

EPPO Datasheet: *Phytophthora kernoviae*

Last updated: 2022-09-20

IDENTITY

Preferred name: *Phytophthora kernoviae*

Authority: Brasier, Beales & S.A. Kirk

Taxonomic position: Chromista: Oomycota: Oomycetes:

Peronosporales: Peronosporaceae

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EPPO Categorization: A2 list

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EPPO Code: PHYTKE



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Notes on taxonomy and nomenclature

Phytophthora kernoviae was first described as a new species in 2005 (Brasier *et al.*, 2005a). It was previously known informally as *Phytophthora* taxon C and as *Phytophthora kernovii* (Anon., undated). Phylogenetically it is in clade 10b of the genus *Phytophthora* and it resides in Waterhouse Group II (Blair *et al.*, 2008; Abad, undated).

HOSTS

Phytophthora kernoviae was first detected in 2003 during surveys for *Phytophthora ramorum* in South-West England. It was causing a large bleeding stem lesion on a beech tree (*Fagus sylvatica*) as well as foliar and stem necrosis on *Rhododendron ponticum* in woodland (Brasier *et al.*, 2005a). Subsequently it was also found in the wider environment causing leaf and stem symptoms on bilberry (*Vaccinium myrtillus*) (Beales *et al.*, 2009). In the United Kingdom and Ireland *Rhododendron* (typically *R. ponticum*) is the primary host for *P. kernoviae*; bilberry (*V. myrtillus*) is also a primary host especially in South-West England. Findings have also been made on a wider range of ornamental hosts outside of woodlands in gardens and nurseries in the UK and Ireland, especially *Magnolia*. (Forest Research, 2022a). Cherimoya or custard apple (*Annona cherimola*) was also reported as a host in New Zealand (Anon., 2008) as well as *Pinus radiata* (radiata pine) (Dick *et al.*, 2014; Fraser *et al.*, 2020).

Host list: *Aesculus hippocastanum*, *Agathis australis*, *Annona cherimola*, *Berberis*, *Castanea sativa*, *Drimys winteri*, *Fagus sylvatica*, *Gevuina avellana*, *Hedera helix*, *Ilex aquifolium*, *Leucothoe fontanesiana*, *Liriodendron tulipifera*, *Lomatia myricoides*, *Magnolia amoena*, *Magnolia cylindrica*, *Magnolia delavayi*, *Magnolia doltsopa*, *Magnolia kobus*, *Magnolia liliiflora*, *Magnolia salicifolia*, *Magnolia sargentiana*, *Magnolia sprengeri*, *Magnolia stellata*, *Magnolia wilsonii*, *Magnolia x brooklynensis*, *Magnolia x soulangeana*, *Pieris formosa*, *Pieris japonica*, *Pinus radiata*, *Podocarpus salignus*, *Prunus laurocerasus*, *Quercus ilex*, *Quercus robur*, *Rhododendron ponticum*, *Rhododendron*, *Sequoiadendron giganteum*, *Vaccinium myrtillus*

GEOGRAPHICAL DISTRIBUTION

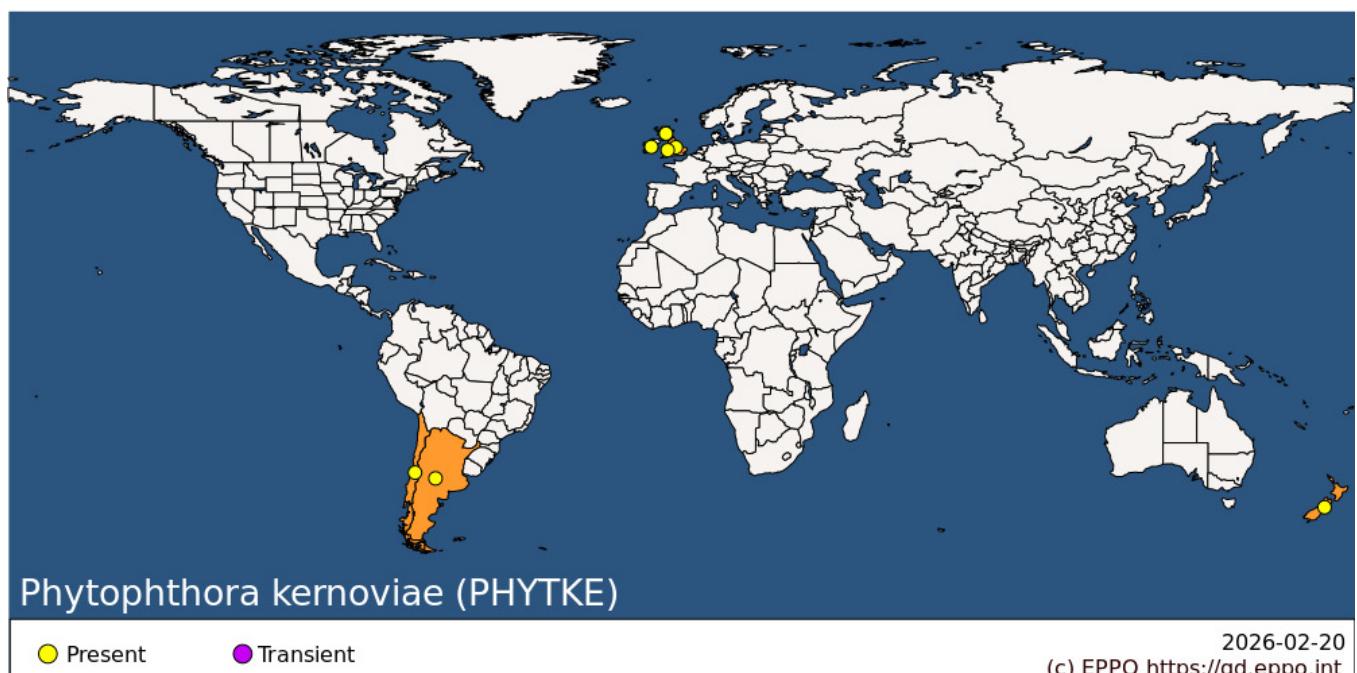
P. kernoviae is present in the United Kingdom (England, Scotland and Wales), Ireland, New Zealand, Argentina and Chile.

The pathogen was first found in 2003 as an unidentified new species in the South-West of England during surveys for *P. ramorum*. It is mostly found in South-West England (Devon and Cornwall) but there have been findings across the United Kingdom (with the exception of Northern Ireland where it has not been found) (EPPO, 2009; Forest Research, 2022a); it has also been found in the Republic of Ireland (EPPO, 2010). These are the only countries in Europe where the pathogen has been found. It is considered to have been introduced to the United Kingdom and Ireland via the nursery trade (Brasier *et al.*, 2005b).

P. kernoviae was first found in New Zealand in 2005 by DNA sequencing of an isolate obtained from rotting fruit of *Annona cherimola* in an abandoned orchard in Northland (North Island) in 2002. Subsequent studies suggest the organism has been present in New Zealand since at least 1953 and is relatively widespread in the North Island, in soil in native forests or recently converted native forests. The earliest record of *P. kernoviae* in New Zealand is now considered to be from soil under symptomless *P. radiata* (radiata pine) sampled in the 1950s, the so-called 'Tokoroa Phytophthora' (Ramsfield *et al.*, 2009).

In Chile, symptomatic fallen leaves of *Drimys winterii* in a native evergreen forest in Southern Chile were found to be infected with *P. kernoviae* in 2012 (Sanfuentes *et al.*, 2016); it was later found in soil and water samples from the Valdividian rain forest (Jung *et al.*, 2018).

The geographical origins of *P. kernoviae* are still debated. *In vitro* investigations showed that it grows best on carrot agar at around 18°C with an upper limit for growth of 26°C, this suggests it is adapted to a temperate climate (Brasier *et al.*, 2005a). The reports from New Zealand and Chile and reports on southern hemisphere hosts in the United Kingdom (*Podocarpus*, *Drimys* and *Gevuina*) suggest a possible southern hemisphere origin for this species (Forest Research, 2022a).



EPPO Region: Ireland, United Kingdom (England, Scotland, Wales)

South America: Argentina, Chile

Oceania: New Zealand

BIOLOGY

P. kernoviae produces sporangia on some, but not all infected hosts. These contain motile infective zoospores. The sporangia are caducous (deciduous and detached primarily by water); this aids dispersal from the aerial parts of infected plants. Local spread is by water splash (sporangia/zoospores) whereas longer distance spread of sporangia may involve some wind assistance e.g. wind-blown mists or wind-driven rain (Sansford, 2008). Once alighted on a host, under suitably moist conditions, each sporangium releases the swimming zoospores, which penetrate susceptible host material. Infection is more likely via wounds or natural openings such as stomata and lenticels. The organism then grows through the infected tissue, killing plant cells in its path, and eventually resulting in symptoms of disease. Under suitable conditions, asexual reproduction then takes place and new sporangia are produced thus completing the lifecycle of the pathogen (Anon., undated).

Note that trees such as beech (*F. sylvatica*) do not produce inoculum from bleeding cankers and are likely to have become infected from nearby sporulating hosts, particularly *R. ponticum* which is invasive in woodlands in the

United Kingdom (Fichtner *et al.*, 2011). *R. ponticum* is an important host of *P. kernoviae*, as it is highly susceptible to infection and supports abundant sporulation (Webber, 2009). Infection of bilberry (*V. myrtillus*) in heathlands in South-West England can take place all year-round under prolonged conditions of high humidity (Fera, 2012).

P. kernoviae has not been found to produce chlamydospores which are the survival structures for many other species of *Phytophthora*. However, it has been found to produce oospores, the product of sexual reproduction *in vitro*, and it is known to be homothallic (able to reproduce sexually without an opposite mating type). Fichtner *et al.* (2011) found oospores of *P. kernoviae* in leaf discs of *R. ponticum* used as baits for detecting the pathogen and in several artificially-inoculated roots, these may facilitate long-term survival of the pathogen. They also detected an oogonium (a female gametangium) in one naturally-infected leaf of *R. ponticum*. Asymptomatic root infection was detected in *R. ponticum* and it was surmised that infected leaves and stems that drop to form leaf litter may serve as primary inoculum for infection of roots. These roots have the potential to yield sporangia leading to infection of above-ground plant parts or of other roots (Fichtner *et al.*, 2011).

Widmer (2011) reported that oospores of *P. kernoviae* persisted in infested sand for 1 year at various temperatures, up to 30°C. Field studies on the longevity of *P. kernoviae* in the natural environment have shown the pathogen to survive for at least 3 years in leaf litter and soil after removal of infected *R. ponticum* (Webber, 2009).

DETECTION AND IDENTIFICATION

Symptoms

Infection with *P. kernoviae* causes a diverse range of symptoms which are described in the EPPO Diagnostic Protocol (EPPO, 2013a). A summary of the main symptoms was given more recently by Forest Research, (2022a).

- - Bleeding cankers on the trunks of beech (*F. sylvatica*). The pathogen kills extensive areas of inner bark, often extending 10 metres or more up the stem. This necrotic zone oozes a black, sticky fluid, forming so-called 'bleeding cankers'. These have also been found on oak (*Quercus robur*)
- Leaf necrosis on *Rhododendron*, *Pieris* and *Magnolia*. On rhododendron leaves there is also often blackening down the mid-vein and stalk
- Extensive dieback of bilberry (*V. myrtillus*), including stem blackening and necrotic leaves which are quickly shed
- Leaf spot, bud blast and blossom blight on *Magnolia*
- Leaf necrosis on a range of other species

Morphology

P. kernoviae is a homothallic species (self-fertile) and it does not produce chlamydospores. Brasier *et al.* (2005) published its description as follows:

Oogonia diameter (range of means of 4 isolates) 23.5–25.5 µm, common range *ca* 21–28 µm; often with tapered stalks.

Antheridia amphigynous. Antheridial length x width (range of means *ca* 11.5–12.5 x 10–10.5 µm), common range *ca* 10–14 x 9–12 µm.

Oospores plerotic, diameter range of means *ca* 21.1–22.5 µm, common range *ca* 19–25 µm.

Sporangia borne on sympodial sporangiophores. Papillate, caducous, from regular ovoid or limoniform to distinctly asymmetrical or 'mouse-shaped' with one rounded and one flatter side. Most have a conspicuous vacuole. Sporangia length x width (range of means) *ca* 38.5–45.5 x 22.5–27 µm, common range *ca* 34–52 x 19–31 µm. Length: width ratio average *ca* 1.5 µm. Sporangial pedicels range of means *ca* 8.6–14.1 µm, common range *ca* 5–19 µm. Hyphae are sometimes denticulate or tuberculate.

Detection and inspection methods

The presence of *P. kernoviae* can be detected in different types of samples, e.g. plant material, water, soil, leaf litter or growing media. Visual inspections alone are not sufficient, because symptoms can vary between different plant species (EPPO, 2013a) and they can be visually undetectable (e.g. root infections, Fichtner *et al.*, 2011), or as is the case with many fungal or fungal-like plant pathogens, they can be latent or suppressed by the use of fungicides.

The EPPO Diagnostic Protocol (EPPO, 2013a) provides detailed information on how to detect *P. kernoviae* in a range of substrates:

- Isolation from water or soil (or growing media) is possible by using a bait test with rhododendron leaves.
- Isolation from plant material (selected plant parts or leaves previously used in a bait test) is possible after a surface disinfection followed by plating the plant material onto a suitable culture medium.

The identification of the pathogen is possible by using morphological methods combined with growth characteristics on culture media or by molecular (DNA-based) methods (EPPO, 2013a).

The typical morphological structures of *Phytophthora* (e.g. sporangia, gametangia, oospores) in culture and the growth characteristics must be checked and measured for identification. An identification key (e.g. Gallegly & Hong, 2008) should be used together with a comparison with the original species description (Brasier *et al.*, 2005a). The unique morphological features of *P. kernoviae* make it relatively easy to identify when grown-out on semi-selective media as described by EPPO (2013a).

There is a range of molecular methods available to detect *P. kernoviae*. EPPO (2013a) only describe validated and real-time PCR tests. Sequencing of the ITS region (using isolates from pure culture) is required for further confirmation of identification.

PATHWAYS FOR MOVEMENT

Release and dispersal of sporangia (see Biology) from infected plants is primarily considered to involve water, such as rain or mist events, and may also involve some wind assistance e.g. wind-blown mists or wind-driven rain-splash (Sansford, 2008). This can carry the spores over greater distances than water splash which enables the movement of motile zoospores between adjacent plants. As with *P. ramorum*, the pathogen has the potential to move in watercourses and irrigation and it is known it can survive in water (Kong *et al.*, 2012, 2012a). *P. kernoviae* can be detected in leaf litter and soil in woodlands where infected *R. ponticum* occurs (e.g. Fichtner *et al.*, 2011) so, as with *P. ramorum*, transportation by humans (for example on shoes or on car tyres) is also possible (Davidson *et al.*, 2005; Frankel, 2008; Grünwald *et al.*, 2008). Brown *et al.* (2006) support the view that plant collectors or the horticultural nursery trade were likely to have been responsible for the introduction of *P. kernoviae* to the United Kingdom. Brasier & Jung (2006) suggest that there is a link between *Phytophthora*-infested nursery stock (referring to the genus *Phytophthora*) and damage to forests with circumstantial evidence of the apparent spread of *P. kernoviae* from out-planted rhododendrons or other nursery stock onto *R. ponticum* and then onto trees in Cornwall. The pathogen has been found infecting plants in nurseries in the United Kingdom (Sansford, 2008) and there is potential for movement of infected plants or plant parts in the nursery trade.

PEST SIGNIFICANCE

Economic impact

Like *P. ramorum*, *P. kernoviae* was identified by the process of Pest Risk Analysis as posing a risk to the environment, private and managed gardens and woodlands as well as to the ornamental plant trade in the United Kingdom and overseas (Sansford, 2008, 2009). Emergency legislation was implemented in the United Kingdom in 2004 (revoked in 2014) to allow action to be taken against it wherever it was found (Anon., 2004). *P. kernoviae* is currently a 'provisional quarantine pest' in the United Kingdom and action is still taken on findings (Defra, undated).

Forest Research (2022a) have summarised the current situation with respect to impact:

P. kernoviae is a pathogen that has had a significant impact on environmentally-important hosts in the United Kingdom including beech trees (*F. sylvatica*) and bilberry (*V. myrtillus*) and this has had consequences for natural ecosystems. On beech the severity of damage can be the same as that caused by *P. ramorum* but currently it seems that for infection to occur, beech (and oak) trees need to be within 5 m of an infected sporulating host, such as *R. ponticum*. Bilberry is a key component of heathland, woodland, grassland and peat bog and infected plants usually die when infected with *P. kernoviae*.

P. kernoviae can also infect a wide range of ornamental garden species. This means there could be significant economic implications for the nursery and garden centre industries, and heritage gardens, if the disease is not managed to minimise its spread and impact. However, there were no findings in trade in the three years to 2019. Data from the Plant Health and Seeds Inspectorate (PHSI) showed that from 2020 onwards there were 13 findings at 9 sites including one retail nursery (A. Gaunt, PHSI, APHA, GB, *personal communication*, August 2022).

There are no data available on the actual impact that the pathogen has caused. However, Drake & Jones (2017) estimated that '*1446 million GBP of public value is at risk in England and Wales per year from an uncontrolled spread of Phytophthora ramorum and Phytophthora kernoviae. The greatest public value at risk, of 578 million GBP/year, is from an uncontrolled spread of these diseases to heritage gardens, while the lowest public value at risk, of 386 million GBP/year, is from disease spread to heathland*'.

In New Zealand, *P. kernoviae* infects cherimoya and *P. radiata*; Scott & Williams (2014) did not consider it to be a major pathogen at that time. However, Fraser *et al.* (2020) described the pathogen as being one of two causal agents of important needle diseases of *P. radiata* in New Zealand but there is no quantification of the likely impact.

Control

In the United Kingdom, control has focused on removing and destroying infected plants that have the potential to sporulate; in woodlands this has largely been *R. ponticum* which produces abundant sporangia and is the main source of infection for beech and oak. However, it is known that like *P. ramorum*, *P. kernoviae* can survive in soil and leaf litter (e.g. Webber, 2009; Fichtner *et al.*, 2011) and so eradication is difficult. There is no cure for infection with *P. kernoviae* and in woodland and forest situations it would be impractical to apply chemical treatments. Clearance of heathland with infected bilberry will still leave residual inoculum.

Biosecurity is important and people who work at infected sites should follow good practice, such as cleaning and disinfecting their tools, equipment, clothes, footwear, and vehicles between sites, to prevent the spread of the pathogen by these means. Guidance on this is available on the United Kingdom Government website (Anon., 2021).

With respect to chemical control for valuable plants in nurseries or in parks and gardens, preventative fungicidal treatments can be useful (Kliejunas, 2010). Metalaxyl, phosphetyl-aluminium, copper sulfate or phosphonate are effective against *P. ramorum* (Garbelotto & Rizzo, 2001; Garbelotto *et al.*, 2002) and no doubt would be effective against *P. kernoviae*.

Phosphite (phosphonate) is used to control and manage many *Phytophthora* diseases in horticultural systems worldwide; it does not kill *Phytophthora* species, but inhibits growth while also stimulating host defence responses (Hunter *et al.*, 2022). Rolando *et al.* (2017) found that phosphite, copper oxychloride and metalaxyl-M have potential (from *in vitro* and *in planta* experiments) to protect commercially planted *P. radiata* from *P. kernoviae* (and *P. pluvialis*). However, *in vitro* experiments by Hunter *et al.* (2022) on the efficacy of phosphite against mycelial growth showed huge intraspecific variability on the effect of the chemical against *P. kernoviae*, and questioned whether diseases caused by *P. kernoviae* such as needle blight of *P. radiata* could be managed effectively with phosphite. The use of an organosilicone adjuvant however enhanced uptake of phosphite into needles of *P. radiata* (Rolando *et al.*, 2014)

Disinfection of contaminated water is possible with copper-based active ingredients (Colburn & Jeffers, 2010).

Sanitation is necessary to maintain pathogen-free plant material. This includes removing and testing symptomatic stock, sterilising potting media and disinfecting tools, benches, workers' gloves, shoes and other equipment (Erwin & Ribeiro, 1996).

No data on research on resistance in host plants to *P. kernoviae* or biological control could be found.

Phytosanitary risk

In the EPPO region, *P. kernoviae* presents a risk to many different plants including trees and shrubs which grow in ecologically-significant environments such as woodland and heathland as well as those which are grown in parks and gardens and move in the nursery trade.

Beech (*F. sylvatica*), oak (*Q. robur*), rhododendron (*Rhododendron* spp.), holm oak (*Q. ilex*) (a Mediterranean species), and a range of ornamental trees and shrubs are at risk as well as *V. myrtillus* (bilberry) which is of ecological importance. *P. kernoviae* can be lethal to some species including beech, rhododendron and bilberry. *R. ponticum* is an invasive species which is also a significant source of infection to trees in woodlands and so whether it is infected or not, its removal would be beneficial to protect other species.

Importantly, *P. kernoviae* appears to be favoured by temperate climates which may explain its current limited distribution (Fraser *et al.*, 2020). Consequently, climate matching would help better determine the risk to the wider EPPO region.

PHYTOSANITARY MEASURES

EPPO (2013b) combines measures for *P. kernoviae* and *P. ramorum* as their biology is similar in many respects. In order to prevent entry or spread of *P. kernoviae*, introduced plants should originate from a pest-free crop, place of production or area provided suitable surveillance, monitoring and testing regimes are in place. A buffer zone around places of production of at least 10 m for known host shrubs should be in place to avoid the risk of infection from sporulating hosts. A 100 m buffer zone is recommended for tall sporulating trees. This would only apply to *P. radiata* as this species has the potential to sporulate but its inoculum potential is unknown.

Introduced host plants should comply with the relevant legislation and certification, such as requirements for phytosanitary certificates, a plant passport in EU countries or a scientific license if a phytosanitary certificate cannot be issued.

Countries should also apply appropriate measures if *P. kernoviae* is detected in areas other than places of production, e.g. parks, gardens, forests. Eradication of the pathogen should be attempted, but if this is not possible, at least measures should be taken to contain the pest, by removing as much infected plant material as possible to reduce the pressure of infection. It is recommended to apply the following measures, depending on the decision for eradication or containment: (1) Prohibition of movement of susceptible plants, plant parts (including trees) and soil/growing media; (2) Phytosanitary measures to prevent spread of the pest; (3) Control measures; (4) Surveillance. The phytosanitary measures include the removing of plant debris, disposing of susceptible plants or plant material by burning or deep burying them, repairing and maintaining footpaths, restricting access to contaminated areas, hygiene measures such as cleaning and disinfecting shoes or machines; these actions can usefully be accompanied by signs to inform the public about the measures mentioned (EPPO, 2013b).

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ACKNOWLEDGEMENTS

This datasheet was prepared in 2022 by Dr Claire Sansford, Independent Plant Health Consultant, York, GB (Former Principal Risk Analyst with Fera, GB). Her valuable contribution is gratefully acknowledged.

How to cite this datasheet?

EPPO (2026) *Phytophthora kernoviae*. EPPO datasheets on pests recommended for regulation. Available online.
<https://gd.eppo.int>

Datasheet history

This datasheet was first published online in 2022. It is maintained in an electronic format in the EPPO Global Database. The sections on 'Identity', 'Hosts', and 'Geographical distribution' are automatically updated from the database. For other sections, the date of last revision is indicated on the right.



Co-funded by the
European Union