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EXOTIC PEST THREATS

UMD Pathology Bulletin, 2008

Sudden Oak Death

Phytophthora ramorum Werres, de Cock & Man in't Veld (Peronosporales: Pythiaceae)

INTRODUCTION:

Sudden Oak Death (SOD) is caused by a recently discovered plant pathogen, a fungal-like organism identified in 2001 as *Phytophthora ramorum* (Werres, de Cock, & Man in't Veld). First detected in the U.S. in 1995 on tanoak in coastal forests of Marin County, California, it killed over 100,000 oak trees in that area within the next decade, earning it the misleading name of SOD. However, diseases caused by *P. ramorum* were first observed in Europe on nursery stock in 1993, and the host range has since been found to include dozens of forest and ornamental plant species in Europe and North America. Consequently, the disease has increasingly been referred to as "ramorum blight".

Coast live oak dying from *P. ramorum* infection. Joseph O'Brien, USDA Forest Service, Bugwood.org

The geographic origin of *P. ramorum* is unknown, and the European and North American pathogens are thought to be two distinct populations. In North America, *P. ramorum* was initially damaging to trees in forested regions, whereas in Europe it was primarily damaging to nursery plants. However, since 1995, *P. ramorum* has expanded its range in Pacific Northwest forests and has also been detected in hundreds of nurseries in North America. *P. ramorum* continues to be detected on new hosts and in nurseries outside of quarantined and regulated areas in North America and Europe.

DISTRIBUTION/SPREAD:

P. ramorum was first detected on ornamental rhododendrons and viburnum in nurseries in Germany and The Netherlands in 1993, and it is currently reported in 17 European countries. Since its detection in North America, *P. ramorum* has been confirmed in nurseries and landscape plantings in British Columbia, Canada; in forests in California and Oregon; and in nurseries in California, Oregon and Washington State. In 2004, infected nursery stock was shipped across the nation and the pathogen was subsequently detected and destroyed in another 21 U.S. states coast to coast, including Alabama, Arkansas, Arizona, Colorado, Connecticut, Florida, Georgia, Louisiana, Maryland, Mississippi, North Carolina, New Jersey, New Mexico, New York, Oklahoma, Pennsylvania, South Carolina, Tennessee, Texas, Virginia and Washington. Since January 2005, all nursery stock shipped interstate from California, Oregon and Washington State is regulated to prevent further movement of this pathogen.

P. ramorum is dispersed from infected plant tissue and spores that may be spread naturally by wind and contaminated water or soil. Spores can be blown great distances by strong winds and in wind-driven rain, and have been found in rainwater pools and run-off, streams, and rivers, adjacent to and far from known infested areas. *P. ramorum* spreads even further due to human activities, primarily the transportation and sale of infected nursery plants. However, it is also spread in soil (spore-infested soil has been recovered from hikers' boot soles, vehicle wheels, gardening tools and equipment, and potting mixes), contaminated irrigation water, infected wood/wood products and greenwaste (especially leaves of foliar hosts), and compost. Live Christmas trees are often planted in home landscapes; both *Psuedotsuga menziesii* var. menziesii and *Abies grandis* are confirmed hosts that are used as Christmas trees.

Other factors impacting spread include the potential role of insect vectors such as bark and ambrosia beetles; vertebrate vectors such as rabbits, deer, pets, etc., which are believed to move the pathogen in soil on their feet; and the climate in the eastern U.S. is predicted to be more conducive to *P. ramorum* infection than it is in the western U.S. The demonstrated susceptibility of some important eastern oak species, which grow in great numbers there, and the extensive trade of potentially infected nursery plants, make the risk of *P. ramorum* becoming established in eastern hardwood forests very high.

HOST PLANTS:

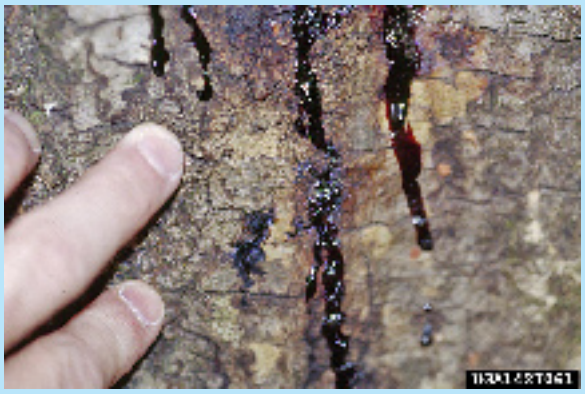
The host range for *P. ramorum* is extensive and continues to grow. In Europe, *P. ramorum* was first observed on ornamental rhododendrons and viburnums in Germany and The Netherlands. It was later isolated on several additional species of nursery plants (Arbutus, Camellia, Hamamelis, Kalmia, Leucothoe, Magnolia, Pieris and Syringa), then in 2003 it was reported by the UK on a southern red oak tree (*Quercus falcata*) and several other tree species including beech (*Fagus sylvatica*), Holm oak (*Q. ilex*), European turkey oak (*Q. cerris*), Sweet chestnut (*Castanea sativa*), and horse chestnut trees (*Aesculus hippocastanum*). The Netherlands reported it on *Q. rubra* and *F. sylvatica*, all located near infected Rhododendron. Two of the affected tree species in Europe are native to North America: southern (*Q. falcata*) and northern (*Q. rubra*) red oaks.

In North America, *P. ramorum* was initially found in Pacific northwest forests, primarily on tanoaks (*Lithocarpus densiflorus*), coast live oaks (*Q. agrifolia*), and California black oaks (*Q. kelloggii)*, but also on a number of understory plants and other tree species such as bay laurel (*Umbellularia californica*), bigleaf maple (*Acer macrophyllum*), California buckeye (*Aesculus californica*), huckleberry (*Vaccinium ovatum*), madrone (*Arbutus menziesii*), manzanita (*Arctostaphylos manzanita*), and *Rhododendron* spp. It has since been found infecting dozens of common ornamental plants and several conifers, including coastal redwood (*Sequoia sempervirens*), Douglas-fir (*Pseudotsuga menziesii*), and grand fir (*Abies grandis*). Throughout the U.S., host plants are widely distributed, overlapping, and abundant. A study determined that 10 different Eastern forest species are susceptible to infection by *P. ramorum*, which means that over half the forests in the eastern U.S. contain potential host trees.

Susceptible plants are divided into foliar hosts (typically shrubs, woody and herbaceous perennial species) and trunk hosts (typically trees). Prominent ornamental foliar hosts include *Rhododendron*, *Viburnum*, *Camellia*, and *Pieris*, and in the East it is also found on lilac (*Syringia*) nursery stock. Prominent trunk hosts are the *Fagaceae* family (oaks). Tanoak (*L. densiflorus*) is the most susceptible of the known hosts to *P. ramorum*, and all sizes and ages can be infected and killed by the disease. The tanoak is unique in that trunks, branches, twigs, leaves and leaf petioles are all susceptible, making it both a trunk and a foliar host. Typically, foliar hosts must be present for trunk hosts to become infected. There are increasing reports of disease outbreaks along urban/forest boundaries on the West Coast where infected ornamental foliar hosts have been planted near tree hosts. As of August 2007, the USDA APHIS lists 70 genera in 35 plant families, and all species in five genera, as proven hosts, and another 64 species as associated plants. For the current list of hosts plants, visit their website at: http://www.aphis.usda.gov/plant_health/plant_pest_info/pram/downloads/pdf_files/usdaprlist.pdf

SYMPTOMS MAY DIFFER ON TRUNK HOSTS

Canker oozing dark stain with no apparent wound in the bark of a coast live oak. Joseph O'Brien, USDA Forest Service, Bugwood.org



Canker bleeding dark colored sap, no apparent wound in bark. Joseph O'Brien, USDA Forest Service, Bugwood.org

In later stages of the disease, the bark may split and bleeding cracks appear on the bark surface. Joseph O'Brien, USDA Forest Service, Bugwood.org

Bark cracks and bleeding on coast live oak. Joseph O'Brien, USDA Forest Service, Bugwood.org

Beneath the bleeding, cankers are sunken or flattened, bark is discolored dark red-brown to black, and outlined by thin black lines. Joseph O'Brien, USDA Forest Service, Bugwood.org

BIOLOGY and DAMAGE:

P. ramorum is a fungus-like organism that thrives in cool, humid climates and produces abundant spores under moist conditions. This pathogen has a complex life cycle involving two sexual mating types (A1 and A2), polycyclic asexual spore forms, two different general categories of host plants, and dissimilar symptomology for the two types of hosts. Most temperate-climate *Phytophthora* pathogens are root-infesting, soil and water-borne organisms. Conversely, *P. ramorum* is among a small number of *Phytophthora* species that infects trees and plants above the soil line (leaves, shoots, woody stems and bark), and is primarily spread aerially although it can be spread through contaminated soil and water.

To complete its sexual cycle, *P. ramorum* requires individuals of the two mating isolates, A1 and A2. However, sexual reproduction is not required to cause disease, and either type of mating isolate alone is able to infect host plants. Initially, only A1 isolates were found in Europe (primarily in nursery stock), and A2 isolates were found in North America (primarily in forest settings). This changed in 2003 with the discovery of A1 and A2 isolates in North America and Europe, respectively, probably due to the transportation of infected nursery stock. That same year scientists confirmed the first cases of nearby forest trees becoming infected by spores from diseased nursery stock. The full impact of these findings is as yet unknown.

Because the two mating types are rarely found together, *P. ramorum* usually reproduces asexually. The fungus develops oval-shaped sacs called sporangia (a particularly diagnostic characteristic), which produce and store infectious, swimming zoospores. Most sporangia are produced during the rainy season in areas with wet climates and constant mild temperatures. When a sporangium lands on a suitable host it releases zoospores, which are blown or splashed onto surrounding leaves and twigs of susceptible hosts. Zoospores colonize the host material, and in conditions of high humidity (close to 100%) and moderate temperature (64-68°F or 18–20°C), new sporangia and hard, round, resting forms called chlamydospores are produced on the lesions in approximately 48 hours. The dark brown chlamydospores accumulate in the soil beneath the plant, where they can survive for years. Chlamydospores can overwinter within host material down to 16°F (-9°C), and survive summers in California.

Infected foliar hosts, such as California bay laurel (*Umbellularia californica*) and rhododendrons (*Rhododendron* spp.), typically exhibit leaf spots and twig dieback, but rarely die from the disease. However, they provide a reservoir for the infectious zoospores, which may then be dispersed to trunk hosts such as oaks and other trees. In some foliar hosts, only leaves are affected (ramorum leaf blight: e.g., bay laurel, maples and buckeye), in others leaf infection is accompanied by twig/branch infections and

dieback (ramorum dieback: e.g., rhododendrons, Pacific madrone, Pacific huckleberry and Toyon/Christmasberry), and in others, wilt symptoms may be observed on shoot tips (e.g., tanoak).

Trunk hosts are considered terminal hosts: they become infected when exposed to spores produced by neighboring foliar hosts, the pathogen does not appear to spread from intact bark cankers, and the hosts often die. Oak leaves are rarely colonized by *P. ramorum*, so re-infection from the host tree is not likely. This is why infection in oaks depends on the presence of adjacent infected foliar hosts. Infections on the trunk develop into bleeding cankers with dark colored sap flowing from the trunk, but no apparent wound in the bark. *P. ramorum* preferentially colonizes the sugar-rich phloem of the host and cankers develop under the bark. The outer bark and xylem are only marginally colonized. Sporulation has not been observed on the intact outer surface of cankers; however, if infected cambium is exposed and water is present, the pathogen is able to sporulate on the exposed surfaces, and has even been recovered from wet wood chips of infected hosts.

Tanoaks seem to be an exception to these patterns of infection. Tanoaks are the most susceptible trunk hosts, and young tanoaks also commonly suffer foliar infections which result in leaf blight and killing the plant from the "top down." Multiple cankers often occur at different heights on tanoaks, whereas on less susceptible oak species cankers normally only occur near the soil line. Once a tree is girdled by cankers, the death process begins and secondary organisms and opportunistic pathogens (e.g., bark and ambrosia beetles, wood decay fungi and canker rots) may hasten the decline of the tree. In highly susceptible species such as tanoaks, death can occur in as little as two years.

For high quality diagnostic and overview images see the Pests and Diseases Image Library Species Content Page, Fungi: Sudden Oak Death: http://www.padil.gov.au/viewPestDiagnosticImages.aspx?id=525

IDENTIFICATION:

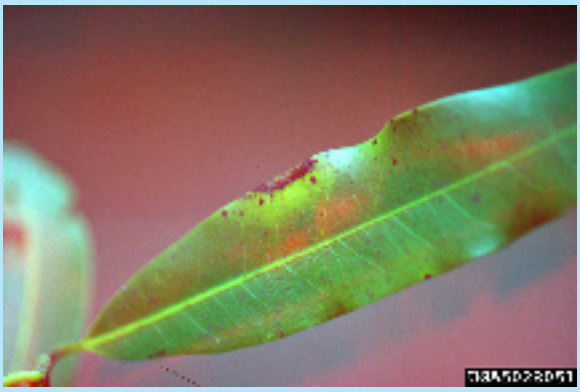
P. ramorum can not be diagnosed by visual inspection of symptoms alone. Many other organisms and injuries produce similar symptoms. Confirmation of *P. ramorum* can only be done by laboratory analysis. However, plants can be screened for disease symptoms to identify samples to submit for further testing. See "what to look for" below.

Submitting samples for identification: For foliar samples collect 10 or more symptomatic leaves in various stages of symptom development. Place the sample in a plastic bag and keep cool, away from direct sunlight. Do not add water. Bring the sample to your state Extension plant diagnostic lab within 24 hours (Visit NPDN.org for a list of labs). In Maryland, samples can also be submitted to the Maryland Department of Agriculture (410-841-5920) or the UMD Home & Garden Information Center (HGIC) (410-342-2507). While bark sampling is the only way to directly confirm disease on an

SYMPTOMS MAY DIFFER ON FOLIAR HOSTS

Symptoms on rhododendron: leaf blight (spots or blotches) at leaf tips and petiole, penetrating from top to bottom. Joseph O'Brien, USDA Forest Service, Bugwood.org

Symptoms on :sweet bay: spots at leaf tip. Joseph O'Brien, USDA Forest Service, Bugwood.org



Symptoms on California laurel: spots along leaf margin. Joseph O'Brien, USDA Forest Service, Bugwood.org

Symptoms on huckleberry: discolored leaves. Joseph O'Brien, USDA Forest Service, Bugwood.org

Symptoms on redwood: needle blight. Joseph O'Brien, USDA Forest Service, Bugwood.org

Symptoms on tanoak: tip blight (Shepherd's crook). Joseph O'Brien, USDA Forest Service, Bugwood.org

infected tree, this procedure can damage the tree and requires special equipment. Contact HGIC at http://www.hgic.umd.edu/ for information on sampling tree hosts.

WHAT TO LOOK FOR:

Symptoms can be grouped into three general disease categories, affecting two types of hosts: cankers on trunk hosts, and leaf blight and twig dieback on foliar hosts. Hosts can exhibit symptoms of one or more of these at the same time. Ornamental nursery plants and forest understory plants typically show foliar and twig symptoms. Oaks and other tree hosts usually display trunk cankers. Symptoms may vary slightly between tree species. Although bleeding sap is typically the earliest symptom on most trees, tanoak usually exhibits wilted twig shoots initially. *P. ramorum* infection in tanoak twigs can lead to shoot tip dieback and Shepherd's crook; leaf flagging is a particularly good indicator of the disease in tanoak.

Symptoms on trunk hosts:

- Bleeding cankers on the trunks of oaks and other tree hosts > 4" dbh (10 cm) (with the exception of tanoaks).
- Cankers typically occur above the soil line, within the first 10 feet (3 m), although occasionally as high as 65 feet (20 m), and cankers can be over 7 feet (2 m) in length.
- Cankers initially bleed a burgundy-red to black oozing sap from an intact bark surface that shows no obvious holes or wounds.
- The bleeding does not have a foul odor.
- In later stages of the disease, the bark may split; beneath the bleeding, cankers are sunken or flattened, with bark discolored dark red-brown to black, and delimited (outlined) by thin black lines in the inner bark.
- Bleeding (oozing) of cankers is easier to detect in dry weather.
- Sudden oak death syndrome: Relatively rapid progression (2 to 4 weeks) from healthy-green to dead-brown, with full complement of dead leaves still on the tree

Symptoms on foliar hosts: leaf blight (spots) and twig symptoms differ on different hosts and generalization is hard, but typically:

- Leaf blight and twig dieback generally occur on ornamental and forest understory plant hosts, but rarely kills them.
- Lesions can occur anywhere on the leaf blade or the petiole and may be accompanied by small branch cankers on some foliar hosts.
- Lesions may penetrate through leaf tissue so that top and bottom have identical spots.
- Leaf spots are usually dark gray to brown with indistinct edges, a watersoaked appearance, and may be surrounded by a halo of yellow or a diffuse margin of black.

- Spots may be triangular in shape and extend along the leaf mid-vein, or irregular in shape and found wherever water collects on the leaf surface (leaf tip, along edges, near petiole).
- Spots may range in size from 2/5" (0.5 cm) to nearly half the leaf surface.
- Many plants drop infected leaves, defoliating the lower part of the plant, eventually leading to dieback of twigs and small branches. (Leaf drop is particularly common on infected camellias.)
- Wilt symptoms have been observed on shoot tips of various hosts (*Lithocarpus* spp., tanoak)
- Christmas trees susceptible to *P. ramorum* may suffer needle blight.

MONITORING:

The USDA Forest Service conducts a national *P. ramorum* survey program of forests and streams, focusing on areas adjacent to nurseries. Aerial surveys of forests are conducted annually for damaged tanoak (*L. densiflorus*) in Oregon and for *Quercus* spp. and tanoak in California. Aerial surveys are used in conjunction with risk models to target areas for ground surveys, and follow-up field visits have resulted in new *P. ramorum* detections. Various survey and quarantine programs for nursery plant material have been initiated at the state and federal levels (see below under "Regulatory").

MANAGEMENT:

The first priority in managing this disease is preventing the introduction of *P. ramorum* into new areas. Quarantine and sanitation protocols for nursery plants, wood products and soil associated with infection sites are enacted to prevent both long and short distance spread. However, there are considerable challenges in controlling this pathogen because of its wide range of hosts, large actual and potential geographic range, occurrence in woodlands, landscapes and nurseries, its complex life cycle, the limited number of eradicant treatments and the efficacy of those treatments.

Regulatory

In the early 2000's, risk assessments for *P. ramorum* were conducted in the U.S., Canada, UK and Europe, resulting in regulatory actions at state, national and international levels. By 2002, APHIS published regulations controlling the movement of *P. ramorum* from twelve infested counties in California and an area under eradication in Oregon, and began to strictly regulate imports of host plants from Europe. As part of the USDA federal quarantine program, a U.S. National Nursery Survey was implemented in 2002, allowing for inspection of nursery plants for evidence of infection with *P. ramorum*. In 2004, in response to 2.3 million potentially infected nursery plants being shipped throughout the nation, a USDA Federal Order was issued to restrict the movement of *P. ramorum* infected nursery plants from California, Oregon and Washington. This was followed in January 2005 by an Emergency Federal Order further regulating interstate shipping of plants from all commercial nurseries in California, Oregon, and Washington. This order also required both host and non-host nurseries be inspected in order to move nursery stock interstate, and that trace forward and trace back activities be conducted if infected nursery material is detected. The U.S. National Nursery Survey ended in 2006, however nursery surveys continue under the January 2005 Emergency Federal Order, and individual states may continue surveys through the USDA Cooperative Agricultural Pest Survey (CAPS) program.

APHIS currently regulates plants in 35 families, 70 genera and over 109 species and seeks to restrict the spread of the disease pathogen into non-infested areas. When *P. ramorum* is confirmed in an area, quarantines are focused on preventing spread of the pathogen through the domestic movement of infected plants, plant products, soil, other growing media, compost, and water. Surveys for *P. ramorum* are conducted wherever potential infestations are reported, and when infected plants are found in forests, a buffer area of at least 0.25 miles from the outermost infected plants is used to establish the quarantined area (0.5 mile in Oregon). When *P. ramorum* is found in nurseries, APHIS requires a delimiting survey of the entire nursery. State regulatory officials coordinate destruction and disposal protocols for this regulated organism.

Cooperative research is being done on hosts, methods of detection, and effective treatments. A massive public education campaign was launched to raise awareness and to help in detecting new *P. ramorum* infections. The State of California even provides facilities to remove soil from shoes and bicycle tires, and closes trails seasonally where *P. ramorum* is known to be present in the soil, water or flora. A cooperative effort among government agencies and industry was initiated to suppress northward movement of *P. ramorum* in California by creating a "No Host Zone." Herbicides were used to kill tanoak in a band seven miles long by two miles wide along the Van Duzen River, 20 miles north of the most northern forest detection in California. By the end of 2005, the USDA had spent more than $55 million on regulatory, research and educational issues related to *P. ramorum*.

Cultural Control

Sanitation is critical to control a polycyclic pathogen such as *P. ramorum*. Sanitation practices where *P. ramorum* is endemic should include removing, testing and destroying symptomatic stock. Removing infected plant debris and humus reduces the level of *P. ramorum* at the soil surface. Disinfecting tools, benches, workers' shoes, hands, gloves and equipment is essential. Sodium hypochlorite (10% chlorine bleach solution) or rubbing alcohol give excellent results, but can be phytotoxic. Commercially available disinfectants are also available (ex., Physan 20, Greenshield). Site sanitation during and after propagation is necessary to maintain pathogen-free material and must include use of pathogen free propagating material and water source, sterilized potting media and pots, and a strict sanitation protocol as above.

Best management practices to avoid infection with *P. ramorum* include not over-watering or applying excess nitrogen. Cultural measures such as pruning low hanging branches and pulling mulch away from the trunk may help reduce moisture on the trunk, thereby preventing canker formation. Irrigation water, particularly re-circulated water, can become infested with and spread *P. ramorum*, so methods to disinfest water such as ozonation, chlorination, filtration and UV irradiation should be utilized.

Non-host plants should be chosen for the landscape in areas where *P. ramorum* is endemic. Certain white oak species (*Q. douglasii*, *Q. lobata*, and *Q. robur*) are not as susceptible to *P. ramorum* as red oak species. Several studies testing host susceptibility suggest resistance to *P. ramorum* is present in several taxa: significant differences in disease susceptibility were observed among species as well as among hybrids of *Rhododendron*. Research in this area continues.

Mechanical/Physical Control

The major eradication methods for *P. ramorum* in forests and nurseries are the removal and destruction of infected plant material. For information on forest postharvest treatments when wood products are to be used, see the Mitigation Measures section, beginning on page 46 of The USDA APHIS Risk Analysis for P. Ramorum, accessible at: http://ww.aphis.usda.gov/plant_health/plant_pest_info/pram/downloads/pdf_files/pra-cphst-11-07.pdf

Biological Control

In vitro laboratory research with biological antagonists indicated that control was possible, but field tests were unsuccessful. Further research is necessary.

Chemical Control

Eradication of *P. ramorum* with chemicals is problematic as large-scale treatment of forests is impractical, and the pesticides available for control of *Phytophthora* species are fungistatic (inhibit the growth of fungi without killing it), not fungicidal (able to kill fungi). The efficacy of chemical control is dependent upon timing, type of application and location of the pathogen in or on the plant.

Trees: The fungicide, Agri-Fos®, has been found effective in preventing healthy trees from becoming infected, but it is only suitable for treating individual landscape trees, not trees in forests. Agri-Fos® (phosphonate) and Pentrabark® were approved in California in 2003 for use together as a treatment for *P. ramorum* on *Quercus* spp. and tanoak.

Nursery stock: No chemical treatments are currently available to treat nursery stock.

Soil fumigants: Chloropicrin, methyl bromide, metam sodium and Dazomet are available for use in nurseries and landscapes with confirmed detections of *P. ramorum.*

LOOK-ALIKE DAMAGE:

Other pathogens and environmental conditions can cause similar symptoms in plant hosts, so it can be very difficult to differentiate *P. ramorum* infections from those caused by other factors.

- Environmental factors, including sunburn, drought, freeze damage, and salinity may produce similar foliar symptoms.
- Herbicide injury, fertilizer burn and over-watering can cause leaf spots, wilt or die-back.
- Newly detected *Phytophthora* species have been found (*P. nemorosa*, *P. kernoviae*, *P. hedraiandra*, and *P. pseudosyringae*) that occupy a similar ecological niche to *P. ramorum*, cause similar symptoms, and are readily confused with *P. ramorum*.
- Other *Phytophthora* can cause bleeding cankers linked to root infections (aerial bleeding cankers not connected to the root collar are a good indication a tree is infected by *P. ramorum*).

- Other diseases can cause symptoms similar to *P. ramorum*: Canker rots, slime flux, leaf scorch, and root diseases.
- Oak wilt and oak decline are diseases in Eastern hardwood forests most likely to be confused with *P. ramorum*. Oak wilt does not cause trunk cankers, and oak decline is a slow-acting complex that kills oaks within 3-5 years of onset of crown symptoms. Dieback associated with *P. ramorum* occurs over a growing season or two.

Remember: Only laboratory testing can ensure an accurate diagnosis of *P. ramorum.*

How to Report a Possible Sighting/Infestation

In Maryland:
University of Maryland Cooperative Extension Exotic Pest Threats Website:
http://hgic.umd.edu/faq/sendAQuestion.cfm

Maryland Department of Agriculture: call 410-841-5920 to report suspect pests;
visit http://www.mda.state.md.us/plants-pests/invasive_species.php for information.

Nationally:
USDA-Animal and Plant Health Inspection Service (APHIS):
http://www.aphis.usda.gov/services/report_pest_disease/report_pest_disease.shtml

National Plant Diagnostic Network: http://www.npdn.org/DesktopDefault.aspx

Where to Get More Information:

UMD Cooperative Extension Exotic Pest Threats Website: http://www.PestThreats.umd.edu/index.cfm

California Oak Mortality Task Force: http://nature.berkeley.edu/comtf/

CSREES National Pest Alert, *P. ramorum*: http://www.csrees.usda.gov/nea/pest/pdfs/suddenoakdeath_pest_alert.pdf

Global Invasive Species Team: http://tncweeds.ucdavis.edu/products/gallery/phyra1.html

Project Participants: Chris Sargent, Research Assistant; Michael Raupp, Entomologist; Sandra Sardanelli, IPM Coordinator; Paula Shrewsbury, Entomologist; David Clement, Pathologist; Mary Kay Malinoski, Entomologist; Karen Rane, Pathologist.

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