

Phytophthora cinnamomi Root Rot and Stem Canker of Peach Trees

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ABSTRACT

Phytophthora cinnamomi, often accompanied by *Pythium* spp., was isolated repeatedly from decayed rootlets of peach trees in 17 of 33 sampled orchards in Maryland and Pennsylvania. Isolates of *P. cinnamomi* from peach or avocado induced necrosis of 85% and 25% of the roots, respectively, in 3 weeks, of 3-month-old peach seedlings growing in infested, aerated nutrient solution. *Pythium irregulare*, *P. vexans*, and *P. ultimum* failed to cause root necrosis in the same tests. In naturally and artificially infested soil, *P. cinnamomi* in greenhouse experiments produced the same symptoms in Elberta peach

Additional key words: *Prunus persica*, *Pythium* spp.,

seedlings as those observed in infected peach trees in the field. High incidence of *P. cinnamomi* stem canker and root rot was observed in orchards replanted with peach trees and in peach trees growing on land newly cleared of hardwoods and conifers. Mortality of trees attributed to *P. cinnamomi* in certain peach orchards with poor soil drainage was as high as 50% in the third growing season. This is the first report demonstrating pathogenicity of *P. cinnamomi* to peach and implicating the pathogen in root rot of peach trees. *Phytopathology* 60:1376-1382.

“wet feet”.

Surveys of peach orchards in Maryland and Southern Pennsylvania for soil-borne fungal pathogens revealed consistent association of *Phytophthora cinnamomi* Rands with dead or dying peach trees. This fungus was usually accompanied in the decayed peach roots by several *Pythium* spp. Both *P. cinnamomi* and *Pythium* spp. were readily isolated from affected peach (*Prunus persica* [L.] Batsch) roots taken from locations where trees failed to become established within 3 to 4 years, or from older trees where sudden collapse and defoliation occurred in late summer.

Several *Phytophthora* spp. other than *P. cinnamomi* have been reported to cause stem canker in young nursery peach trees (2, 8, 9, 13). This fungus has been isolated from decayed rootlets of nursery peach trees in Australia (7), but no experimental data on the pathogenicity of *P. cinnamomi* to peach trees and its role in peach root rot are available. In these studies, we investigated the pathogenicity of *P. cinnamomi* to peach and its role in peach root rot. A short account of this work was reported (6).

MATERIALS AND METHODS.—*Phytophthora cinnamomi* was isolated from rootlets and discolored bark from the lower trunk on pimarcin-vancomycin (PV and P₁₀VP) selective media (11, 12). Segments of decayed roots 2 cm long were surface-sterilized by dipping them in 70% ethyl alcohol, drying on a paper towel, then plating onto selective media. Small pieces of bark collected from the margin of an advancing canker were similarly surface-sterilized or leached for 24 hr in 0.5 liter of sterile water on a magnetic stirrer, then plated. Isolations were made from 20 root segments and/or bark pieces from each tree.

Pathogenicity of two isolates of *P. cinnamomi* and four isolates of *Pythium* spp. to peach was determined in artificially infested, aerated, complete nutrient solution as described by Bingham & Zentmyer (1), with a final concn of iron of 5 ppm. One-month-old peach seedlings grown in steam-sterilized sand were transplanted into 3-gal crocks with the nutrient solution. When new roots were well-developed, 4-6 weeks after

the plants were transplanted into the nutrient, inoculum of *P. cinnamomi* or *Pythium* spp. was placed in the crocks. The inoculum consisted of 7-day-old cultures grown on V-8 juice agar. One-half of one petri dish (10 cm diam) of the agar and mycelia was wrapped in cheesecloth and suspended in the nutrient in each crock with four peach seedlings. In these tests, the pathogenicity and virulence for each isolate was determined by visually estimating the percentage of necrosis of the roots 3 weeks after inoculation.

Pathogenicity of the *P. cinnamomi* isolates was also determined in artificially and naturally infested soil in the greenhouse. Inoculum consisting of a 4-week-old culture grown on sterile vermiculite saturated with a basal synthetic medium (5) was thoroughly mixed with a steam-sterilized soil:sand:peat moss mixture (5:1:1, v/v) at the rate of 50 ml/1,500 ml of soil. Naturally infested soil was obtained from a site where naturally infected peach trees had been removed 1 year prior to soil collection. The controls received vermiculite saturated with the medium but without the fungus. Three-month-old Elberta peach seedlings, growing in steam-sterilized soil in 3-inch pots, were transplanted into 6-inch pots of infested soil and incubated 3 months in the greenhouse. Each treatment consisted of five replicates. Soil temp ranged from 31.0 to 13.3 C (mean, 21.5 C) during the experimental period.

RESULTS.—Symptoms and incidence.—In early summer, peach trees from which *P. cinnamomi* was isolated showed small chlorotic leaves, retarded terminal growth, partial defoliation, and extensive necrosis of feeder and smaller lateral roots (Fig. 1). In late summer, many of the diseased trees, particularly at sites with poor soil drainage, wilted and defoliated (Fig. 2). These peach trees had severe root rot, and/or developed extensive cankers on the lower trunk that sometimes girdled the tree. Excessive gumming is associated with the canker (Fig. 3-A). Removal of the outer bark from the affected trunk reveals discoloration and zonation in the inner bark that often extends to the main branches (Fig. 3-B).

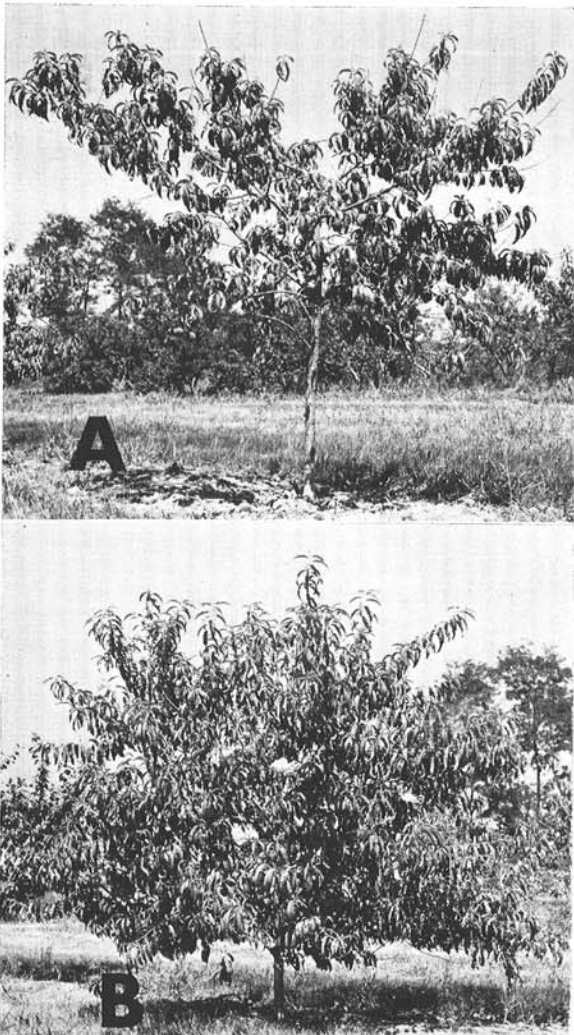


Fig. 1. Five-year-old Sunhigh peach trees: A) With early symptoms of *Phytophthora cinnamomi* root rot. B) Apparently healthy.

Incidence of infected peach trees by *P. cinnamomi* in surveyed orchards varied from none to 70% of the trees. The age of infected trees ranged from 1 to 15 years. Trees 1 to 4 years old had greater incidence of stem canker than did older trees. High incidence of *P. cinnamomi* root rot was observed in peach orchards replanted to peach trees as well as in trees planted in newly cleared land. In one orchard at Beltsville, Maryland, 70% of 800 peach trees, planted 1 year after the land was cleared of a natural stand that consisted predominantly of oak (*Quercus* spp.) and (*Pinus* spp.), were dead or dying in the second growing season. *Phytophthora cinnamomi* was readily isolated from roots of pine trees adjacent to this planting.

Fungi associated with diseased peach trees.—*Phytophthora cinnamomi* and several *Pythium* spp. were repeatedly isolated from the decayed rootlets and cankers on the lower trunk of peach trees. Fungi developing from the infected tissue were transferred from

PV or P₁₀VP media onto V-8 juice agar with β -sitosterol (5) and identified. *Phytophthora cinnamomi* was the predominant isolate from the rootlets, although it was often accompanied and masked by faster-growing *Pythium* spp. Careful microscopic examination of each *Pythium* colony that developed from the rootlets was necessary to ascertain whether *P. cinnamomi* was developing from the same rootlets. The most prevalent species of *Pythium* associated with dead rootlets was *P. irregulare* Buis. followed by *P. vexans* d By. and *P. ultimum* Trow, respectively. *Phytophthora cinnamomi* was usually the only fungus isolated from the stem canker at the lower trunk, and only occasionally was accompanied by *P. vexans* in the dead bark collected at or below the ground line.

Pathogenicity tests.—*Phytophthora cinnamomi* readily infected roots of Elberta peach seedlings growing in infested nutrient solution. The pathogen invaded rootlets at the tip. Infections progressed gradually toward the base of small rootlets, spread into larger secondary roots, and caused brown discoloration and necrosis in the invaded tissue (Fig. 4, above). The peach isolate of *P. cinnamomi* caused necrosis of 85% of the roots of 3-month-old peach seedlings (Fig. 4-A, above), while an avocado isolate (SB216-1) was less virulent, causing only rot of about 25% of the roots within 3 weeks (Fig. 4-B, above). The peach isolate was also more virulent to 2-month-old Lula avocado (*Persea americana* Mill) seedlings than was the avocado isolate, inducing rot of 95% and 40% of the roots, respectively, within 7 days. Both isolates formed chlamydospores in the invaded root tissue of both avocado and peach seedlings.

Two isolates of *P. irregulare* and one isolate each of *P. vexans* and *P. ultimum* from peach failed to induce root necrosis in infested nutrient solution, and there was no difference between inoculated and noninoculated peach seedlings (Fig. 4, below).

Since our surveys of peach orchards revealed a greater incidence and severity of root rot and higher mortality of peach trees at sites with poor soil drainage than in the orchards with good soil drainage, we also investigated the effect of soil water on *P. cinnamomi* peach root rot. To create poor soil drainage conditions and periodic excess of soil water, artificially and naturally infested soils in which peach seedlings were growing were water-saturated periodically by subirrigation for 3 months in one series of experiments. Each pot was placed in a 2-inch deep saucer kept filled with water for 48 hr once each week, after which the pots were removed from the saucers and placed on the bench and watered as needed the remainder of the week. Under these conditions, *P. cinnamomi*-peach isolate induced stunting, wilting, dieback, and severe root rot in peach seedlings (Fig. 5-A, C). The avocado isolate of this pathogen was less virulent, but caused severe root rot and considerable stunting (Fig. 5-B) as compared to noninoculated peach seedlings (Fig. 5-D). Fresh wt of both tops and roots of peach seedlings grown in the infested soil was significantly reduced compared to that of the controls in noninfested soil (Table 1).

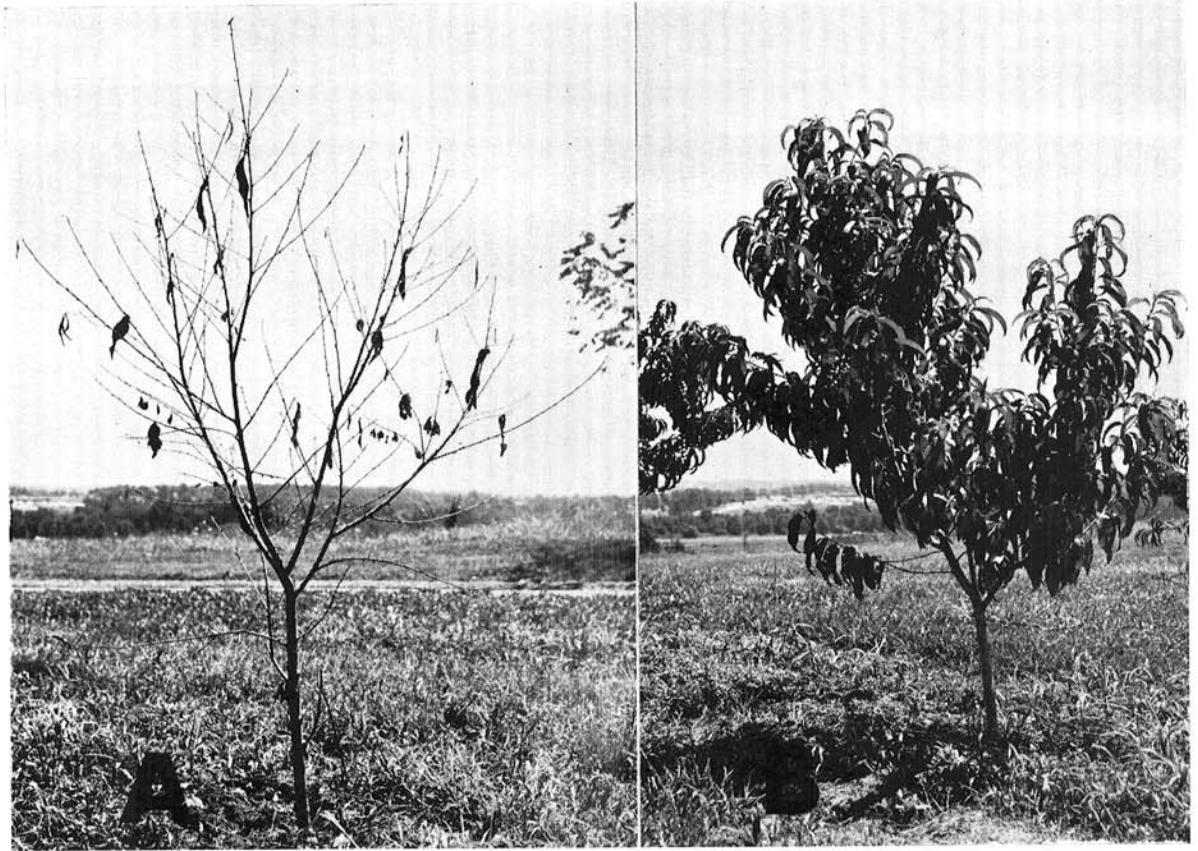


Fig. 2. Three-year-old peach trees. A) With advanced symptoms of *Phytophthora cinnamomi* root rot in late summer. B) Comparable healthy peach tree.

Since we frequently isolated *P. cinnamomi* from slightly stunted or symptomless peach trees in commercial orchards with apparent good soil drainage, we attempted to determine the capability of this pathogen to cause root rot of peach trees in well-drained soil.

In these experiments, peach seedlings were planted in infested soil and watered only when the soil became dry and wilting was evident. Under these experimental conditions, the peach isolate of the pathogen caused substantial root rot in the peach seedlings in both arti-

TABLE 1. Pathogenicity of *Phytophthora cinnamomi* to 3-month-old Elberta peach seedlings in artificially and naturally infested soil in the greenhouse

Treatment	Fresh wt ^a				Rootlets from which <i>P. cinnamomi</i> recovered ^b	
	Periodic ^c saturation of soil		No saturation ^d of soil		Saturation ^c of soil	No saturation ^d of soil
	Tops	Roots	Tops	Roots		
Control, noninfested soil	g 70 ab	g 45 de	g 68 b	g 100 a	% 0 e	% 0 e
Artificially infested soil with <i>P. cinnamomi</i> , avocado isolate	43 de	28 fg	64 bc	47 cd	60 abc	10 e
Artificially infested soil with <i>P. cinnamomi</i> , peach isolate	7 f	5 h	51 cd	35 ef	50 bcd	60 abc
Naturally infested field soil	11 f	7 h	28 e	17 gh	40 cd	70 ab

^a Based on two experiments, five replicates/treatment. Numbers with the same letter do not differ from each other at the .05 level of significance (Duncan's multiple range test).

^b Twenty 2-cm segments of discolored rootlets were plated on pimarcin-vancomycin medium from each peach seedling.

^c Each 6-inch pot was placed in a saucer with 2 inches of water 48 hr each week, then removed, placed on the bench, and watered as needed.

^d Watered only when soil became dry and when wilting was noted on the seedlings.

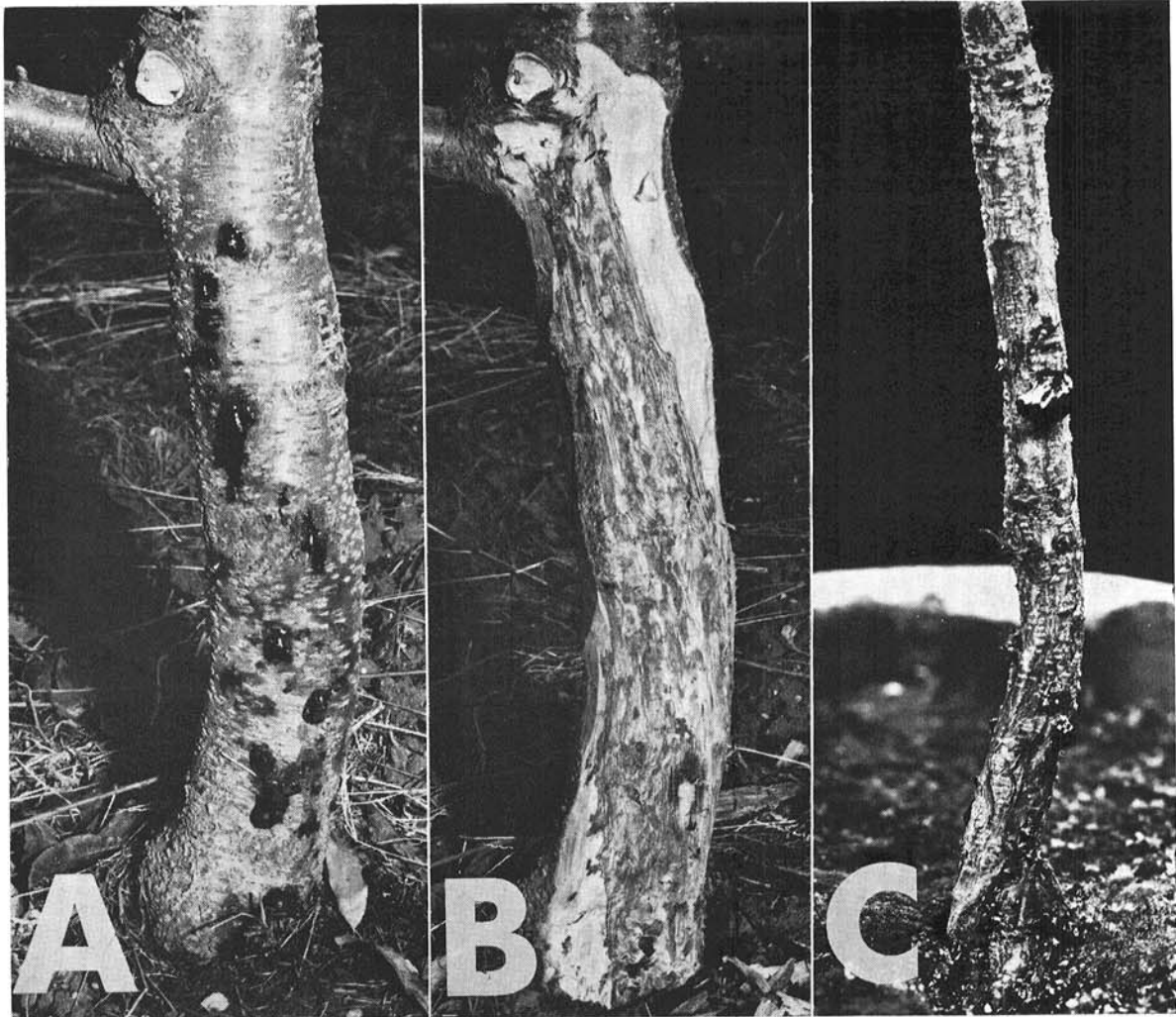


Fig. 3. Stem canker in peach trees caused by *Phytophthora cinnamomi*. **A)** Four-year-old peach tree with extensive canker and characteristic gumming from the affected trunk. **B)** Outer bark of A removed to show zonation and discoloration in the affected bark. **C)** Stem canker in 6-month-old peach seedling grown in soil artificially infested with *Phytophthora cinnamomi* in the greenhouse.

ficially and naturally infested soil (Fig. 5-E, G). The avocado isolate again was less virulent than was the peach isolate, although the seedlings grown in artificially infested soil with the avocado isolate developed considerably more necrosis of feeder and smaller roots (Fig. 5-F) than did the controls (Fig. 5-H). Both peach and avocado isolates of *P. cinnamomi* significantly reduced fresh wt of roots, while only the peach isolate reduced fresh wt of tops of inoculated seedlings compared to those of the controls (Table 1).

Phytophthora cinnamomi induced severe canker at the lower trunk in the seedlings grown in naturally infested soil, but no canker developed on seedlings in artificially infested soil. This resulted in significant differences between fresh wt of both tops and roots of seedlings grown in artificially infested and those grown in naturally infested soil (Table 1, Fig. 5-E, G). Naturally infested soil was a heavy clay, with slower drainage and water-transmission capacity than that of the

artificially infested soil. This difference in the physical properties of the soils resulted in more favorable conditions for infection of the lower trunk in the seedlings grown in naturally than in the artificially infested soil. The pathogen was readily reisolated from decayed rootlets of inoculated seedlings (Table 1).

DISCUSSION.—Evidence is presented that *P. cinnamomi* is pathogenic to peach trees. The pathogen causes severe root rot and/or extensive canker at the lower trunk, and death of peach trees. This is the first report of isolation of *P. cinnamomi* from naturally infected peach trees in the USA. Although isolation of this fungus has been reported from decayed root of nursery peach trees in Australia (7), the present work is believed to be the first to demonstrate pathogenicity of *P. cinnamomi* to peach and to determine its role as a pathogen in peach orchards.

Several *Pythium* spp. were consistently isolated from dead rootlets of peach trees infected by *P. cinnamomi*

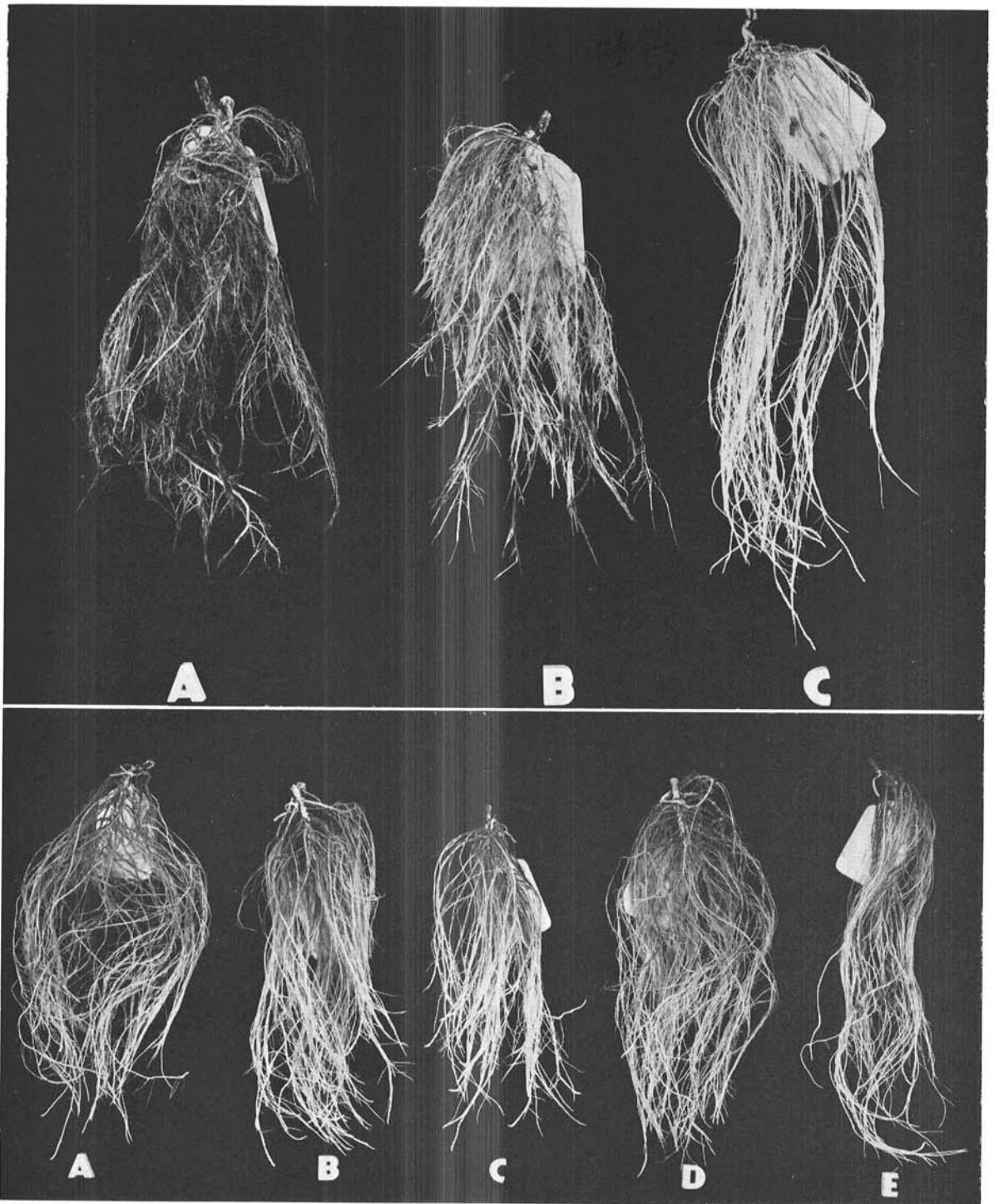


Fig. 4. (Above) Roots of 3-month-old peach seedlings grown in nutrient solution infested with *Phytophthora cinnamomi*. **A)** Peach isolate. **B)** Avocado isolate. **C)** Control, noninoculated. Note discoloration of rootlets in A and B. (Below) Roots of 3-month-old peach seedlings grown in nutrient solution artificially infested with *Pythium* spp. **A, B)** *Pythium irregulare* isolates from Maryland and Georgia, respectively. **C)** *Pythium ultimum*. **D)** *Pythium vexans*. **E)** Noninoculated. Note absence of root necrosis.

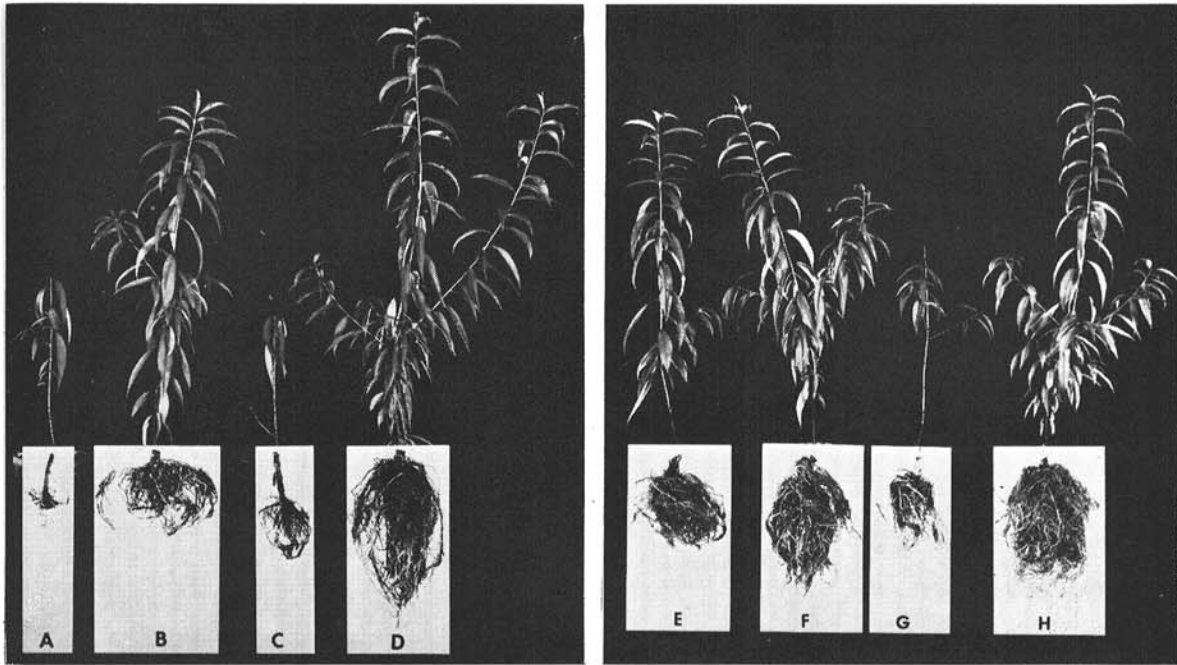


Fig. 5. Six-month-old peach seedlings grown for 3 months in soil infested with *Phytophthora cinnamomi*. A, B, C, D) Soil periodically saturated with water. E, F, G, H) Nonsaturated soil. A, E) Soil artificially infested with a peach isolate. B, F) Soil artificially infested with an avocado isolate. C, G) Naturally infested soil from peach orchard. D, H) Noninfested soil.

in the field. In most cases, both *Pythium* spp. and *P. cinnamomi* were isolated from the same rootlets plated on PV or P₁₀VP media. Feeder root necrosis of peach trees has been attributed to *P. irregulare* and *P. vexans* in Georgia (3). But in this investigation, four isolates of three species of *Pythium* failed to induce necrosis of peach roots in infested nutrient solution, while *P. cinnamomi* did. *Pythium irregulare*, *P. vexans*, *P. mamillatum*, and *P. debaryanum* failed to induce in 2-month-old peach seedlings grown in infested soil any of the symptoms associated with the diseased peach trees in the field (4). Thus, it appears that *Pythium* spp. isolated from decayed feeder roots of peach trees in the mid-Atlantic states are secondary invaders and that they are not the primary cause of root rot in peach trees.

Our results suggest strongly that *P. cinnamomi* can cause substantial loss of peach trees, particularly on sites where excess soil water occurs periodically. But even at sites with good soil drainage, this pathogen may weaken peach trees by destroying a portion of the roots. Unexplained death of peach trees, particularly at the sites where an excess of soil water may occur for short periods, has been frequently attributed to "wet feet". Our results indicated that saturation of soil with water for short periods does not impair growth of peach trees unless *P. cinnamomi* is present in the soil.

Phytophthora cinnamomi is a soil-borne pathogen with an extremely wide host range and geographical distribution (10). We observed substantial numbers of peach trees severely affected by *P. cinnamomi* in re-

planted peach orchards and in orchards that were planted on newly cleared land where the predominant natural stand consisted of *Quercus* spp. and *Pinus* spp. Therefore, it is advisable to determine whether or not this pathogen is present in soil before planting of peach trees regardless of the preceding crop. Planting of peach trees where *P. cinnamomi* is known to occur, particularly on sites with poor soil drainage, should be avoided.

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