell-Smithii, and P. Skutchii, ninguna de las cuales se ha mostrado injerto-compatible con el aguacate. Resistencia leve a moderada se ha encontrado en varios tipos de plantillas de aguacate incluyendo la variedad Duke.

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