Phytophthora Root and Crown Rot of Cherry Trees

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ABSTRACT

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Phytophthora cambivora, P. megasperma, and *P. drechsleri* were isolated repeatedly from decayed roots and trunk cankers of dead and dying sweet cherry trees affected with crown and root rot in California. The three *Phytophthora* spp. were often isolated from the same orchard with a high incidence of dead trees and occasionally from the same individual tree. In artificially infested soil, *P. cambivora* and *P. megasperma* induced severe root and crown rot, whereas *P. drechsleri* caused feeder root necrosis only in Mahaleb and Mazzard rootstocks. The symptoms in artificially inoculated cherry rootstocks were the same as those observed in naturally infected trees in the field. *Phytophthora cambivora* and *P. megasperma* were more virulent than *P. drechsleri* to Mahaleb rootstock. Within 3 months in soil artificially infested with *P. cambivora* or *P. megasperma* mortality was higher in 1-year-old Mahaleb than in Mazzard seedlings. In surveyed commercial orchards the incidence of dead trees attributed to *Phytophthora* root and crown rot ranged from a few to more than 75% of trees affected. Orchards with poorly drained soil and trees on Mahaleb rootstock were more severely affected with *Phytophthora* crown and root rot than orchards on well-drained soil or trees on Mazzard rootstock. This is the first report implicating *P. cambivora, P. megasperma,* and *P. drechsleri* directly in root and crown rot and death of cherry trees in commercial orchards.

Additional key words: Prunus mahaleb, P. avium, "wet feet," soil-borne diseases.

Crown and root rot disorders are responsible for a considerable annual loss of trees in commercial cherry orchards in California. *Armillaria mellea* (8) and *Poria ambigua* (3) were often recognized as causal agents of crown and root rot in certain commercial cherry orchards. However, if these two pathogens were not associated with affected trees, the disease was usually attributed to "wet feet" or "sour sap" (2, 11). *Phytophthora* spp. have been suspected (3, 12), but they have not been directly or experimentally implicated as a cause of crown and root rot of cherry trees.

A survey of commercial cherry orchards in the Stockton-Lodi and Morgan Hill-Hollister areas revealed that the highest incidence of root and crown rot usually occurred in orchards which are subject to poor soil water drainage and to periodic standing of water around lower trunk of trees. Furthermore, crown and root rot reached epidemic proportion following an unusually high rainfall during late fall, winter, and early spring in 1973 and 1974. Careful examination of dead and dying trees in numerous orchards showed that *A. mellea* and *P. ambigua* were associated with a few affected trees in a few surveyed orchards. However, three different *Phytophthora* spp. were repeatedly isolated from decayed roots and bark cankers of cherry trees affected with crown and root rot. The same *Phytophthora* spp. were also readily recovered from soil in affected cherry orchards.

The present studies were undertaken to identify the *Phytophthora* spp. associated with diseased cherry trees and to determine their possible role in root and crown rot of cherry trees. A short account of this work was reported (7).

MATERIALS AND METHODS

Isolation and identification of Phytophthora spp. from infected trees and soils.—Initially we used corn meal agar (Difco) (CMA) and P_{10} VP (14) selective media for isolation of *Phytophthora* spp. from infected tissues of cherry trees. We failed to recover *Phytophthora* spp. on CMA, but three different *Phytophthora* spp. were isolated occasionally on P_{10} VP selective medium. However, the most frequent recovery of the three *Phytophthora* spp. from decayed rootlets or bark of the lower trunk of infected trees was achieved by a modified P_{10} VP medium (PVP) that contained: pimaricin (Myprozine, potency 92.2%, American Cyanamid Co.), 5 mg; vancomycin hydrochloride (Vancocin, Eli Lilly & Co.), 300 mg; pentachloronitrobenzene (PCNB) technical grade, 25 mg; corn meal agar (CMA) (Difco) 17 g; and distilled water, 1 liter. Segments of decayed rootlets approximately 2 cm long were dipped in 70% ethyl alcohol, dried on a paper towel, then plated by pressing the rootlet segments into the medium. Small pieces of bark collected from the margin of an advancing canker on larger roots or trunks were similarly surface sterilized and

plated. Twenty to 40 root and/or bark pieces were plated from each cherry tree. The plates were incubated at 20 C in the dark and examined daily for 10 days for development of *Phytophthora* spp. from the plated tissues.

Isolation of *Phytophthora* spp. from soil was accomplished by the following procedure: soil samples containing roots were collected from three different points within the drip line of each cherry tree. The three sub-samples from each tree were combined and thoroughly mixed. Approximately 500 cc of this combined sample was placed in a container and flooded with enough water to create a layer of free water approximately 1 cm deep at the surface of the soil. Two ripe, green and unblemished Bartlett pear fruits were placed in each container and pressed 3-4 cm deep into the flooded soil. After incubation at 20 C for 72 hours the fruits were removed from the soil, washed, and incubated for an additional 24 hours at 22 ± 2 C. Pear fruits invaded by *Phytophthora* spp. developed brown spots at or below the water line. Small pieces of the fruit tissue from the advancing margin of the brown spot were plated onto PVP, incubated, and observed for development of *Phytophthora* spp. as described earlier in this section. *Pythium* spp. are commonly present in orchard soils and they often accompany *Phytophthora* spp. in decayed rootlets of cherry trees and in the pear fruits used to trap *Phytophthora* from soil. The majority of *Pythium* spp. grow faster and often mask *Phytophthora* spp. on PVP medium. Careful microscopic examination of each *Pythium* colony developing from the rootlet or from decayed tissue of the bait pear fruits was necessary to ascertain whether *Phytophthora* was developing from the same plated tissue.

Phytophthora spp. developing on PVP from infected cherry rootlets and bark or from decayed tissue of bait pear fruits were transferred to CMA, V-8 juice agar (V8A–containing: commercial V-8 juice, 200 ml; $CaCO_3$, 2 g; agar, 17 g; and distilled water, 800 ml), and clear V-8 juice agar (CV8A–containing: V-8 juice filtered through Whatman No. 1 filter paper, 50 ml; β-sitosterol dissolved in 20 ml of warm ethyl alcohol, 20 mg; $CaCl_2$, 111 mg, agar, 17 g; and distilled water, 950 ml). This medium was adjusted to pH 5.5 with 0.1 N KOH before autoclaving.

Cardinal temperatures for vegetative growth and colony type of various isolates were studied on CMA. Production, type, and size of sporangia were studied on V8A. Sporangia were produced readily by all cherry isolates studied when V8A disks with mycelia from the edge of an advancing colony were flooded with 1.5% nonsterile soil extract and incubated at 21 or 24 C for 12-24 hours. Soil extract was prepared by suspending 15 g of sandy loam orchard soil in 1 liter of distilled water, agitating the suspension with a magnetic stirrer for 24 hours at 23 ± 1 C, then filtering it through Whatman No. 2 filter paper. Production of sex organs and compatibility types of the cherry isolates were studied on CV8A medium. The cherry isolates of *Phytophthora* spp. were identified from descriptions of Drechsler (4), Waterhouse (16, 17, 18) and Tucker (15).

Pathogenicity tests.—Pathogenicity of cherry isolates of *P. cambivora* (Petri) Buisman, *P. megasperma* Drechsler, and *P. drechsleri* Tucker to Mahaleb (*Prunus mahaleb* L.) and Mazzard (*P. avium* L.), which are common rootstocks for sweet cherry (*P. avium* L.), was determined under growth chamber conditions. Inocula for the pathogenicity tests were prepared by growing the *Phytophthora* isolates for 4-6 weeks at 21 ± 1 C in 1-liter jars containing 500 cc of sterile vermiculite thoroughly moistened with V-8 juice broth (commercial V-8 juice, 200 ml; $CaCO_3$, 2 g; and distilled water, 800 ml). The inoculum repeatedly was rinsed with sterile water over cheesecloth in a Büchner funnel to remove unassimilated nutrients, and then mixed with steam-pasteurized UC mix (1) and sand (3:1, v/v) at the rate of 10 cc inoculum/1,000 cc of the mixture. The controls received vermiculite with the V-8 juice broth but no *Phytophthora* spp. inoculum. Six-month- to 1-year-old Mahaleb and Mazzard seedlings growing in steam-pasteurized soil in 7-cm diameter pots were transplanted into 1.9-liter crocks with artificially infested UC mix:sand mixture and incubated for 3 months in the growth chamber. Temperature and light in the growth chamber were alternated and maintained at 18 ± 1 C during the 10-hour-dark period and at 23 ± 1 C during the 14-hour light (5,380 lux) period. The plants were fertilized weekly with 20-20-20 water-soluble general purpose fertilizer and Nutra-min. element concn. (E. C. Geiger, Box 285, Harleysville, PA) throughout the experimental period. To create periodic excesses of soil moisture that occur in cherry orchards with poor soil drainage and during irrigation, the artificially infested and noninfested soils in which Mahaleb and Mazzard were growing also were water-saturated periodically by flood-irrigation. Each container was flood-irrigated every 2 weeks allowing free water to stand on the soil surface and around the lower trunks of the seedlings for 48 hours. Between the flood-irrigation the seedlings were watered as needed.

RESULTS

Field symptoms and incidence of the disease.—Cherry trees from which *Phytophthora* spp. were isolated often failed to grow in the spring (Fig. 1-B). However, some infected trees which started to grow showed small, chlorotic, and often drooping leaves and dieback of terminal branches. These trees usually died during the summer months. In contrast, some cherry trees collapsed and died suddenly during the first hot days of early summer, even though they grew vigorously during the previous season (Fig. 1-C). These trees had severe root rot or extensive cankers on the lower trunk (Fig. 1-D, E). Cherry trees on both Mahaleb and Mazzard rootstock developed severe root rot, whereas the incidence of crown rot was higher on Mahaleb than on Mazzard rootstocks. Furthermore, the trunk cankers on Mahaleb often extended to 60-80 cm above the ground (Fig. 1-E) but the trunk cankers, if present on Mazzard, were limited to the crown area (Fig. 1-D).

The incidence of crown and root rot in surveyed affected orchards varied from a few to more than 85% infected trees (Fig. 1-A). The age of infected trees ranged from 2 to 35 years, but the incidence of crown rot was greater in 3- to 8-year-old trees than in older cherry trees. Likewise, the incidence of infected trees on soils with poor internal water drainage and at low sites within individual orchards, that are subject to standing water, was greater

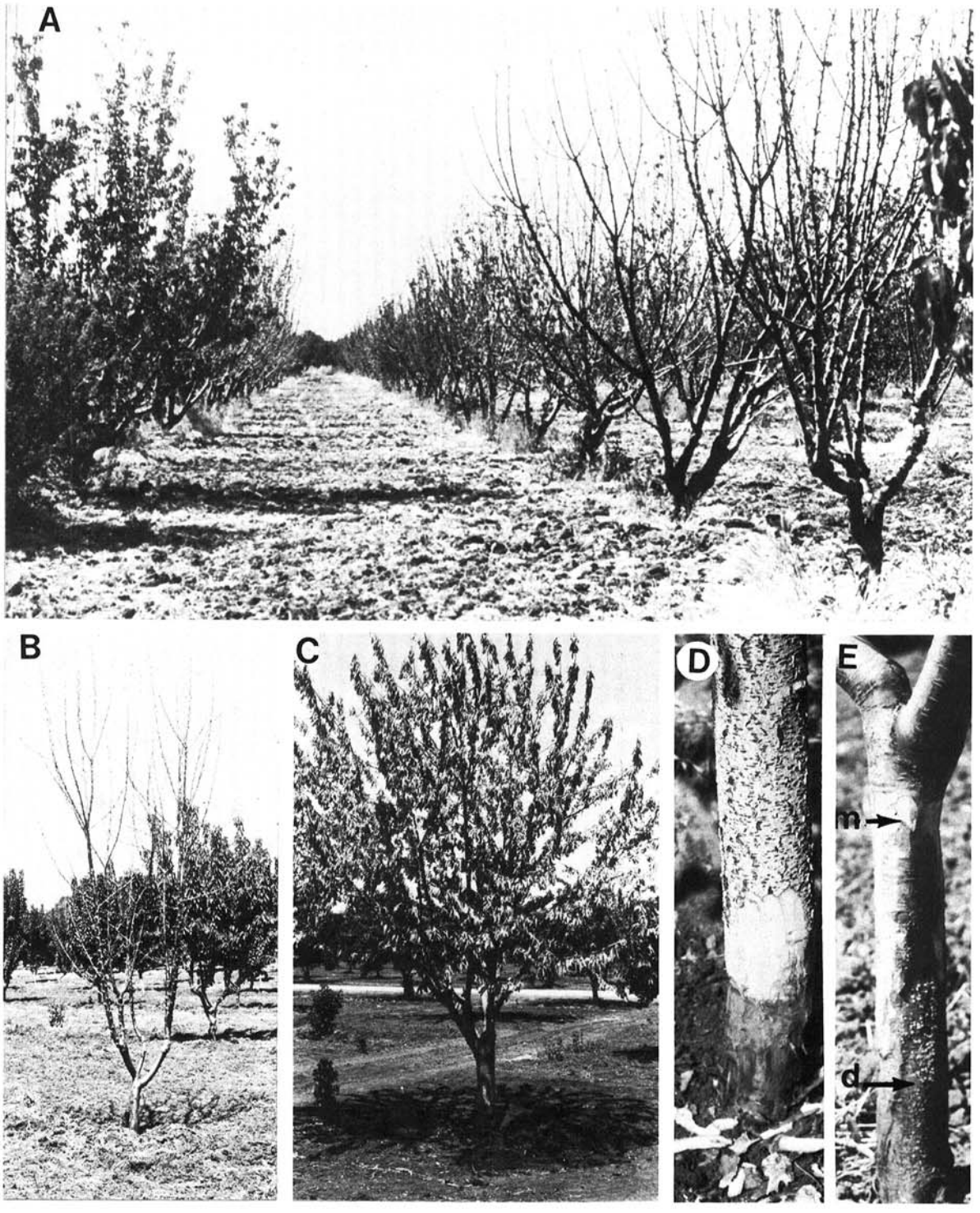

Fig. 1-(A to E). Naturally infected sweet cherry trees with symptoms of Phytophthora root and crown rot. **A)** Seven-year-old cultivar Royal Ann trees on Mahaleb rootstock in a commercial orchard with a high incidence of Phytophthora root and crown rot. **B)** Five-year-old tree (foreground) that failed to grow in the spring naturally infected with *Phytophthora cambivora*. **C)** Eight-year-old tree with severe Phytophthora root rot that collapsed in early summer. **D)** Typical crown rot symptoms on Mazzard rootstock infected with *Phytophthora cambivora* and *Phytophthora megasperma*. **E)** Extensive trunk canker in Mahaleb rootstock caused by *Phytophthora cambivora*, note sunken bark area at the lower trunk (d) and upper margin of the canker (m) near the scaffold branches.

than that on well-drained soils. Thus, numerous cherry orchards in the Stockton-Lodi area were severely affected with *Phytophthora* crown and root rot following unusually excessive rainfall in late fall, winter, and early spring of 1973 and 1974. It was estimated that over 10% of the cherry trees were killed by *Phytophthora* root and crown rot in San Joaquin County during 1973 and 1974 (W. R. Schreader, *unpublished*).

Taxonomy of Phytophthora spp. associated with cherry trees.—Three apparently different *Phytophthora* spp. were isolated repeatedly from soil collected in cherry orchards affected with crown and root rot. The same species also were recovered consistently from decayed rootlets and lower trunk cankers of cherry trees. The three *Phytophthora* spp. often were recovered from the same tree. These pathogens were isolated readily from soil, rootlets, and trunk cankers from late fall through early spring. However, they were isolated only sporadically from soil and decayed rootlets from May through October. Recovery of *Phytophthora* on PVP medium from bark pieces collected from the margin of trunk cankers above ground level usually was unsuccessful during the summer months, although the pathogens were recovered often from the same tree from the canker margin that was below ground level.

Isolates recovered from cherry trees were identified as *P. cambivora, P. megasperma,* and *P. drechsleri.* To confirm their identity, we studied the characteristics of four cherry isolates of each species, because these species have not been reported previously to be associated with cherry trees.

Phytophthora cambivora.—Cherry isolates of this species produced uniform and profusely fluffy cultures on CMA at 21 C. The mycelial growth rate increased from 9 to 30 C then decreased at 34 C. No growth occurred at 5 and 36 C within 96 hours. Primary hyphae were uniform, 7.7 μm in diameter, slightly undulate, without septa when young; but septa were present in older hyphae. Hyphae were extensively branched. Secondary branches, formed at right angles, were constricted at the base, uneven, 3.8 - 13.4 μm in diameter, and usually terminated with numerous nonbotryose hyphal swellings (Fig. 2-A). No sporangia formed on solid agar media: but sporangia broadly ovate, nonpapillate and well-rounded at the base sporangia measuring 44-69 × 33-48 μm (mean 38 × 54 μm) formed readily on undifferentiated sporangiophores when disks of V8A were placed in 1.5% soil extract and incubated at 21 or 24 C for 24-32 hours. Typical sporangia of a cherry isolate of this species are shown in Fig. 2-B. Proliferation of sporangiophores was by continued growth of the filament at base of nondischarged sporangia or by forming repeatedly new sporangia usually within emptied ones. The cherry isolates formed no chlamydospores or sex organs in single cultures grown on CMA, V8A, or CV8A. Sex organs were readily formed within 10 days at 21 C when cherry isolates of *P. cambivora* were paired on CV8A with known A^2 compatibility types of *P. cinnamoni* (P213), *P. drechsleri* (P447), *P. cryptogea* (P201) and *P. cambivora* (P919). None of the cherry isolates produced sex organs in paired cultures with known A^1 compatibility types of the above-mentioned species. Thus, cherry isolates of this species are designated as the A^1 compatibility type. Sex organs formed in the interspecific pairings differed greatly in morphology and size and only a small number of oogonia had bullate protuberances. However, cherry isolates of *P. cambivora* when paired with the A^2 type of *P. cambivora* (P919) produced an abundance of morphologically uniform sex organs with bullate protuberances. Typical sex organs from this pairing are shown in Fig. 2-C. The oogonia were terminal, spherical, and ranged 38-48 μm (mean 44 μm) in diameter. A single elongated sleevelike amphigynous antheridium formed per oogonium (Fig. 2-C) ranging 19-38 μm in length and 15-21 μm in width. The majority of antheridia had a transverse septum and one to several distal protuberances or lobes. A single spherical oospore, 37-44 μm (mean 40 μm) in diameter, almost filled the oogonium. The oospore wall on CV8A was golden or honey-colored. Sporangia and sex organs of the cherry isolates of *P. cambivora* differed somewhat in morphology and size from those reported in the original description of *Blepharospora cambivora* Petri (9), synonym of *P. cambivora* (Petri) Buisman (17). The cherry isolates produced smaller sporangia and larger sex organs than those reported for the type culture of *P. cambivora* (16). However, the reproductive organs of the cherry isolates resemble morphologically very closely those of the type culture (16, 18). Therefore our cherry isolates can clearly be identified as *P. cambivora* (Petri) Buisman.

Phytophthora megasperma.—Cultures of the cherry isolates growing on CMA at 24 C had uneven margins and were slightly radiating and fluffy. The mycelial growth rate on CMA increased from 5 to 24 C then decreased at 30 C. No growth occurred at 33 C within 96 hours. Hyphae were coenocytic when young and septate in older cultures. Primary hyphae were fairly uniform measuring 7.5 μm in diameter and extensively branched with lateral branches at a right angle in relation to the primary hyphae. The lateral branches, uneven in thickness, ranged 5.8 - 9.6 μm in diameter (Fig. 2-D). The cherry isolates formed a few sporangia on solid media, whereas they formed sporangia readily and abundantly within 12-24 hours at 21-24 C when disks of V8A with young mycelia were flooded with 1.5% nonsterile soil extract. The majority of sporangia were obpyriform to ovate, nonpapillate with well-rounded base and measured 39-67 × 23-35 μm (mean 30 × 51 μm) (Fig. 2-E). They were borne terminally on simple nondifferentiated sporangiophores that proliferated either by continuous growth at the base of nondischarged sporangia or by growth through empty ones forming a new sporangium within or outside the empty sporangia. No chlamydospores or hyphal swellings were formed by any of the four cherry isolates on CMA or V8A. However, they readily formed sex organs on CV8A within 7 days and within 14 to 17 days on CMA incubated at 21 C in the dark. Typical sex organ of the cherry isolates is shown in Fig. 2-F. Oogonia on CV8A were smooth, spherical, and terminal, measuring 29-45 μm with an average diameter of 38 μm. A single spherical oospore yellowish to golden color ranging from 28-42 μm (mean 35 μm) in diameter almost filled each oogonium. A single paragynous antheridium spherical, pyriform, or prolate ellipsoidal 7-15 × 7-15 μm (mean 11 × 13 μm) was broadly appressed to each oogonium. Antheridia usually had a distal protuberance or lobe. The culture, hyphae and cardinal temperatures of the cherry isolates of *P. megasperma*

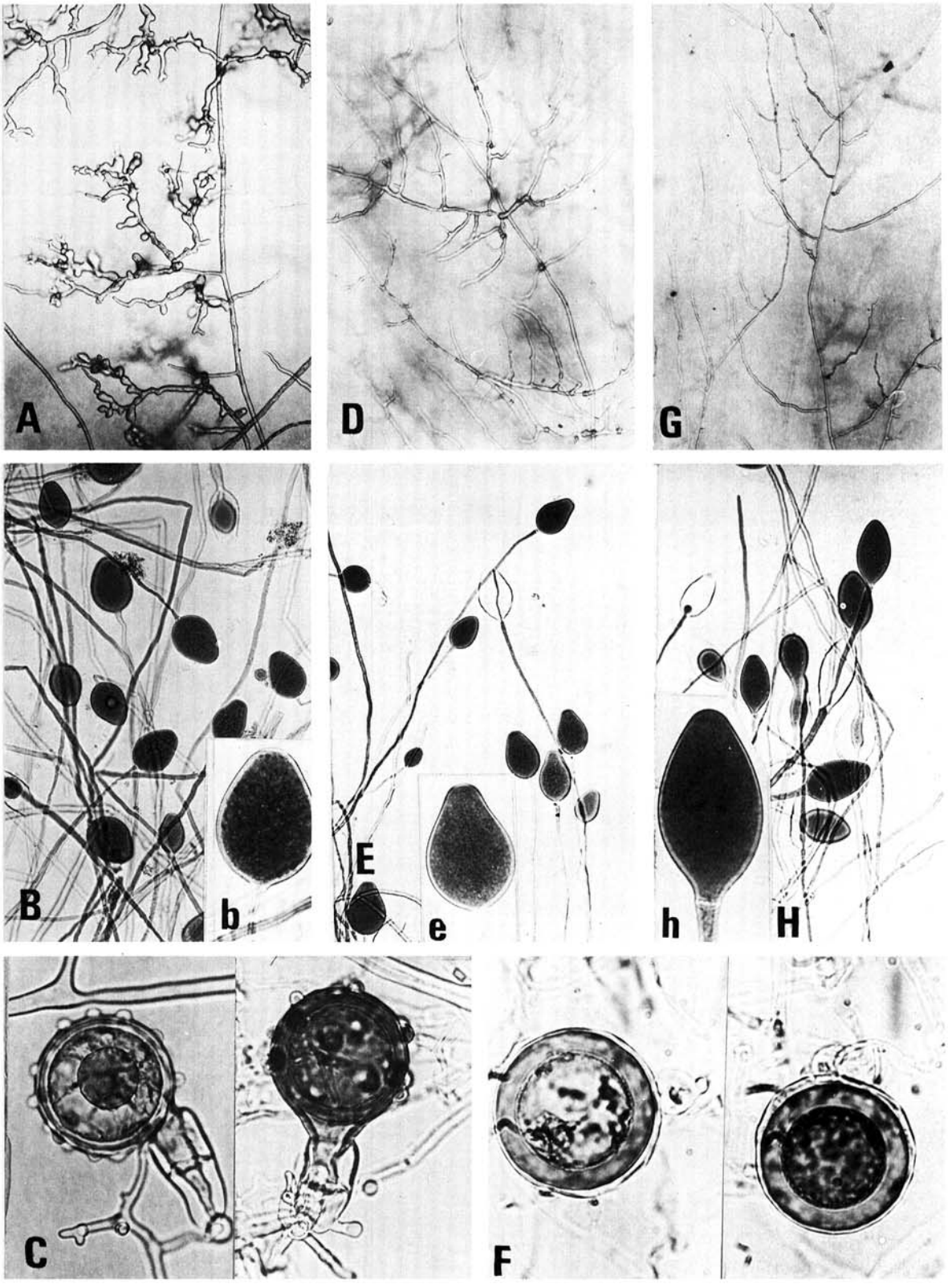

Fig. 2-(A to H). Cultural characteristics of *Phytophthora* spp. causing root and crown rot of sweet cherry trees. (A, B, C) *Phytophthora cambivora*. **A)** Hyphae with typical swellings developed on corn meal agar after 4 days at 24 C (×97.5). **B)** Sporangia that developed on disks of V8A flooded with 1.5% soil extract after 24 hours at 24 C (× 150); b) Typical sporangium (× 375). **C)** Oogonia and oospores P541 × P919 on CV8A exhibiting typical bullate protuberances with elongated, amphigynous antheridia with distal lobes (× 502). (D, E, F) *Phytophthora megasperma*. **D)** Hyphae showing typical branching on corn meal agar after 4 days at 24 C (× 97.5). **E)** Sporangia that developed on V8A disks flooded with 1.5% soil extract after 16 hours at 24 C (× 150); e) typical obpyriform sporangium (× 375). **F)** Typical oogonia and oospores with paragynous antheridia that are broadly appressed to the oogonia (×600). (G, H) *Phytophthora drechsleri*. **G)** Hyphae developing on corn meal agar after 4 days at 24 C, note sparse branching at an acute angle in contrast to those in A and D (×97.5). **H)** Sporangia that developed on V8A disks flooded with 1.5% soil extract after 16 hours at 24 C (× 201); h) Typical sporangium (× 502).

were very similar to those as reported in the original description of the species (4). However, sporangia of the cherry isolates were predominantly (approximately 70%) obpyriform and more closely resembled both in shape and size the sporangia of *P. megasperma* var. *sojae* Hildebrand (17) than the sporangia of *P. megasperma* Drechsler (4). In contrast, the size and the morphology of the oospores of the cherry isolates resembled more closely those of *P. megasperma* Drechsler. Because the cherry isolates had more characteristics in common with *P. megasperma* Drechsler than with *P. megasperma* var. *sojae* Hildebrand our isolates are identified as *P. megasperma* Drechsler.

Phytophthora drechsleri.—Cultures of cherry isolates growing on CMA at 24 C were slightly radiating to rosettelike and moderately fluffy. The mycelial growth rate on CMA increased from 3 to 31 C then decreased at 37 C. No growth occurred at 3 and 39 C within 96 hours. Hyphae were continuous when young, septate when older, uniform in thickness, 5.7 μm in diameter and sparingly branched. Lateral branches are at acute angle in relation to the main hyphae (Fig. 2-G).

Cherry isolates produced a few sporangia on solid CMA, V8A, and CV8A. They produced numerous sporangia within 12 to 24 hours when V8A disks with young mycelia were flooded with 1.5% nonsterile soil extract and incubated at 21 to 27 C. Sporangia were nonpapillate, ovate to ellipsoidal or pyriform, measuring 38-58 × 21-31 μm (27 × 49 μm); and they usually were tapered at the base (Fig. 2-H). The sporangia were borne terminally on simple undifferentiated sporangiophores that often widened toward the base of the sporangia. The sporangiophores resumed growth either through the base of the evacuated sporangia forming a new sporangium within or outside of the walls of empty ones or continued to elongate immediately below the septum at the base of the nonevacuated sporangium. The cherry isolates formed no sex organs in single cultures on CMA, V8A, or CV8A. They also failed to form fully differentiated sex organs when paired on CV8A with the A^2 or A^1 compatibility types of *P. cambivora* (P919, A^2; P541, A^1), *P. drechsleri* (P446, A^1; P444, A^2) and *P. cryptogea* (P443, A^2; P441, A^1). A repulsion zone was observed at the junction of the colonies of these *Phytophthora* spp. and the cherry isolates. However, the cherry isolates when paired with the A^2 *P. drechsleri* (P447) and *P. cryptogea* (P201) produced a few oogonia and antheridia that had a deep brown pigment in the oogonial wall. The presence of fully developed oospores within these oogonia was doubtful. In contrast, cherry isolates induced formation of sex organs in the paired cultures with the A^2 type of *P. cinnamomi* (P213). The sex organs in these pairings apparently were produced by P213 only since they were morphologically identical to the sex organs produced by P213 when paired with the A^1 *P. cinnamomi* (P433). The cherry isolates were designated as the A^1 compatibility type.

The general morphology of cultures and sporangia as well as the cardinal temperatures of the cherry isolates were similar or within the limits for the species reported by Waterhouse (16). They were also similar to those of two isolates, *P. drechsleri* (P209 and P208), obtained from the collection of *Phytophthora* species at the Department of Plant Pathology, University of California, Riverside. Thus, our cherry isolates were designated as *P. drechsleri* Tucker.

Pathogenicity tests.—In the first experiment we compared the relative virulence of cherry isolates of *P. cambivora, P. megasperma* and *P. drechsleri* to Mahaleb seedlings in artificially infested soil. *Phytophthora cambivora* and *P. megasperma* were equally virulent to 6-month-old Mahaleb seedlings (Table 1); they completely destroyed the root system (Fig. 3-A, B, Table 1). *Phytophthora cambivora* induced stem canker whereas *P. megasperma* caused crown rot in the Mahaleb seedlings similar to those observed in naturally infected trees in the field (Fig. 1-D, E).

In contrast, *P. drechsleri* was less virulent to the Mahaleb seedlings than *P. cambivora* and *P. megasperma. Phytophthora drechsleri* induced decay of feeder roots primarily but occasionally invaded larger secondary roots; it also caused considerable stunting of Mahaleb seedlings (Fig. 3-A). However, it caused no crown rot or death of Mahaleb seedlings growing for 3 months in artificially infested soil.

Phytophthora cambivora and *P. megasperma* were isolated more frequently from dead cherry trees in the field than *P. drechsleri*. Furthermore, we observed a higher incidence of severe root and crown rot and death of cherry trees on Mahaleb than on Mazzard rootstock. Thus, in the second experiment we investigated relative virulence of these two pathogens to 1-year-old Mahaleb and Mazzard rootstock seedlings (Table 1). Both *P. cambivora* and *P. megasperma* induced considerable root rot in Mazzard and Mahaleb seedlings in this experiment (Fig. 3-B, D, Table 1). However, Mahaleb seedlings appeared to be more susceptible than Mazzard seedlings to both pathogens (Table 1).

Phytophthora drechsleri, in contrast to *P. cambivora* and *P. megasperma,* failed to cause decay of larger secondary roots or induce crown rot in Mahaleb seedlings growing in artificially infested soil (Table 1). Thus, in another experiment we directly inoculated 10, 1-year-old Mahaleb seedlings with *P. drechsleri, P. cambivora* or *P. megasperma* by placing a small amount of mycelium into bark wounds on the stems of the seedlings. *Phytophthora drechsleri* failed to induce bark canker in the mahaleb seedlings within 3 months in the greenhouse. In contrast, all Mahaleb seedlings inoculated with *P. cambivora* and *P. megasperma* developed stem cankers with an average length of 15 and 10 cm, respectively. *Phytophthora drechsleri* and *P. cambivora* were usually recovered from the same decayed bark piece (3 × 5 mm) collected from trunk cankers of naturally infected cherry trees. This suggests that invasion of the crown and larger roots of Mahaleb rootstock by *P. drechsleri* is probably aided by *P. cambivora* when the two pathogens are present in naturally infested soil.

To determine if a possible synergistic interaction of *P. drechsleri* and *P. cambivora* occurs during the invasion of larger roots and crown of Mahaleb rootstock by *P. drechsleri,* we planted Mahaleb seedlings in artificially infested soil containing either *P. drechsleri* or *P. cambivora* or both pathogens (Table 1). Mahaleb seedlings growing in soil infested with *P. drechsleri* alone developed necrosis of feeder roots only and no decay of larger secondary roots (Fig. 3-B); no crown rot or mortality of the seedlings occurred within 3 months

TABLE 1. Relative virulence of *Phytophthora cambivora, P. megasperma* and *P. drechsleri* to Mahaleb and Mazzard cherry rootstocks in artificially infested soil in a growth chamber

		Experiment 1[a]						Experiment 2[a]						
		Fresh wt. (g)			Fraction[b] of plants		Rootlets from which *Phytophthora* recovered[e]	Fresh wt. (g)			Fraction[b] of plants		Rootlets from which *Phytophthora* recovered[e]	
Treatment	Rootstock	Tops	Roots	Root rot[c] (%)	With crown rot[d]	Dead	(%)	Tops	Roots[c]	Root rot[d] (%)	With crown rot	Dead	(%)	
Control, non-infested soil	Mahaleb	23 X	7 Y	0 Z	0/5	0/5	0 Z	49 Y	17 Y	5 Z	0/5	0/5	0	Z
	Mazzard							50 Y	26 YZ	4 Z		0/5	0	Z
Soil artificially infested with:														
P. megasperma	Mahaleb	5 Z	3 Z	99 X	4/5	4/5	70 Y	16 Z	5 Z	99 U	1/5	5/5	100	V
	Mazzard							11 Z	8 Z	99 U	1/5	1/5	87	VW
P. drechsleri	Mahaleb	13 Y	6 Y	39 Y	0/5	0/5	90 Y							
P. cambivora	Mahaleb	4 Z	2 Z	100 X	5/5	4/5	65 Y	18 Z	6 Z	100 U	3/5	2/5	100	V
	Mazzard							12 Z	9 Z	97 U	1/5	1/5	100	V
P. drechsleri and *P. cambivora*	Mahaleb							11 Z	7 Z	100 U	5/5[f]	5/5	100[f]	V

[a]Average of five replicates per treatment. Numbers with the same letter do not differ from each other ($P=0.05$) (Duncan's multiple range test).

[b]Number of plants with crown rot or dead per number of plants in the treatment within 3 months. Plants in Experiment 1 and Experiment 2 were 6-month- and 12-month-old, respectively, when planted in artificially infested soil.

[c]Percent of the root system rotted as estimated by visual observation 3 months after inoculation.

[d]Phytophthora was recovered from cankers at the base of all seedlings showing crown rot symptoms.

[e]Twenty, 2-cm segments of discolored rootlets were plated on pimaricin-vancomycin-pentachloronitrobenzene medium from each plant.

[f]Both *P. cambivora* and *P. drechsleri* were recovered from every plant in this treatment.

(Table 1). *Phytophthora cambivora* alone induced severe decay of the root system (Fig. 3-B) and caused stem canker or crown rot in three and death of two out of five inoculated Mahaleb seedlings, respectively, within 3 months (Table 1). However, five out of five Mahaleb seedlings developed stem canker and died within 1 month when planted in soil artificially infested with both *P. drechsleri* and *P. cambivora* (Table 1). Both these *Phytophthora* spp. were readily recovered from stem cankers and decayed larger secondary roots of Mahaleb seedlings in artificially infested soil. The more rapid rate of disease development and the higher incidence of trunk canker and the higher mortality in Mahaleb rootstock in soil infested with both *P. drechsleri* and *P. cambivora* than in the soil containing only *P. drechsleri* or *P. cambivora* indicates that a synergistic interaction of these

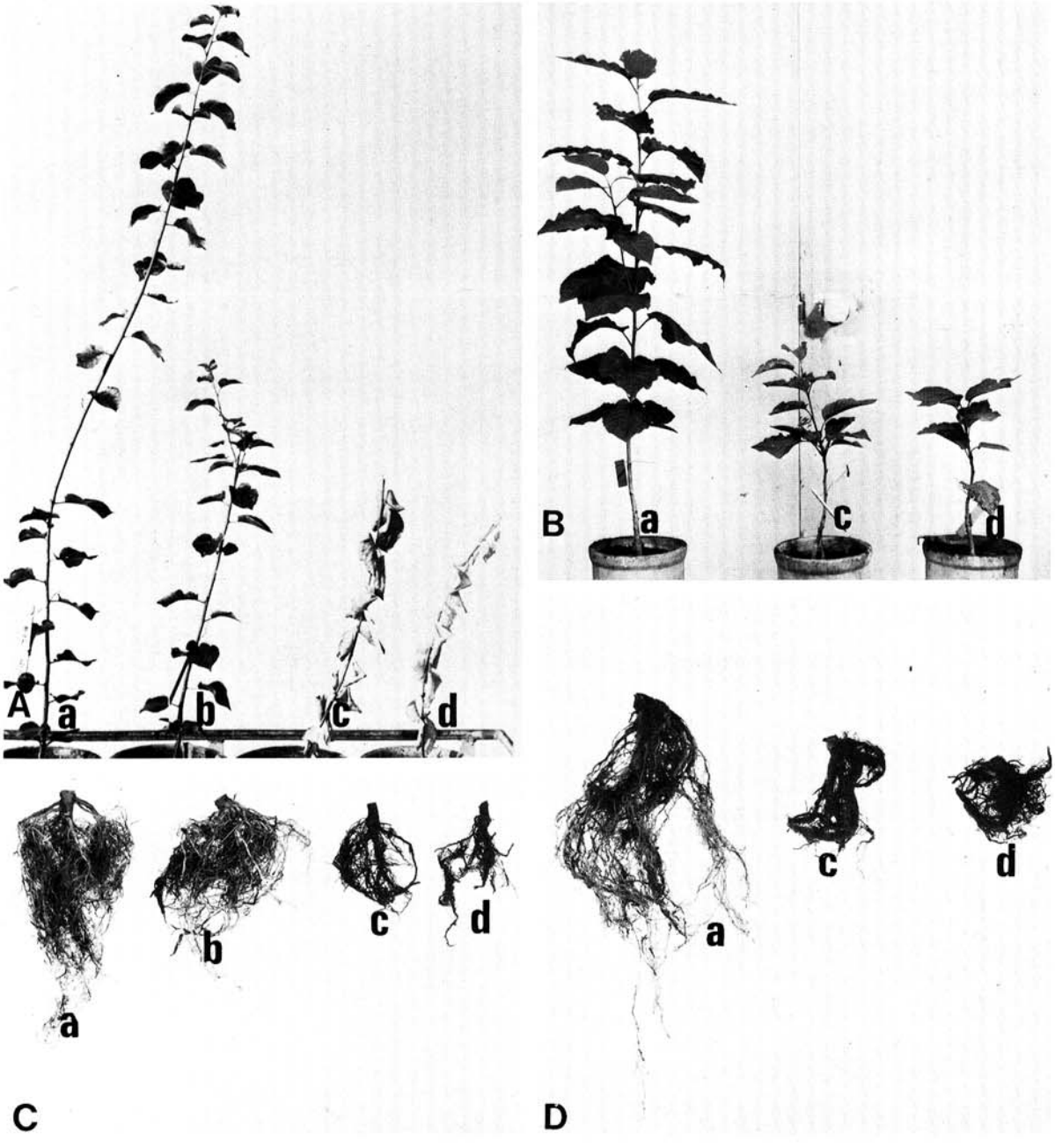

Fig. 3-(A to D). Tops and roots of 6-month-old Mahaleb seedlings (**A**, **B**) and 1-year-old Mazzard seedlings (**C**, **D**) grown for 3 months in noninfested soil (a), and artificially infested soil with *Phytophthora drechsleri* (b), *Phytophthora megasperma* (c) and *Phytophthora cambivora* (d).

two pathogens occurs in causing crown rot of Mahaleb rootstock.

DISCUSSION

Our results showed that *P. cambivora, P. megasperma,* and *P. drechsleri* are commonly associated with cherry trees affected with crown and root rot. The present work is believed to be the first to establish by pathogenicity tests the role of these *Phytophthora* spp. as pathogens of cherry trees and to implicate directly these pathogens as a major primary factor in root and crown rot and death of cherry trees in commercial orchards in California. The symptoms of crown and root rot of cherry trees that resembled those symptoms caused by *Phytophthora* spp. in other fruit trees have been observed previously; however, numerous attempts by various workers to isolate the suspected *Phytophthora* pathogens had failed (H. J. O'Reilly, *personal communication*). We also failed to isolate *Phytophthora* from various deciduous fruit trees using CMA but readily isolated these pathogens from the same affected trees using PVP medium and the procedure described in this paper. Our survey of commercial deciduous fruit and nut tree orchards affected with crown and root rot revealed that *P. drechsleri, P. megasperma,* and *P. cambivora* are widely distributed in California and often associated with crown and root rots of the following deciduous fruits: peach [*Prunus persica* (L.) Batsch], apricot (*P. armeniaca* L.), almond (*P. amygdalus* Batsch), European plum (*P. domestica* L.), and apple (*Malus sylvestris* Mill.). Preliminary pathogenicity tests have shown that *P. cambivora, P. megasperma* and *P. drechsleri* isolated from specific fruit species are pathogenic to that particular fruit species. However, it is not known whether the *Phytophthora* isolates from certain fruit species are species-specific in their pathogenicities. However, there is sufficient evidence that the isolates of *P. megasperma* causing root rot of alfalfa in California are host-specific for alfalfa (5). *Phytophthora drechsleri* is associated with root rot of safflower in California (13), but it is not known whether the safflower pathogen also is virulent to fruit trees. McIntosh (6) reported that an isolate of *P. drechsleri* recovered from a pasture soil caused a few lesions on rootlets of young pear and cherry seedlings, but that it was not pathogenic to peach and apricot seedlings in artificially infested soil.

This appears to be the first record of the occurrence of *P. cambivora* in California; only twice before has this pathogen been isolated elsewhere in the North American Continent (6, 10). In contrast, this pathogen is widely distributed in Europe where it is associated primarily with root rot and basal trunk cankers of chestnut, beech and Norway maple (18). McIntosh (6) in his survey of orchards in British Columbia for the presence of *Phytophthora* spp. recovered *P. cambivora* only once from an orchard soil among 1,800 samples assayed. Since *P. cambivora* has been found so infrequently in orchard soils, it was not considered to be of importance as a fruit tree pathogen in British Columbia (6). In contrast, *P. cambivora* is a real threat to the fruit industry in California because of its wide distribution, its frequent association with dead and dying trees and its pathogenicity to various deciduous fruit and nut trees.

Our results stongly suggest that *P. cambivora, P. megasperma,* and *P. drechsleri* can cause substantial losses of cherry trees particularly on sites where excess soil water occurs periodically. Furthermore, these results indicate that Mahaleb rootstock is more susceptible than Mazzard to *P. cambivora* and *P. megasperma;* thus a higher incidence of dead or dying cherry trees on Mahaleb rootstock has been observed in commercial cherry orchards. Although these *Phytophthora* spp. may weaken cherry trees by partial destruction of the root system even at sites with good soil drainage, the highest incidence of dead trees was observed in orchards that were subject to excess soil moisture resulting from poor soil drainage and/or from excessive irrigation. Thus, planting of cherry trees on the Mahaleb rootstock where *P. cambivora, P. megasperma,* and *P. drechsleri* occur, particularly on sites with poor soil drainage, should be avoided. In addition, all cultural practices that prevent occurrence of standing water around the base of trees or prolonged saturation of soil with water should be helpful in minimizing losses in cherry trees caused by *Phytophthora* root and crown rot.

Research on the relative resistance of various cherry rootstocks to *Phytophthora* spp. and on the effects of different levels of soil moisture on severity of *Phytophthora* crown and root rot are in progress.

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