Understanding *Phytophthora ramorum* in Irish larch forests

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Phytophthora ramorum is a fungus-like pathogen that poses a significant threat to forests in the island of Ireland. Of most concern is the recent host range expansion from low value *Rhododendron* to Japanese larch in commercial forest plantations in Ireland and Northern Ireland. This factsheet describes new information on the biology and detection of the pathogen and provides updated information on disease management.

KEY RECOMMENDATIONS

- Larch forests should be regularly surveyed for symptoms of infection by *Phytophthora ramorum*. Symptoms include bleeding resinous cankers on the trunk and dieback from the crown. Possible diseased trees should be reported to the DAFM Forest Service in Ireland (forestprotection@agriculture.gov.ie) or the DARDNI Forest Service in Northern Ireland (planthealth@dardni.gov.uk)
- Forest users and workers should adopt suitable biosecurity protocols to help prevent spread of disease in forests. Footwear, tyres, machinery and tools should be thoroughly cleaned and treated with a suitable biocide on entering and exiting a forest
- International travellers should prevent the introduction of non-native invasive microorganisms into Ireland by not transporting unlicensed plants with them and by cleaning any footwear they may have used before returning to Ireland.

BACKGROUND

Phytophthora is a group of fungus-like organisms that contains over 140 species. Many *Phytophthora* species are important plant pathogens, for example *Phytophthora infestans* (cause of potato late blight). *Phytophthora ramorum* is one of the most damaging *Phytophthora* species world-wide, infecting hundreds of plant species across Europe and North America. Disease caused by *P. ramorum* was first noticed in the early 1990's almost simultaneously in plant nurseries in Europe and in forests in California. In mainland Europe, it causes a serious blight of ornamental plants, especially *Rhododendron*, *Camellia* and *Viburnum*. In North America it causes a forest disease called Sudden Oak Death, killing millions of *Quercus* trees in deciduous forests of California and Oregon. It also costs millions annually to the ornamental nursery industry in Europe and North America.

In Ireland, *P. ramorum* was first detected in 2002 on imported *Rhododendron* and *Viburnum* at several garden centres and in 2003 it was detected in the wild, infecting *Rhododendron ponticum*. In 2010 it was observed on Japanese larch in Ireland and Northern Ireland, and has since been recognised as a serious threat to forestry. Under current plant health policy, *P. ramorum* control has resulted in the removal of more than 1300 ha of larch forests on the island of Ireland and 17,000 ha in Britain. *Phytophthora ramorum* has been a regulated quarantine pathogen within the EU since 2002, with confirmed infected trees in forests removed and susceptible hosts within a 250 meter radius also removed as a precautionary measure. The harvested wood may only be moved and processed once a special phytosanitary permit has been granted by the regulatory body.

SYMPTOMS

Symptoms of infection on Japanese larch often become evident during the spring and summer. The time between notice of first symptoms and tree death can be rather short, and this seemingly rapid mortality of larch trees has led to "Sudden Larch Death" being used to describe the disease epidemic (Fig. 1). Infection on individual larch trees can be indicated by dieback of the crown (Fig. 2), resinous cankers on the trunk, excess cone production and by blackening and retention of needles. On *Rhododendron*, lesions along the midrib and at the tip of the leaf, stem decay and dieback can be a sign of *P. ramorum* infection. On European beech, *P. ramorum* typically manifests itself as bleeding cankers (Fig. 3).

Figure 1 Aerial view of Japanese larch forest affected by *Phytophthora ramorum* in Ireland

Figure 2 Severe dieback in the crown of a Japanese larch tree caused by *Phytophthora ramorum*

Figure 3 Bleeding cankers on a beech tree caused by *Phytophthora ramorum*

BIOLOGY AND EPIDEMIOLOGY

There are four clear lineages (i.e. populations) of *P. ramorum* world-wide, the EU1, EU2, NA1 and NA2 lineages. In Ireland, we have found that only the EU1 lineage is present, and displays a genetic diversity pattern consistent with multiple introductions. In Northern Ireland, both the EU1 and EU2 lineages are present, with the EU2 lineage being much more frequent than the EU1 lineage. The genetic diversity pattern in Northern Ireland is consistent with a single discrete introduction of the EU2 lineage. Experiments carried out by PHYTOFOR researchers have found that there is little danger of hybridisation between the lineages in Ireland and Northern Ireland, as they are the same mating type. Glasshouse trials carried out as part of the PHYTOFOR project have indicated that there is a difference in pathogenicity between the two lineages, with the EU2 being significantly more damaging to Japanese larch than the EU1 lineage. Furthermore, we have also found that damage caused by *P. ramorum* on Japanese larch exceeds that on European larch. Analysis of the gene expression of the two larch species during infection by *P. ramorum* by the PHYTOFOR project indicates that European larch is better able to fend off attack by *P. ramorum* because it responds more quickly, and produces more defensive compounds than Japanese larch does.

The cool, wet maritime climate of the island of Ireland, particularly in coastal regions, provides ideal conditions for *P. ramorum* infection and spread among plants (Fig. 4). Experiments carried out as part of the PHYTOFOR project have shown that *P. ramorum* can survive and grow at temperatures from 0 – 28°C, with research from the USA showing that sub-freezing or >42°C temperatures over prolonged periods (>1 week) are needed to eradicate the pathogen from infected leaf tissue. Furthermore, spread and infection by *P. ramorum* is enhanced in the presence of excess moisture, a situation frequently provided by rainfall, dew and high humidity, associated with an Atlantic influenced climate. PHYTOFOR research has shown that aerial spread (i.e. in wind and rain) is much more important than terrestrial spread (i.e. in leaf debris and in streams) in driving the current *P. ramorum* disease epidemic in Japanese larch forests. This dissemination method better explains the rapid spread of the epidemic between distant Japanese larch forests in Ireland.

DETECTION

Aerial surveys followed by ground visits are used by the plant health authorities to collect suspected *P. ramorum* infected samples for laboratory testing. Using conventional laboratory tests, *P. ramorum* infection in *Rhododendron* is much easier to identify than infection in Japanese larch. One British study found that conventional methods were less than 20% effective in detecting *P. ramorum* in laboratory infected Japanese larch samples, compared to 90% effective for *Rhododendron*. This may be due to the high amounts of inhibitors (e.g. tannins) in the Japanese larch tissues. Molecular testing methods on the other hand are much more accurate in identifying the pathogen where it is present, irrespective of the host plant. Multi-laboratory ring tests carried out by PHYTOFOR have further confirmed the importance of using molecular tests to detect *P. ramorum* in suspected infected forest samples.

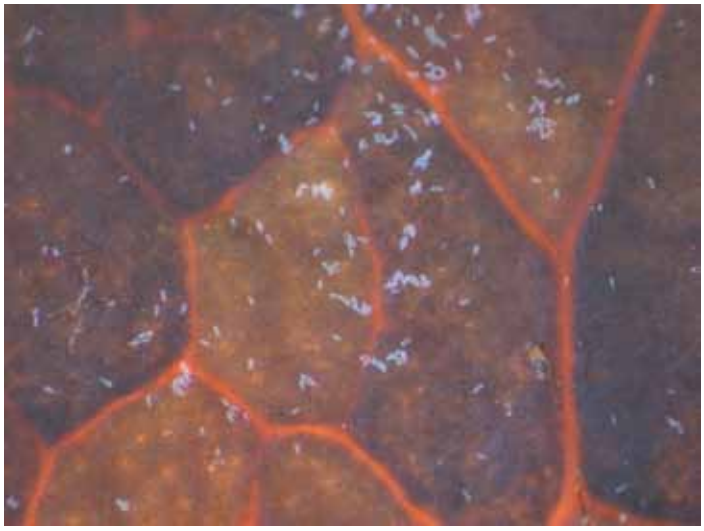

Figure 4 Sporangia of *Phytophthora ramorum* produced on the surface of an infected *Rhododendron* leaf (x60)

Figure 5 Illegal dumping of horticultural waste at a forest entrance

DISEASE MANAGEMENT

The PHYTOFOR project has shown that the spread of *P. ramorum* by rain splash ceases once previously infected trees are removed and the adjacent forest is clear felled. Removal of the trees also allows solar radiation to increases the ground temperature and dry out the litter layer. These factors may be responsible for the low levels of infective potential of the litter and soil detected by sampling during the PHYTOFOR project. However, as a precaution, forest land that has been clear-cut as a result of *P. ramorum* infection should not be replanted with tree species that are susceptible to *P. ramorum*. Species of larch, beech and chestnut should be especially avoided as replanting choices as these are particularly susceptible hosts. The PHYTOFOR project found a lack of infective potential in clear-cut sites. British scientists also found diminishing infective potential over time post-harvest and this suggests that the period between clear-cut and replanting should be as long as possible. This recommendation is further supported by replanting trials carried out by the PHYTOFOR project, where no reinfection has occurred in any of 8 tree species planted in previously infected forest sites that were left fallow for almost 3 years post clear-cut.

As *P. ramorum* is a quarantine organism, strict biosecurity rules should be followed when entering and exiting a *P. ramorum* infected site to prevent further spread. Sampling at an infected larch forest by the PHYTOFOR project has shown that *P. ramorum* can be found in litter, soil and water therefore it is important to physically remove all litter, plant material and soil from surfaces (e.g. footwear, tyres and tools) that may have come into contact with infected material. It is also important to use a suitable biocide to prevent further spread of *P. ramorum* and other pathogens in the Irish environment. The transport of plants or plant material into, or out of Irish forests should be avoided unless the material is known to be disease free. Dumping of horticultural and garden waste in or near to forests has been noted as a widespread problem in Irish forests by the PHYTOFOR project (Fig. 5). The need for good biosecurity practices in our everyday lives extends beyond those who frequent or work in forests. People returning from abroad need to take care not to inadvertently introduce invasive alien organisms into the island of Ireland. *Phytophthora ramorum* and *Hymenoscyphus fraxineus* (Chalara, Ash dieback) are examples of invasive alien pathogens that have recently been introduced into the Irish country side to the detriment of Irish plant health. We recommend that people returning from abroad do not bring any biological material (e.g. plants, insects) back with them unless they have been cleared at customs by the designated official. Further important steps include thoroughly cleaning any footwear you may have used abroad before you venture into the Irish countryside.

OTHER *PHYTOPHTHORA* SPECIES PRESENT IN IRISH FORESTS

The PHYTOFOR project has revealed much about the biology and epidemiology of *P. ramorum* in Irish larch forests. During the process of sampling for *P. ramorum* a number of other *Phytophthora* species were also detected. The most dangerous of these to Irish plant health is *Phytophthora kernoviae*. This plant pathogen was first discovered in Cornwall in Britain in 2003, and has since been found in Ireland (in 2008), New Zealand (pre 1950) and Chile (in 2014). It has never been found in Northern Ireland. *Phytophthora kernoviae* is thought to be native to New Zealand and Chile, while having been introduced sometime in the 20th century to Ireland and Britain. It is very damaging to tree species (e.g. European beech), ornamental plants (e.g. *Rhododendron*) and to native shrubs (e.g. *Vaccinium*) and causes symptoms very similar to *P. ramorum* on these hosts. Biologically it differs to *P. ramorum* in some ways. Research carried out by PHYTOFOR found it has a narrower range of growth temperatures and is less damaging to *Rhododendron* foliage than *P. ramorum* (Fig. 6). These characteristics may in part be responsible for its restricted distribution in Ireland to date, with infections in the wild being mainly confined to the south west of the country.

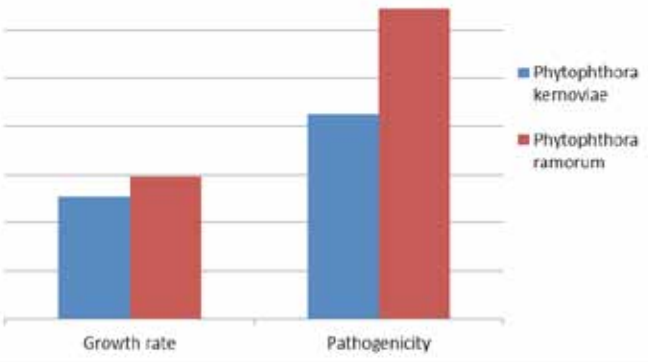

Figure 6 Comparison of *Phytophthora kernoviae* and *Phytophthora ramorum* based on their radial growth rate and their pathogenicity to *Rhododendron* in lab trials at 20°C

Other *Phytophthora* species detected in Irish forests by the PHYTOFOR researchers include *Phytophthora pseudosyringae*, *Phytophthora cinnamomi*, *Phytophthora alni* (Fig. 7), *Phytophthora gonapodyides* and *Phytophthora chlamydospora*. The first three species listed are plant pathogens, with *P. pseudosyringae* emerging as a worrying threat to Irish forests following it detection in Japanese larch, European beech and Southern beech in Ireland. The final two species listed are usually found in streams and rivers, where they function as decomposers of decaying plant letter and sometimes as opportunistic pathogens. One significant trend world-wide, which has also been noted in the PHYTOFOR research, is the increasing number of invasive alien *Phytophthora* species being detected in natural habitats. Many of these pathogens are being brought in to the country on infected plants, and could represent a serious threat to Irish ecosystems in the near future.

Figure 7 Dieback of Alder caused by *Phytophthora alni*

FURTHER INFORMATION

Department of Agriculture, Food and the Marine, Ireland - Forest Service: http://www.agriculture.gov.ie/forestservice/foresthealthandseeds/

Department of Agriculture, Food and the Marine, Ireland - Horticulture and Plant Health: http://www.agriculture.gov.ie/farmingsectors/planthealthtrade/

Department of Agriculture and Rural Development, Northern Ireland – Plant and Tree Health: http://www.dardni.gov.uk/index/plant-and-tree-health.htm

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