Guide to Diseases of *Phytophthora ramorum* in Ornamental Nurseries

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Introduction

*Phytophthora ramorum*, a newly discovered plant pathogen, has caused widespread mortality in native oaks in many coastal areas of central and northern California and in southwestern Oregon. On oaks, the disease is commonly called Sudden Oak Death, because trees typically appear to die rapidly. In infested wildlands (forests and woodlands) the pathogen has been detected on several other trees, shrubs, vines and herbaceous native plants, where it causes less destructive leaf blights, stem cankers, and tip dieback.

In Europe, the pathogen has been detected for many years causing similar leaf spot and twig dieback diseases, but there it occurs primarily on ornamental plants in nurseries and gardens. It has been tracked moving from infected nursery outplantings, to neighboring shrubs, and then causing lethal infections of adjacent trees. This heightens the concern that infected nursery stock could move the pathogen to new areas and cause wildland infestations.

Camellias, rhododendrons and other popular ornamental plants are susceptible to *P. ramorum* infection, and the pathogen has been detected on nursery stock in California, the Pacific Northwest, and Canada. International, federal state quarantines are in effect, requiring nursery inspections, and if the pathogen is found, affected nursery stock must be destroyed as a means of eradication.

The pathogen can move long distances through nursery shipments of infected nursery stock. North American detections in wildlands and nursery stock have nearly all been found to be from a unique North American genotype, but in 2003, isolations from nursery stock in the Pacific Northwest and Canada contained the unique European genotype. This implies that the pathogen may have moved to North America from Europe, possibly in nursery stock. In February 2004, *P. ramorum* was found on Camellias in a large southern California nursery. Potentially infected stock was shipped to 40 states and several countries. By September 2004, traces of these nursery shipments and a national survey have detected the pathogen’s presence in 21 states at 157 sites and in British Columbia.

In addition to providing a brief introduction to the history and biology of the pathogen, this guide contains photos and descriptions of *P. ramorum* symptoms on ornamental plants that will aid in plant inspection and early detection of the disease in nurseries. Nursery management practices are suggested that will help prevent the introduction and development of disease in nurseries.
Background

**Disease occurrence on wildland hosts in the US**—Sudden Oak Death was first detected in the Central California Coast in the mid-1990s. Tens of thousands of tanoaks (*Lithocarpus densiflorus*), black oaks (*Quercus kelloggii*) and coast live oaks (*Quercus agrifolia*) have died due to *P. ramorum* infection. In Marin, Santa Cruz and Monterey Counties, portions of the wildland-urban interface forest changed dramatically: tree crowns seemed to turn brown in a few weeks, giving the impression of instantaneous mortality.

In summer 2000, an unknown *Phytophthora* species was isolated from the dying trees, proven to cause the mortality, and recognized as the same species as a yet unnamed *Phytophthora* species found on European nursery and garden plants in 1993. This pathogen was subsequently named *Phytophthora ramorum* S. Werres & A.W.A.M. de Cock in 2001.

As of summer 2004, *P. ramorum* has been detected in wildlands in 14 counties in California and in Curry County, southwestern Oregon (see map). Symptoms range from lethal bark cankers on several oak species and tanoak to leaf spots and twig dieback on native rhododendron. It has been found in three forest types: California coastal evergreen forests, redwood forests with tanoak understory, and in Oregon forests dominated by tanoak. A current list of susceptible plants—wildland and ornamental hosts—can be found on the California Oak Mortality Task Force website: www.suddenoakdeath.org.

**Table 1.** Wildland plants known to be susceptible to *Phytophthora ramorum* in the US (summer, 2004)

<table>
<thead>
<tr>
<th>Plant Name</th>
<th>Plant Part(s) Affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bigleaf maple (<em>Acer macrophyllum</em>)</td>
<td>Foliar</td>
</tr>
<tr>
<td>California bay laurel / pepperwood / Oregon myrtle (<em>Umbellularia californica</em>)</td>
<td>Foliar &amp; twig</td>
</tr>
<tr>
<td>California black oak (<em>Quercus kelloggii</em>)</td>
<td>Trunk</td>
</tr>
<tr>
<td>California buckeye (<em>Aesculus californica</em>)</td>
<td>Foliar &amp; twig</td>
</tr>
<tr>
<td>California coffeeberry (<em>Rhamnus californica</em>)</td>
<td>Foliar</td>
</tr>
<tr>
<td>California hazelnut (<em>Corylus cornuta</em>)</td>
<td>Foliar</td>
</tr>
<tr>
<td>California honeysuckle (<em>Lonicera hispidula</em>)</td>
<td>Foliar</td>
</tr>
<tr>
<td>Canyon live oak (<em>Quercus chrysolepis</em>)</td>
<td>Trunk</td>
</tr>
<tr>
<td>Cascara (<em>Rhamnus purshiana</em>)</td>
<td>Trunk</td>
</tr>
<tr>
<td>Coast live oak (<em>Quercus agrifolia</em>)</td>
<td>Foliar &amp; twig</td>
</tr>
<tr>
<td>Coast redwood (<em>Sequoia sempervirens</em>)</td>
<td>Twig</td>
</tr>
<tr>
<td>Douglas-fir (<em>Pseudotsuga menziesii var. menziesii</em>)</td>
<td>Foliar &amp; twig/branch</td>
</tr>
<tr>
<td>Evergreen huckleberry (<em>Vaccinium ovatum</em>)</td>
<td>Twig</td>
</tr>
<tr>
<td>Grand fir (<em>Abies grandis</em>)</td>
<td>Foliar &amp; twig/branch</td>
</tr>
<tr>
<td>Madrone (<em>Arbutus menziesii</em>)</td>
<td>Foliar &amp; twig</td>
</tr>
<tr>
<td>Manzanita (<em>Arctostaphylos manzanita</em>)</td>
<td>Foliar &amp; twig/branch</td>
</tr>
<tr>
<td>Pacific rhododendron (<em>Rhododendron macrophyllum</em>)</td>
<td>Foliar</td>
</tr>
<tr>
<td>Poison oak (<em>Toxicodendron diversiloba</em>)</td>
<td>Trunk</td>
</tr>
<tr>
<td>Wood Rose (<em>Rosa gymnocarpa</em>)</td>
<td>Trunk/Foliar &amp; twig</td>
</tr>
<tr>
<td>Salmonberry (<em>Rubus spectabilis</em>)</td>
<td>Foliar &amp; twig/branch</td>
</tr>
<tr>
<td>Shreve oak (<em>Quercus parvula v. shrevei</em>)</td>
<td>Foliar</td>
</tr>
<tr>
<td>Tanoak (<em>Lithocarpus densiflorus</em>)</td>
<td>Trunk</td>
</tr>
<tr>
<td>Toyon (<em>Heteromeles arbutifolia</em>)</td>
<td>Foliar &amp; twig/branch</td>
</tr>
<tr>
<td>Western starflower (<em>Trientalis latifolia</em>)</td>
<td>Foliar</td>
</tr>
</tbody>
</table>
Disease occurrence on ornamentals in the US - In 2000, *P. ramorum* was detected on rhododendron plants in a Santa Cruz County nursery located in a forest with many susceptible species and immediately surrounded by dead and dying oak and tanoak trees. In 2003, *P. ramorum* was detected in several nurseries located in Santa Cruz County, the Bay Area, Central Valley, and Placer County in California; and in the Pacific Northwest in Oregon, Washington, and British Columbia. In the spring of 2004, *P. ramorum* was detected in *Camellia* nursery stock shipped from a large southern California nursery to many locations throughout the United States and Canada.

Disease occurrence on ornamentals and native hosts in Europe - In 1993, rhododendrons and viburnums in Germany and the Netherlands showed twig dieback, cankers, and leaf spots. The unrecognized *Phytophthora* species isolated from the plants was largely ignored until 2000, when the morphologically similar organism associated with oak and tanoak mortality in California was discovered. In Europe (summer 2004), the pathogen has been found in over 400 nurseries and public gardens in 9 countries on 13 genera. Most of the diseases found on these ornamental species are covered in the next section. Until late 2003, *P. ramorum* had only been found in plant nurseries and gardens, and not on native trees. However, beech, horse chestnut, turkey oak, sweet chestnut and Holm oak in woodland settings have been found infected at multiple sites in England. These sites were associated with previously identified infected rhododendron plantings. Infected red oaks, an important lumber species native to the eastern US, have been found in gardens in the Netherlands and the UK, and were found associated with infected rhododendrons planted nearby.

Biology

*P. ramorum*, while having many features in common with fungal organisms, is not a true fungus. Technically it belongs in the kingdom Chromista (also known as Straminipila), related to diatoms and brown algae. *Phytophthora* species are Peronosporomycetes (Oomycetes) or “water molds” and require a moist environment to actively grow and reproduce. The genus *Phytophthora* has over 60 species, many of which are important plant pathogens. The body of the organism is made up of thread-like strands, each strand called a hyphae, and collectively called mycelium. Mycelium develops through leaf, bark, and vascular tissue.

*P. ramorum* produces several reproductive structures important for pathogen spread and survival, including **sporangia**, **zoospores** and **chlamydospores** (see Figure 2).

Sporangia give rise to the zoospores, which are bi-flagellate spores that can swim in water. Chlamydospores are resistant, resting spores that help the pathogen survive extreme temperatures, dryness and other harsh conditions. *P. ramorum* exists within a temperature range of 36 to 80 °F with an optimum temperature of 68 °F. These spore structures commonly form on leaf surfaces of susceptible leaves and twigs following prolonged wetting. They are moved in contaminated soil, from plant to plant via windblown rain, or by direct contact of infected leaves. In California’s forests the pathogen sporulates prolifically on California bay laurel trees (*Umbellularia californica*) that serve as reservoirs for inoculum (Figure 3). Infected California bay laurel can also
be an important source of inoculum when in close proximity to nursery stock.  

*P. ramorum* is **heterothallic**, meaning that sexual reproduction can only occur between two different mating types, called A1 and A2. The European *P. ramorum* genotype is predominantly A1 mating type, and the North American genotype is A2. **Oospores**, the sexual spore, which can result from the union of A1 and A2 strains, have not been observed under natural conditions. However, the European mating type was found in two Pacific Northwest nurseries and one Canadian nursery. In two Pacific Northwest nurseries (under the same ownership) both the North American A2 and European A1 strains were found. This raises concerns that both mating types might eventually meet and reproduce sexually to create new, potentially more virulent hybrids, capable of exploiting new habitats and host species.  

There may be differences in the virulence and symptom expression between the European and North American genotypes. The symptoms described in this guide for Rhododendron, Camellia, Viburnum, Pieris, Douglas-fir, and grand fir are based on observations made in North America infected with the North American genotype. The disease descriptions given in this guide for other ornamentals are based on observations in Europe infected with the European genotype.  

**Symptoms on Ornamental Nursery Hosts**  

Although hosts of *P. ramorum* show a range of symptoms, in general the disease is characterized by irregular, necrotic leaf lesions, instead of distinct leaf spots. A leaf infection can develop down the petiole into twigs. Sometimes infections can occur initially on or develop into stems and cause blights, where stem and associated leaves wilt, become necrotic, and die. A distinct dark zone line can mark the advance of the infection on some species such as California bay laurel. Under natural conditions, California bay laurel tends to be infected on the tip of the leaf, where the leaf hangs down and water accumulates (see Figure 3). This characteristic can be seen in some nursery hosts as well. Infection often occurs in leaf areas where free water remains on leaves for long periods, such as deep in the leaf-canopy, near or touching the soil, and between overlapping or “cupped” leaves.  

Symptoms due to fertilizer burn, chemical injury, drought injury, freeze damage, sunburn and root damage can look similar to *P. ramorum* infection. The best way to distinguish abiotic damage on foliage from that caused by plant diseases including *P. ramorum* is to check the underside of the leaf and lesion margins. In a bbiotic injury, margins of the lesions will be abrupt and distinct, not diffuse (see Figure 6). Check for environmental problems, flooding, or openings in shade cloth that may explain the plant damage. Abiotic injury is often found distributed over the entire plant, while *P. ramorum* leaf spots are often found on only a few leaves or on one portion of the plant.  

**Rhododendron** (Ericaceae)

**Figure 4.** *Phytophthora ramorum* symptoms on Rhododendron. A & B: leaf lesions on *R.* ‘Todmorden’; C: stem and bud necrosis on a rhododendron from Germany.

**Symptoms** of *P. ramorum* on rhododendrons include primarily leaf lesions, although small-branch dieback is observed in European landscapes and plant mortality in native rhododendrons is sometimes observed in Oregon forests. Leaf lesions penetrate through the leaf so the area of necrosis is identical on both sides of the leaf. Lesions can be triangular in shape and extend along the leaf mid-vein or located where water remains on the leaf for extended periods. Lesions are frequently seen along the edges, near the petiole and at the leaf tip. During an active infection, lesion margins have diffuse edges which become less diffuse and more distinct as the weather becomes warmer and drier. Infected leaves may fall prematurely from the plant. Small branch infections produce brown to black cankers. Leaves located distally to the cankers can wilt, roll and eventually defoliate due to lack of water. Branch infections can move distally or proximally, and through the petiole into the leaf base. This growth through the petiole results in the classic triangular-shaped lesion of *Phytophthora* species.

**Figure 5.** Symptom progression (approximately 3 weeks) of a laboratory infected *R.* ‘Cunningham’s White’. (Aa & Ab) indicate initial leaf infection sites. Infection Aa develops through petiole, forming stem canker (B). Infection develops upward and downward in stem, and into leaf petioles and bases of leaves (C).

Steve Tjosvold, UC Cooperative Extension
Azaleas have not been found infected with *P. ramorum* but laboratory inoculation studies indicate that some azaleas, particularly deciduous azaleas, are susceptible (e.g., ‘Northern Hi-lights’ and California-native *Rhododendron occidentale*). Cultivars showing resistance include ‘Purple Splendor’ and ‘Hinocrimson’.

Other diseases and conditions that may cause leaf necrosis and be confused with *P. ramorum* infection include other *Phytophthora* species that infect the aerial portion of rhododendrons, including *P. cactorum*, *P. citricola*, *P. hibernalis*, *P. nicotianae* (=*P. parasitica*) and *P. syringae*. Abiotic factors that can cause leaf necrosis include chemical injury, drought, cold, sun scald, and fertilizer burn (see Figure 6). Wilting and death of an entire plant is more likely caused by root weevils or root-infecting *Phytophthora* species, not *P. ramorum*.

### Rhododendron species and cultivars confirmed infected with *Phytophthora ramorum*

- *R. augustini*
- *R. 'Baden Baden'*
- *R. balfourianum*
- *R. brachycarpum*
- *R. catawbiense*
- *R. 'Catawbiense Boursalt'*
- *R. Catawbiense Grandiflorum'*
- *R. caucasicum*
- *R. 'Colonel Coen'*
- *R. 'Cunningham's White,'*
- *R. 'Everestianum'*
- *R. ferrugineum*
- *R. 'Gomer Waterer'*
- *R. macrophyllum*
- *R. 'Mrs. G.W. Leak'*
- *R. 'Nancy Evans'*
- *R. ponticum*
- *R. repens*
- *R. 'Roseum Elegans'*
- *R. 'Schneewolk'*
- *R. 'Todmordon'*
- *R. 'Unique'*
- *R. 'Vulcan'*
- *R. yakushimanum*  

### Species resistant to *Phytophthora ramorum* in laboratory studies

- *R. arborescens*
- *R. carolinianum*
- *R. macrosepalum*
- *R. maximus*
- *R. minus*
- *R. poukanense*
- *R. simsii*
- *R. viscosum*

Figure 6. Leaf necrosis on rhododendron leaves caused by unknown, noninfectious disorders. 
*Steve Tjosvold, UC Cooperative Extension*

Figure 7. Rhododendron ‘Vulcan’ showing symptoms of both *P. ramorum* and rust. 
*Canadian Food Inspection Agency*
Symptoms of *P. ramorum* on camellias are limited to leaf lesions which can vary in size from a half-centimeter in diameter to covering nearly half the leaf depending on environmental conditions. Lesions are located primarily at the leaf tip or the edge of the leaf. Lesions can be surrounded by diffuse margins or thick black zone lines. Infected leaves abscise prematurely, and the lower part of the plant can defoliate. No tip die-back or small branch cankers caused by *P. ramorum* has been observed on *Camellia* species.
Not many other diseases are likely to be confused with *P. ramorum* on camellias. Scorch symptoms are most commonly confused with *P. ramorum* infection on certain specific camellia varieties in areas that receive reflective heat and sun on the exposed leaves of the plant. *Pestalotia* sp. and *Pestalotiopsis* sp. can act as weak secondary pathogens following leaf scorch and can cause necrosis.

**Figure 13.** Limited leaf lesions on *C. sasanqua* ‘Bonanza’ in a dry climate. *Sandy Jordan, USDA APHIS*

**Figure 14.** Symptoms of sun scorch on camellia. *Tomas Pastalka, CDFA*
Symptoms of *Phytophthora ramorum* on pieris (Andromeda) include necrotic leaf spots similar to those on rhododendron, as well as branch tip dieback. Infected leaves often abscise prematurely.

**Pieris species and cultivars confirmed infected with *Phytophthora ramorum***

<table>
<thead>
<tr>
<th>Species and Cultivar</th>
<th>Species and Cultivar</th>
<th>Species and Cultivar</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>P. floribunda x japonica</em></td>
<td><em>P. formosa x japonica</em></td>
<td><em>P. japonica x formosa</em></td>
</tr>
<tr>
<td><em>P. formosa var. forrestii</em></td>
<td><em>P. japonica 'Flaming Silver'</em></td>
<td></td>
</tr>
<tr>
<td><em>P. formosa var. forrestii x P. japonica</em></td>
<td><em>P. japonica 'Variegata'</em></td>
<td></td>
</tr>
</tbody>
</table>

Other diseases of pieris include aerial *Phytophthora* species that cause leaf lesions similar to *P. ramorum*. *Phytophthora* species also cause root rots (*P. citricola, P. nicotianae* [=*P. parasitica*]) in pieris, but these are likely to affect the whole plant rather than individual leaves or twigs. Initial symptoms on new growth can resemble that caused by *Botrytis*. 

October 2004 draft

**Pieris** (Ericaceae)
Symptoms of *P. ramorum* on viburnums include stem cankers and/or necrotic leaf lesions. Stem cankers can occur at the base of the plant close to the soil line or on smaller branches throughout the plant canopy. As a stem canker grows, leaves normally attached to the stem in the canker area die and defoliate. As the stem becomes girdled by the canker, the leaves located between the canker and the stem tip wilt and eventually turn brown. These brown leaves usually stay attached to the stem. Leaf infections occur initially on the leaf tip, edge or petiole. A leaf infection can grow through the leaf, into the leaf petiole, and into the stem to form a canker.

<table>
<thead>
<tr>
<th><em>Viburnum</em> species and cultivars confirmed infected with <em>Phytophthora ramorum</em></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>V. bodnatense</em></td>
</tr>
<tr>
<td><em>V. x burkwoodii</em></td>
</tr>
<tr>
<td><em>V. davidii</em></td>
</tr>
</tbody>
</table>

**Other diseases or conditions** - Frost damage can cause the blackening of young shoots and dieback. Whole plants wilt due to drought, anaerobic conditions caused by overwatering, or root diseases caused by *Phytophthora* species.
**Kalmia** (Ericaceae)

![Image of Kalmia leaves infected with P. ramorum.](Central Science Laboratory, DEFRA (UK) (Crown Copyright))

**Figure 20.** Kalmia latifolia leaves infected with *P. ramorum*.

**Symptoms** on *Kalmia* (mountain laurel) have been found only on leaves. The disease is manifested as necrosis along the leaf margins and down the midvein.

*Kalmia latifolia* is the only species to have been found infected with *P. ramorum*.

*Kalmia angustifolia* has been shown in laboratory studies to be resistant to *P. ramorum*.

Two other diseases known to cause leaf spotting in mountain laurel are *Mycosphaerella colorata* which causes small silver to white spots, and *Phomopsis kalmiae* which causes round brown lesions with a distinct zone line, as opposed to the single amorphous necrotic lesion caused by *P. ramorum*.

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**Leucothoe** (Oleaceae)

![Image of Leucothoe leaves infected with P. ramorum.](Stephen Eales, PHSI (UK) (Crown Copyright))

**Symptoms** observed on leucothoe tend to begin at the leaf tips. The pathogen subsequently grows through the leaf tissues toward the leaf base, causing a brown to black discoloration. No cankers on the stem have been observed.

The only cultivar found to be affected is *Leucothoe fontanesiana* ‘Rainbow’, and no other cultivars have been tested for resistance.

**Another disease** that can cause leaf lesions in leucothoe is *Cylindrocladium*, but unlike *P. ramorum*, it can girdle and kill stems.

**Figure 21.** Leaf lesions caused by *P. ramorum* on leucothoe. Central Science Laboratory, DEFRA (UK) (Crown Copyright)
**Syringa** (Oleaceae)

**Symptoms** on *Syringa* (lilac) include leaf lesions along the edges of leaves and the death of leaf buds before opening, which results in the appearance of “dieback.”

**Cultivars** found to be infected include *Syringa vulgaris* ‘Belle de Nancy,’ ‘Katherine Havermeyer,’ and ‘Common Purple.’

**Other diseases** of lilac include bacterial shoot, stem and leaf blight caused by *Pseudomonas syringae*. Bacterial blight affects the new succulent growth of leaves and shoots of lilac in cool, wet conditions. Infected new tissue turns soft and black, and infected leaves remain attached to the stem. *Ascochyta syringae* blight affects shoots and flower stalks of lilac, but forms fruiting bodies which are visible with a hand lens, while no structures are visible on *P. ramorum*-infected tissue. Both bacterial and ascochyta blight can affect the stems of lilacs, whereas *P. ramorum* primarily affects the leaves of lilac.

**Other Hosts**

Isolated instances of *P. ramorum* infections have also been found in other nursery stock in Europe. These include containerized yew (*Taxus baccata*) in the UK, causing leaf and stem dieback, and strawberry tree (*Arbutus unedo*) in Spain, resembling the large leaf lesions on its Pacific coast relative madrone (*Arbutus menziesii*).

**Phytophthora ramorum** in Christmas tree plantations

*P. ramorum* can infect newly-expanding branch tips of Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) and grand fir (*Abies grandis*). Christmas trees plantations need to be inspected especially in the spring during the period of new shoot elongation, and again prior to harvest. Precautions need to be taken to prevent the introduction and establishment of the pathogen.

To date, Douglas-fir and grand fir have only been found infected in locations where they are grown under heavily infested California bay laurel. It appears that close proximity to California bay laurel or another source of inoculum is necessary for infection of these coniferous species. Tree plantations should be inspected for the presence of California bay laurel and other hosts, and Christmas trees should be checked for tip dieback. Infected California bay laurel trees near the perimeter of tree plantations may produce inoculum that can spread and cause infection of nearby host plants. Removal of the trees may be warranted.
Quarantines, Regulations, and Official Inspections

Movement of *P. ramorum* hosts is regulated by California, Oregon, the United States, Canada, the European Union, the Czech Republic, South Korea, Australia, and New Zealand. These quarantines define restricted plant parts and require annual inspections of nurseries in infested areas, and pre-shipment inspections for host plants from infested counties destined for uninfested counties. In April 2004, the USDA APHIS placed all nurseries with host plants in California under regulation. Regulations describe **hosts** and **associated hosts** and their parts that are regulated. “Hosts” are naturally infected by *P. ramorum*, and scientific steps have been taken to confirm pathogenicity (Koch’s postulates). This is reviewed and accepted. “Associated hosts” are also found naturally infected, and *P. ramorum* has been cultured and/or detected using PCR (see *Sampling and Diagnosis*), but Koch’s postulates have not been completed or documented and reviewed.

Regulations are continually updated to reflect new findings on *P. ramorum*’s host range and mode of spread. For complete information on regulated hosts and regulations see the USDA APHIS, Plant Protection and Quarantine web site [http://www.aphis.usda.gov/ppq/ispm/sod/](http://www.aphis.usda.gov/ppq/ispm/sod/), or the Regulations section of the California Oak Mortality Task Force web site [www.suddenoakdeath.org](http://www.suddenoakdeath.org), or consult your local county Agricultural Commissioner’s office or state agriculture department.

Nursery Inspection and Scouting

Systematic and careful inspection of nursery crops and propagative plant material is essential to prevent introduction of *P. ramorum* and limit its spread within and from contaminated nurseries. The pathogen must be detected early, while at very low levels. It may be like “trying to find a needle in a hay stack,” but there are many steps the nursery operator and agricultural inspector can take to make the job less onerous. For this discussion, we will focus on detecting *P. ramorum*; a more comprehensive scouting program is needed for general pest management.

**A trained scout** - A scout or inspector must be trained to recognize *P. ramorum* symptoms and symptoms of other disorders that might mimic it. Designate one nursery staff member as the scout and ask all employees to report unusual related conditions or concerns to the scout.

**Maps and Record keeping** - A *nursery layout map* that includes the approximate locations of targeted species is useful for the scout to get oriented and develop a strategy for scouting. A *scouting map* includes species and cultivar names, locations, approximate quantity, and sources of targeted plants in scouted areas. During the scouting walk-
through, record the scouting date, observations, and sampling information directly onto the scouting map. The recorded information should be reviewed and used to develop an efficient scouting strategy each time the nursery is scouted.

**Systematic inspection** - Begin the inspection with an overview of the area from the crop perimeter or with a quick walk-through. If suspicious symptoms are apparent, immediately examine them more closely to attempt to identify the problem. If no symptoms are apparent, start by walking a systematic path through the crop. A common scouting technique is to move relatively quickly down a walkway and scan both sides of adjacent production beds, back and forth. If suspicious symptoms are seen, inspect plants more closely. A good-quality 10 X magnification hand lens can help identify many tiny pests or early disease symptoms (although *P. ramorum* spores cannot be seen at this magnification).

If plants are found with suspicious leaf spots or other symptoms, a sample should be taken (see **Sampling**) and the plant marked with plastic tape or a flag with the location noted on the scouting map. Also, a few plants can be selected at random to closely inspect for early stages of lesion development. In these pots, the scout should look for inconspicuous leaf spots and fallen leaves with characteristic lesions.

Scouting can be prioritized to highest risk stock. Stock or cuttings of hosts from outside sources should be monitored closely. Disease symptoms might take weeks to several months to develop and become apparent, and until then plants may appear healthy. Fungicides that have activity on *Phytophthora* might prevent new infections and therefore detection. It would be best not to apply these fungicides while evaluating the disease status. Note these outside-source plants on scouting maps so they can be scouted weekly. Scouting should be intensified a few weeks after bud break and especially in rainy spring periods when environmental conditions are highly conducive to pathogen infection and development. For nurseries surrounded by native hosts, scout areas immediately adjacent to these hosts, especially wet areas, near puddles, or rain runoff zones.

**Practice good sanitation** - Agricultural inspectors and other nursery visitors should use caution to avoid moving contaminated plant material and soil between nurseries. Shoes, tools and vehicle tires should be thoroughly washed of soil and then sanitized with a registered disinfectant such as Lysol®. Extra precaution should be taken when working in areas known to be infested; disposable overboots may be used and disposed of on site.

**Sampling and Diagnosis**

Select a fresh, representative sample of symptomatic plant parts including some associated leaves and stems. The sample should be placed in a plastic bag and labeled with date, genus, species, cultivar, and nursery location. The sample should be kept cool, away from direct sunlight, and delivered to the diagnostic laboratory within 24 hours. Test kits can be used at the nursery to help rule out *Phytophthora* species as the cause (see ELISA, below).

Send samples to your state’s plant pathology diagnostics laboratory, or contact your local Agricultural Commissioner’s office.
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The annual federal quarantine inspection requires submission of a minimum of 40 symptomatic leaves for testing. Asymptomatic (symptom-free) leaves may be collected only if less than 40 symptomatic leaves are available. More frequent sampling can confirm pest-free status and aid in early detection. Processing is a free service, provided by the state, and can build customer confidence in the disease-free state of the inspected nursery.

Once the sample is received at the diagnostic laboratory there are three laboratory methods that might be used to aid diagnosis:

1. **ELISA** (Enzyme-Linked Immunosorbent Assay, such as used in some field test kits) is used as a quick pre-screen to detect many species of *Phytophthora*. An ELISA test specific to *P. ramorum* is not available;

2. **PCR** (Polymerase Chain Reaction) uses DNA extracted from plant tissue or laboratory cultures. In PCR, the size of the DNA band amplified from the unknown must match exactly that from known *P. ramorum* DNA.;

3. **Selective culture media** (such as PARP) can be used to isolate *P. ramorum* and other *Phytophthora* species from infected plant tissue. Plant tissue is selected from the leading edge of a canker or lesion and placed in selective media. Morphological characteristics of the mycelium, sporangia and chlamydospores can be used to aid in identification.

USDA APHIS has standardized regulatory diagnostic protocols; for more information, see [http://www.aphis.usda.gov/ppq/ispm/sod/survey.html](http://www.aphis.usda.gov/ppq/ispm/sod/survey.html).

**Disease Management**

For most nurseries, the foremost objective of pest management programs is to prevent the introduction of the pathogen into the nursery via infected plant material or other means. This can be, in part, accomplished by careful inspection of new incoming host propagative material and stock. Symptoms are not always readily apparent on stock initially. So, a weekly, systematic monitoring of stock by a trained nursery scout helps insure that the pathogen has not been introduced (see Inspection and Scouting). Other practices that should be helpful include:

- All nursery personnel need to be aware of the issues and disease symptoms regarding this pathogen and should be ready to alert the nursery scout or other authority if characteristic symptoms are seen.

- Insure that incoming host plant material from infested counties (the regulated areas) has been properly inspected by agricultural inspectors.

- Infected leaves often drop from plants. For high-risk incoming shipments, off-load the nursery stock in an area that can be cleaned of leafy debris. Sweep debris from the receiving area and delivery truck and bag for disposal. Loading and delivery areas should be as far from production areas as possible.

- Maintain good shipping and receiving records to facilitate trace-backs and trace-forwards if contaminated stock is detected.
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For those nurseries surrounded by native host trees and shrubs and in an immediate area where *P. ramorum* is found:

- Periodically inspect nearby native hosts for disease symptoms. Infected California bay laurel trees near the perimeter of nurseries may produce inoculum that can spread and cause infection of nearby host plants, so removal of the trees may be warranted.

- Rain runoff coming down slope from areas containing infected hosts may contain *P. ramorum*. Consider berms to prevent water and soil movement into production areas from hillsides surrounding the nursery.

- Irrigation water pumped from streams and ponds in areas of infected native hosts may be contaminated with *P. ramorum*. Consider having this water periodically tested to detect *P. ramorum*. If it is found to be present, consider alternative irrigation sources, such as well water, or disinfection treatments.

Other cultural practices that can be useful to reduce disease risk:

- Avoid irrigation practices where the foliage is wetted for prolonged periods. If sprinklers are used, irrigate in the morning to allow for thorough and quick drying of foliage.

- Monitor and maintain irrigation systems to insure the most uniform application of water to the crop. Correct low spots, areas of poor drainage, and clogged or leaking irrigation heads.

- Monitor irrigation-water sources, other than well water, for *P. ramorum*. Use disinfection systems if using recycled water.

- Wounded leaves (even tiny wounds or scratches) are much more susceptible to infection. Avoid handling host plants if they might be wounded when environmental conditions favor disease.

- Avoid soil or container soil contact with foliage or any splashing water from soil to foliage. Use raised benches, gravel or other means to elevate susceptible plants above soil. Transplants, even on gravel beds, appear to be very susceptible to disease due to the close proximity of foliage to soil, runoff water, or rain splash. Raised benches may be warranted for transplants.

- Plants or plant parts that are suffering from poor vigor, disorders, or other serious problems should be removed from production areas and destroyed. A small number of plants or plant parts could be bagged and disposed. If a cull pile is needed temporarily, the pile should be covered with a clear polyethylene sheet until the culls can be destroyed or composted.

- Propagate cuttings only from disease-free hosts.
• Use only new or disinfested containers and soil. Potting soil piles should be as far from infected native hosts or cull piles as possible and covered with clear polyethylene sheeting. Potting soil components should not be mixed on bare soil.

• Disinfect tools and shoes that have been in contact with contaminated plants or soil (see Inspection and Scouting).

**Fungicides**

• If applications of fungicides are made to nursery stock they should be made as preventative treatments. Currently, even the most active fungicides do not stop the development of *P. ramorum* once foliar lesions are present. They need to be applied before environmental conditions favor pathogen infection, for example, before a period of rainy weather that would allow water to linger on leaf surfaces for many hours. Some fungicides applied to the foliage move into the leaves and are not washed off by rain or sprinkler irrigation, while others provide a protective layer of chemical on the leaf surface. Some can be applied to the soil, where they are adsorbed and move upward to the leaves, where they protect the leaves from infection. Some have residual activity that can last for several weeks after they are applied.

• The regular and blanket use of fungicides will drive the mechanism that develops resistant pathogen strains. Fungicides with specific modes of action--as many *Phytophthora*-active fungicides are--will be especially vulnerable. Minimizing fungicide use, in any way, is the first priority to prevent resistant strains from developing. When fungicides are used, use different chemical classes, either in rotation or combining products in tank mixes. Fungicides active on *P. ramorum* may already be used in the nursery to control other foliar or soil-inhabiting *Phytophthora* species or related pathogens (such as downy mildews), and their use should be considered in planning the overall fungicide treatment strategy.

• Fungicides active on *Phytophthora* should not be applied to high-risk nursery stock or cuttings that will be monitored for *P. ramorum* infection because detection of symptoms may be delayed or masked (see Inspection and Scouting).
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Resources


DEFRA Plant Health Information Sheet: Phytophthora ramorum: a potential threat to our trees, woodland and heathland http://www.defra.gov.uk/planth/pestnote/sudden.htm
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Penn State University Cooperative Extension Plant Disease website: http://www.cas.psu.edu/docs/CASDEPT/PLANT/ext/lilac.html


University of Illinois Plant Disease IPM website: http://www.ipm.uiuc.edu/diseases/series600/rpd601/index.html