

## ORIGIN OF PHYTOPHTHORA CINNAMOMI

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In recent years there has been considerable speculation on the possible origin of the avocado root rot fungus, *Phytophthora cinnamomi*, with theories proposed by research workers in different parts of the world involved in studies of this fungus.

In a review of research on *Phytophthora cinnamomi* in New Zealand and Australia, where the fungus attacks a wide variety of native trees and shrubs, Newhook and Podger (5) discussed the possible origin of the pathogen at length. They concluded that *P. cinnamomi* had been introduced into the Australia-New Zealand region relatively recently, possibly in the late 18th century. Other information presented more recently in Australia indicates that the fungus may be a native fungus in eastern Australia (7). Shepherd (8) proposed that *P. cinnamomi* entered Australia over a million years ago from a center of origin in the New Guinea-Celebes region.

Crandall and Gravatt (3), working in the eastern United States, proposed that *P. cinnamomi* was introduced into various southern ports in the United States in the 18th century and speculated that the fungus had its origin in Asia. In the eastern U.S., *P. cinnamomi* has caused severe root rot problems on chestnut and short-leaf pine in particular, as well as occurring on a wide variety of forest nursery stock and ornamental plants including camellia and rhododendron.

This paper presents information relative to the question of the indigenous nature of *P. cinnamomi* in California and in the Americas, based on some of my research over the past 25 years. Information of this type is significant in regard to disease prevention and control. If *P. cinnamomi* is not native to the soil in southern California where avocados are grown, exclusion of the fungus from new plantings by all possible means (clean nursery stock, prevention of soil and water movement from infested areas, etc.) is even more important.

### Tests in Southern California

Soil samples have been taken from many areas of native chaparral in southern California, particularly in small arroyos or drainage areas that retained some moisture during the dry season. With a few exceptions samples were taken above cultivated areas so that there would be no possibility that *P. cinnamomi* may have spread into the drainage areas from avocado groves or other possible sources.

Roots from the soil samples were cultured on several media in the laboratory, with the early samples cultured on cornmeal agar and some more recent ones on cornmeal agar containing antibiotics to reduce competition of other fungi and bacteria, and permit *P.*

*cinnamomi* to grow if present. In addition many of the soil samples were placed in clay pots or other containers in the greenhouse and planted with Topa Topa avocado seedlings, susceptible to *P. cinnamomi*. The seedlings were grown in the soil for several months and the soil was kept wet to favor development of the root rot fungus.

From over 300 soil and root samples cultured in southern California from undisturbed areas above any areas of cultivation, no *Phytophthora cinnamomi* was recovered. Root rot did not develop in any of the avocado seedlings planted in these soil samples in the greenhouse. A few rotted or necrotic roots from these plants were cultured in the laboratory but no *P. cinnamomi* was recovered. The root rot fungus recovered in culture from only one sample; this was from a small arroyo containing native vegetation that was below an area where avocado trees were affected with Phytophthora root rot. The fungus undoubtedly was carried into the arroyo by drainage water from the avocado grove.

### Tests in Latin America

In the course of trips to Mexico, Central and South America and the Caribbean over the past 25 years, in the search for rootstocks resistant to *Phytophthora cinnamomi* (9), I have collected root samples from many native avocado trees and related species of *Persea*, growing in swamps, rain forests, and other types of native habitat. There are over 80 species of the genus *Persea* native in the area from southern United States to southern South America (4). Samples were also taken in areas where the avocado has been brought into cultivation in many of the Latin American countries.

Root samples were collected in Argentina, Brazil, Chile, Colombia, Costa Rica, Cuba, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Mexico, Puerto Rico, St. Croix (Virgin Islands), Trinidad, and Venezuela. As with the sample from California, roots were cultured on cornmeal agar or on cornmeal agar containing antibiotics.

Samples were collected from 373 trees from 18 countries in Latin America in this attempt to determine if *P. cinnamomi* might be a native fungus in the Latin American area. Results are summarized in Table 1. The root rot fungus was not recovered from any native trees of *Persea* growing in an undisturbed situation, in areas remote from any possible contamination from cultivated crops. A number of the samples were taken in areas that would be expected to be favorable for the development of *P. cinnamomi*—areas of high rainfall and in soils with considerable clay. In no case were any diseased native avocado trees or other species of *Persea* seen in native, undisturbed soils.

The root rot fungus was found in several locations where avocado trees were growing as native or escaped trees in coffee plantations or in contact with other cultivated crops; this was the case in the case of two avocado trees in the State of Veracruz, Mexico, and from trees of *Persea schiedeana* in Veracruz, Mexico and in Alta Verapaz, Guatemala. These trees were not in indigenous forest situations.

*P. cinnamomi* was recovered from many avocado trees affected with root rot in most of the countries of Latin America, as shown in Table 1. These samples were from trees brought into cultivation or in semi-cultivation in plantings around dwellings, in fence rows, etc.

## Conclusions

In all of these samples taken to date the avocado root rot fungus, *Phytophthora cinnamomi*, has not been isolated from undisturbed, non-agricultural soils in California or in Latin America.

It thus appears unlikely that the root rot fungus is a native fungus in soils in southern California. It was probably brought in from some subtropical or tropical area and gradually spread throughout much of southern California by means of nursery stock and other means of soil movement.

This theory is substantiated by the fact that in many cases where *P. cinnamomi* has been found in new plantings in southern California, in soil recently cleared of native vegetation, the infection has been traced to infected nursery stock and to subsequent spread from the new infection centers. Also the climate of southern California is not favorable to the survival of a soil fungus of the type of *P. cinnamomi* that requires moist soil in which to survive. Prior to irrigation it would have been difficult for a fungus of this type to survive the long, hot, dry period with little or no rainfall from April to November.

The negative results from all of the cultures from various countries in Latin America also provide indication that the root rot fungus may not be native in those areas either. Additional samples will be taken as opportunity permits; if possible susceptible crops will be planted in some of the native soils as was done with the California samples.

If *P. cinnamomi* is not a native fungus in Latin America, how did it come to this hemisphere? There seems to be a good possibility that it was carried with plant material and accompanying soil from the Malaysian-eastern Australian area on early voyages and explorations throughout the Pacific and to the Americas. It could have been brought into ports in Mexico and other Latin American areas and then spread out into some of the countries with nursery stock and movement of agricultural stocks. Possibly the fungus was brought into Hawaii also on voyages from the South Pacific.

*P. cinnamomi* may then have been brought into California from some of the tropical areas in Latin America or Hawaii in the late 19th century or early in this century, with avocado seeds or plants or with other types of plants. In the early days of the avocado industry in California, avocado seeds and seedlings were commonly brought into California from Mexico, Guatemala, Hawaii, and other tropical areas. The fungus could have been transported in soil accompanying plants or in seed, before quarantine restrictions were placed on such importations.

Dr. Wilson Popenoe in 1912 commented on avocado seeds that had been brought into California from Mexico and Guatemala (6). Dr. Ira Condit also published several notes on avocado importations into California in the early days of the industry. In 1916, Condit (1) quoted Dr. Franceschi, noted for his culture of avocados and other subtropical crops in the Santa Barbara area, who said that the first avocado trees were brought into California from Mexico in 1871. Dr. Franceschi reported that, "One of these trees died in infancy . . . while another died later . . ." This could have been the case of the introduction of *P. cinnamomi*, as well as the avocado, into California. Dr. Franceschi also noted that an avocado tree that he saw in Los Angeles in 1892 had been brought

from Guatemala, ". . . together with many other rare and interesting trees . . ."

Dr. Condit, in an early check list of avocado varieties published in 1926 (2) noted that a number of avocado varieties were introduced into California as seedling trees or as seeds, from Mexico, Guatemala, Costa Rica, Cuba, Ecuador, Samoa, and Venezuela.

Thus, it seems very likely that *P. cinnamomi* is not a native fungus in California, but was introduced here 70 or 80 years ago or earlier, and then spread by means of nursery stock of many types and by soil movement. It also appears likely that this avocado root rot fungus is not native to Latin America; it may have been brought into that area many years ago with plant importations from the Malaysian-eastern Australia area.

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TABLE 1. CULTURES FOR *PYTOPHTHORA CINNAMOMI* FROM ROOT SAMPLES COLLECTED FROM NATIVE SPECIES OF *PERSEA* AND FROM CULTIVATED AVOCADO TREES IN LATIN AMERICA.

Country	Root Cultures	
	From Native Avocado Trees Number of Samples*	From Cultivated Avocado Trees Number of Samples Number with <i>P. cinnamomi</i>
Argentina		14 3
Brazil	1	5 2
Chile	4	11 6
Columbia	1	3 0
Costa Rica	7	19 15
Cuba		1 1
Ecuador		6 0
El Salvador	4	8 5
Guatemala	20	42 1
Haiti		2 1
Honduras	6	51 19
Jamaica		2 0
Mexico	15	101 16
Peru	?	3 2
Puerto Rico		41 14
St. Croix		2 1
Trinidad		1 1
Venezuela	1	

\* No *P. cinnamomi* isolated from native avocado trees or other native species of *Persea* growing in undisturbed, non-agricultural site.

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