

Understanding *Phytophthora ramorum*

Key Findings from UK Research

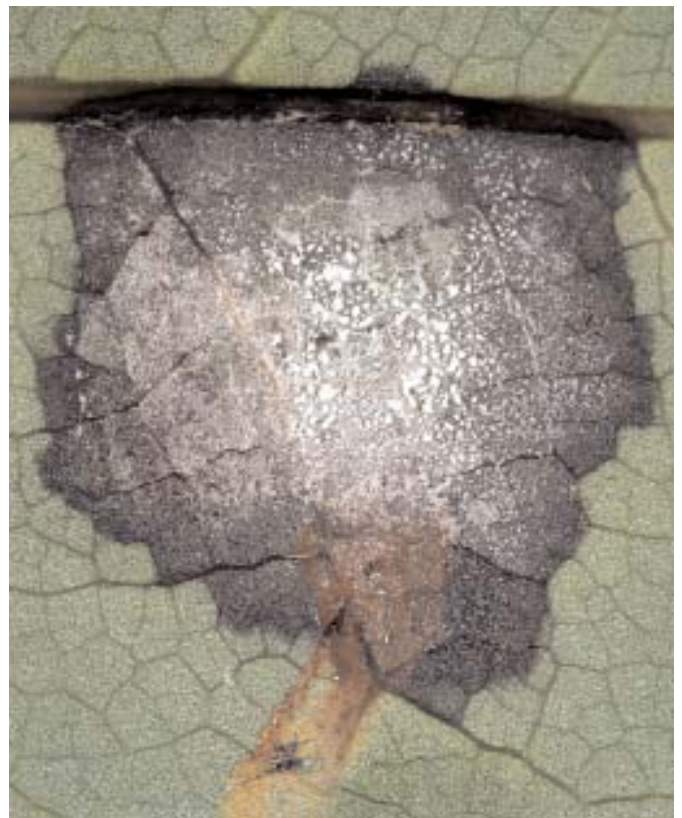




Defra, the Forestry Commission and the Horticultural Development Council have commissioned research to investigate the biology, epidemiology and management of *Phytophthora ramorum* in the UK; the European Union has also contributed to a European project, involving UK scientists, investigating the wider threat to Europe. The results have increased our understanding of the pathogen and helped develop policy and disease management strategies. This fact sheet provides information on a number of the key findings from UK research.

Hosts and Symptom Types

- *Phytophthora ramorum* causes a range of different symptoms, depending on the host that is infected. They include: leaf necrosis; shoot dieback and wilt; and inner bark necrosis on mature trees leading to bleeding cankers.
- Some shrub species only develop leaf-blight symptoms (e.g. leucothoe), whilst others develop a dieback as both leaves and stems are infected (e.g. pieris, rhododendron, and viburnum).
- Some tree species also have susceptible foliage (e.g. ash, holm oak and magnolia), whilst others have only susceptible bark and develop bleeding trunk cankers (e.g. beech, red oak and Turkey oak). Only rarely have both foliar infections and inner-bark necrosis been found naturally on the same host species of tree, but this has been the case for sweet chestnut.
- Laboratory tests have predicted various potential ornamental and environmental hosts, many of which have subsequently been found as natural hosts. The pathogen has a very wide natural and potential host range. Experimental data summarising the susceptibility of hundreds of host species and plant parts is available on the European project website (<http://rapra.csl.gov.uk>).
- The broad-leaved trees considered most at risk, based on their experimental bark susceptibility, include European beech, southern beech, red oaks, Turkey oak, sycamore, sweet chestnut and horse chestnut. English and sessile oaks, as well as lime, birch and alder, are considered less at risk but are not completely immune.
- UK heathland plants such as bilberry (*Vaccinium myrtillus*) and Scottish heather (*Calluna vulgaris*) have also been shown to be potentially at risk in laboratory studies. *C. vulgaris* is recorded as a natural host in mainland Europe and a *Vaccinium* species, huckleberry, is a host in the USA.



P. ramorum sporangia on a Californian bay laurel leaf



American northern red oak (*Q. rubra*) logs with outer bark removed 5 weeks after inoculation to show inner bark lesions

Infection and Disease Development

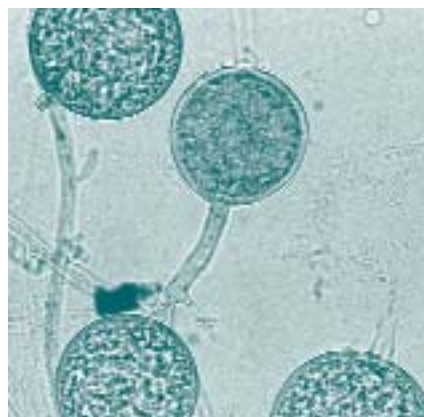
- Host susceptibility may vary according to season, genetic background and whether the plants are wounded or not. Foliage and shoot tips are usually more susceptible to infection when tissues are young. Infection can occur through natural openings and wounds on foliage and bark. Wounding often enhances disease development and expression, but is not essential for infection of many susceptible hosts. The amount of pathogen inoculum needed to cause infection varies from host to host.
- With trees, bark thickness and resin production can affect susceptibility. In tests using logs, thin-barked European beech and red oak species were most susceptible; relatively greater numbers of both have been found naturally infected in the UK and Europe. However, Turkey oaks, which have thicker bark and are also susceptible in the log tests, have also been found naturally infected in the UK.
- To date, all trees infected with *P. ramorum* have been in close association with infected rhododendron. Foliar hosts such as rhododendron are the primary sources of inoculum for initiating bark cankers on susceptible trees. Laboratory tests show that the foliage of holm oaks has a similar capacity for spore production so, if infected in sufficient numbers, holm oaks could pose a risk to nearby susceptible species.
- With tree cankers, *P. ramorum* is not limited to the inner bark (phloem and cambium). It can also be isolated from the underlying sapwood (xylem) and can spread within this vascular tissue, leading to multiple lesions in the overlying bark.
- In laboratory root-inoculation experiments, the pathogen could occasionally be isolated from apparently symptomless roots of potted plants. However, there is currently no evidence that roots are a primary route of infection for above-ground parts, either from these experiments or from observations of naturally or horticulturally grown plants.
- There is no laboratory evidence for truly latent infections in foliage. Results from laboratory studies have shown that the time between foliage infection and visible disease expression is typically between 3 and 14 days depending on host and temperature. However, this may be longer in the field and on different plant parts.

Spore Production, Dispersal and Spread

- Laboratory tests have shown that light, temperature, humidity and nutrient status all appear to influence production of sporangia (the stage responsible for dispersal and infection). Decreased nutrient availability and increased humidity, light and air flow result in increased sporangial production.
- Inoculum levels of *P. ramorum* show a seasonal variation in the natural environment. For example, *P. ramorum* was detected more frequently in watercourses during spring and autumn than in summer.
- Sporangial production varies with host species and age of leaf tissue. In laboratory tests with UK plant species, the greatest sporulation was observed on leaves of ash, bilberry, dog rose, holm oak, lilac and rhododendron. Evergreen, foliar hosts, especially rhododendron, are considered the most important sources of inoculum for initiating tree infections. Sporangia are not produced on bark lesions on trees.
- Spore dispersal has been detected during rainfall. Aerial dispersal is thought to be via rain splash or wind-driven rain.
- No evidence of disease spread via insect vectors has been found, although there is circumstantial evidence that vertebrate vectors may play a role in dispersal. Research has shown that the pathogen can be carried in soil and leaf litter adhering to footwear prior to cleaning and disinfection.
- *P. ramorum* is also regularly recovered from watercourses at infected sites, though the significance of this potential dispersal pathway is not yet fully known. Surveys have shown that the pathogen is not significantly detected in watercourses in the wider environment away from infection hot spots.
- Risk maps and biological data predict that warmer and wetter parts of the UK are most likely to favour disease development.
- The production of chlamydozoospores (long-term survival structures) in foliage varies markedly with host. Experimentally, some hosts support the production of large numbers of chlamydozoospores (e.g. Californian bay laurel and lilac), others moderate numbers (e.g. rhododendron) and others few if any (e.g. camellia).
- Potentially, oospores (long-lived sexually produced spores) can also be produced by *P. ramorum* but this requires two opposite mating types (A1 and A2). However in laboratory tests, European isolates of the A1 mating type do not readily cross with American isolates of the A2 mating type suggesting that the breeding system may not be functional.



P. ramorum sporangia



P. ramorum chlamydozoospores



P. ramorum sporangia with zoospores

Survival of the Pathogen

- The pathogen is regarded as a cool-temperate organism with an optimum temperature for growth of around 20°C and a minimum and maximum temperature for growth of 2°C and 30°C respectively.
- Sporangia and chlamydozoospores are robust and are able to survive extremes of temperature (especially low temperature) and pH in experiments using laboratory cultures: sporangia and chlamydozoospores survived exposure to -2°C for 24 hours; chlamydozoospores were killed by exposure to 40°C for 24 hours or -25°C for just 4 hours; sporangia died after a 2-hour exposure to 40°C or -25°C.
- *P. ramorum* has been recovered throughout the year in the UK from plants, plant debris and watercourses and in soil up to a depth of 15 cm.
- In the UK, chlamydozoospores survived in plant debris for two consecutive winters in contained, quarantine experiments outside.
- There is evidence that it can survive in rhododendron stumps and directly infect re-growth from the stump.



Infected re-growth from a rhododendron stump

Control and Management

- The effectiveness of various fungicides was greatest when they were applied prior to the arrival of inoculum, i.e. to protect plants. Significant differences in the efficacy of fungicides on different host species have been found.
- Efforts are focused on developing a robust and durable control strategy to reduce the significant risk of fungicide resistance developing rapidly. Some *P. ramorum* isolates obtained from ornamental nursery plants have already shown resistance to Metalaxyl-M.
- Preliminary experiments with small-scale slow sand filters have shown that this technology can effectively remove zoospores and sporangia from contaminated water.
- In natural and semi-natural environments, the removal of rhododendron plants and leaf debris has helped lower inoculum levels and can reduce or prevent the chance of re-infection. Control of re-growth has also been shown to be significant in preventing the build-up of inoculum.

If you suspect the presence of this disease you must immediately inform your local Plant Health and Seeds Inspector (PHSI) who will advise on the action to be taken. Contact details for all PHSI offices are available on the Defra website or from the PHSI HQ, York.



Further Information

More detailed information on specific research projects and their results, *P. ramorum* hosts (including species experimentally determined to be susceptible) and the current status of the disease in the UK is available on the Defra and Forestry Commission websites. Best practice guides for the nursery and garden centre industry, established parks and gardens, and a general information leaflet about the disease are also available. These can be downloaded from the Defra website or paper copies can be obtained from the PHSI HQ, York:

Tel: 01904 455174

Fax: 01904 455197

Email: planthealth.info@defra.gsi.gov.uk

Defra Website: www.defra.gov.uk/planth/pramorom.htm

Forestry Commission Website: www.forestry.gov.uk/forestry/INFD-66THS4

Horticultural Development Council Website: www.hdc.org.uk

