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Nursery Guide for Diseases of *Phytophthora ramorum* on Ornamentals

Diagnosis and Management

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Introduction

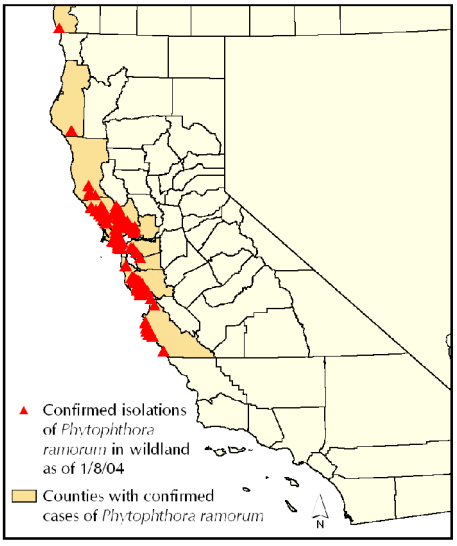
Phytophthora ramorum, a newly discovered plant pathogen, has caused widespread mortality in native oaks (commonly called Sudden Oak Death) and leaf blights, stem cankers and tip dieback on several other wildland plants in many coastal areas of central and northern California and in southwestern Oregon. In many European countries, the pathogen has caused similar diseases primarily on ornamental nursery crops. In Europe, it has been tracked moving from infected nursery outplantings, to neighboring shrubs, and then to lethal infections of adjacent landscape trees. This heightens the concern that infected nursery crops could move the pathogen long distances to new areas and infect new hosts. The pathogen has been detected primarily in nurseries in California, the Pacific Northwest, and Canada, but recently it has been traced being shipped on *Camellia* from a large southern California nursery to many locations throughout the United States. European isolates of the pathogen have been detected in nurseries in the Pacific Northwest and Canada. Federal and state quarantines require inspection of nursery stock from infested counties, and if the pathogen is found, affected nursery stock must be destroyed as a means of eradication.

Figure 1. Coast live oak mortality, Santa Cruz Co., CA, 1999. *Steve Tjosvold, UC Cooperative Extension*

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 to late 1990s. Tens of thousands of tanoaks (*Lithocarpus densiflorus*), black oaks (*Quercus kelloggii*) and coast live oaks (*Quercus agrifolia*) have died. 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 plants in 1993. This pathogen was subsequently named *Phytophthora ramorum* S. Werres & A.W.A.M. de Cock in 2001.

As of spring 2004, *P. ramorum* has been detected in wildlands in 12 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- willdland 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 (spring, 2004)

Plant Name	Plant Part(s) Affected
Bigleaf maple (*Acer macrophyllum*)	Foliar
California bay laurel/pepperwood/Oregon myrtle (*Umbellularia californica*)	Foliar & twig
California black oak (*Quercus kelloggii*)	Trunk
California buckeye (*Aesculus californica*)	Foliar & twig
California coffeeberry (*Rhamnus californica*)	Foliar
California hazelnut (*Corylus cornuta*)	Foliar
California honeysuckle (*Lonicera hispidula*)	Foliar
Canyon live oak (*Quercus chrysolepis*)	Trunk
Cascara (*Rhamnus purshiana*)	Foliar
Coast live oak (*Quercus agrifolia*)	Trunk
Coast redwood (*Sequoia sempervirens*)	Foliar & twig
Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*)	Twig
Evergreen huckleberry (*Vaccinium ovatum*)	Foliar & twig/branch
Grand fir (*Abies grandis*)	Twig
Madrone (*Arbutus menziesii*)	Foliar & twig/branch
Manzanita (*Arctostaphylos manzanita*)	Foliar
Pacific rhododendron (*Rhododendron macrophyllum)*	Foliar & twig/branch
Poison oak (*Toxicodendron diversiloba*)	Twig/branch
Wood Rose (*Rosa gymnocarpa*)	Foliar
Salmonberry (*Rubus spectabilis*)	Foliar
Shreve oak (*Quercus parvula v. shrevei*)	Trunk
Tanoak (*Lithocarpus densiflorus*)	Trunk/Foliar & twig
Toyon (*Heteromeles arbutifolia*)	Foliar & twig/branch
Western starflower (*Trientalis latifolia*)	Foliar

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 native 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.

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, 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.

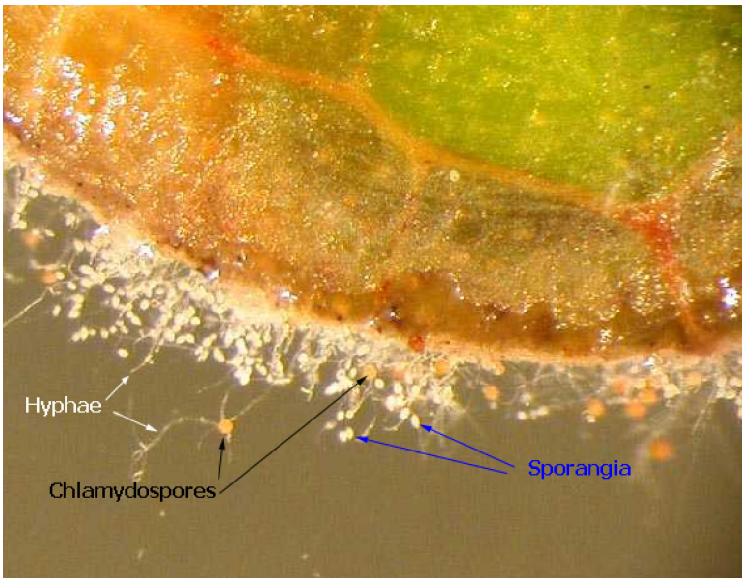


Figure 2. Hyphae, sporangia, and chlamydospores on a leaf disk in laboratory medium. *Jennifer Parke, Oregon State University*

Figure 3. P. ramorum symptoms on California bay laurel leaves. *Steve Tjosvold, UC Cooperative Extension*

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 stramenopiles), related to diatoms and brown algae. *Phytophthora* species are 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 virulent plant pathogens. The body of the organism is made up of thread-like strands, one 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 from plant to plant via windblown rain, in contaminated soil, or 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 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* population is predominantly A1 mating type, and the North American population is A2. **Oospores**, the sexual spore, result from the union of A1 and A2 strains, but this spore type has not been observed under natural conditions. However, three Pacific Northwest nursery infestations and the Canadian infestation included the European population, A1 type, and in two of the Pacific Northwest nurseries 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.

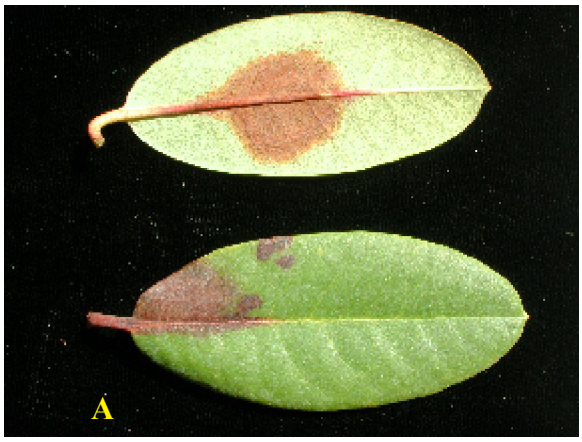
Symptoms on Ornamental Nursery Hosts

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 between overlapping, shaded, or "cupped" leaves or where lower leaves touch container soil.

Abiotic symptoms that can look similar include sunscald, fertilizer burn, chemical injury, drought injury, freeze damage and root damage. The best way to distinguish abiotic damage from that caused by *P. ramorum* is to check the underside and leaf margins. For abiotic 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 result in plant injury. Abiotic injury is often found distributed over the entire plant, while *P. ramorum* leaf spots are often found on only a few leaves or one portion of the plant.

We present a detailed description of *P. ramorum* symptoms on ornamental plants and Christmas tree stock. Native plant nurseries should use pictures and descriptions of symptoms on native plants. See: Davidson, et al. 2003. Sudden oak death and associated diseases caused by Phytophthora ramorum. Online. Plant Health Progress doi:10.1094/PHP-2003-0707-01-DG: http://www.suddenoakdeath.org/pdf/davidson2003.pdf

Rhododendron (Ericaceae)



A & B *Steve Tjosvold, UC Cooperative Extension*

BBA, Germany

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. Lesion margins have diffuse edges which are most easily observed on the underside of the leaf. Infected leaves may fall prematurely form 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.

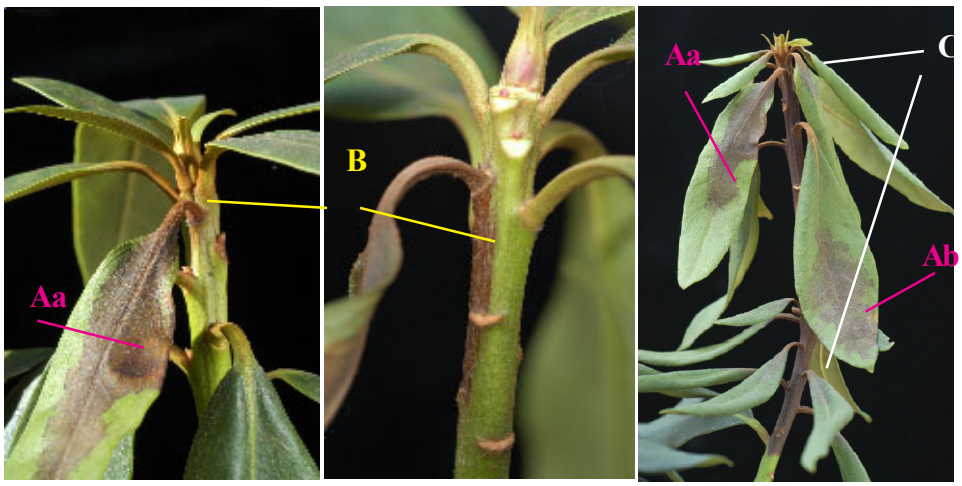


Figure 5. Symptom progression (approximately 3 weeks) of a laboratory infected *R.* 'Cunningham's White'. (**Aa & Ab)** indicate initial leaf infection sites. Infection **Aa** develops through petiole, forming stem canker **(B)**. Infection develops upward and downward in stem, and into leaf petioles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

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

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 Hilights' and California-native *R. 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 *Phytopthora* 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.*

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*

Camellia (Theaceae)

Figure 8. *P. ramorum* symptoms on camellia. *Terry Brokenshire, Horticulture, Guernsey (UK) (Crown Copyright)*

Figure 10. *P. ramorum* symptoms on *Camellia japonica* 'Mrs.Charles Cobb'. *Cheryl Blomquist, CDFA*

Figure 11. Infected *C. japonica* x *saluenensis* 'Coral Delight' *Cheryl Blomquist, CDFA*

Figure 9. *P. ramorum* symptoms on *Camellia sasanqua* 'Bonanza'. *Cheryl Blomquist, CDFA*

Figure 12. Infected *C. japonica* 'Kumasaka' Note sparse foliage due to leaf abscission. *Cheryl Blomquist, CDFA*

Symptoms of *P. ramorum* on camellias are limited to leaf lesions which can vary in size from a half a 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, especially in *Camellia sasanqua*, where the lower part of the plant can defoliate. No tip dieback or small branch cankers caused by *P. ramorum* has been observed on *Camellia* species.

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

Camellia species and cultivars confirmed infected with _Phytophthora ramorum_

C. japonica 'Cleopatra'	*C. japonica* 'Kumasaka'	*C. sasanqua* 'Bonanza'
C. japonica 'Jordan's Pride'	*C. japonica* 'Mrs. Charles Cobb	*C. sasanqua* 'Jean May'
C. japonica 'Joshua E. Youtz'	*C. japonica* 'Silver Waves'	*C. sasanqua* 'Setsugekka'
C. japonica 'Kramer's Supreme'	*C. japonica* x *saluenensis* 'Coral Delight'	*C. sasanqua* 'Showa-no-sakae'

No information is available on resistant species or cultivars

Figure 14. Symptoms of sun scorch on camellia. *Tomas Pastalka, CDFA*

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 and Pestalotiopsis* can act as weak secondary pathogens following leaf scorch and can cause necrosis.

Pieris (Ericaceae)

Figure 15. Branch tip dieback on *Pieris japonica* 'Variegata' *Jan Hedberg, Oregon Department of Agriculture*

Figure 16. *P. ramorum* leaf (A) and stem (B) lesions on *Pieris*. *Central Science Laboratory, DEFRA (UK) (Crown Copyright*)

Symptoms of *Phytophthora ramorum* on pieris (Andromeda) include necrotic leaf spots similar to those on Camellia, as well as branch tip dieback.

Pieris species and cultivars confirmed infected with _Phytophthora ramorum_

P. floribunda x japonica
P. formosa var. forrestii
P. formosa var. forrestii x P. japonica
P. formosa x japonica
P. japonica 'Flaming Silver'
P. japonica 'Variegata'
P. japonica x formosa

No information is available on resistant species or cultivars

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*.

Viburnum (Caprifoliaceae)

Figure 17. *P. ramorum* stem (A) and leaf (B) lesions on *Viburnum tinus. Cheryl Blomquist, CDFA*

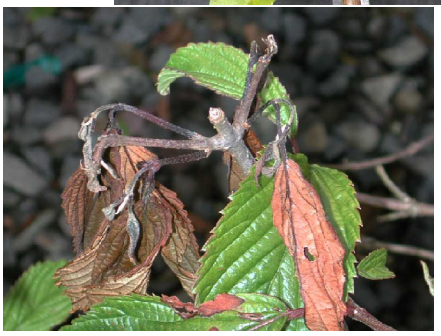


Figure 18. Tip dieback in *V. plicatum tomentosum* caused by *P. ramorum. Oregon Department of Agriculture*

Figure 19. Stem lesion in viburnum caused by *P. ramorum. Central Science Laboratory, DEFRA (UK)*

Symptoms of *P. ramorum* on viburnums include stem cankers and/or leaf necrosis. 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.

Viburnum* species and cultivars confirmed infected with *Phytophthora ramorum

V. bodnatense	*V. fragrens*	*V. plicatum*	*V.* 'Schneewolke'
V. x burkwoodii	*V. lantana*	*V. plicatum tomentosum*	*V. tinus*
V. davidii	*V. opulus*	*V. pragnense*	*V. utile*
V. ferreri			

No information is available on resistant varieties

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)

Central Science Laboratory, DEFRA (UK) (Crown Copyright)

Stephen Eales, PHSI (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 shown below.

Leucothoe (Oleaceae)

Symptoms observed on leucothoe tend to begin at the leaf tips. The pathogen subsequently grows through the leaf tissues towards 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)

Figure 22. *P. ramorum* symptoms on lilac. *Alexandra Schlenzig, Scottish Agricultural Science Agency*

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' and 'Katherine Havermeyer'. There is no information available on resistant cultivars

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 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; strawberry tree (*Arbutus unedo*) in Spain, resembling the large leaf lesions on its Pacific coast relative madrone (*Arbutus menziesii*); and lingonberry (*Vaccininum vitus-idaea*) with leaf spotting symptoms in a single shipment of plants intercepted in Poland.

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 precautions 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, and removal of the trees may be warranted.

Figure 23. Tip dieback in grand fir Christmas tree stock. *Michelle Nachand, Santa Clara County Agricultural Commissioner's Office*

Quarantines and Official Inspections

Movement of *P. ramorum* hosts is regulated by California, Oregon, United States, Canada, the European Union, 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. Regulations are continually updated to reflect new findings on *P. ramorum's* host range and mode of spread. For complete information on regulations see the Regulations section of the California Oak Mortality Task Force website: www.suddenoakdeath.org, or consult your local county Agricultural Commissioner's office.

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 specie 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 in an 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 pest or disease symptoms (although *P. ramorum* spores can not 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 until then plants may appear healthy. Note outside-source plants on scouting maps for weekly examination. 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.

Send samples to your state's plant pathology diagnostics laboratory, or contact your local Agricultural Commissioner's office.

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 tests 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.

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. This can be, in part, accomplished by careful inspection of new incoming host propagative material and stock and systematic and regular scouting of nursery stock to 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.

- Maintain good shipping and receiving records to facilitate trace-backs and trace-forwards if contaminated stock is detected.

For those nurseries surrounded by native host trees and shrubs and in an immediate area where *P. ramorum* is found there are additional factors and practices that should be considered:

- 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, and 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* during winter and spring. Consider alternative irrigation sources, particularly in winter and spring. Consider having water periodically tested to detect P. ramorum.

- 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.

- Fungicides do not kill *P. ramorum* once an infection is established. However, fungicides may help prevent infection and slow spread. Consider applying appropriate fungicides to host crops just before environmental conditions favor disease, such as in rainy weather. Rotation of different chemical classes help prevent resistance from developing. Use only registered fungicides.

- 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 plant contact with soil, use raised benches, gravel or other means to elevate susceptible plants.

- 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.

- Potting soil piles should be as far from infected native hosts as possible and covered with clear polyethylene sheeting.

- Loading and delivery areas should be as far from production areas as possible.

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