Phytophthora Root and Crown Rots of Peach Trees in the Eastern Great Lakes Region

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ABSTRACT

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Phytophthora megasperma, P. cryptogea, and *P. cactorum* were isolated from necrotic root and crown tissues of declining and dead peach trees on nine, four, and one farm(s), respectively, in New York and Ohio. Symptomatic trees in many of these orchards had been diagnosed previously as suffering from winter injury or root asphyxiation following an excessively wet autumn and spring. When woody peach seedlings were transplanted into artificially infested potting soil and flooded for 48-hr periods at 2 wk intervals, *P. cactorum* and most isolates identified as *P. cryptogea* were highly virulent, causing >90% root rot and a 60–100% incidence of crown rot; isolates of *P. megasperma* displayed more variable levels of virulence, causing 19–80% root rot and a 0–60% incidence of crown rot. These results indicate that root and crown rots caused by *P. megasperma, P. cryptogea,* and *P. cactorum* may be significant causes of decline and death of peach trees in New York and Ohio.

Numerous 2- to 10-yr-old peach (*Prunus persica* (L.) Batsch) trees throughout the commercial fruit-growing districts south of lakes Erie and Ontario began to decline, wilt, and die during the spring and summer of 1986. The causes of this syndrome frequently were diagnosed as winter injury, presumably the result of a delayed acquisition of dormancy following intensive and prolonged rainfall the previous autumn, and/or root asphyxiation resulting from these same rains and additional intensive precipitation the current spring. However, most affected trees showed neither the necrosis of the bark and cambium on the lower trunk typical of winter injury nor the characteristic blue-purple mottling of roots exposed to prolonged anaerobic conditions. Rather, affected trees consistently displayed distinct cankers on the crown or the primary woody roots, similar to those caused by several *Phytophthora* spp. on other deciduous fruit trees (7,14,15).

Phytophthora spp. have been associated previously with diseased peach trees in California (11,17,18), the southern United States (4,6,16), and the mid-Atlantic region (9,13). With the exception of those from California, however, the preceding reports generally have emphasized disease outbreaks on nursery trees (4,16), the presence of extensive cankers on the trunk and lower scaffold branches (4,6,13), or the involvement of *Phytophthora* spp. (i.e., *P. cinnamomi* Rands, *P. nicotianae* var. *parasitica* (Dast.) Waterh.) uncommon in the Great Lakes region (6,13,16). Because the symptoms and geographic distribution of the disease that we observed did not appear consistent with previous reports of Phytophthora root rot and stem canker on peach in the eastern United States, this study was initiated to determine the association of *Phytophthora* spp. with the aforementioned symptoms and to ascertain the identity and relative virulence of the species of *Phytophthora* involved. A brief portion of this work has been reported previously (20).

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MATERIALS AND METHODS

Isolation and identification of *Phytophthora* spp. The procedures used for isolating and identifying *Phytophthora* spp. in this study were the same as those recently described in detail for a similar study on raspberries (19). Briefly, bark tissue from the margin of cankers on the crown or woody roots, and segments of necrotic rootlets when present, were plated onto a modified selective medium containing pimaricin, ampicillin, rifampicin, PCNB, and hymexazol, i.e., P_5ARPH (8), and incubated at 19 C in the dark. Emerging colonies with hyphae resembling those of *Phytophthora* spp. were subcultured and stored, then all isolates were identified concurrently on the basis of colony morphology, mycelial characteristics, cardinal temperatures for growth, and the production, morphology, and dimensions of sporangia, oogonia, and antheridia. Representative isolates of different species subsequently were compared for similarities and differences in protein electrophoretic banding patterns with other isolates of *Phytophthora* spp. recovered from various deciduous fruit crops (1).

Pathogenicity and virulence of *Phytophthora* spp. The experimental procedures employed to determine pathogenicity and relative virulence of representative isolates were similar to those described previously (14,18,22). Peach seedlings (Halford cultivar) initially were grown in a greenhouse for 8 wk in 7.5-cm-diameter pots containing a mix of steam-pasteurized sandy loam field soil and fine vermiculite (1:2, v/v). Seedlings then were pruned back to a height of 10–15 cm and transplanted into individual 0.95-L plastic pots containing the same soil mix, which was infested at a rate of 2% (v/v) with fine-textured vermiculite that previously had been soaked with dilute vegetable juice broth and colonized by a particular isolate of a *Phytophthora* sp. Five replicate seedlings were used to test each of 12 different isolates of *P. megasperma* Drechs., six isolates of *P. cryptogea* Pethyb. & Laff., and one isolate of *P. cactorum* (Leb. & Cohn) Schroet. Five additional replicate seedlings were used for each of two uninoculated treatments, which received a similar rate of uncolonized vermiculite at the time of transplanting. Three weeeks after transplanting and at 2-wk intervals thereafter, all pots except those containing one group of uninoculated seedlings were flooded for 48 hr by plugging the drain hole at the bottom and adding water until 5–10 mm of free water collected on the soil surface. The remaining group of uninoculated seedlings was grown for the entirety of the experiment without subjection to flooding to determine the effect of periodic waterlogging in the absence of a *Phytophthora* sp. Plants were watered as needed between flooding periods and were fertilized weekly with a modified dilute Hoagland's solution (22). The soil temperature ranged from 18 to 23 C, and natural light was supplemented as necessary to provide a 16-hr photoperiod.

The pathogenicity and relative virulence of individual isolates were assessed after 14 wk by washing the soil mix from each plant's root system, determining the incidence of crown rot, measuring the fresh weights of roots and shoots, and visually estimating the percentage of the root mass rotted. The experiment was conducted twice, and each set of data was analyzed separately using the Waller-Duncan exact Bayesian *k*-ratio LSD rule for mean separation. Results from both experiments were similar, so data from a single representative experiment are presented.

RESULTS

Field symptoms. Within the nine orchards examined, the proportion of symptomatic trees ranged from <10% in three orchards to nearly 90% in one orchard. Diseased trees were almost always planted in relatively heavy, slow-draining soils or located in sections of the orchard where water was most prone to accumulate (Fig. 1). Affected trees sometimes collapsed and died suddenly after budbreak but often showed weak growth with sparse, chlorotic foliage in the spring, followed by a progressive decline, wilt, and collapse as the weather became warmer in the early summer. Because these same symptoms occasionally appeared to result from trunk damage caused by rodent feeding or mechanical injury, the most reliable diagnostic symptom of infection by a *Phytophthora* sp. was a characteristic orange-brown necrosis of the inner bark on the crown and/or woody roots. These tissues eventually turned dark brown and decayed after the tree died. They could be seen readily, however, by excavating the soil from the base of a declining tree or extracting the tree from the soil, then removing the outer bark with a knife. A distinct margin between healthy and necrotic tissues was always apparent on such trees (Fig. 2). In some orchards, lesions were observed only on the woody primary roots in the spring, although crown cankers commonly developed by early summer. In other orchards, numerous incidences of crown rot were evident at the onset of symptom expression following budbreak. Necrosis of the secondary and tertiary root system also

Fig. 1. Distribution of dead and declining peach trees infected with *Phytophthora megasperma*. Downslope from the healthy tree in the foreground are two declining trees and, in the lowest-lying section of the orchard, a large group of dead trees.

Fig. 2. Symptoms of crown rot caused by *Phytophthora cryptogea* on a young peach tree. The outer bark has been removed to reveal a distinct margin between healthy and necrotic tissues (bottom arrow). Top arrow points to the region of the graft union.

was common in many orchards, but this symptom was more variable and less diagnostic than the aforementioned lesions on the woody roots and crowns.

Identity and frequency of *Phytophthora* spp. *Phytophthora* spp. were isolated from dead or declining peach trees in all nine orchards investigated. Isolates were subsequently identified as *P. megasperma* from nine orchards, *P. cryptogea* from four orchards, and *P. cactorum* from one orchard (Table 1). Eighteen of 19 isolates of *P. megasperma* had relatively large oogonia (mean diameter ranging from 41.0 to 56.5 μm) and temperature maxima for vegetative growth ≤30 C, typical of most isolates of *P. megasperma* described previously from other deciduous fruit crops (14,19,25); such isolates have been designated by Hansen et al (5) as belonging to the BHR subgroup of the species. The remaining isolate (NY 412) had smaller oogonia (mean diameter of 33.0 μm) and made rapid vegetative growth at 30 C with a temperature maximum ≥36 C, characteristics typical of the "small oogonium/high temperature" isolates of *P. megasperma* previously described from apple, apricot, and cherry trees (25); such isolates have been designated by Hansen et al (5) as belonging to the AC subgroup of the species. The presence of specific, characteristic bands in subsequent electrophoresis of soluble mycelial proteins confirmed the identification of this isolate (1).

Table 1. Frequency of isolation of *Phytophthora* spp. from declining peach trees in New York and Ohio

Orchard location	Orchard designation	Isolation frequency[x]	*Phytophthora* spp. isolated (no. of trees)[y]
New York	A	2/3	*P. cryptogea* (1)
			P. megasperma (1)[z]
	B	5/7	*P. megasperma*
	C	1/4	*P. megasperma*
	D	3/3	*P. cryptogea* (2)
			P. megasperma (2)
	E	3/5	*P. cryptogea* (3)
			P. megasperma (1)
	F	2/3	*P. megasperma*
Ohio	G	2/4	*P. megasperma*
	H	3/3	*P. cactorum* (1)
			P. cryptogea (1)
			P. megasperma (2)
	I	2/3	*P. megasperma* (1)
			P. megasperma, AC subgroup (1)

[x] Number of trees from which a *Phytophthora* sp. was isolated/number of symptomatic trees sampled.
[y] Number of trees from which the indicated *Phytophthora* sp. was isolated in that orchard.
[z] All isolates of *P. megasperma* but one were of the morphological type associated with the BHR subgroup of this species (5,25); morphological characters and protein electrophoretic banding patterns produced by the remaining isolate were typical of isolates in the AC subgroup (5,25).

Table 2. Pathogenicity and relative virulence of isolates of three *Phytophthora* spp. recovered from dead and declining peach trees in New York and Ohio[u]

Phytophthora spp.	Isolate no.	Orchard designation[v]	Root rot (%)[w,x]	Crown rot incidence[y]	Fresh weight (g)[w]	
					Roots	Shoots
Uninoculated, not flooded	···	···	2.2 g	0/5	15.7 a	21.2 a
Uninoculated, flooded	···	···	3.8 g	0/5	12.6 b	17.5 ab
P. megasperma, AC subgroup	NY 412	I	19.0 fg	0/5	9.3 cd	12.5 def
P. megasperma[z]	NY 397	B	27.0 ef	0/5	8.2 def	16.0 bcd
P. megasperma	NY 400	C	28.0 def	0/5	7.7 d–g	13.4 cde
P. megasperma	NY 398	B	31.0 def	0/5	6.0 e–i	7.8 ghi
P. megasperma	NY 404	F	43.0 cde	1/5	8.3 de	10.3 efg
P. cryptogea	NY 361	A	44.0 cde	1/5	5.6 f–i	8.6 fgh
P. megasperma	NY 406	G	46.0 cde	1/5	5.8 e–i	10.3 efg
P. megasperma	NY 395	B	50.0 cde	0/5	5.5 ghi	7.0 g–j
P. megasperma	NY 362	A	51.0 cd	2/5	6.1 e–h	10.5 efg
P. megasperma	NY 399	B	56.0 c	2/5	5.1 g–j	7.2 ghi
P. megasperma	NY 418	G	58.0 bc	1/5	4.4 h–k	5.6 h–k
P. megasperma	NY 403	E	66.0 bc	1/5	3.4 i–l	4.4 i–l
P. megasperma	NY 408	H	80.0 ab	3/5	3.4 i–l	4.6 h–l
P. cryptogea	NY 414	E	90.0 a	3/5	1.6 l	1.6 kl
P. cryptogea	NY 415	E	92.0 a	3/5	2.6 jkl	3.0 jkl
P. cryptogea	NY 417	H	96.0 a	4/5	1.5 l	1.2 l
P. cryptogea	NY 416	E	98.8 a	5/5	2.2 kl	2.3 kl
P. cactorum	NY 411	H	100.0 a	5/5	1.3 l	0.9 kl
P. cryptogea	NY 413	D	100.0 a	5/5	1.2 l	1.8 kl

[u] Eight-week-old peach seedlings (cv. Halford) were transplanted into soil mix infested with the indicated isolate and grown for 14 wk in a greenhouse with 48-hr flooding episodes imposed at 2-wk intervals.
[v] Orchard designations are the same as those used in Table 1. When more than one isolate of a given *Phytophthora* sp. was tested from the same orchard, each isolate was recovered from a different tree.
[w] Mean value of five replicate seedlings per treatment. Means not followed by a common letter are significantly different ($P = 0.05$) according to the Waller-Duncan exact Bayesian k-ratio LSD rule.
[x] Statistical analysis performed after arcsine transformation of the data.
[y] Number of seedlings with crown rot/number of seedlings tested.
[z] Unless designated otherwise, all isolates of *P. megasperma* belong to the BHR subgroup.

All isolates provisionally identified as *P. cryptogea* formed oospores only when paired with a known A_2 mating type isolate of *P. cryptogea* and were morphologically similar to isolates of *P. cryptogea* recently described from raspberry (19). Sporangia, produced singly on undifferentiated sporangiophores, were nonpapillate, ovoid to obpyriform, and rounded at the base and proliferated internally. The mean sporangium dimensions for the six isolates examined were 43.0–49.2 × 28.3–38.4 μm, and mean length:breadth ratios ranged from 1.29 to 1.53. All isolates produced relatively thin, acutely branched hyphae on Difco cornmeal agar (CMA), but three different subgroups were noted on the basis of colony morphology and growth rates: 1) NY 413, 414, 415, and 416 produced radial to rosette colonies with scalloped margins on CMA and uniform to rosette colonies with sporadic tufts of aerial mycelium on V-8 Juice agar (V8A); 2) NY 361 produced radial to rosette colonies with smooth margins on CMA and rosette colonies with numerous, pronounced tufts of aerial mycelium on V8A; and 3) NY 417 (originally designated as an unidentified *Phytophthora* sp. [20]) produced a colony type similar to the second group on CMA and to the first group on V8A, although with less aerial mycelium. All isolates made slight growth on CMA at 4 C, maximum growth at 25 C, and no growth at 36 C. The radial growth rate of NY 417, however, was approximately 1.5 times that of the other isolates at 19–30 C and 4–12 times that of the other isolates at 33 C. Isolates within these three groups subsequently were found to produce distinct but overlapping electrophoretic banding patterns for native mycelial proteins (1).

Pathogenicity tests. Five of the six isolates of *P. cryptogea* and the lone isolate of *P. cactorum* were highly virulent, causing 90–100% root rot and a 60–100% incidence of crown rot on test seedlings; the remaining isolate of *P. cryptogea* (NY 361) caused only 44% root rot and crown rot on one of five seedlings tested (Table 2). Isolates of *P. mega-*

sperma often were less virulent than those of *P. cryptogea* and *P. cactorum*, although they were highly variable (Table 2). For instance, isolates of the BHR type caused root rot severities ranging from 27 to 80% and crown rot incidences ranging from 0 to 60%, whereas the single isolate belonging to the AC subgroup caused no crown rot, insignificant levels of root rot, and minor (although statistically significant) reductions in root and shoot fresh weights compared with the flooded control plants. Flooding in the absence of a *Phytophthora* sp. caused no discernible root rot but did result in a statistically significant reduction in root fresh weight compared with unflooded plants that were similarly uninoculated (Table 2).

DISCUSSION

These data are the first to implicate *Phytophthora* spp. as causal agents of peach tree decline and death in the Great Lakes region, and they suggest that previous occurrences of Phytophthora root and crown rots of peach in New York and Ohio may have been misdiagnosed as winter injury or root asphyxiation. Furthermore, it appears that the disease we observed often differed in symptomatology and etiology from that reported as "Phytophthora root rot and stem canker" of peach trees in the southern and mid-Atlantic regions of the United States (6,13).

Mircetich and Keil (13) isolated *P. cinnamomi* from peach trees in 17 of 33 sampled orchards in Maryland and southern Pennsylvania and reported that diseased trees often developed extensive trunk cankers that extended up to the main scaffold branches. Similarly, Haygood et al (6), in a survey of more than 20 commercial peach orchards in Mississippi, isolated *P. cinnamomi* and *P. nicotianae* var. *parasitica* from four and three orchards, respectively, and reported that trees infected with these pathogens often developed cankers extending up into the scaffold branches. The same authors also isolated *P. cactorum* from two orchards and reported that this species caused cankers generally extending <50 cm up the trunks. In contrast, the cankers that we observed were confined almost entirely to the roots and crowns of symptomatic trees, rarely extending above the soil line, and were associated predominantly with *P. megasperma* and *P. cryptogea*. Similarly, lesions never extended above the soil line in our pathogenicity experiments when peach seedlings were grown in soil mix infested with *P. megasperma*, and lesions caused by *P. cryptogea* never extended more than 0.5 cm above the soil line. However, cankers caused by the lone isolate of *P. cactorum* often extended 5–10 cm above the soil line in these experiments. Bielenin and Jones (2) demonstrated a similar relative propensity for *P. megasperma, P. cryptogea*, and *P. cactorum* to cause stem cankers when inoculated into sour cherry (*P. cerasus* L.) trees, and Mircetich (11) also noted the lack of extensive trunk cankers on peach trees infected with *P. megasperma* and *P. cryptogea* in California orchards.

The high frequency of isolation of *P. megasperma* in this study is consistent with previous reports in which *P. megasperma* was the species of *Phytophthora* most frequently isolated from declining sour cherry trees in Michigan (2) and from symptomatic apple and cherry trees in New York (7,21). *P. megasperma* also is reported to be among the *Phytophthora* species most frequently isolated from declining apricot, peach, and sweet cherry trees in California (10,11,14,22). It is uncertain whether the lack of reports of *P. megasperma* on peach trees in the southern United States is due to a restricted distribution of the pathogen, limitations on infection imposed by high soil temperatures (25) or other environmental factors, or merely reflects a lack of diagnoses or published accounts thereof.

Five of the six isolates identified as *P. cryptogea* in the present study were among the most virulent isolates tested in our pathogenicity experiments. Isolates identified as *P. cryptogea* also have been shown to be moderately to highly virulent on peach trees in California (11) and on other deciduous fruit crops in California (3,12,22), Michigan (2), and New York (19,21). However, the heterogeneity among isolates identified as *P. cryptogea* recently has been documented (1) and discussed (1,19) and should be considered when interpreting previous or future reports of *P. cryptogea* on peach or other deciduous fruit plants.

Although the occurrence of Phytophthora root and crown rots on peach trees appears to be sporadic in the eastern Great Lakes region, the economic consequences of an outbreak often are severe. Therefore, in the short term it is important that growers learn to recognize this disease and minimize the risk of significant losses by selecting and modifying planting sites to maximize rapid drainage of free water away from the crown zone of the trees (23,24). In the long term, it is hoped that an additional measure of protection will be provided by current breeding and evaluation programs seeking to identify peach rootstocks with improved resistance to Phytophthora root and crown rots.

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