Phytophthora Blight and Dieback in North Carolina Nurseries During a 2003 Survey

C. Y. Warfield, J. Hwang, and D. M. Benson, Department of Plant Pathology, North Carolina State University, Raleigh 27695

ABSTRACT

Warfield, C. Y., Hwang, J., and Benson, D. M. 2008. Phytophthora blight and dieback in North Carolina nurseries during a 2003 survey. Plant Dis. 92:474-481.

A survey of 14 nurseries growing hybrid rhododendron, *Pieris* spp., or *Viburnum* spp. was conducted as part of the 2003 Sudden Oak Death Pilot National Survey to determine if *Phytophthora ramorum*, the causal agent of sudden oak death, had been introduced to nurseries in North Carolina. Over 220,000 hybrid rhododendrons, 1,700 plants of *Pieris* spp., and 2,800 plants of *Viburnum* spp. were surveyed. Across nurseries, blight and dieback incidence averaged 2.4% for *Pieris* spp. and 10% for rhododendron. *P. ramorum* was not recovered by isolation or detected by polymerase chain reaction in the 347 plant samples collected. Three species of *Phytophthora* were isolated from hybrid rhododendron and *Pieris* spp., but no *Phytophthora* isolates were recovered from *Viburnum* spp. *P. citricola* and *P. cambivora* were isolated most frequently (61 and 39 isolates, respectively), while 2 isolates of *P. cactorum* were recovered. Occasionally, two *Phytophthora* spp. were found in the same block of rhododendrons within a nursery, but only one species was recovered from an individual plant. Most cultivars of rhododendron surveyed, including 'English Roseum,' 'Nova Zembla,' and 'Roseum Elegans,' had less than 0.5% incidence of *Phytophthora* blight and dieback, whereas 'Lee's Dark Purple' had 3.8% disease incidence across all nurseries surveyed.

Phytophthora ramorum Werres, De Cock & Man in't Veld, the causal agent of sudden oak death on coast live oak (*Quercus agrifolia*), tanoak (*Lithocarpus densiflorus*), and California black oak (*Q. kelloggii*), is established in areas of 14 coastal counties of northern California and 1 county in southern Oregon and could pose a serious threat to the health of red (black) and white oak species in the eastern forests of the United States if this pathogen were to be introduced and become established (33,34,42,43). In 2003, *Q. ilex* (a member of the white oak group) was found naturally infected with *P. ramorum* in the United Kingdom (11). To date, no species of white oak have been found with the disease in the United States; however, greenhouse studies have demonstrated that

P. ramorum can cause stem lesions on two white oak species (*Q. alba* and *Q. prinus*) in addition to nine other Eastern forest species evaluated using artificial inoculation (42). *P. ramorum* primarily attacks the vascular system of susceptible live oak and tanoak trees just beneath the bark, girdling and killing the tree (10,34). The most common symptoms on other hosts are leaf lesions, shoot blight, and stem dieback; however, infections usually are not fatal (10,29,30,41).

P. ramorum has a broad host range which currently includes 20 plant families and 35 genera (49). As of February 2007, there were 45 proven hosts of *P. ramorum*, including 9 species currently grown as nursery crops in North Carolina. Among these nine plant species are six genera recognized as highly susceptible to *P. ramorum* in U.S. nursery settings (30,38,48). These include *Camellia*, *Rhododendron* (excluding azaleas), and *Viburnum*, which had the highest disease incidence of *P. ramorum* in nursery surveys conducted in California, Oregon, and Washington in 2003, 2004, and 2005 (44). These three genera, in addition to *Pieris*, *Kalmia*, and *Syringa*, also have been found infected with *P. ramorum* in container nurseries in Europe (1,2,16,25,51,53).

The first detection of *P. ramorum* in a U.S. nursery occurred in January 2001 on a containerized rhododendron in Califor-

nia, followed by nursery detections in Oregon and Washington in May and June 2003 (6). During 2003 and early 2004, *P. ramorum*-infected camellia plants were inadvertently shipped from a California nursery supplier to wholesale growers and dealers in 40 states. Trace-forward inspections resulted in the detection and destruction of infected plants at 122 nursery or dealer sites in over 20 states in 2004, including nine sites in North Carolina (45). In 2005, 99 sites in seven states had nursery-related *P. ramorum* detections (5,47). In 2006, *P. ramorum* was detected in 62 nurseries in 11 states (7,50). *P. ramorum* can move on infected nursery stock from the west to east coast of the United States and those infected plants, if placed in the landscape, could expose eastern oak woodlands to a serious exotic pathogen. To date, however, there have been no confirmed cases where *P. ramorum* has become established in the eastern landscape or woodlands from an infected nursery plant. To address spread of *P. ramorum* in the nursery industry, hosts and associated hosts in California, Oregon, and Washington are regulated as nursery stock and require annual inspection and testing before they can be shipped interstate (46).

Symptoms of leaf blight and dieback caused by other *Phytophthora* spp. have been widely reported on nursery-grown ornamental crops. During nursery surveys in the early 1970s, *P. cactorum* was isolated from branches and crowns of rhododendron surveyed in the Pacific Northwest, northern California, the southeastern United States, and the New England states (18). *P. cambivora* was isolated in the early 1970s from shoots of a hybrid rhododendron grown in a Denmark nursery (23). Nursery surveys conducted during the summer months in North Carolina in the late 1970s found *P. cactorum*, *P. citricola*, *P. heveae*, and *P. nicotianae* causing blight and dieback symptoms in hybrid rhododendron (3). More recently in Oregon, the species listed above plus *P. cinnamomi*, *P. citrophthora*, *P. gonapodyides*, *P. hibernalis*, *P. syringae*, and *P. ramorum* were isolated from rhododendron leaves exhibiting blight and dieback symptoms during statewide nursery surveys in 2001 to 2003 (28). Because symptoms caused by *P. ramorum* cannot be distinguished from

Corresponding author: C. Warfield
E-mail: cywarfield@ucdavis.edu

Current address of C. Warfield: University of California Cooperative Extension, Half Moon Bay, CA 94019.

Current address of J. Hwang: Department of Entomology, Soils, and Plant Sciences, Clemson University, Clemson, SC 29634.

Accepted for publication 18 October 2007.

doi:10.1094/PDIS-92-3-0474

© 2008 The American Phytopathological Society

other common *Phytophthora* spp. by visual inspection, diagnosis of *P. ramorum* in infected plant tissue is determined by morphological characteristics of the isolate (52) and DNA analysis by polymerase chain reaction (PCR; 26).

The objective of this study was to survey ornamental nurseries in North Carolina to document whether or not *P. ramorum* was present, as well as to determine the status of *Phytophthora* blight and dieback incidence in nursery crops in North Carolina. A survey of hybrid rhododendron, *Pieris* spp., and *Viburnum* spp. was conducted during spring 2003. Camellia was not recognized as a host of *P. ramorum* at the time and was not included in the survey.

MATERIALS AND METHODS

Selection of nurseries. A letter was mailed to all North Carolina state-certified nurseries growing broadleaf evergreens. The letter requested nursery participation in the Pilot National Survey if (i) hybrid rhododendron, *Pieris* spp., *Kalmia latifolia*, or *Viburnum* spp. were being grown at the nursery and (ii) if liners or cuttings had been bought in from west coast or European nurseries. Fourteen nurseries in the piedmont and mountain regions of North Carolina (Fig. 1), ranging in size from 0.24 to 24 ha, were selected for the survey based on the criteria listed above and their willingness to participate. One nursery produced field-grown stock while the others all produced containerized plants. Among the nurseries, seven grew only hybrid rhododendron, five grew both hybrid rhododendron and *Pieris* spp., one grew *Pieris* spp. and *Viburnum* spp., and one grew all three hosts.

Nursery survey and plant sampling. The first nursery was surveyed on 7 May and the last nursery on 12 June 2003. New growth of target plants had emerged but was not fully mature. At some western North Carolina locations with high altitude, nursery operators had just finished respacing plants after overwintering them in tight blocks. The entire population of plants of the three host species of interest was surveyed at each nursery. A map of the nursery layout was provided by the owner or plotted freehand to establish block numbers for future reference. The survey team, including the authors and their technicians, previously had held a training session so that all surveyors were familiar with symptom recognition. Surveyors visually examined each plant in a block, noted the species and cultivar, and recorded the total number of plants in the block on a data sheet. Any plant with symptoms suspect for *Phytophthora* leaf blight or dieback was counted and recorded as infected. A maximum of 40 symptomatic plants were sampled at a given nursery. Symptomatic foliage or shoot tips from individual plants were collected and placed in a resealable plastic

bag marked with the sample number, cultivar, block number, and a nursery code along with the date. A wooden garden stake was placed in the pot of the sampled plant and the sample number was recorded on the data sheet and stake for future reference. Hand pruners were sprayed with 70% alcohol between samples. Bagged samples were placed in an insulated ice chest for transport to the laboratory, where they subsequently were stored at 4°C prior to processing.

Detection of *Phytophthora* spp. in samples. Generally, 6-mm-diameter leaf disks were cut from the margin of symptomatic tissue using a cork borer. Petiole and stem tissue samples were dissected into 2- to 3-mm-long pieces. Up to five leaf disks or tissue pieces from a single plant sample were plated onto PARP medium with cornmeal agar (22). Culture plates were incubated at 20°C and examined weekly beginning at 4 days for up to 6 weeks. Hyphal tips of resulting colonies were subcultured on cornmeal agar, and morphological characters were used to group isolates and identify to species when possible (13,39).

The identity of each group of isolates was confirmed by a restriction fragment length polymorphism PCR identification method that utilizes a set of universal primers, internal transcribed spacer (ITS)5 and ITS4, to amplify the ITS region of rDNA, followed by a comparison of restriction enzyme digest products of the ITS region (32). Several isolates, representing each group of *Phytophthora* isolates recovered during our survey, were grown in pea broth for 7 days at room temperature and DNA was extracted by a hexadecyltrimethylammonium bromide procedure as previously described (20). The restriction enzymes *Hae*III, *Msp*I, or *Rsa*I were used to digest the amplified DNA fragments, confirming the identity of two groups of our isolates. A second PCR-based identification method (9) was necessary for confirmation of the third group of *Phy-*

tophthora isolates, which could not be identified using the method of Ristaino et al. (32). The second protocol utilized primers ITS6 and ITS4 and the restriction enzymes *Alu*I and *Msp*I with a final concentration of MgCl₂ in the master mix adjusted to 2 mM (8). Amplified PCR product was digested at 37°C for 3 h followed by 65°C for 10 min. The digested product was resolved and visualized on a 1.5% agarose gel containing ethidium bromide (0.5 µg/ml) at 55 mA for 2 h. Fragment sizes in base pairs were calculated with the shareware software program SEQAID II, which is available online from Kansas State University (31).

At the time tissue samples were prepared for culture isolation, an additional leaf disk or stem piece from the same plant sample was bulked with tissue from up to four other plant samples from two or more blocks within a nursery. The bulked tissue was frozen in liquid nitrogen and macerated in a Mini-BeadBeater-1 (Biospec Products Inc., Bartlesville, OK). Ground tissue was processed for DNA extraction by use of a DNeasy Plant Mini Kit (Qiagen, Inc., Valencia, CA) following the manufacturer's protocol. Total genomic DNA was eluted in a final volume of 100 µl and stored at -20°C. The extracted DNA was amplified and visualized for the presence of *P. ramorum* using a nested-PCR assay approved for the Pilot National Survey by the United States Department of Agriculture Animal and Plant Health Inspection Service (USDA-APHIS; 26). DNA of *P. ramorum*, provided by L. Levy (USDA-APHIS, Beltsville, MD), was used as a positive control that resulted in a 291-bp amplification product after the second round of PCR.

RESULTS

Nursery survey. Overall, 229,132 hybrid rhododendron, 1,727 *Pieris* spp., and 2,896 *Viburnum* spp. were surveyed across the 14 North Carolina nurseries, with a total of 347 plant samples col-

Fig. 1. Sudden oak death risk/hazard map for North Carolina. The even-sided hexagons are considered high-risk areas for establishment of *Phytophthora ramorum* based on the presence of likely hosts, potential pathways of introduction (nurseries), and climatic factors within the region. Counties shown in gray represent the location, and the dots represent the zip code of the nurseries included in the 2003 Pilot National Survey in North Carolina. Map courtesy of William Smith, United States Department of Agriculture Forest Service, Research Triangle Park, NC.

lected (Table 1). The survey crew typically consisted of five trained surveyors. The time required to survey and collect samples was highly variable. For instance, Nursery B was a 1.5-h drive each way and required over 6 h onsite for the five-person team to survey. Nursery F was a 3-h drive but, with only 2,400 rhododendrons and 170 *Pieris* spp. plants, took only about 1 h for the team to survey. In all, we spent about 317 man-hours to survey the 14 nurseries.

Phytophthora spp. isolated. *P. ramorum* was not isolated from any of the 347 plant samples collected, nor was it detected by the nested-PCR protocol (Table 1). In all, 92 nested PCR assays consisting of up to five plant samples per reaction were run. We found 9 of 92 reactions suspect for *P. ramorum* after running the nested-PCR assay. However, the products were slightly larger in size and the intensity of the products was faint compared with the positive control (Fig. 2a). When the product of the first-round PCR (*P. ramorum* specific primer set) from each suspect, composite sample was resolved and visualized on a gel, no amplicon of the appropriate size (687 bp) for *P. ramorum* was observed (Fig. 2b). *P. ramorum* was not recovered from any tissue samples cultured in which the tentatively false positives were observed.

Although *P. ramorum* was not detected, three other *Phytophthora* spp. were isolated from 29.4% of the plant samples collected at 10 of the 14 nurseries surveyed

(Table 1). Four nurseries had no detectable *Phytophthora* spp. *P. citricola*, *P. cambivora*, and *P. cactorum* were recovered from both hybrid rhododendron and *Pieris* spp. No isolates of *Phytophthora* were recovered from *Viburnum* spp. *P. citricola* was detected in seven nurseries, *P. cambivora* in five nurseries, and *P. cactorum* in two nurseries. Among the *Phytophthora* isolates recovered, *P. citricola* (51%) and *P. cambivora* (48%) were isolated with similar frequency on the hybrid rhododendron samples collected, but *P. citricola* (91.3%) was isolated more frequently than *P. cambivora* (4.3%) on *Pieris* spp. *P. cactorum* only accounted for 1.0 and 4.3% of the *Phytophthora* isolates recovered from rhododendron and *Pieris* spp., respectively. *P. citricola* was the only species of *Phytophthora* isolated at 4 of the 10 nurseries, and *P. cambivora* was the only species recovered at 2 of the 10 nurseries (Table 1). Both *P. citricola* and *P. cambivora* were recovered from three nurseries. *P. cambivora* and *P. cactorum*, and *P. citricola* and *P. cactorum*, both were detected in one nursery each. In both nursery A and nursery F, two *Phytophthora* spp. were recovered from the same cultivar within the same nursery block but on separate plants (Table 2). In the other three nurseries where multiple *Phytophthora* spp. were detected, only one species was recovered within a nursery block (Table 2).

Disease incidence by host surveyed. In hybrid rhododendron across all nurseries surveyed, incidence of foliar blight and

dieback symptoms averaged 2.4%, with a range of 0.5 to 8.6% depending on the nursery (Table 1). However, based on the actual recovery of *Phytophthora* spp. from these nurseries, the average disease incidence averaged 0.6%, with a range of 0 to 5.9% for all 229,132 hybrid rhododendrons surveyed. Typical symptoms of foliar blight and dieback on rhododendron included diffuse, brownish lesions on the tips or margins of expanding immature leaves or v-shaped lesions starting at the petiole attachment. Eventually, the discoloration extended down the petiole and into the stem. Subsequently, the pathogen moved from the initially infected leaf petiole to adjoining petioles in the whorl, moving upward into new leaves and causing a dieback symptom. However, at the time of the survey, the pathogen had not progressed down the stems from infected new growth into mature tissue from the previous growing season.

At seven nurseries, incidence of foliar blight and dieback in *Pieris* spp. ranged from 0 to 49.6%, with a mean of 10% (Table 1). Based on the actual recovery of *Phytophthora* spp. from these nurseries, the average disease incidence was 8.7% for all 1,727 *Pieris* spp. surveyed. Symptoms in *Pieris* spp. started at the leaf tip or margin and spread irregularly down the midrib into the leaf petiole and stem. Discolored tissues were brown in color. The blighted tips often had a shepherd's crook appearance. The flower racemes also were brown and necrotic.

Table 1. Incidence of blight and dieback, and results of polymerase chain reaction (PCR) and culture isolation for detection of *Phytophthora ramorum* and other *Phytophthora* spp. in 347 plant samples collected at 14 North Carolina nurseries in 2003^a

Nursery code	County	No. of plants ^c	Dieback (%) ^d	Samples ^e	<i>P. ramorum</i>		<i>Phytophthora</i> spp. ^b	
					PCR +	Cult +	Cult –	Cult +
Hybrid rhododendron								
A	Chatham	5,052	3.2	41	0	0	38	2 Pcit; 1 Pcam
B	Guilford	92,732	0.1	22	0	0	20	2 Pcit
E	Yadkin	2,455	8.6	12	0	0	12	0
F	Burke	2,402	6.8	42	0	0	10	6 Pcit; 26 Pcam
G	Avery	2,305	0.6	10	0	0	10	0
H	Yancey	14,361	0.1	14	0	0	10	4 Pcam
I	Madison	59,432	0.2	41	0	0	31	10 Pcit
J	Haywood	34,927	0.2	29	0	0	8	1 Pcat; 20 Pcit
K	Henderson	960	2.1	10	0	0	10	0
M	Moore	324	2.1	7	0	0	2	5 Pcam
N	Moore	13,945	2.1	41	0	0	39	2 Pcam
P	Guilford	187	0.5	1	0	0	1	0
T	Randolph	50	4.0	2	0	0	2	0
Total		229,132	$\bar{X}$ = 2.4	272	0	0	194	79
<i>Pieris</i> spp.								
F	Burke	169	3.6	1	0	0	0	1 Pcit
J	Haywood	113	49.6	2	0	0	0	2 Pcit
K	Henderson	234	1.7	2	0	0	0	2 Pcit
L	Rutherford	340	0.0	0	...	...	...	...
M	Moore	386	1.6	4	0	0	2	1 Pcat; 1 Pcam
P	Guilford	454	14.1	30	0	0	14	16 Pcit
T	Randolph	31	0.0	0	...	...	...	...
Total	...	1,727	$\bar{X}$ = 10.0	39	0	0	16	23

^a Results for PCR and culture (Cult) are positive (+) or negative (-).

^b *Phytophthora* spp. were identified as *P. citricola* (Pcit), *P. cambivora* (Pcam), or *P. cactorum* (Pcat).

^c Number of plants surveyed.

^d Dieback percentage is the total number of plants with leaf lesions, foliar blight, or dieback symptoms compared to the total number of plants surveyed at a nursery.

^e Number of samples collected.

Phytophthora spp. were not isolated from any of the *Viburnum* samples collected (data not shown).

Disease incidence among cultivars of hybrid rhododendron. About 90 cultivars were in cultivation among the 13 nurseries surveyed that were growing rhododendron. Forty of these cultivars were represented by at least 500 plants per cultivar. The cultivars with the greatest number of plants being grown across all nurseries included: 'English Roseum' (35,561 plants), 'Roseum Elegans' (33,143 plants), 'Nova Zembla' (21,397 plants), 'PJM' (13,104 plants), and 'Chionoides' (9,456 plants), followed by 'Catawbiense Album,' 'Catawbiense Boursault,' and 'Roseum Pink,' with more than 8,500 plants surveyed for each of these cultivars. Based on recovery of *Phytophthora* spp., *Phytophthora* blight and dieback was confirmed for 12 hybrid rhododendron cultivars, in addition to a number of unlabeled cultivars at the time of the survey (Table 3). Incidence of *Phy-*

tophthora blight and dieback among these 12 cultivars was 0.6% or less, with one exception. Disease incidence was higher (3.8%) in 'Lee's Dark Purple' but the number of plants surveyed was small, with only 1,277 plants surveyed across four nurseries (Table 3).

Disease incidence among *Pieris* spp. A relatively small number of *Pieris* spp. plants ($n = 1,700$) were surveyed. Among four nurseries where 649 *Pieris japonica* 'Mountain Fire' were grown, disease incidence was 6.5% (Table 4). An unlabeled group of *Pieris* plants at nursery J had almost 50% disease incidence among 133 plants (Table 1).

DISCUSSION

Phytophthora ramorum was neither isolated nor detected by PCR on any of the nursery crops surveyed in North Carolina during May and June 2003. Nine amplified products after the nested-PCR protocol yielded bands that could be suspect for the

presence of *P. ramorum*. However, those bands were slightly larger than the amplified product of *P. ramorum* and further visualization of the first-round products from each reaction, as well as the failure to isolate this pathogen in culture, led us to conclude that these reactions were false positives. The primer sets used in this study for the detection of *P. ramorum* can cross-react with a limited number of other *Phytophthora* spp. including *P. cambivora* (4,10,15,27). Due to the high sensitivity of the nested-PCR protocol, cross-contamination from other samples or the laboratory environment can also easily cause false-positive reactions. *P. cambivora* was isolated from tissue samples composing two of the false-positive composite samples, but no *Phytophthora* spp. were recovered from tissue samples from the other seven false-positive composite samples.

Favorable climatic conditions for growth of *P. ramorum*, based on laboratory studies, include ambient temperatures between

Fig. 2. a, Nine false-positive reactions (labeled a to i) for *Phytophthora ramorum* were obtained after a nested-polymerase chain reaction (PCR) assay performed on plant samples collected in North Carolina nurseries in 2003. **b,** Visualization of only first-round PCR products supports nonspecific amplification in the nested-PCR assay, as indicated by the absence of a 687-bp amplicon for samples a to i compared with the *P. ramorum* DNA positive control. Molecular weight markers (M).

2 and 28°C (12), with an optimum of 20°C (52), and at least 12 h of leaf wetness over 10 days or more for the best expression of symptoms (48). Although weather data was not available for individual nurseries in our survey, data collected by the State Climate Office of North Carolina was obtained from weather stations located in closest proximity to each nursery site. For the 2 weeks preceding each sampling date,

the average daily temperatures ranged from 13.6 to 24.6°C across all nurseries. The duration of leaf wetness could not be determined; however, the number of days with measurable precipitation ranged from 5 to 13 days in the 14 days prior to sampling at each of the nurseries surveyed. Although ambient temperatures were within the favorable range for *P. ramorum*, the frequency and diversity of other *Phy-*

tophthora spp. recovered may have been higher had the survey been conducted later in the season, when conditions would be more favorable for warm-season *Phytophthora* spp. such as *P. nicotianae*. We did find a low incidence of *Phytophthora* blight and dieback caused by other *Phytophthora* spp. in hybrid rhododendron (0.6%) and *Pieris* spp. (8.7%). Most hybrid rhododendron cultivars surveyed had less than 0.5% incidence of *Phytophthora* dieback across all nurseries.

P. citricola and *P. cambivora* were the most frequently isolated *Phytophthora* spp. on rhododendron in this survey. Although *P. citricola* has been encountered commonly in the past, the occurrence of *P. cambivora* as a blight and dieback pathogen of rhododendron had not been reported previously in North Carolina (21). *P. cambivora* was as prevalent as *P. citricola*, with recovery at five nurseries growing rhododendron and *Pieris* spp. in our survey. *P. cactorum* also was isolated from one rhododendron plant in our survey. In nursery surveys in Minnesota from 2002 to 2005, *P. citricola* (55%), *P. cactorum* (16%), and *P. citrophthora* (17%) were the most common *Phytophthora* spp. isolated from rhododendron (36). *P. cambivora* and *P. cactorum* previously have been reported causing foliar blight on rhododendron in Oregon (28). *P. cactorum*, *P. citricola*, *P. citrophthora*, and *P. nicotianae* were isolated from nursery-grown rhododendron in Ohio, where they were reported to be causing necrotic foliar lesions or twig dieback symptoms during the month of August (40).

In addition to *P. ramorum*, several *Phytophthora* spp. causing leaf blight and dieback of rhododendron have been reported recently. *P. hibernalis* was found causing leaf spots on nursery-grown rhododendron in California and Oregon (4). *P. inflata* was isolated from leaf lesions or blighted twigs in nursery-grown *Rhododendron ponticum* in Scotland (35) and rhododendron in Ohio (40). *P. insolita* was isolated from nursery-grown rhododendron in Ohio, where it was causing foliar lesions (40). *P. hedraiaandra* was detected in a nursery in Minnesota, where this pathogen was causing leaf lesions and shoot dieback on *Rhododendron* cv. Mikkeli (37). Shoot blight caused by *P. tropicalis* was reported on *R. catawbiense* cv. Maximum Roseum at a garden center in Virginia (19).

P. citricola was the most frequent *Phytophthora* sp. isolated from the *Pieris* plants sampled in our survey. *P. cactorum* also was recovered from *Pieris* spp. in this survey, but from only one plant. *P. citricola* recently was found causing a foliar blight in containerized nursery stock of *Pieris japonica* 'Fleming' grown in California (24). *Phytophthora citricola* and *P. citrophthora* caused serious losses on *Pieris japonica* in the early 1970s in Ohio nurseries (14,17). In a 2003 nursery survey

Table 2. Incidence of blight and dieback, and *Phytophthora* spp. isolated in 2003 from hybrid rhododendron and *Pieris* spp. within nursery blocks at 10 nurseries surveyed in North Carolina

Nursery, block ^a	Host	<i>Phytophthora</i> spp.	Dieback (%) ^b
A			
15	<i>Rhododendron</i> 'English Roseum'	<i>P. cambivora</i> , <i>P. citricola</i>	5.0
19	<i>Rhododendron</i> 'English Roseum'	<i>P. citricola</i>	4.1
B			
142	<i>Rhododendron</i> 'Catawbiense Album'	<i>P. citricola</i>	0.6
169	<i>Rhododendron</i> 'Roseum Elegans'	<i>P. citricola</i>	0.8
F			
1	<i>Rhododendron</i> 'Lee's Dark Purple'	<i>P. cambivora</i>	22.2
1	<i>Rhododendron</i> 'Nova Zembla'	<i>P. cambivora</i>	25.7
1	<i>Rhododendron</i> Roseum Elegans	<i>P. cambivora</i> , <i>P. citricola</i>	22.9
2	<i>Pieris japonica</i> 'Mountain Fire'	<i>P. citricola</i>	3.6
3	<i>Rhododendron</i> 'English Roseum'	<i>P. cambivora</i> , <i>P. citricola</i>	9.5
4	<i>Rhododendron</i> 'Catawbiense Boursault'	<i>P. cambivora</i>	20.0
4	<i>Rhododendron</i> 'English Roseum'	<i>P. cambivora</i> , <i>P. citricola</i>	11.3
5	<i>Rhododendron</i> 'English Roseum'	<i>P. cambivora</i>	0.6
H			
1	<i>Rhododendron</i> cvs.	<i>P. cambivora</i>	0.2
17	<i>Rhododendron</i> 'Catawbiense Boursault'	<i>P. cambivora</i>	1.7
18	<i>Rhododendron</i> cvs.	<i>P. cambivora</i>	0.8
21	<i>Rhododendron</i> 'Catawbiense Grandiflorum'	<i>P. cambivora</i>	0.6
I			
6	<i>Rhododendron</i> 'English Roseum'	<i>P. cambivora</i>	0.3
15	<i>Rhododendron</i> 'Chionoides'	<i>P. citricola</i>	0.1
33	<i>Rhododendron</i> 'Scintillation'	<i>P. citricola</i>	5.4
36	<i>Rhododendron</i> 'Roseum Elegans'	<i>P. citricola</i>	1.6
42	<i>Rhododendron</i> Roseum Elegans	<i>P. citricola</i>	2.1
50	<i>Rhododendron</i> 'English Roseum'	<i>P. citricola</i>	2.9
53	<i>Rhododendron</i> 'English Roseum'	<i>P. citricola</i>	0.3
J			
1	<i>Rhododendron</i> 'Blue Peter'	<i>P. citricola</i>	1.1
1	<i>Pieris</i> sp.	<i>P. citricola</i>	50.0
2	<i>Pieris</i> sp.	<i>P. citricola</i>	40.0
3	<i>Rhododendron</i> cvs.	<i>P. citricola</i>	0.1
4	<i>Rhododendron</i> cvs.	<i>P. citricola</i>	0.3
5	<i>Rhododendron</i> 'Roseum Elegans'	<i>P. citricola</i>	0.4
6	<i>Rhododendron</i> 'Roseum Elegans'	<i>P. cactorum</i>	1.3
9	<i>Rhododendron</i> 'Catawbiense Boursault'	<i>P. citricola</i>	0.8
10	<i>Rhododendron</i> cvs.	<i>P. citricola</i>	1.4
16	<i>Rhododendron</i> cvs.	<i>P. citricola</i>	0.6
K			
2	<i>Pieris</i> sp.	<i>P. citricola</i>	6.8
5	<i>Pieris</i> sp.	<i>P. citricola</i>	12.5
M			
2	<i>Rhododendron</i> cvs.	<i>P. cambivora</i>	3.8
3	<i>P. japonica</i> cvs.	<i>P. cactorum</i>	0.6
4	<i>P. japonica</i> cvs.	<i>P. cambivora</i>	3.9
7	<i>Rhododendron</i> cvs.	<i>P. cambivora</i>	1.9
N			
55	<i>Rhododendron</i> 'Yaku Princess'	<i>P. cambivora</i>	2.0
81	<i>Rhododendron</i> 'English Roseum'	<i>P. cambivora</i>	2.9
P			
A5	<i>P. japonica</i> 'Scarlet O'Hara'	<i>P. citricola</i>	25.0
A5	<i>P. japonica</i> 'Scarlet O'Hara'	<i>P. citricola</i>	20.0
A5	<i>P. japonica</i> 'Scarlet O'Hara'	<i>P. citricola</i>	6.0
A5	<i>P. japonica</i> 'Mountain Fire'	<i>P. citricola</i>	26.7
A5	<i>P. japonica</i> 'Mountain Fire'	<i>P. citricola</i>	18.0

^a Only nurseries in which *Phytophthora* spp. were recovered are included in table. Blocks represented by different numbers within a nursery were physically separate from each other.

^b Dieback represents the percentage of plants within a block exhibiting foliar blight or dieback symptoms for a given cultivar or species.

in Oregon, *Phytophthora cambivora*, *P. cinnamomi*, *P. nicotianae*, *P. syringae*, *P. citrophthora*, and *P. heveae* were reported from *Pieris* spp. (28). Leaf spots and necrosis of shoot tips caused by *P. tropicalis* was reported on *Pieris japonica* cv. Temple Bells at a garden center in Virginia (19).

Across the 10 nurseries in this survey where *Phytophthora* spp. were isolated, incidence of Phytophthora blight and dieback was 0.6% for hybrid rhododendron. In a similar North Carolina survey in 1980, Benson et al. (3) found an incidence of 2.8% in hybrid rhododendron at 10 nurseries surveyed. Among cultivars in which *Phytophthora* spp. were recovered, disease incidence was surprisingly low, with less than 0.5% incidence for most cultivars across all nurseries surveyed in 2003. In contrast, disease incidence for a given cultivar was generally higher for that cultivar when evaluated within a single nursery or nursery block compared with the overall disease incidence across all nurseries growing the cultivar. Three nurseries had a least one block of either rhododendron or *Pieris* cultivars with 20 to 50% disease incidence. Over 22% of each of three rhododendron cultivars growing in one nursery block were infected with *Phytophthora* spp. at nursery F.

Phytophthora citricola and *P. cactorum*, *P. citricola* and *P. cambivora*, and *P. cambivora* and *P. cactorum* were isolated from rhododendron or *Pieris* spp. in the same or separate nursery blocks within a given nursery. The current sampling protocol for the USDA-APHIS National Nursery Survey recommends sampling a representative number of plants within a nursery block, but not every single plant must be sampled (48). The presence of multiple *Phytophthora* spp. within the same nursery or nursery block demonstrates the potential that exists for failure to detect *P. ramorum* in nursery surveys even though a representative sample is being taken.

The overall low incidence of disease observed in our survey may be due to more effective disease management strategies as well as the fact that our survey was conducted early in the growing season, before optimal conditions for disease development for most warm-season *Phytophthora* spp. Limited fungicide data was provided at 7 of the 14 nurseries surveyed. From the information obtained, a monthly, mist-blown fungicide application of fosetyl-Al beginning in mid-April and continuing until October was common. Fungicide applications were made in at least three nurseries within 2 to 3 weeks prior to our survey, which may have masked disease symptoms or potentially influenced our success in isolating *Phytophthora* spp. from the tissue sampled. Fungicides containing the active ingredient mancozeb were used by five of the six nurseries. The use of thiophanate-methyl, mefenoxam,

propiconazole, iprodione, and myclobutanil also was reported. Fungicides had not yet been applied at the nursery in our survey with the highest *Phytophthora* blight incidence on rhododendron.

Incidence of *Phytophthora* blight and dieback was greater in *Pieris* spp. than in hybrid rhododendron, even though the individual cultivars or species of *Pieris* spp. were considerably fewer than the hybrid rhododendron. Although the numbers of *Pieris* spp. and *Viburnum* spp. surveyed were small, these two host genera have been associated with outbreaks of *P. ramorum* in nurseries in the United States and Europe (16,24,25,28,52,53). We recovered *P. citricola*, *P. cambivora*, and *P. cactorum* from diseased *Pieris* spp. in this survey, but no *Phytophthora* spp. from *Viburnum* spp.

Regular nursery surveys are important to monitor the presence of *Phytophthora* spp. causing blight and dieback in ornamental crops for early detection of the regulated pathogen *P. ramorum* given the continuous

movement of nursery stock in the United States. Our survey established that, as of 2003, *P. ramorum* had not been introduced into representative nurseries in North Carolina. The number of nurseries surveyed represented less than 5% of state-certified nurseries in North Carolina growing broadleaf evergreens, leaving the possibility that *P. ramorum* could have been introduced in North Carolina nurseries but went undetected. In addition, because camellias were not a recognized host at the time of the survey, no camellia plants were surveyed. Today, 29 hosts or associated hosts of *P. ramorum* are being grown throughout the North Carolina nursery industry. Trace-forward surveys in spring 2004 of containerized *Camellia* spp. shipped from a large southern California nursery supplier did detect the presence of *P. ramorum* at nine wholesale nurseries or dealer sites in North Carolina (45). Perimeter surveys of those locations in 2004, 2005, and 2006 failed to find any evidence that *P. ramorum* had been introduced to the

Table 3. Incidence of *Phytophthora* blight and dieback among cultivars of hybrid rhododendron among North Carolina nurseries surveyed in 2003

Cultivar ^b	No. of nurseries ^a		No. of plants		
	Growing	Infected	Surveyed	Infected ^c	Dieback (%) ^d
Blue Peter	2	1	160	1	0.6
Catawbiense Album	6	1	9,062	29	0.3
Catawbiense Boursault	7	3	8,843	24	0.3
Catawbiense Grandiflorum	5	2	6,543	15	0.2
Chionoides	7	1	9,456	40	0.4
English Roseum	12	5	35,561	163	0.5
Lee's Dark Purple	4	1	1,277	48	3.8
Nova Zembla	8	2	21,397	62	0.3
Roseum Elegans	9	5	33,143	105	0.3
Roseum Pink	4	1	8,734	4	0.1
Scintillation	3	1	6,334	33	0.5
Yaku Princess	2	1	2,540	4	0.2
Unlabeled/mixed cultivars	6	3	6,314	58	0.1

^a Number of nurseries growing the cultivar (Growing) and number with infected plants (Infected).

^b Only hybrid rhododendron cultivars in which *Phytophthora* spp. were recovered from collected tissue samples are included in table.

^c Number of plants of a given cultivar exhibiting foliar blight or dieback symptoms across all nurseries surveyed.

^d Dieback represents the percentage of plants exhibiting foliar blight or dieback symptoms among a given cultivar across all nurseries surveyed.

Table 4. Incidence of *Phytophthora* blight and dieback among cultivars of *Pieris japonica* and *Pieris* spp. surveyed at seven North Carolina nurseries in 2003

Cultivar ^b	No. of nurseries ^a		No. of plants		
	Growing	Infected	Surveyed	Infected ^c	Dieback (%) ^d
Compacta	1	0	90	0	0
Dorothy Wyckoff	1	0	18	0	0
Laundry Hospital	1	0	69	0	0
Mountain Fire	4	2	649	42	6.5
Scarlet O'Hara	1	1	112	18	16.1
White Cascade	1	0	56	0	0
Unlabeled <i>P. japonica</i> cvs.	1	1	386	5	1.3
Unlabeled species ^e	2	2	347	60	17.3

^a Number of nurseries growing the cultivar (Growing) and number with infected plants (Infected).

^b Cultivars of *P. japonica*, unless otherwise noted.

^c Number of plants of a given cultivar exhibiting foliar blight or dieback symptoms across all nurseries surveyed.

^d Dieback represents the percentage of plants exhibiting foliar blight or dieback symptoms among a given cultivar.

^e Either *P. japonica*, *P. floribunda*, *P. formosa*, or other *Pieris* sp.

surrounding landscape. The North Carolina Department of Agriculture and Consumer Services conducted subsequent surveys in North Carolina nurseries as part of the National Nursery Survey in 2004, 2005, and 2006. No additional detections of *P. ramorum* have been made in North Carolina since the introduction of infected camellias found during trace-forward surveys in spring 2004 (5,7,45).

ACKNOWLEDGMENTS

The USDA-APHIS Pilot National Survey provided funding for this survey. We thank K. Parker and G. Parra for their assistance in surveying and subsequent processing of plant samples; S. Spencer, North Carolina Department of Agriculture and Consumer Services for assistance with the mass mailing to North Carolina nurserymen; and W. Smith, USDA Forest Service, Research Triangle Park, NC, for providing the sudden oak death risk map for North Carolina.

LITERATURE CITED

- Beales, P. A., Brokenshire, T., Barnes, A. V., Barton, V. C., and Hughes, K. J. D. 2004. First report of ramorum leaf blight and dieback (*Phytophthora ramorum*) on *Camellia* spp. in the UK. *Plant Pathol.* 53:524.
- Beales, P. A., Schlenzig, A., and Inman, A. J. 2004. First report of ramorum bud and leaf blight (*Phytophthora ramorum*) on *Syringa vulgaris* in the UK. *Plant Pathol.* 53:525.
- Benson, D. M., Jones, R. K., and Barker, K. R. 1982. Disease loss assessment for azalea, rhododendron, and Japanese holly in North Carolina nurseries. *Plant Dis.* 66:125-128.
- Blomquist, C., Irving, T., Osterbauer, N., and Reeser, P. 2005. *Phytophthora hibernalis*: A new pathogen on *Rhododendron* and evidence of cross amplification with two PCR detection assays for *Phytophthora ramorum*. Online. *Plant Health Progress* doi:10.1094/PHP-2005-0728-01-HN.
- California Oak Mortality Task Force. 2005. Sudden oak death and *Phytophthora ramorum* summary report: a compendium of the 2005 COMTF monthly newsletters. K. Palmieri and S. J. Frankel, eds. Published online.
- California Oak Mortality Task Force. 2006. California Oak Mortality Task Force. Chronology. U.S.A. *Phytophthora ramorum* nursery chronology. Current September 2006. Published online.
- California Oak Mortality Task Force. 2006. California Oak Mortality Task Force Report October 2006. Published online.
- Cooke D. E. L., and Duncan J. M. 1997. Phylogenetic analysis of *Phytophthora* species based on the ITS1 and ITS2 sequences of ribosomal DNA. *Mycol. Res.* 101:667-677.
- Cooke, D., and Smith, J. 2007. PhytID—Identification of plant pathogenic *Phytophthora* species by ITS fingerprinting. Current January 2007. Published online. <http://phytid.org/index.htm>
- Davidson, J. M., Werres, S., Garbelotto, M., Hansen, E. M., and Rizzo, D. M. 2003. Sudden oak death and associated diseases caused by *Phytophthora ramorum*. Online. *Plant Health Progress* doi:10.1094/PHP-2003-0707-01-DG.
- Denman, S., Kirk, S. A., and Brasier, C. M. 2005. *Phytophthora ramorum* on *Quercus ilex* in the United Kingdom. *Plant Dis.* 89:1241.
- Englander, L., Browning, M., and Tooley, P. W. 2006. Growth and sporulation of *Phytophthora ramorum* in vitro in response to temperature and light. *Mycologia* 98:365-373.
- Erwin, D. C., and Ribeiro, O. K. 1996. *Phytophthora Diseases Worldwide*. The American Phytopathological Society, St. Paul, MN.
- Gerlach, W. W. P., Hoitink, H. A. J., and Ellett, C. W. 1974. Shoot blight and stem dieback of *Pieris japonica* caused by *Phytophthora citricola*, *P. citrophthora* and *Botryosphaeria dothidea*. *Phytopathology* 64:1368-1370.
- Hayden, K. J., Rizzo, D., Tse, J., and Garbelotto, M. 2004. Detection and quantification of *Phytophthora ramorum* from California forests using a real-time polymerase chain reaction assay. *Phytopathology* 94:1075-1083.
- Herrero, L., Toppe, B., Klemsdal, S. S., and Stensvand, A. 2006. First report of *Phytophthora ramorum* in ornamentals plants in Norway. *Plant Dis.* 90:1458.
- Hoitink, H. A. J., Daft, G., and Gerlach, W. W. P. 1975. *Phytophthora* shoot blight and stem dieback of azalea and pieris and its control. *Plant Dis. Rep.* 59:235-237.
- Hoitink, H. A. J., and Schmitthenner, A. F. 1974. Relative prevalence and virulence of *Phytophthora* species involved in Rhododendron root rot. *Phytopathology* 64:1371-1374.
- Hong, C. X., Richardson, P. A., and Kong, P. 2006. *Phytophthora tropicalis* isolated from diseased leaves of *Pieris japonica* and *Rhododendron catawbiense* and found in irrigation water and soil in Virginia. *Plant Dis.* 90:525.
- Hwang, J., and Benson, D. M. 2005. Identification, mefenoxam sensitivity, and compatibility type of *Phytophthora* species attacking floriculture crops in North Carolina. *Plant Dis.* 89:185-190.
- Hwang, J., Warfield, C. Y., Parker, K. C., and Benson, D. M. 2006. First report of *Phytophthora cambivora* on hybrid rhododendron in North Carolina. Online. *Plant Health Progress* doi: 10.1094/PHP-2006-0828-01-BR.
- Kannwisher, M. E., and Mitchell, D. J. 1978. The influence of a fungicide on the epidemiology of black shank in tobacco. *Phytopathology* 68:1760-1765.
- Koch, J. 1971. Rhododendron blight caused by *Phytophthora cambivora*. *Friesia* 9:418-425.
- Koike, S. T., Browne, G. T., Bhat, R. G., and Lee, R. C. M. 2005. *Phytophthora* leaf spot and foliar blight of *Pieris japonica* caused by *Phytophthora citricola* in California. *Plant Dis.* 89:1013.
- Lane, C. R., Beales, P. A., Hughes, K. J. D., Griffin, R. L., Munro, D., Brasier, C. M., and Webber, J. F. 2003. First outbreak of *Phytophthora ramorum* in England, on *Viburnum tinus*. *Plant Pathol.* 52:414.
- Levy, L., and Mavrodieva, V. 2004. USDA Animal and Plant Health Inspection Service. Emergency and Domestic Programs. *Phytophthora ramorum*. Protocols. PCR detection and DNA isolation methods for use in the *Phytophthora ramorum* national program. Rev. Aug 2004. Published online.
- Martin, F. N., Coffey, M., Berger, P., Hamelin, R., Tooley, P., Garbelotto, M., Hughes, K., and Kubisiak, T. 2006. Validation of molecular markers for *Phytophthora ramorum* detection and identification using a standardized library of isolates. (Abstr.) *Phytopathology* 96:S74.
- Osterbauer, N. K., Griesbach, J. A., and Hedberg, J. 2004. Surveying for and eradicating *Phytophthora ramorum* in agricultural commodities. Online. *Plant Health Progress* doi:10.1094/PHP-2004-0309-02-RS.
- Parke, J., Pscheidt, J., and Linderman, R. 2003. *Phytophthora ramorum* a guide for Oregon nurseries. Ore. State Univ. Ext. Serv. December 2003. EM8840.
- Parke, J. L., Linderman, R. G., Osterbauer, N. K., and Griesbach, J. A. 2004. Detection of *Phytophthora ramorum* blight in Oregon nurseries and completion of Koch's postulates on *Pieris*, *Rhododendron*, *Viburnum*, and *Camellia*. *Plant Dis.* 88:87.
- Rhoads, D. D., and Roufa, D. J. 1989. SEQIID II. Kansas State University, Manhattan, KS. Published online.
- Ristaino, J. B., Madritch, M., Trout, C. L., and Parra, G. 1998. PCR amplification of ribosomal DNA for species identification in the plant pathogen genus *Phytophthora*. *Appl. Environ. Microbiol.* 64:948-954.
- Rizzo, D. M., Garbelotto, M., Davidson, J. M., Slaughter, G. W., and Koike, S. T. 2002. *Phytophthora ramorum* and sudden oak death in California: I. host relationships. U. S. Dep. Agric. For. Serv. Gen. Tech. Rep. PSW-GTR-184:733-740.
- Rizzo, D. M., Garbelotto, M., Davidson, J. M., Slaughter, G. W., and Koike, S. T. 2002. *Phytophthora ramorum* as the cause of extensive mortality of *Quercus* spp. and *Lithocarpus densiflorus* in California. *Plant Dis.* 86:205-214.
- Schlenzig, A. 2005. First report of *Phytophthora inflata* on nursery plants of *Rhododendron* spp., *Gaultheria shalon* and *Vaccinium vitis-idaea* in Scotland. *Plant Pathol.* 54:582.
- Schwingle, B. W., Smith, J. A., and Blanchette, R. A. 2007. *Phytophthora* species associated with diseased woody ornamentals in Minnesota nurseries. *Plant Dis.* 91:97-102.
- Schwingle, B. W., Smith, J. A., Blanchette, R. A., Gould, S., Blanchette, B. L., Blanchette, Pokorny, J., and Cohen, S. D. 2006. First report of dieback and leaf lesions on *Rhododendron* sp. caused by *Phytophthora hedraiaandra* in the United States. *Plant Dis.* 90:109.
- Shishkoff, N. 2006. Susceptibility of Camellia to *Phytophthora ramorum*. *Plant Health Progress* doi: 10.1094/PHP-2006-0315-01-RS.
- Stamps, D. J., Waterhouse, G. M., Newhook, F. J., and Hall, G. S. 1990. Revised tabular key to the species of *Phytophthora*. *CAB Int. Mycol. Inst. Mycol. Pap.* 162.
- Testa, A., Schilb, M., Lehman, J. S., Cristinzio, G., and Bonello, P. 2005. First report of *Phytophthora insolita* and *P. inflata* on rhododendron in Ohio. *Plant Dis.* 89:1128.
- Tjosvold, S. A., Buermeyer, K. R., Blomquist, C., and Frankel, S. 2005. Nursery guide for diseases caused by *Phytophthora ramorum* on ornamentals: diagnosis and management. University of California Division of Agriculture and Natural Resources. Pub. 8156.
- Tooley, P. W., and Kyde, K. L. 2007. Susceptibility of some Eastern forest species to *Phytophthora ramorum*. *Plant Dis.* 91:435-438.
- Tooley, P. W., Kyde, K. L., and Englander, L. 2004. Susceptibility of selected ericaceous ornamental host species to *Phytophthora ramorum*. *Plant Dis.* 88:993-999.
- Tubajika, K. M., Bulluck, R., Shiel, P. J., Scott, S. E., and Sawyer, A. J. 2006. The occurrence of *Phytophthora ramorum* in nursery stock in California, Oregon, and Washington states. Online. *Plant Health Progress* doi:10.1094/PHP-2006-0315-02-RS.
- USDA Animal and Plant Health Inspection Service (APHIS). 2004. Emergency and Domestic Programs. *Phytophthora ramorum*. Program Updates. 26 July 2004. Published online.
- USDA Animal and Plant Health Inspection Service (APHIS). 2004. Emergency and Domestic Programs. *Phytophthora ramorum*. Spotlights. 2004 Emergency and Federal Order. Rev. 21 December 2004. Published online.
- USDA Animal and Plant Health Inspection Service (APHIS). 2005. Emergency and Domestic Programs. *Phytophthora ramorum*. Program Updates. 16 November 2005. Published online.
- USDA Animal and Plant Health Inspection Service (APHIS). 2005. Emergency and Domestic Programs. *Phytophthora ramorum*. Protocols. Survey. *Phytophthora ramorum* 2006 National Nursery Survey, Survey Manual. Rev. 20 December 2005. Published online.
- USDA Animal and Plant Health Inspection Service (APHIS). 2006. Emergency and Do-

- mestic Programs. *Phytophthora ramorum*. Spotlights. APHIS list of regulated hosts and plants associated with *Phytophthora ramorum* Rev. 11 September 2006. Published online.
50. USDA Animal and Plant Health Inspection Service (APHIS). 2007. Emergency and Domestic Programs. *Phytophthora ramorum*. Program Updates. December Report. 24 January 2007. Published online.
 51. Varela, P., Vázquez, J. P. M., and Casal, O. A. 2003. First report of *Phytophthora ramorum* on *Camellia japonica* in Spain. Plant Dis. 87:1396.
 52. Werres, S., Marwitz, R., Man In't Veld, W. A., De Cock, A. W. A. M., Bonants, P. J. M., De Weerd, M., Themann, K., Ilieva, E., and Baayen, R. P. 2001. *Phytophthora ramorum* sp. nov., a new pathogen on *Rhododendron* and *Viburnum*. Mycol. Res. 105:1155-1165.
 53. Žerjav, M., Munda, A., Lane, C. R., Barnes, A. V., and Hughes, K. J. D. 2004. First report of *Phytophthora ramorum* on container-grown plants of rhododendron and viburnum in Slovenia. Plant Pathol. 53:523.