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Diseases of the Avocado

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The fruit of various species of *Persea*, a genus native to Mexico, Guatemala, and other Central American and South American countries, has been used for food by the inhabitants of those countries for centuries. Selections from those wild trees, of varied fruiting habits, have resulted in the development of the cultivated avocado trees of California, Florida, and Texas.

Avocado trees were introduced into California in the latter half of the nineteenth century, but the principal development of the industry in California and Florida has taken place since 1930. The industry is of even more recent origin in Texas.

A number of diseases of varying severity affect the roots, trunk, branches, leaves, and fruit of the avocado tree. The diseases are caused primarily by fungi, although one virus disease is known. Several troubles are the result of deficiencies or excesses of certain elements used by the trees.

PHYTOPHTHORA ROOT ROT is the most serious problem in avocado culture in California, where it used to be known as "decline." Root rot of avocado also occurs in Costa Rica, Florida, Peru, South Africa, Honduras, Puerto Rico, Mexico, and Texas. The disease has been of little consequence in Florida, although it seems to be on the increase. Root rot was first noted in 1950 in Texas.

Two factors are involved—the soil fungus *Phytophthora cinnamomi* and wet soil conditions brought about by poor drainage.

The causal fungus was first identified by R. D. Rands in 1922 on cinnamon trees in Sumatra and was first reported on avocado by C. M. Tucker in Puerto Rico in 1928. *P. cinnamomi* since has been found on an increasingly large number of plants, including pine, pineapple, heather, camellia, rhododendron, cinchona, chestnut, peach, yew, a number of deciduous and coniferous nursery trees, and Lawson cypress. V. A. Wager reported the isolation of *P. cinnamomi* from avocado roots in California in 1942.

Root rot increased greatly in California between 1940 and 1953. By 1953 it was estimated that 2,500 acres had been affected, or approximately 175,000 trees, including trees that either had died or were in various stages of disease.

Root rot occurs in California on two main soil types—heavy soils and soils having a permeable surface horizon of relatively shallow depth underlain by an impervious layer of clay or rock. In either case drainage is impeded and moisture conditions favorable for development of *Phytophthora cinnamomi* may occur. In other areas where root rot is found, and on other crops, it is also a disease of heavy or poorly drained soils. On well-

drained soils the fungus rarely causes damage.

A gradual deterioration sets in of the above-ground parts of the tree affected with root rot. The general appearance indicates root destruction. Early symptoms include a lighter green color than is normal for leaves, a tendency for leaves to wilt in the presence of an amply moist soil, and a lack of new growth. As the disease progresses, branches die back, many leaves are shed, newly formed leaves are generally small and yellowish green, and fruit does not reach normal size. Frequently an abnormally heavy set of fruit happens soon after symptoms of the disease first appear—evidently a reflection of the fact that much of the root system is rotted and food material has accumulated in the top.

The gradual decline in vigor and productivity of the tree usually goes on for several years, although occasionally the deterioration is more rapid. Many of the small feeder roots on affected trees are blackened, brittle, and dead; healthy roots are difficult to find.

The causal fungus is one of the "water molds." It thus needs wet soil conditions for its best development and for production of its two spore stages, swimming spores (zoospores) and resistant spores (oospores). The fungus thrives at moderate temperatures, making no growth below 50° F. nor above 90° F.

No adequate control measures have yet been found for the disease. At the University of California Citrus Experiment Station, investigations have been started on several aspects of control, including soil fumigation, soil fungicides, soil amendments, resistant rootstocks, crop rotations, and irrigation.

In years when rainfall is not excessive, careful irrigation can do much to retard the progress of the disease and prolong the life of affected trees. It has been observed that water use is markedly reduced in trees affected with root rot, evidently because of the destruction of the small feeder roots. Hence, if all trees in a grove, healthy and diseased alike, are given the same amount of water in one irrigation, water will accumulate in the soil around the diseased trees and accentuate the disease situation. To correct this, the soil-moisture conditions around each diseased tree must be determined at the time of irrigation, and individual trees should be irrigated on the basis of water use. This can be done effectively only where groves are irrigated with low sprinklers. Any condition contributing to the development of excessively wet soil conditions is favorable to progress of the root rot disease; hence particular care should be taken to, avoid the occurrence of excess water in the grove.

Soil fumigation has various possible applications to the problem. Research in California has shown that several fumigants, such as chloropicrin at 30 to 40 gallons to the acre and D-D mixture at 100 to 150 gallons an acre, will kill *Phytophthora cinnamomi* in soil. Field fumigation, however, has usually resulted in good growth of replants for a period of only 2 to 4 years, followed by recurrence of the disease. These plots were in areas of widespread infection; recurrence of the disease probably resulted from reinvasion of the treated locations by the fungus. The response of the resistant oospores to fumigants is not known, and there is a possibility that some of the reinfection came from germination of those spores. Fumigation may be useful under certain conditions, as in treating nursery soil or in eliminating the fungus from small isolated spots of infection in the grove.

In tests with soil fungicides, the organic fungicide nabam (disodium ethylene bisdithiocarbamate) has been found to be effective in killing *Phytophthora cinnamomi* in the soil. Research on this treatment is in its preliminary phases, but materials of this type have possibilities for application to various hosts of the fungus, as they are less injurious to higher plants than the common soil fumigants. Soil applications of alfalfa meal (ground stems and leaves) have also been shown in many cases to have some beneficial effect on diseased trees in California; this is attributed to the great increase in saprophytic fungi and bacteria in the soil resulting from these applications, and the possible antibiotic action of some of these micro-organisms against *P. cinnamomi*.

Phytophthora cinnamomi is very sensitive to drying of the soil. Air-drying a light loam to 1 percent moisture has resulted in kill of the fungus and excellent growth of replants in greenhouse experiments. In irrigated groves the spread of the fungus through the soil may be retarded by maintaining a dry, nonirrigated zone at the edge of an area where the disease is present. It may also be possible to make use of this principle in eliminating the fungus from nursery soil where trees are grown in large tar-paper pots.

The method of control that has the most possibility of success in the long run is the development of a rootstock that is resistant to root rot. Tests of 22 varieties of avocado seedlings, including Guatemalan, West Indian, and Mexican types, in California have shown all are similar in susceptibility. Other species of *Persea* from Mexico and Central America are being tested.

Inoculations with *Phytophthora cinnamomi* and limited field observations indicate that persimmon, cherimoya, macadamia nut, and citrus trees are either resistant or immune to root rot. These crops are possibilities for use in replanting areas where avocado trees have been removed because of root rot, at least in California. Other types of subtropical plants may be more adaptable in other regions. The principle of crop rotation is an old and valuable one in control of root rots of annual crops, and may have similar value in controlling avocado root rot.

It should be emphasized that little or no avocado root rot occurs on well-drained soils. A preventive measure, with respect to future plantings, is to plant only clean nursery stock on well-drained soils. Obviously, this is not a remedy for the problem in the case of the thousands of trees already planted on poorly drained soil. Nor does it take into account the fact that in some areas, because of the frost hazard, the best land for avocado plantings is hillside land, where the soil is often heavy or shallow.

Development of a rootstock that is resistant to the disease, that is compatible with present scion material, and that possesses no obvious disadvantages with respect to production or other diseases may ultimately solve the problem. Meanwhile, present measures to permit living with the disease include careful irrigation practices, drying the soil, replanting with resistant crops, and possibly use of temporarily alleviating measures, such as application of alfalfa meal or soil fungicides.

VERTICILLIUM WILT of avocado trees has been known as such since 1948, when I isolated the soil fungus *Verticillium albo-atrum* from affected trees and demonstrated the pathogenicity of the fungus to the avocado. 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. It is possible that lack of oxygen could cause such symptoms, but since 1948 *V. albo-atrum* has been invariably isolated from trees with these symptoms in California.

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 of the affected trees observed in California have recovered completely and have shown no further symptoms. Similar observations have been reported in Florida.

Several suggestions as to control 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 plants affected by the fungus include tomato, pepper, eggplant, berries, apricot, potato, and a number of flower crops.

Severe pruning of diseased trees immediately after first symptoms of the disease appear may speed recovery. Avocado trees that are or have been affected with verticillium wilt should not be used as sources of budwood. It is possible that the disease may be transmitted in bud-wood, as with verticillium wilt of rose.

SUN BLOTCH, the only known virus disease of avocado, was first described in California in 1928. Its virus nature was established by W. T. Horne in 1931. It is of common occurrence in California, but has been observed only a few times in Florida.

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 vein chlorosis may occur in the leaves, but the stem and fruit symptoms are the most common. Affected trees tend to have a recumbent, willowy type of growth, and some 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.

Sun blotch is readily transmitted through budwood or graft wood. It is possible that the disease may also be transmitted through the seed, although this has not been proved under controlled, insectproof conditions. The disease has been observed occasionally on young seedling avocado trees growing under conditions in which it is unlikely that insect transmission could be involved.

Control measures include careful selection of disease-free scion and seed sources and the removal of all seedlings showing sun blotch symptoms, as well as of all off-type seedlings, from nursery plantings.

CANKERS of roots, trunks, or branches of avocado trees may be caused by several organisms. *Phytophthora cactorum* and *P. cinnamomi* are the two fungi most commonly

involved in California in cankers of the lower trunk and root-stock. Artificial inoculations show that *P. citrophthora*, the fungus that causes brown rot of lemon fruits and brown rot gummosis of citrus trees, is capable of invading avocado trunks. A canker of minor importance on branches and trunks is caused by the fungus *Botryosphaeria ribis*.

Symptoms in the top of the tree vary from gradual loss of vigor and chlorosis of leaves to sudden death of the entire top. 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 in the cankered area is cut into, it is found to be brown in color and to have a noticeably sour odor. 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. A similar trouble known as collar rot has been reported from Florida.

If detected in a sufficiently early stage, cankers can be controlled by cutting out infected tissue and painting the treated area with a fungicidal paint such as bordeaux paste. In California the Guatemalan varieties of avocado appear to be more susceptible than other varieties to these cankers. It is therefore desirable to bud these varieties high and to avoid covering the bud union with soil in low-budded trees.

DOTHIORELLA ROT, the most important rot of avocado fruit in California, is caused by the fungus *Botryosphaeria ribis* (imperfect stage: *Dothiorella gregaria*). The disease is a serious problem on the Fuerte variety in plantings near the coast. 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, it 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 tip-burn of leaves; use of low rather than overhead sprinklers; picking of fruit before it reaches the peak of maturity, as it is not so severely affected in early season; and spraying trees.

Research in the 1930's indicated that 8-8-100 bordeaux mixture plus 6 pounds of wettable sulfur gave good control. It has been shown since then that Crag Fungicide 658 (1.5 pounds to 100 gallons), bordeaux 6-6-100, Cuprocide (2 pounds to 100 gallons), and zineb (2 pounds to 100 gallons) are effective in controlling the fruit rot. If rainfall is relatively light, as during the period from 1948 to 1951 in California, two sprays give good control, the first in mid-September and the second in early November.

CERCOSPORA SPOT OR BLOTCH, caused by *Cercospora purpurea*, is the most important disease of avocado in Florida. 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 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, the next most important disease of avocado in Florida, is caused by the fungus *Sphaceloma perseae*, which 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 russeted 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. The disease 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; very susceptible varieties need additional early applications.

There is considerable variation in susceptibility of the different varieties of avocado to this disease. Lula is listed as very susceptible; Hall, Taylor, and Booth 7 and 8 moderately susceptible; and Fuchsia, Pollock, Booth 1, Waldin, Itzamna, Linda, and Collinson quite resistant.

A THIRD COMMON DISEASE of avocado fruit in Florida, but one causing less damage than the blotch or scab, is anthracnose, or black spot, caused by *Colletotrichum gloeosporioides*. This disease is characterized by 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.

POWDERY MILDEW (*Oidium* species; perfect stage unknown) occasionally is found in Florida on foliage in nurseries 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 lime-sulfur or sulfur dusts if the problem becomes acute.

NONPARASITIC DISEASES brought about either by deficiencies or excesses of certain elements occasionally are found on the avocado.

One of the most common is zinc deficiency, which results in a little-leaf condition, mottling of the leaves, and often a deforming of the fruit. If the deficiency is prolonged, the branches may die back. Best results for control in both California and Florida have been obtained with sprays. Either zinc sulfate and hydrated lime (5 pounds of $ZnSO_4$ and 2-5 pounds of lime to 100 gallons of water) or zinc oxide (2 pounds to 100 gallons) may be used. For severe cases in Florida, twice the indicated dosage of zinc sulfate and lime is recommended. Sprays should be applied soon after new growth appears.

Iron deficiency occasionally occurs in California, primarily in trees on calcareous soils. It is characterized by yellowing of the major portion of the leaf, with the veins remaining green. Little change is caused in fruit size or shape or in leaf size. Soil applications of sulfur and similar acidifying materials have generally been only moderately successful. Reduction in water applications to trees in the problem soils has usually resulted in a lessening of the chlorosis.

Copper deficiency has been reported in Florida on young avocado trees. Symptoms include development of S-shaped shoots and lateral branches, premature defoliation, a multiple-bud condition, and dieback. This trouble is usually corrected by soil or spray applications of copper sulfate.

The presence of excess chlorides in soil or irrigation water is the primary cause of tipburn of leaves in California. Tipburn causes a considerable reduction of green-leaf area, with consequent weakening of the tree. The dead areas are also commonly invaded by fungi such as *Botryosphaeria ribis*, which then spread to the fruit. Control of tipburn is difficult unless water with a lower chloride content is available to use in leaching the soil.

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