

Phytophthora Cinnamomi Root Rot of Avocados under Tropical Conditions¹

BOWEN S. CRANDALL²

Reprinted from Phytopathology, Feb. 1948.

¹A contribution from the Estación Central de Colonización en Tingo Maria, Peru, a technical agricultural service organization for the Orient of Peru, operated jointly by the Dirección de Colonización y Asuntos Orientales, Ministry of Agriculture of Peru and by the Office of Foreign Agricultural relations, U. S. Department of Agriculture. This study was made possible by funds provided through the Interdepartmental Committee on Scientific and Cultural Cooperation and funds from the Peruvian Government.

²Pathologist, Office of Foreign Agricultural Relations, United States Department of Agriculture, and Chief, Department of Plant Pathology and Entomology, Estación Central de Colonización en Tingo Maria.

EDITOR'S NOTE: Tingo Maria, Peru is in the State of Huanico on the eastern slope of the Andes, at an elevation of 2200 feet, with tropical conditions and an average annual rainfall of well over 100 inches.

Introduction

In 1944, soon after the start of organized pathological work at the Estación Experimental Agrícola de Tingo Maria and about 8 years after the opening of the region to colonization, dying and declining avocado trees, *Persea americana* Mill., were observed. The first cases were large, mature trees located on the properties of small landowners. These trees showed clear cases of collar rot followed by quick death and from them *Phytophthora cinnamomi* Rands was isolated. Later the same year the disease was found in seedling and mature avocados being grown by the Station and *P. cinnamomi* was again isolated. Apparently the first recognition of the disease in this area, at least in this part of South America, was reported in 1945 (3). The disease is apparently the limiting factor to avocado growing in this region. Because of the controversial nature of the evidence presented by various workers on the relationship between *P. cinnamomi*, wet soil, and the decline or collapse disease, it was necessary to undertake sufficient work to solve the problem locally, in order that recommendations could be made in regard to the avocado program. The results herein reported are based on observations and experiments on trees growing under conditions of high rainfall and often on poorly drained soils. The work was designed to determine whether *P. cinnamomi* is the primary cause of the decline or collapse disease, and if so, whether a resistant rootstock can be found or methods of planting or site selection be used to eliminate the disease or hold it to a minimum.

History of the Disease

Avocado root rot caused by **Phytophthora cinnamomi** was first reported from Puerto Rico in 1920 by Tucker (10, 11). These first reports showed that conditions of waterlogging and **P. cinnamomi** had to be present to cause the disease. Wager (12) in 1940 reported the disease in California and expanded the experimental work demonstrating the connection between conditions on poor soil drainage and ability of the parasite to cause disease. Specific experimental evidence was presented showing that avocados growing in pots could be artificially infected with **P. cinnamomi** and disease symptoms produced if the pots were submerged for a period as short as 2 or 3 days, while no infection or disease symptoms would appear in trees given normal watering. In 1941 Wager (13) reported the disease from Western Transvaal and Natal in South Africa. Field observations stressed the appearance of the disease on trees growing in heavy clay soils or on poorly drained sites. Stevens and Piper (9) reported what was later determined to be the same disease from Florida in 1941. Wager (14) in 1942 amplified his earlier work demonstrating the relation between wet soil and the disease.

An open discussion on decline of avocado trees on wet soil was reported in the 1937 California Avocado Association Yearbook (1). It seems evident that the problem under discussion was the root disease caused by **Phytophthora cinnamomi**, then unknown in California. The suggestion that waterlogging was causing the decline was questioned when it was brought out that the avocado came originally from regions of high rainfall. Various reasons were advanced to support the argument that waterlogging caused the disease, among them that in the tropics the trees grow on well drained soils or that they are adapted to the local condition. A heavy loss observed in Mexico after an unusually wet season was mentioned and the suggestion made that sudden change could be disastrous. Decline was again discussed, by Rounds (8) in the 1939 Yearbook of the Association, and also, in the 1941 Yearbook (2) when Wager's work (12) was mentioned. In 1943 Klotz and Sokoloff (6) tentatively expressed the view that **P. cinnamomi** and other pathogenic fungi might attack the roots after they were predisposed by injury following waterlogging. Parker and Rounds (7) in 1943 showed the relation of soil moisture and drainage to decline of mature avocado trees and while citing work such as Wager's (14) in relation to soil moisture and decline did not mention the connection of **P. cinnamomi** with this decline. In 1944 Harvey (5) reported the results of a survey made in California by the Emergency Plant Disease Prevention Project to determine the incidence of **P. cinnamomi** in relation to avocado decline. He isolated **P. cinnamomi** from the roots of 164 out of 268 healthy appearing trees growing in close proximity to declining trees. Zentmyer, Klotz, and Miller in 1945 (17) presented experimental evidence that tends to show that avocados decline in flooded pots regardless of the presence or absence of **P. cinnamomi**. Zentmyer and Klotz in 1947 (15) stated that **P. cinnamomi** may be a primary factor in decline of avocado trees but later the same year (16) stated that poor drainage generally initiates the trouble. They further report that waterlogging and **P. cinnamomi** appear to be involved in decline and that trees in waterlogged soils will decline without the fungus being present but that the presence of **P. cinnamomi** will accelerate the decline.

The relationship between soil moisture, drainage and **P. cinnamomi** is recognized on

other hosts. Crandall, Gravatt, and Milburn (4) showed the relationship of the recession of the American chestnut and chinkapin with conditions of soil drainage and also report a number of nursery diseases of various hosts clearly linked with predisposing conditions of flooded soils. The relationship between high moisture conditions and parasitism by the genus **Phytophthora** in general is well known.

Geographical Distribution

Phytophthora cinnamomi is not listed in La Flora Fungosa Peruana by Garcia Rada and Stevenson published in 1942, on avocado or other hosts. The writer has heard verbal accounts of epidemic losses of avocados from root rot in other regions of Peru which occurred some years ago and that could have been caused by **P. cinnamomi**. However, so far as has been determined, the disease is present only in the Tingo Maria region. There seems no reason to suppose, however, that it may not be of widespread occurrence on avocados wherever they are grown under environmental conditions favorable to the fungus.

Symptoms of the Disease

In this region two distinct methods of attack have been observed on both seedling and mature trees. The first is characterized by appearance of chlorosis followed shortly by sudden wilting and death. The second is a slow decline of the trees characterized by die-back of the branches and often typical drouth symptoms in the leaves. In small trees with slow decline symptoms, death usually follows during the same season but mature trees seem to partially recover during the dry season. Some trees under observation for three years are still in little worse condition than when first observed.

Light brown girdling cankers in the cambium and phloem tissue at the collar region and immediately below are found on trees showing chlorosis and sudden wilting. The advancing margin of the infection extending into healthy tissue is irregular and wedge shaped. The surface of this infected area is black or darker brown than the surrounding healthy bark. Isolated islands of infection and dead or infected small rootlets may be present or absent. In contrast, trees showing slow decline, either completely lack the infection at the collar or it is present on one side or portion of the collar only. The small rootlets are dead or infected, and islands of infection may be present or absent on the lateral and main roots.

Isolation and Inoculation

During the wet season **Phytophthora cinnamomi** appeared in all of the tissue cultures from the active cankers in the collar region, in 97 per cent from the smaller rootlets, in 18 per cent from the larger roots, and in 9 per cent from the islands of infection on the larger roots when special techniques for **Phytophthora** isolation were used.³ Isolation attempts during the dry season and isolation by routine methods have been uniformly unsuccessful.

Six one-year-old criollo avocados growing in boxes were used for a preliminary proof of

pathogenicity following the first isolation of **Phytophthora cinnamomi** from a dying tree. Three were inoculated by placing a mycelial mat of the **Phytophthora** in the soil against the collar and three were left uninoculated as checks. The trees were not watered artificially but were left outside during the rainy season. The three inoculated trees died before the end of the wet season while the three check trees were still healthy at the end of the following dry season. **Phytophthora** was recovered from the dying inoculated trees.

A project was set up primarily to test the resistance, by inoculation, of the different races of avocado. In October, 1945, the Station received, through the U.S. Bureau of Plant Industry, Office of Foreign Plant Introduction, 100 seeds of the Gottfried variety (Mexican race), 39 seeds of the Family variety (an old Florida selection and probably from a cross of the West Indian and Mexican races), and 32 seeds of West Indian seedling selections. Eighty-two of the Gottfried variety, 11 of the Family, and 10 of the West Indian seeds germinated and produced healthy plants. These were used with 130 criollo avocados, 19 of which were reserved as uninoculated checks in a separate bed. The plants were in well drained beds of friable clay-loam and the varieties were separated by drainage canals. The plants were inoculated in late January and early February by placing mycelial mats of **Phytophthora cinnamomi** against the collar of each tree. Two months later 80 per cent of all inoculated plants were dead or dying, and before the end of the dry season in September a 100 per cent loss had occurred.

Phytophthora cinnamomi was isolated from the dying plants. The uninoculated check plants showed no symptoms of disease throughout the wet season and the following dry season. By January, 1947, they uniformly showed symptoms of root rot and quickly declined. **P. cinnamomi** was isolated from these plants.

Epidemiology

Tingo Maria is at an elevation of approximately 2200 feet on the Huallaga River, a tributary of the Amazon in the Peruvian montaña. The year is divided into rather distinct wet and dry seasons. Records since 1940 show an average rainfall for the 6 dry months of April through September of 43.25 inches, and of 91.66 inches for the 6 wet months of October through March. The driest month was July, 1943, with 1.2 inches, and the wettest month was December, 1945, with 25.8 inches. The wet season of 1940-41 had the most rainfall, a total of 106.7 inches for the 6-month period. The 1944-45 wet season had 78.6 inches and the 1945-46 wet season 99.1 inches. Soil pH of avocado sites ranges from 4.5 to 7.0.

Losses from root disease have been more noticeable either at the beginning or toward the end of the wet season, probably because symptoms are more in evidence at these times. The disease apparently appears at any time during the wet season and with the exception of trees parasitized during the wet season but dying after the onset of dry weather, is apparently inactive during the drier months.

Avocados are not grown in the region in large plantings. The majority of the small land owners have a few trees each to produce fruit for home use and limited local sale. The bulk of these trees are criollo seedlings. No losses of epidemic proportions in any given

area have occurred. From time to time a loss of one or two isolated trees is observed. In almost every case observed of trees developing chlorosis and sudden wilting, healthy trees remain on closely adjacent sites. Individuals and small groups have died on poorly drained sites but healthy individuals remain on adjacent equally poorly drained sites. Likewise similar losses on well drained sites have been adjacent to apparently healthy trees. Examination of the root systems of these apparently healthy trees has disclosed that the roots and rootlets were generally in good condition, although some rootlets were dead and some isolated cankers were present. The direct cause of the wilting and death were girdling cankers at the collar. **Phytophthora cinnamomi** was isolated from the girdling cankers.

Only one instance of what might be called slow decline or die-back has been observed. This is in a grove of mature and semi-mature trees located on the grounds of the Experiment Station. This group presents in greater or less degree, the die-back and decline symptoms. Only a few have died and the condition of the remainder appears little worse now than 3 years ago. At least partial recovery seems to take place during each dry season. Partial excavation of the root systems has shown a surprising lack of living small rootlets. **Phytophthora cinnamomi** has been isolated from the dying rootlets on these trees. The trees are growing on a site which is well drained but with heavy clay soil.

During the current wet season symptoms of drought in the leaves and die-back appeared in beds of seedling avocados being grown for use as budding stocks in the same general area but on a loamy soil. Higher and better drained parts of the beds were at first unaffected. Examination of the seedlings with drought symptoms and die-back showed that almost all the small rootlets were dead or dying. No collar infections were found. **Phytophthora cinnamomi** was isolated from a high percentage of the dying small rootlets.

Conclusions

Studies of the disease made in this region, under environmental conditions which are probably normal for the avocado, perhaps give a clearer picture of the disease as a whole than studies made in regions where the tree has been introduced and is growing under abnormal conditions. Any controversial issues of the role of pathogen versus wet feet do not seem to be important where the tree is growing normally under rather wet conditions. The reported experiments which tend to show that **Phytophthora cinnamomi** is a pathogen only when the tree is subjected to conditions of poor drainage, actually probably only reproduce conditions which often occur in regions where the tree is in its normal environment.

Viewed in relation to the appearance of this disease in the Tingo Maria region the various views previously summarized do not present a controversial issue. Each presents a portion of the picture and the sum total seems merely to show that under certain conditions the disease is not a factor unless soil conditions approach those often normally present in the tropics during the wet season. Undoubtedly trees grown under dry conditions with root systems developed for these conditions would suffer if the environmental conditions change toward the wet side. Likewise such trees would then

be growing under conditions ideal for attack by **Phytophthora cinnamomi**.

Seen under local, normal conditions this disease does not appear different, except possibly in degree, from other root diseases caused by **Phytophthoras**. Like many such **Phytophthora**-induced diseases, conditions of high soil moisture are usually required before the fungus parasitizes its host. Whether these conditions constitute predisposing conditions by adversely affecting the host or whether they only create the conditions necessary for growth of the fungus is beside the point. Probably, dependent upon the amount of shift of the environmental conditions away from the optimum for the host and toward that of the parasite, both occur. The writer personally feels that in this and other tropical and subtropical **Phytophthora**-induced root diseases the effect of the change toward wetter environment is more important to the fungus parasite than the host. Improvement of planting techniques and site selection with the objective of better soil drainage have given beneficial results in the case of this disease as well as others, when a susceptible host must be grown in the presence of a **Phytophthora** parasite.

In the face of this disease, widespread planting of avocados is not being encouraged in this zone. For such trees as are planted only the better drained sites on sandy or loose, friable soils are recommended. The uniform susceptibility of the avocado races thus far tested indicates that development or selection of a resistant rootstock is not a likely possibility unless some resistant parent type exists. Search is still being made for such a type.

Summary

Phytophthora cinnamomi, root rot of avocados, has been found in the Tingo Maria region on well and poorly drained soils, on light and heavy soils, and on mature and nursery age trees. In all cases examined, healthy trees were growing on the same sites and under similar conditions but without disease. Two manifestations of the same disease have been studied. Mature and nursery age trees which develop chlorosis and sudden wilting (what apparently is called quick decline in California) are infected at the collar region with girdling cankers. Slow decline and die-back on both mature and nursery age trees apparently are caused by infection and death of the smaller rootlets, with the main roots and collar generally free from infection. **Phytophthora cinnamomi** has been isolated from both types of infections. The pathogenicity of the strains isolated has been demonstrated by artificial inoculation on trees growing under normal wet season conditions, with symptoms of chlorosis and sudden wilting. The fungus has been recovered from inoculated trees following the appearance of the symptoms. Uninoculated check trees, growing under identical environmental conditions, have remained healthy.

³These methods principally consisted of placing carefully selected sections in sterile water blanks for periods varying from 3 to 5 days with frequent changes of water and then lightly surface sterilizing before planting on cornmeal agar.

LITERATURE CITED

1. Anon. Joint meeting and open forum of the California Avocado Association and Avocado Departments of County Farm Bureaus, Whittier, May 7, 1937. California Avocado Association Yearbook 1937: 156-167. 1937.
2. Anon. Discussion of tree decline at the Annual Avocado Institute and Field Day. California Avocado Society Yearbook 1941: 133. 1941.
3. Crandall, Bowen S. Three Phytophthora diseases observed in the region of Tingo Maria, Peru. U.S. Dept. Agr., Plant Dis. Repr. 29:536. 1945.
4. Crandall, Bowen S., G. F. Gravatt, and Margaret Milburn Ryan. Root diseases of Castanea species and some coniferous and broadleaf nursery stocks, caused by Phytophthora cinnamomi. Phytopath. 35: 162-180. 1945.
5. Harvey, James V. Fungi associated with decline of avocado and citrus in California (II). U.S. Dept. Agr., Plant Dis. Repr. 28: 1028-1031. 1944.
6. Klotz, L. J. and V. P. Sokoloff. The possible relation of injury and death of small roots to decline and collapse of citrus and avocado. California Citrograph 28(4): 86-87. 1943.
7. Parker, E. R. and M. B. Rounds. Avocado tree decline in relation to soil moisture and drainage in certain California soils. Amer. Soc. Hort. Science Proc. 44: 71-79. 1944.
8. Rounds, M. B. Avocado tree decline. California Avocado Association Yearbook 1939: 53. 1939.
9. Stevens, H. E. and R. B. Piper. Avocado diseases in Florida. U. S. Dept. Agr. Circ. 582. 1941.
10. Tucker, C. M. Report of the Plant Pathologist Porto Rico (Mayaguez) Agricultural Experiment Station Report 1928: 29-35. 1929.
11. -----, Report of the Plant Pathologist. Porto Rico (Mayaguez) Agricultural Experiment Station Report 1927: 25-27. 1929.
12. Wager, Vincent A. The dying back of avocado trees in Southern California. California Avocado Association Yearbook 1940: 40-43. 1940.
13. -----, The dying back or decline disease of avocado trees. Farming in South Africa 16 (182): 185-186. 1941.
14. -----, Phytophthora cinnamomi and wet soil in relation to the dying back of avocado trees. Hilgardia 14: 519-532. 1942.
15. Zentmyer, G. A. and L. J. Klotz. Phytophthora cinnamomi in relation to avocado decline. (Abstr.) Phytopath. 37: 25. 1947.
16. ----- and -----, The role of microorganisms in avocado tree decline. (Abstr.) Phytopath. 37: 366. 1947.
17. -----, and P. A. Miller. The pathological aspects of avocado decline. California Citrograph 31(1): 20-27. 1945.