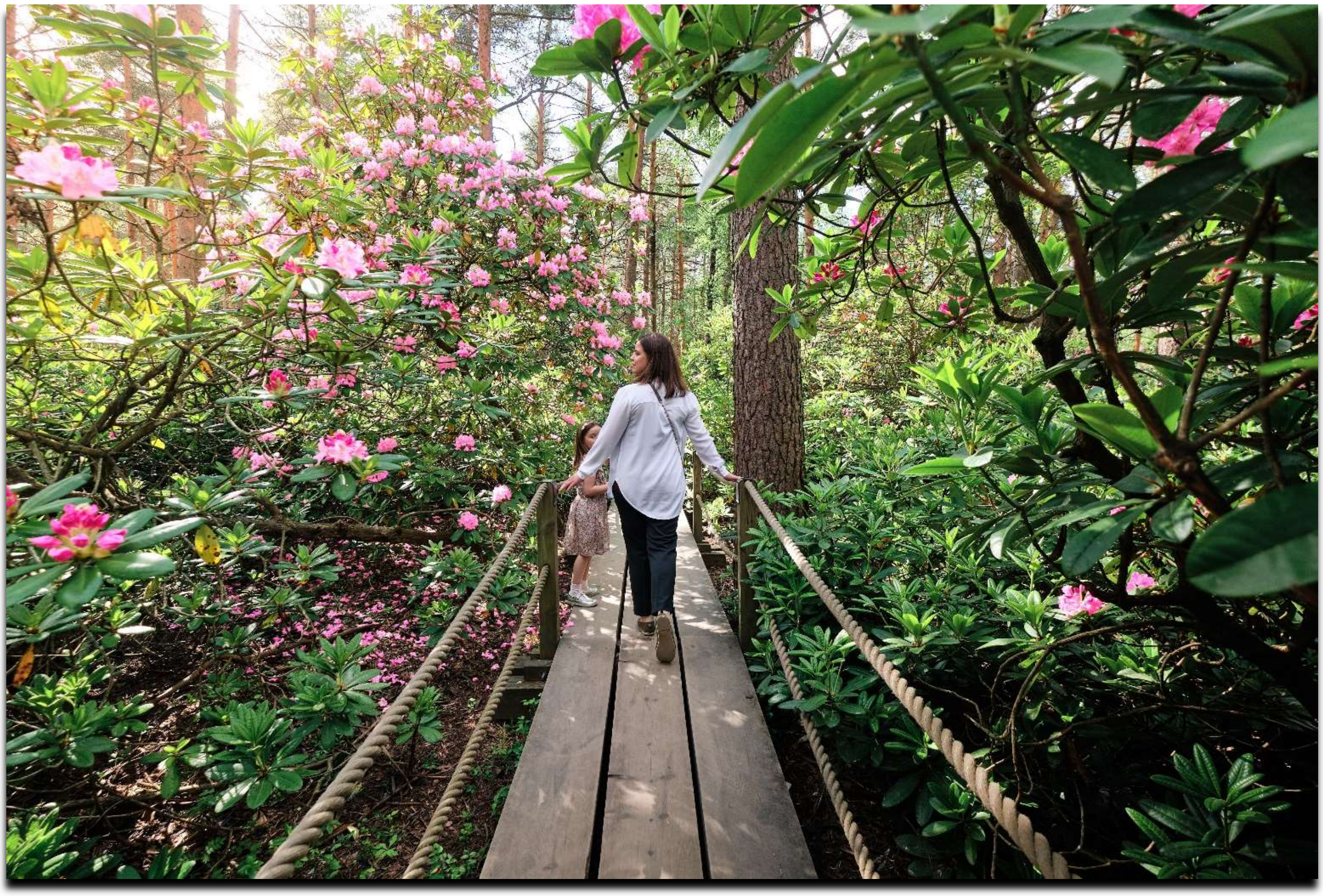
Vitenskapskomiteen for mat og miljø
Norwegian Scientific Committee for Food and Environment



VKM Report 2023: 19

Updated pest risk assessment of *Phytophthora ramorum* in Norway

Scientific Opinion of the Panel on Plant Health of the Norwegian Scientific Committee for Food and Environment

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Cover photo: Mother and her daughter are walking in Rhododendrons Park. It is one of the most popular and beautiful places in Helsinki, Finland. Photo by: Lev Karavanov.

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Preparation of the opinion

The Norwegian Scientific Committee for Food and Environment (Vitenskapskomiteen for mat og miljø, VKM) appointed a project group to draft the opinion. The project group consisted of four VKM members and two VKM staff members.

Three referees commented on and reviewed the draft opinion. The VKM Panel on Plant Health evaluated and approved the final report.

Authors of the opinion

All authors have contributed to the report in a way that fulfills the authorship principles of VKM (VKM, 2019). The principles reflect the collaborative nature of the work, and the authors have contributed as members of the project group and the VKM Panel on Plant Health.

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Acknowledgment

VKM would like to thank the referees Johanna Boberg, Niklas Björklund, SLU, and Matteo Garbelotto U.C. Berkeley for reviewing and commenting on the manuscript. VKM emphasizes that the referees are not responsible for the content of the final opinion. In accordance with VKM's routines for approval of risk assessments (VKM, 2018), VKM received the referee comments before evaluation and approval by the Panel on Plant Health, and before the opinion was finalized for publication.

Competence of VKM experts

Persons working for VKM, either as appointed members of the Committee or as external experts, do this by virtue of their scientific expertise, not as representatives for their employers or third-party interests. The Civil Services Act instructions regarding conflicts of interest apply to all work prepared by VKM.

Contents

Summary

Key words: VKM, pest risk analysis, Norwegian Scientific Committee for Food and Environment, Norwegian Food Safety Authority, Sudden oak death, *Phytophthora ramorum*

Introduction

The Norwegian Food Safety Authority has asked the Norwegian Scientific Committee for Food and Environment for an updated pest risk assessment of *Phytophthora ramorum* in Norway. The previous risk assessment of *P. ramorum* for Norway is from 2009. Since then, the pathogen has been detected repeatedly in Norway, primarily in parks, garden centres, and nurseries in southwestern Norway. The knowledge base concerning *P. ramorum* has changed since the last pest risk assessment, with increased genetic knowledge about different populations, lineages, and mating types. The risks associated with *P. ramorum* have also changed, since the disease has become epidemic in new host plants, such as larch trees in England. This updated pest risk assessment will provide important input to the Norwegian Food Safety Authority's efforts to develop the Norwegian plant health regulation.

Methods

VKM established a project group with expertise in plant health, forest pathology, horticultural plant pathology, plant disease modelling, and pest risk assessment. The group conducted systematic literature searches and scrutinized the relevant literature. In the absence of Norwegian studies, VKM relied on literature from other countries. The group did a quantitative risk assessment describing the level of confidence in the conclusions and identifying uncertainties and data gaps. The report underwent pre-submission commenting and external expert reviewing before final approval and publication.

Results and conclusions

Phytophthora ramorum is present in the PRA area but has a restricted distribution, mainly being detected in the southern and southwestern parts of Norway.

The only *P. ramorum* lineage considered to be present in Norway is EU1 with mating type A1. The other lineage in Europe, EU2, has so far mainly been documented from the UK. The most widely distributed multilocus genotype of *P. ramorum* in Norway is EU1MLG1, which became dominant in Europe (including Norway) after 2008. In North America, the NA1, NA2, and EU1 lineages are known from both nurseries and forests. NA1 and NA2 are of the opposite mating type (A2) than European lineages. Recently, various other lineages of *P. ramorum* have been described from Asia. The main risks for future problems with *P.*

ramorum in Norway are related to entry and establishment of non-European isolates (of all lineages), as well as emergence of new genotypes in European *P. ramorum* populations.

There are several options for diagnosing *P. ramorum* to species and lineage (mainly EU1, EU2, NA1, and NA2). From a management perspective it is more important to distinguish these entities than mating type and isolate groups (genotypes). The latter are mainly relevant for research purposes or in cases of unexpected disease developments, such as new hosts, increased spread or more severe symptoms on known hosts. However, for more detailed regulation, monitoring, and management of *P. ramorum* it could also be useful to test for genotypes, i.e. to distinguish EU1MLG1 from other genotypes.

Rhododendron remains the most important host plant for *P. ramorum* in Norway, both in terms of imported plants and detections (mainly in nurseries, garden centres, and public parks). Species in other ornamental plant genera, such as *Viburnum*, *Pieris*, and *Kalmia,* are also listed as major hosts in Europe, and *P. ramorum* has been detected at least once on species in all these genera in Norway. In the US, *Rhododendron*, *Viburnum*, *Pieris*, *Syringa*, and *Camellia* are considered to be the main ornamental hosts. In Norway, there has been one documented detection of *P. ramorum* on *Syringa*. *Vaccinium* and several tree species are potential hosts in the wider environment in Norway, but these hosts are most likely to be infected on sites where rhododendrons are affected by *P. ramorum*.

We consider the probability of entry of *P. ramorum* to Norway to be very likely, with a low level of uncertainty. Plants for planting, in particular rhododendron and other ornamental hosts, remain the most important entry pathway for *P. ramorum*. Due to the high import volumes to Norway from Europe, nurseries in the EU are still the main sources of infected plants.

If efforts to prevent import of infected plants and to eradicate *P. ramorum* infestations are discontinued, we consider it very likely that the pathogen will eventually establish in or spread to new areas in Norway. There is a high potential for establishment and spread of *P. ramorum* along the southwestern and southern coast of Norway, where climatic conditions are favourable for the pathogen and rhododendron and other hosts are common.

We consider the overall probability of spread of *P. ramorum* in Norway after establishment to be moderately likely, with a medium level of uncertainty. Despite repeated detections of the pathogen in some locations, further spread seems to be local and limited. New sites with *P. ramorum* outbreaks have been rare in Norway in the last decade. Whether this is due to import regulations, eradication efforts (removal of infected plants) or other factors is difficult to determine. Despite the limited spread of *P. ramorum* in Norway so far, the potential for persisting infections and spread in areas with a conducive climate (high precipitation) cannot be ignored.

Phytophthora ramorum still meets the criteria for being regulated as a potential quarantine pest, at least all other lineages than EU1 – thought to be the only lineage present in Norway. For the EU1 lineage, a possible categorization for European isolates is 'regulated non-quarantine pest', whereas non-European EU1 isolates fulfil the criteria of being a quarantine pest. Within the EU1 lineage there are different isolate groups, and new genotypes may arise. If the genotype of EU1 isolates detected in imported plant materials differs from isolates that are already present in Norway, European EU1 isolates also fit the category 'quarantine pest'.

The potential effect of introducing new lineages, mating types or isolate groups is considered to be similar for new areas in Norway and areas where *P. ramorum* is already present. If the pathogen becomes widely spread and/or more genotypically diverse, the potential for damage is considered to be high, due to disease development in infected trees and the possibility of shifts in host plants. In addition to preventing new introductions, it is important to limit domestic spread of the pathogen from known infestations and, if possible, to eradicate *P. ramorum* from those sites. The longer *P. ramorum* is present at a site, and the more widespread the pathogen becomes, the higher is the risk that the pathogen will adapt to (new) local hosts and environmental factors.

Monitoring host plants for symptoms and testing for the presence of *P. ramorum,* especially on imported plants, remain the best risk-reducing options. Other effective risk-reducing options are prompt removal and destruction of infected ornamental hosts, in particular rhododendron, and to not replant with susceptible plant species. For infected trees, the best management measures depend on the situation, but infected larch trees should always be removed and destroyed. For non-transmissive tree species, such as beech, the risk of inadvertently spreading the pathogen during felling activities should be weighed against the risk associated with leaving an infected tree on site. Finally, it can be useful to run public awareness campaigns about the importance of cleaning soil from footgear and other items after visiting areas where *P. ramorum* is present (both in Norway and abroad), as well as other risk-reducing options for private gardens.

Sammendrag på norsk

Stikkord: Mattilsynet, risikovurdering, VKM, Vitenskapskomiteen for mat og miljø, Ramorum-greinvisning, *Phytophthora ramorum*

Innledning

Mattilsynet har bedt Vitenskapskomiteen for mat og miljø om en oppdatert risikovurdering av *Phytophthora ramorum* i Norge. Den forrige norske risikovurderingen av *P. ramorum* er fra 2009. Siden den gang har patogenet blitt påvist gjentatte ganger i Norge, først og fremst i parker, hagesentre og planteskoler i sørvest-Norge. Kunnskapsgrunnlaget om *P. ramorum* har endret seg siden forrige risikovurdering, med økt kunnskap om ulike populasjoner, genetiske linjer og krysningstyper. Risikoen forbundet med *P. ramorum* har også endret seg, siden sykdommen har blitt epidemisk i nye vertsplanter, som lerketrær i Storbritannia. Denne oppdaterte risikovurderingen vil gi Mattilsynet viktige innspill i arbeidet med å videreutvikle den norske plantehelseforskriften.

Metoder

VKM etablerte en prosjektgruppe med ekspertise innen plantehelse, skogpatologi, hagebrukspatologi, modellering av plantesykdommer og risikovurdering. Gruppen gjennomførte systematiske litteratursøk og leste relevant litteratur. I mangel av norske studier støttet gruppen seg i stor grad på litteratur fra andre land. Gruppen gjorde en kvantitativ risikovurdering der den beskrev graden av tillit til sine konklusjoner og identifiserte usikkerheter og datahull. Rapporten ble kommentert og vurdert av eksterne eksperter før endelig godkjenning og publisering.

Resultater og konklusjoner

Phytophthora ramorum finnes i Norge, men utbredelsen er begrenset og patogenet er hovedsakelig påvist i de sørlige og sørvestlige delene av landet.

Den eneste genetiske linjen av *P. ramorum* som er bekreftet å være til stede i Norge er EU1 med krysningstype A1. Den andre genetiske linjen i Europa, EU2, er så langt hovedsakelig funnet i Storbritannia. Den mest utbredte multilocus-genotypen av *P. ramorum* i Norge er EU1MLG1, som ble dominerende i Europa, inkludert Norge, etter 2008. I Nord-Amerika er linjene NA1, NA2 og EU1 kjent fra både planteskoler og skog. NA1 og NA2 tilhører en annen krysningstype (A2) enn de europeiske linjene. Nylig er flere andre *P. ramorum*-linjer blitt beskrevet fra Asia. Den største risikoen for ytterligere problemer med *P. ramorum* i Norge er knyttet til innførsel og etablering av ikke-europeiske isolater (av alle linjer), og at det skal oppstå nye genotyper i europeiske *P. ramorum*-populasjoner.

Det finnes flere metoder for å diagnostisere *P. ramorum* til art og genetisk linje (hovedsakelig EU1, EU2, NA1 og NA2). Fra et forvaltningsperspektiv er det viktigere å skille genetiske linjer enn krysningstyper eller isolatgrupper (genotyper). Krysningstyper og isolatgrupper er viktigst i forskningsøyemed eller når det oppstår uventet sykdomsutvikling, som økt spredning, forekomst i nye verter eller mer alvorlige symptomer i kjente verter. Det kan imidlertid være nyttig å teste for genotyper, for eksempel for å skille EU1MLG1 fra andre genotyper, hvis en ønsker mer detaljert overvåking, forvaltning og regulering av *P. ramorum*.

Rododendron er den viktigste vertsplanten for *P. ramorum* i Norge, både når det gjelder antall importerte planter og antall påvisninger (hovedsakelig i planteskoler, hagesentre og offentlige parker). Arter i andre prydplanteslekter, som *Viburnum*, *Pieris* og *Kalmia*, regnes også som hovedverter for *P. ramorum* i Europa, og patogenet er påvist minst én gang i Norge på arter i alle disse slektene. I USA anses arter av *rododendron, Viburnum, Pieris, Syringa* og *Camellia* å være de viktigste vertene blant prydplanter. I Norge har det vært én dokumentert påvisning av *P. ramorum* på *Syringa* (syrin). Bærlyngslekten *Vaccinium* og flere treslag er mulige verter i norsk natur, men disse vertene er mest utsatt for smitte dersom de vokser på lokaliteter der *P. ramorum* forekommer på rododendron.

Vi vurderer det som svært sannsynlig, med lav usikkerhet, at *P. ramorum* fortsatt vil bli innført til Norge. Planter-for-planting, spesielt rododendron og andre prydplanter, er fortsatt den viktigste innførselsveien for *P. ramorum*. På grunn av de høye importvolumene til Norge fra Europa er planteskoler i EU fortsatt hovedkilden til smitte.

Dersom man i Norge avslutter innsatsen for å hindre import av infiserte planter og å utrydde *P. ramorum*-angrep, anser vi det som svært sannsynlig at patogenet etter hvert vil spre seg til og etablere seg i nye områder. *Phytophthora ramorum* har et stort potensial for å spre og etablere seg langs sørvest- og sørkysten av Norge. Her er det gunstige klimatiske forhold for patogenet, og rododendron og andre vertsplanter er vanlige.

Vi vurderer den samlede sannsynligheten for videre spredning av *P. ramorum* i Norge etter etablering som middels sannsynlig, med middels usikkerhet. Til tross for gjentatte påvisninger av patogenet enkelte steder synes videre spredning å være lokal og begrenset. Utbrudd av *P. ramorum* i nye områder har vært sjeldne det siste tiåret. Det er vanskelig å fastslå om dette skyldes importbegrensninger, forvaltningsinnsats (særlig fjerning av infiserte planter) eller andre faktorer. Til tross for begrenset spredning av *P. ramorum* i Norge til nå, kan en ikke se bort fra muligheten for at vedvarende forekomst av patogenet kan føre til spredning i områder med et gunstig klima (særlig mye nedbør).

Phytophthora ramorum oppfyller fortsatt kriteriene for å være regulert som en karanteneskadegjører. Dette gjelder i hvert fall alle andre genetiske linjer enn EU1, som er antatt å være den eneste genetiske linjen som finnes i Norge. En mulig kategorisering for europeiske EU1-isolater er "regulert ikke-karanteneskadegjører", mens ikke-europeiske EU1-

isolater oppfyller kriteriene for å være en karanteneskadegjører. Innenfor EU1-linjen finnes det ulike isolatgrupper og nye genotyper kan også oppstå. Hvis en i importert plantemateriale finner EU1-isolater med en genotype som skiller seg fra isolater som allerede finnes i Norge, vil slike europeiske EU1-isolater også oppfylle kriteriene for å være en karanteneskadegjører.

Risikoen forbundet med å introdusere nye genetiske linjer, krysningstyper eller isolatgrupper anses å være lik for nye områder i Norge og områder hvor *P. ramorum* allerede finnes. Skadepotensialet vurderes som høyt dersom patogenet blir vidt utbredt og/eller mer genotypisk mangfoldig, både på grunn av sykdomsutvikling i infiserte planter og på grunn av faren for at patogenet skal utvikle evnen til å infisere nye plantearter. I tillegg til å forhindre ny innførsel av *P. ramorum* til Norge er det viktig å begrense innenlands spredning av patogenet og, hvis mulig, å utrydde *P. ramorum* der patogenet allerede finnes. Jo lengre *P. ramorum* er til stede på et sted, og jo mer utbredt patogenet blir, desto høyere er risikoen for at det vil tilpasse seg (nye) lokale verter og miljøforhold.

De mest effektive risikoreduserende tiltakene mot *P. ramorum* er fortsatt å overvåke vertsplanter for symptomer og å teste for tilstedeværelse av *P. ramorum*, spesielt på importerte planter. Andre effektive risikoreduserende tiltak er å umiddelbart fjerne og ødelegge infiserte prydplanter, spesielt rododendron, og å ikke plante på nytt med mottakelige arter. For infiserte trær vil hva som er best tiltak avhenge av situasjonen, men infiserte lerketrær bør alltid fjernes og destrueres. For vertstrær som ikke kan overføre *P. ramorum*, som bøk, bør en veie risikoen for utilsiktet spredning av patogenet i forbindelse med trefelling opp mot risikoen forbundet med å etterlate et infisert tre på stedet. Det kan også være nyttig med informasjon til allmenheten om viktigheten av å rense jord fra fottøy og andre gjenstander etter besøk i områder der *P. ramorum* finnes (både i Norge og i utlandet), samt informasjon om andre risikoreduserende tiltak for private hager.

Abbreviations and glossary

AFLP	Amplified Fragment Length Polymorphisms, a PCR-based tool for genetic fingerprinting.
Chlamydospore	a thick-walled and resistant asexual spore.
COX	Mitochondrial cytochrome *c* oxidase; the gene encoding the protein that is responsible for cellular oxygen consumption and energy generation of ATP through aerobic respiration, COX mitochondrial sequence in then the DNA sequence encoding mitochondrial cytochrome *c* oxidase.
Disease cycle	the chain of events that plant pathogens use during plant disease development, such as recognition, attachment, germination, penetration, infection, development and reproduction/sporulation.
Genotype	the genetic makeup of an organism; all the genes of an organism.
HIPD	host-induced phenotypic diversification. HIPD is the rapid phenotypic adaptation observed in the pathogen (e. g. *P. ramorum*), when it encounters new plant hosts in a non-native habitat. Large genome rearrangements in *P. ramorum* are responsible for the observed HIPD.
Hyphae	(singular: *hypha*) are long, thin filamentous threads of fungal matter that often make branches.
Isolate	an individual of *P. ramorum* in the context of being isolated from a source (a plant, water, etc). An isolate can become a strain when it has been identified, characterized, and is often given a strain name that consists of a combination of a few letters and numbers.
Köppen-Geiger	one of the most used climate classification systems, which is divides the climate into 5 major groups: A (tropical), B (arid), C (temperate), D (continental), and E (polar), which in turn are divided into subgroups. It was invented by Wladimir Köppen and developed further by Rudolf Geiger.
Lineage	a group of individuals originating from a common ancestor. Examples of different lineages of *P. ramorum* are EU1, EU2, NA1 and NA2.

Mating type one of two 'sexes', in fungi often designated as + or -. For *P. ramorum*, they are designated A1 and A2. Hyphal tips of isolates/strains of opposite mating type can fuse to form the sexual spore, called oospore. If the isolates/strains are of the same mating type, they cannot mate.

Microsatellite marker genetic markers that utilize repeated sets of nucleotides in the DNA, so called motifs (ranging from 1 to 6 base pairs), which appears 5–50 times in a genome. They are used in population genetics to measure the levels of relatedness between subgroups and individuals.

MLG MultiLocus Genotype, a unique combination of alleles across two or more loci of an individual organism.

Nwt = non-wildtype. The genotype has changed, as compared to the wildtype (*wt*), i. e. the original genotype.

Oospore non-motile, sexual spore, resistant to environmental stressors, which can serve as a resting spore.

PCR Polymerase Chain Reaction. It is a laboratory technique that can produce millions of copies of a specific area of DNA. It is often used as a first step towards identification of organisms or groups of organisms.

PCR-RFLP Polymerase Chain Reaction - Restriction Fragment Length Polymorphism. This laboratory technique can be employed to distinguish genetic differences between individuals. The principle is to use restriction enzymes that digest the DNA fragments that previously have been amplified by PCR and look for patterns or differences in the digestion profiles.

Phenotype the observable traits or characteristics of an organism. The phenotype dependent on the environment, thus that the influence of the environment on the genotype will determine the phenotype.

PRA Pest Risk Assessment.

SNP Single Nucleotide Polymorphism. Substitution of a single nucleotide (A, T, G or C) at a specific position in the genome that occurs in at least 1% of the population.

Sporangium (*pl. sporangia*) = non-motile, asexual spore. Can germinate and produce hyphae or release zoospores.

Spore	general designation for a propagule of a fungus or oomycete. Can be sexual or asexual.
Strain	an isolate that has been worked on, and/or identified to the species level.
wt	wildtype. The original genotype (not changed).
SV	Structural Variants. Changes in the genomic DNA. Genetic events that give rise to structural variants are deletions, duplications, insertions, inversions and translocations.
Zoospore	motile, asexual spores (with flagella), released from a sporangium.

Background as provided by the Norwegian Food Safety Authority

In 2009 VKM published a pest risk assessment of *Phytophthora ramorum* in Norway, commissioned by Mattilsynet. In the report, VKM concluded i.a. that there is a high probability that infested plants will also be imported into Norway in the future and that presence of host plants and a favourable climate gives a high probability of further establishment and spread in most of the country. However, it was indicated there was some uncertainty regarding the size of the endangered area, as the distribution of the most susceptible host plants in particular could be a limiting factor.

Since the risk assessment was published in 2009, there have been several introductions of *P. ramorum* to Norway, and the pest has been repeatedly detected in open fields, in garden centers and in nurseries, mostly in Western Norway. In cooperation with NIBIO Mattilsynet has carried out surveys from 2003 onwards, the last time in 2020. In addition, import controls and controls in Norwegian production nurseries have been carried out. In the cases where the pest has been found, official measures with the purpose of pest eradication have been carried out. Consignments found infested at import controls have been refused entry.

The knowledge base has changed since the last pest risk assessment. There is increased genetic knowledge concerning populations, lineages and mating types, and also changes in the risk picture since the disease has become epidemic in new host plants, for example larch trees in England.

Regulation

In Norway the pest is currently regulated in Forskrift om tiltak mot *Phytophthora ramorum* (Werres et al. 2001), (Regulations 17 March 2003 no. 341 on measures against *Phytophthora ramorum* (Werres et al. 2001), which was laid down as a temporary measure in 2003, pursuant to the Regulations relating to plants and measures against pests § 40. Mattilsynet is now in the process of revising the national plant health regulations and in this connection, it is also relevant to consider the future regulatory status of *P. ramorum*. We have therefore looked at how other European countries have regulated this pest.

In its regulation, the EU has distinguished between "EU isolates" and "non-EU isolates". EU isolates of *P. ramorum* are listed as regulated non-quarantine pests (RNQP), included in parts D, E and J of Annex IV to the Commission Implementing Regulation 2019/2072, with associated measures to prevent the occurrence of the pest (EU isolates) in plants for planting of the same plant categories in Annex V. Furthermore, the EU has listed *P. ramorum* ("non-EU isolates") on the list of the Union quarantine pests not known to occur in the Union territory (Annex II, part A) and included special requirements for the introduction of specified plants (Annex VII point 32.5) and specified wood (Annex VII point 111) originating in Canada, United Kingdom, United States, and Vietnam.

The UK has distinguished between European and non-European isolates in their legislation. *P. ramorum* ("non-European isolates") is regulated as a quarantine pest in The Plant Health (Phytosanitary Conditions) (Amendment) (EU Exit) Regulations 2020, Schedule 1/Annex 2 – list of GB quarantine pests part A (Pests not known to occur in Great Britain). In the same regulations, *P. ramorum* ("European isolates") is listed in Annex 2A - List of provisional GB quarantine pests.

Terms of reference as provided by the Norwegian Food Safety Authority

The Norwegian Food Safety Authority (Mattilsynet) asks the Norwegian Scientific Committee for Food and Environment (VKM) to perform an updated pest risk assessment of *Phytophthora ramorum* in Norway. In its report, VKM is asked, in particular, to include:

1. Description of lineages, mating types, and isolate groups of *P. ramorum*, as well as updated knowledge of their occurrence in Norway, the rest of Europe, and elsewhere in the world. The report should also provide information on the total distribution and establishment of *P. ramorum* in Norway.

2. Overview of diagnostic possibilities for distinguishing different lineages, mating types and isolate groups of *P. ramorum*.

3. Updated information on host plants for *P. ramorum*.

4. Updated assessment of possible pathways for introduction for *P. ramorum*, including which host plants and other articles that, when imported, will entail a particularly high risk of introducing the pest to Norway, as well as differences in risk when importing from different countries or regions.

5. Updated knowledge of the future potential for establishment and spread of *P. ramorum* in Norway, particularly in those areas of the country where so far few or no detections have been made in parks/gardens or in natural vegetation.

6. Pest categorization of *P. ramorum* against criteria for what characterizes a potential quarantine pest or a potential regulated non-quarantine pest for Norway. If there are

differences in the assessment for different lineages, mating types or isolate groups this should be described in more detail.

7. Assessment of effects if *P. ramorum* is further spread to areas in Norway where few or no findings have been recorded to date, including the consequences of the possible establishment of new lineages, mating types and isolate groups. This includes the potential for damage to various types of cultivated plants, forests and uncultivated plants, as well as any other economic and environmental effects in the short and long term. In addition, a corresponding assessment of the effects for parts of the country where the pest has been repeatedly found.

8. Identification of relevant risk-reducing options and evaluation of their effectiveness and feasibility:

    a. in connection with imports, domestic plant production, and plant sales

    b. when found in a park/garden and in natural vegetation, including an assessment of the possibility of eradication or containment of the pest where it has already been detected and possibly established in Norway.

Methodology and Data

Data and information gathering

Data on the imports of rhododendrons and azaleas (codes 06023009 and 06023090) was downloaded from Statistics Norway (SSB), table 08801 ("External trade in goods", by commodity number (HS) and country 1988-2022) using the SSBs JSON query (Statistisk sentralbyrå, 2023). Data on *Phytophthora ramorum* host species, distribution, and interceptions was downloaded from the EPPO Global Database using the EPPO API (EPPO, 2023a). Data on the geographical distribution of selected host trees was downloaded from EUFORGEN (Caudullo et al., 2023) and data on the occurrence of *P. ramorum* was compiled from several sources. All data was prepared and handled in (R Core Team, 2023). Occurrence data for *P. ramorum* from Norway was reverse geocoded from sampling addresses provided by the Norwegian Food Safety Authority using opencage (Possenriede et al., 2021). Climate classifications were extracted from Köppen-Geiger climate classification maps compiled by Beck Beck et al. (2018).

Literature search and selection

Literature searches were performed in Ovid MEDLINE(R) and Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Daily and Versions(R), Embase, ISI Web of Science, Epistemonikos, Scopus, and CABI. These databases were chosen to ensure comprehensive study retrieval. The literature search was performed by senior librarians at the Norwegian Public Institute of Public Health on 20.12.2022 and the exact search terms are presented in Appendix II.

The main searches resulted in a total of 916 records after duplicates were removed, both automatically and during primary screening of the EndNote bibliography (Appendix II). During primary screening, titles and abstracts of all publications retrieved were independently screened against the inclusion criteria (i.e. the terms of reference as provided by the Norwegian Food Safety Authority).

Articles that did not appear to meet the inclusion criteria were excluded from further analysis. If it was unclear whether the publication was of relevance to the study, it was retained for further screening. Full text articles that passed the primary screening were retrieved, compared again against the inclusion criteria, and assessed for relevance and quality. The primary and secondary screenings as well as quality assessment of papers were performed by at least two members of the project group. Any disagreements were solved in the project group. The primary screening resulted in 340 full text articles, of which 73 papers passed the secondary screening and were included in the opinion (Figure 1). To strengthen the data basis of the opinion, additional manual searches for papers and relevant grey literature were also performed. Manual searches included 'snow-balling', i.e. retrieving interesting articles referred to in papers found in the main literature searches using Google, Google Scholar, or PubMed via EndNote. The manual searches retrieved 33 relevant papers and documents that were included in the opinion (Figure 1).

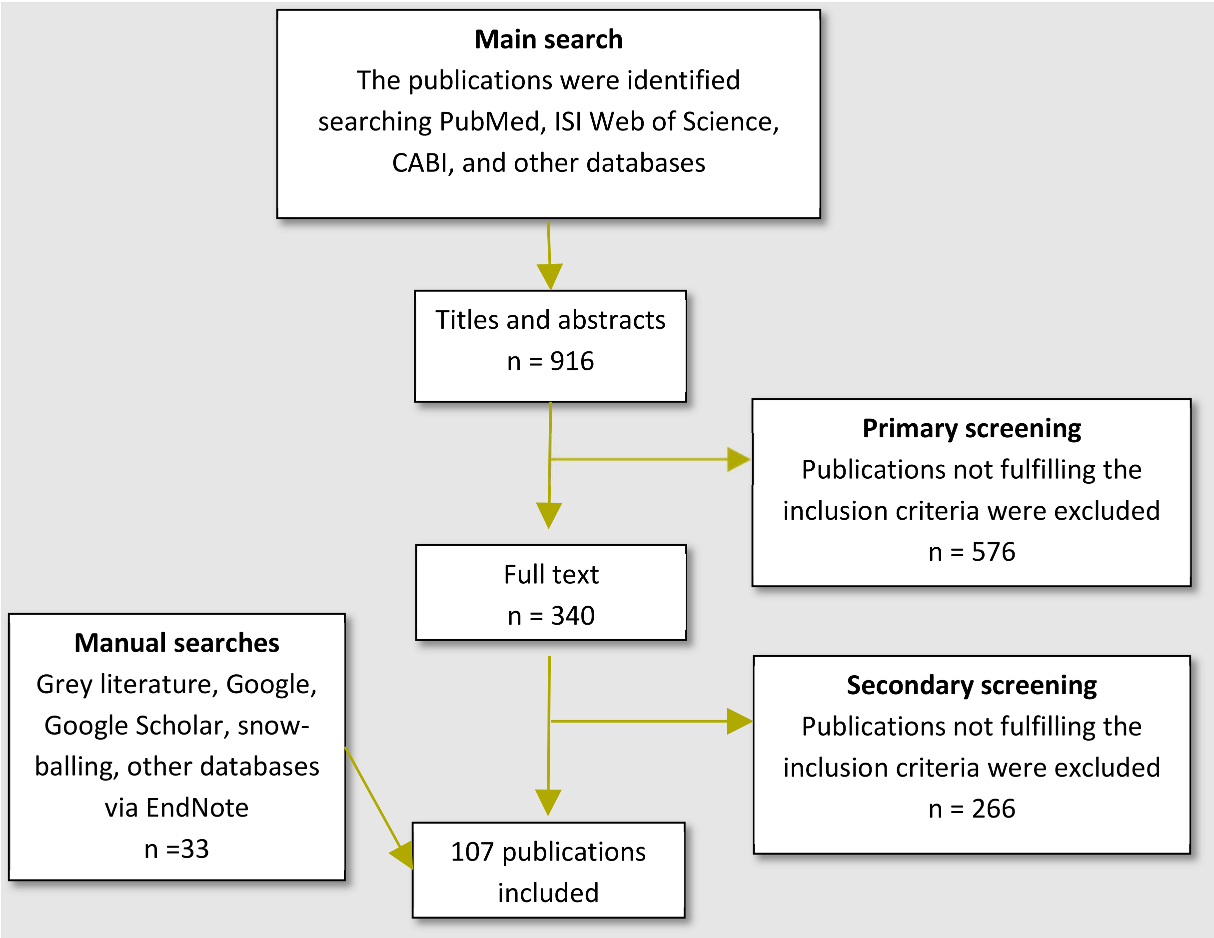

Figure 1. Flowchart for the literature search for studies on *Phytophthora ramorum* published between 2008 and 2022 (until week 50).

Ratings of probabilities and uncertainties

The probabilities of entry and establishment of *P. ramorum* are presented and rated separately, following a fixed five-level scale: very unlikely, unlikely, moderately likely, likely, very likely. Descriptors for these qualitative ratings are presented in Appendix I Table A1-1 (for entry) and Table A1-2 (for establishment). Levels of uncertainty are rated separately for probability of entry and establishment, following a fixed three-level scale: low, medium, high. Descriptors for these qualitative ratings of uncertainty are presented in Appendix I Table A1-3.

Assessment

1 Initiation

1.1 Identity of pest

1.1.1 Scientific name

The pest is a clearly defined species: *Phytophthora ramorum* Werres, De Cock & Man (Werres et al., 2001)

EPPO Code: PHYTRA

1.1.2 Synonyms

No synonyms were identified.

1.1.3 Common names

English names: Ramorum bleeding canker, sudden oak death, Ramorum dieback, Ramorum blight, water mould.

Norwegian name: ramorum-greinvisning

1.1.4 Taxonomic position

Kingdom: Chromista, Phylum: Oomycota, Class: Oomycetes, Order: Peronosporales, Family: Peronosporaceae, Genus: Phytophthora

1.1.5 Infection biology

Unlike most other *Phytophthora* species, *P. ramorum* is not considered a root pathogen. Instead, it causes two different types of above-ground symptoms: cankers on stems and necroses on the foliage (leaf or needle lesions, shoot dieback), see Figure 2.

Figure 2. Symptoms of infection by *Phytophthora ramorum* on rhododendron (left) and on the trunk of a beech tree (right). The beech was surrounded by rhododendrons prior to efforts to eradicate the invasive shrub in UK forests. However, as rhododendron plants were resprouting from roots, leaf spots and wilting symptoms caused by *P. ramorum* became visible on the resprouting plants (left). Photos by Iben M. Thomsen.

Infection mode, principal symptoms, and the overall disease cycle of *P. ramorum* depend on the host plant (Parke and Peterson, 2019). The disease cycle also differs between nursery and forest infections (Parke and Lucas, 2008). Details of the pathogen's disease cycle in different host plants are not yet understood. However, sporangia, which is the primary inoculum from trees and shrubs, are usually produced on infected foliage and spread by wind and rain splash to the canopy of healthy trees or shrubs nearby. Here, sporangia infect the foliage directly or release zoospores that infect the plant. Secondary inoculum, consisting of sporangia and zoospores, is then produced on newly infected leaves. This inoculum can either reinfect the same plant and cause stem cankers when rain carries spores down the trunk, or it can act as primary inoculum and spread to new trees or understorey shrubs. This life cycle is operating when the host plant species is transmissive (i.e., is a host on which *P. ramorum* can sporulate), but it is not relevant for so-called dead-end hosts (i.e. hosts on which the pathogen cannot sporulate). For further information on host plants, see Chapter 1.4.1. Both sporangia and zoospore formation require moist conditions, but zoospores also need free water to spread. Coastal forests and nurseries in California can be very moist due to dense fog, rainfall (Garbelotto et al., 2017), or irrigation (Serrano et al., 2020), and these conditions trigger the production of sporangia.

Chlamydospores are another type of asexual propagule that is produced in infected plant tissue. Its role in the epidemiology of *P. ramorum* is poorly investigated, but it is presumed that any chlamydospores that are present when infected leaves drop to the ground, stay in the soil and remain dormant until favourable (humid) conditions appear. The level of heat treatment needed to eradicate infection of *P. ramorum*-infected bay laurel leaves (55 °C treatment for 2 weeks) is probably due to the heat-resistance of chlamydospores (Harnik et al., 2004), since chlamydospores (and sporangia) form on infected bay leaves (Davidson et al., 2005). Chlamydospores can form a persistent soil inoculum in both nursery settings and forests. In soil, asymptomatic root infections can occur on the roots and later lead to stem and leaf symptoms.

In nurseries, the primary dissemination pathway of *P. ramorum* is direct leaf-to-leaf contact during humid conditions, in addition to leaf-to-soil contact (Serrano et al., 2020). Irrigation water may probably also disseminate *P. ramorum* when applied as overhead sprinkling, and excess irrigation water and flooding in nurseries appears to be an efficient way for the pathogen to spread (Garbelotto, *pers. comm*). However, the importance of this pathway, as well as air dispersal, still needs to be investigated. Introduction of infested plants and soil into nurseries by humans has started many infections and been responsible for long-distance disease dissemination between continents (apsnet.org 2023).

1.1.6 Lineages, mating types and isolate groups of *Phytophthora ramorum*

Extensive research on *P. ramorum* has revealed a complicated population structure that is related to geographical distribution, mating types, and isolate groups within different lineages. Table 1 gives an overview of terms used in studies of *P. ramorum* lineages, mating types, and other isolate groupings. Note that the terms 'isolate' and 'strain' are mostly synonymous. The designation 'isolate' is given at the beginning of an identification process, shortly after isolation and before a microorganism has been identified. As soon as identification work has started and the isolate becomes deposited in a culture collection, the same individual is called a strain.

1.1.6.1 Lineages

The term 'lineage' may be used for a large set of *P. ramorum* isolates that have a shared evolutionary history, are closely related, and sometimes are considered clonal. Isolates within a lineage have similar growth characteristics, similar reactions to environmental factors, and share other genotypic or phenotypic traits. The nomenclature for *P. ramorum* lineages is described in Grünwald et al. (2009), where lineages are designated with a twoletter identifier for the continent (or region) where they were first found, followed by a number indicating their order of discovery. Lineage is mostly used to describe geographical distribution and reflects separate introductions of the pathogen in Europe (lineages EU1 and EU2) and North America (NA1 and NA2), or its presence in different native locations in Asia (see Table 2 for further lineages). Lineages were originally distinguished using AFLPs (amplified fragment length polymorphisms) (Ivors et al., 2004), microsatellites (Ivors et al., 2006), or SNPs (single-nucleotide polymorphisms) in the *COX* (cytochrome c oxidase) mitochondrial sequence (Kroon et al., 2004). More recently, other methods to detect *P. ramorum* lineages have been published, using approaches such as microsatellites (Gagnon et al., 2017), polymerase chain reaction-restriction fragment length polymorphism (PCR-RFLP) (Elliott et al., 2009; King et al., 2015; Kroon et al., 2004), and real-time PCR (Feau et al., 2019; Gagnon et al., 2014) (see Chapter 3.1). Real-time PCR identification (Feau et al., 2019), which does not require isolation of the pathogen, was validated by Puertolas et al. (2021) and is included in the revised EPPO protocol (EPPO, 2023b).

The various *P. ramorum* lineages differ in pathogenicity, reactions to environmental factors, host species, and several other traits (Eyre et al., 2014; Garbelotto et al., 2021b; Søndreli et al., 2021). Thus, even if the characteristics of a specific lineage may be known for certain settings (e.g. in nurseries, parks with rhododendron or various forest types), introducing the lineage into a different environment with new potential hosts or a competing lineage can cause unpredictable changes in pathogen behaviour.

At the time of the previous PRA of *P. ramorum* in Norway (Sundheim et al., 2009), three ancient clonal lineages were known; one from Europe (EU1) and two from North America (NA1 and NA2). EU1 had also occasionally been found in North American nurseries. By 2021, another European lineage, EU2 (Franceschini et al., 2014; Van Poucke et al., 2012) and eight new lineages from Japan and the border region between China and Vietnam (Indochina) had been identified (Jung et al., 2021). In addition, the EU1 lineage has now also been found outside nurseries in the USA (Garbelotto et al., 2021a; Grünwald et al., 2016).

The Asian lineages are considered more ancient than the European and North American ones, dating back 0.5 to 1.6 million years. The European and North American lineages separated from the Asian lineages approximately 165 000 to 500 000 years ago, and EU1 is considered more ancient than NA1 and NA2 (Goss et al., 2009a). The introduction of these lineages into Europe and North America is very recent and took place within the last 30-40 years (Ivors et al., 2006; Mascheretti et al., 2008). So far, EU1 and NA1 seem to be the most aggressive lineages, and they dominate their geographical range in Europe and North America, respectively. EU1, NA1, and NA2 used to belong to sexually reproducing populations but now reproduce almost exclusively asexually/clonally.

A recent study by Jung et al. (2021) supports the hypothesis that the origin of *P. ramorum* is in Asia. However, Jung et al. (2021) did not find any of the four lineages introduced to

Europe and North America, their ancestors, or any closely related lineages. They therefore concluded that more lineages likely will be discovered in Asia. Since each of the four lineages known in Europe and North America appears to be the result of separate introductions by unknown pathways, there is a strong possibility that further Asian lineages could become invasive. The entry of new linages with unknown pathogenicity and potential for infection and spread presents a substantial risk for further disease problems.

Tabell 1. Overview of important terms used to describe the population structure found in *Phytophthora ramorum*. Bold text mark types that are present or, in the case of MLGs, dominant in Norway.

Term	Based on /Related to	Types known	References
Lineages	Genetics, morphology, or geographical distribution. In Europe and North America, as a result of separate introductions of the pathogen.	Europe: **EU1**, EU2 (Britain) North America: NA1, NA2, EU1* Indochina: IC1, IC2, IC3, IC4, IC5 Japan: NP1, NP2, NP3	Franceschini et al. (2014); Goss et al. (2009b); Grünwald et al. (2009); Ivors et al. (2006); Ivors et al. (2004); Jung et al. (2021); O'Hanlon et al. (2016); Puertolas et al. (2021)
Mating types	Ability to produce sexual oospores with isolates of the opposite mating type.	**A1**, A2 A1 is found in Europe (EU1, EU2) and in a few nurseries in USA and in British Columbia, Canada (EU1 introductions) A2 is found in USA (NA1, NA2). A1 and A2 are found in Asia.	Werres and Kaminski (2005), Goss et al. (2011); Jung et al. (2021); O'Hanlon et al. (2016); Vercauteren et al. (2010)
Multilocus genotypes (MLGs)	Microsatellite markers. Only studied in lineage EU1 (outbreaks in larch in UK), and in lineage NA1 in USA.	**EU1MLG1**, EU1MLG2-n One MLG cluster is specific for UK. Another cluster is common in Europe and causes ramorum blight on larch.	Croucher et al. (2013); Harris et al. (2018); Mascheretti et al. (2009); Mascheretti et al. (2008); Yuzon et al. (2020)
Phenotypes	Growth characteristics in culture. Related to host species for *nwt* (NA1).	Many, including wild type (*wt)* and non-wild type (*nwt)* phenotypes	Elliott et al. (2018a); Jung et al. (2021); Kasuga et al. (2016); Kasuga et al. (2012)
Structural variants (SVs)	Large-scale somatic mutations, e.g. based on host-induced phenotypic diversification (HIPD).	Genotypes, phenotypes (*wt*, *nwt*)	Yuzon et al. (2020)
Clusters	Groups of isolates that share the same characteristics.	MLG, SV, *wt*, *nwt*	Harris et al. (2018)

*EU1 was originally introduced from Europe into North America and has subsequently spread along the west coast of the US northwards to British Columbia in Canada (Goss et al., 2011).

1.1.6.2 Mating types

The term 'mating type' is related to sexual reproduction in heterothallic fungi or oomycetes. Recombination of genes and formation of sexual spores (oospores) can only occur when two *P. ramorum* isolates of different mating types meet (Table 2). So far, only two mating types have been identified for *P. ramorum*: mating type A1 and A2. Interestingly, A1 is primarily found in Europe and A2 in North America. This contrasts with the situation in East Asia, where both mating types occur, sometimes in the same geographical area. Sexual recombination probably still takes place there (Jung et al., 2021).

Tabell 2. Overview of the population structure in *Phytophthora ramorum*, as described in the following publications: Elliott et al. (2018a); Harris et al. (2018); Jung et al. (2021); Vercauteren et al. (2011a); Vercauteren et al. (2011b); Werres and Kaminski (2005); Yuzon et al. (2020).

Lineage	Distribution	Mating type[1]	Multilocus genotypes (MLGs)[2]
EU1	Europe North America	A1 (almost exclusively)	EU1MLG1 + other MLGs in Europe EU1BR: 5 MLGs only in Britain
EU2	Britain	A1	?
NA1	North America	A2	Clusters, structural variants
NA2	North America	A2	?
NP1-NP3	Japan	A1 (NP1) A2 (NP2, NP3)	NP1: four isolates, two locations NP2-NP3: single locations
IC1-IC5	Asia (northern Vietnam near China)	A1 dominant A2 (IC2, IC3)	IC1: 40 isolates (six locations); IC2-IC5: only 1-4 isolates and single locations

[1] Mating type A2 was detected in three isolates of EU1 in Belgium in 2002 and 2003, but not afterwards. The isolates were probably products of somatic recombination from an A1 isolate (Vercauteren et al., 2011a). [2] See Table 1.1 for an explanation of MLGs.

Because a separate, single mating type is present in Europe and North America, there has been concern that the opposite mating type could be accidentally introduced via plant trade. Such introductions could enable the pathogen to recombine sexually, and this could lead to greater genetic variation and the possible appearance of isolates with more pathogenic potential (wider host range, more infectious, and more virulent) (Martin, 2008; Sundheim et al., 2009). However, despite extensive inter-continental movement of infected plant materials during the past 10 years, this has not happened. No oospores have yet been documented in the wild or in nurseries on these two continents (Jung et al., 2021). In British Columbia, Canada, where EU1 has been found in nurseries and a few forests, a recent study using genomic biosurveillance concluded that NA2 and EU1 had formed sexual hybrids. This conclusion was based on analysis of genomic variation in *P. ramorum*, but the epidemiological consequences of this finding have not yet been ascertained (Hamelin et al., 2022). Oospore formation and viability are generally low when *P. ramorum* isolates of different mating types are crossed in the lab, and for this reason testing of mating types is often done by using other *Phytophthora* species of known mating types (Jung et al., 2021). In summary, existing evidence indicates that sexual reproduction is not important in the life cycle of *P. ramorum*, at least not in its introduced range.

Many independent studies of the EU and NA lineages suggest that asexual reproduction (via sporangia) is a major driver of genetic variation in *P. ramorum* populations through accumulated mutations, mitotic recombination, and other genomic rearrangements (Chandelier et al., 2014; Croucher et al., 2013; Dale et al., 2019; Elliott et al., 2018a; Harris et al., 2018; Mascheretti et al., 2009; Mascheretti et al., 2008; Vercauteren et al., 2011b). We believe that continuous diversification of *P. ramorum* isolates already present in Europe through asexual reproduction is more likely to cause genetic variation that could increase the likelihood of establishment on new hosts or in new geographical areas, than the occurrence of the opposite mating type. Still, even if the largest threat is the introduction of any new lineages, it is prudent to avoid the accidental introduction of the opposite mating type. The introduction of a new lineage from Asia, or the NA1 and NA2 isolates from North America, would likely introduce the A2 mating type and thus allow for sexual reproduction.

1.1.6.3 Multilocus genotypes (MLGs) and other groupings of **Phytophthora ramorum**

Various isolate groups of *P. ramorum* have been described, using different methods. Usually, isolates are grouped after culture morphology (phenotypes), host species, pathogenicity, locations, or specific genetic traits (genotypes).

Harris et al. (2018) studied the EU1 lineage and identified many unique multilocus genotypes using microsatellite markers. They described two distinct population clusters: one cluster was only found in Britain and formed a unique British population, whereas the other was widespread across Europe, including parts of Britain. It was the European-wide cluster that started to kill larch trees in western parts of Britain in 2009, not the unique British cluster. In particular, the problems in larch were caused by the EU1MLG1 type, which became dominant in several European countries after 2009 (Harris et al., 2018). According to Harris et al. (2018), EU1MG1 comprised 40% of the entire set of isolates in the study and 82% of the isolates in the European population cluster. In contrast, EU1MLG1 occurred only twice among all isolates collected before 2009. EU1MG1 also dominated in other studies of *P. ramorum* populations (>80% in Switzerland, >60% in Belgium and Spain, and 50% in Scotland). MLGs present in Norway were tested in a survey of isolates collected from 2002-08 (Timmermann et al., 2018)). Interestingly, EU1MG1 was already dominant in the *P. ramorum* isolates from Norway collected before 2009, making up 78% of all tested isolates, but six other MLGs were also present. EU1MG1 was prevalent in isolates collected outdoors (i.e., not in import consignments or in nurseries), but two other MLGs were also detected outdoors.

MLG analyses of NA1 lineage isolates from California and Oregon have shown that although hundreds of genotypes are present, only four MLG clusters dominate in California (Croucher et al., 2013). These four clusters have different geographic distributions (Garbelotto and Hayden, 2012), which has been explained by founder effects, i.e., the reduction in genetic variability that occurs when a small group of individuals establishes in a new area. One cluster is ancestral to the other three, which may have adapted to different climates of their respective invaded regions following an initial introduction from Asia. Elliott et al. (2018a) studied the NA1 lineage and described three distinct isolate clusters based on phenotypic analysis of colony morphology. Isolates growing as uniform, roughly circular colonies close to the culture media were considered the 'wild type' (*wt*). Isolates with irregular colony shape and variable or slower growth rate were called 'non-wild type' (*nwt*). Isolate cluster 1 was considered "the basal state of the NA1 clone of *P. ramorum*" in California and included only *wt* isolates. Cluster 2 also consisted of *wt* isolates but was less virulent in an infection experiment on rhododendron leaves. It did not differ significantly from cluster 1 based on genomic analysis. Cluster 3 only had *nwt* isolates and differed from cluster 1 and 2 both phenotypically and genetically.

One of the most worrying character traits of *P. ramorum* is the ability of isolate groups to interact with different host plants and environmental factors. These interactions may induce development of genotypically and geographically distinct isolate clusters, which persist and, in some cases, become dominant in an area. The pathogen's ability to produce new genotypes and adapt to new settings, even without sexual recombination, increases the risk of unanticipated disease outbreaks like Sudden Oak Death (SOD) and ramorum disease on larch.

1.1.6.4 Conclusions on lineages, mating types, and other isolate groupings

From research published over the last two decades, it can be concluded that *P. ramorum* is capable of diversifying even when only one mating type is present. Phenotypic and genotypic changes can be host-driven or be related to the broader environment, including climatic factors. The widespread mortality of larch trees in the UK after 2009 shows that the consequences can be devastating when a new genotype appears and becomes dominant.

Evaluating the risk associated with introduction of new lineages, mating types, and genotypes to Norway is closely tied to the population structure of *P. ramorum* isolates. Different genotype groups have already been found in Norway. Based on the assumptions that the only *P. ramorum* lineage present in Norway is EU1 with mating type A1, and that EU1MLG1 is the dominant genotype, there are two main risks: (i) introduction of new lineages or the A2 mating type and (ii) introduction of new EU1 genotypes. New introduction of EU1 is most likely to happen from Europe via plant import and is unlikely from North America or Asia. Even though Norway has the same EU1 lineage as the rest of Europe, multiple introductions of the same lineage should be avoided because there is variability both within genotypes and phenotypes of the same genotype. This is true even for isolates belonging to the dominant genotype of EU1MLG1. Finally, management efforts to prevent the spread of genotypes that are already present in Norway should be considered, as having more than one MLG in an area could complicate matters. In California, authorities actively try not to mix the four dominant MLG clusters (Garbelotto, pers comm.).

1.1.7 Historical detections of *Phytophthora ramorum*

An overview of the first detections of *P. ramorum* in different countries in Europe and North America up to 2010 is presented by Redlin et al. (2014). In most cases, introductions were the result of import of nursery plants (plants for planting). Some host plants have been much more common as a means of introduction. The first report of *P. ramorum* in Europe came from a diseased rhododendron plant in a nursery in the Netherlands in 1993 (Werres et al., 2001). The next European country to report the pathogen was Germany in 1995. Again, it was found on rhododendron hedge plants at a nursery and in the irrigation water of that nursery. In 2000/2001, several reports appeared that described a new and devastating tree disease, sudden oak death, in forests in California and Oregon (Rizzo (Maloney et al., 2002; Rizzo et al., 2002; Rizzo and Garbelotto, 2003). However, closer scrutiny revealed that the same disease had been reported from the California Bay area already in the mid-1990's. *Phytophthora ramorum* was independently confirmed as the causal agent of the disease, as reviewed by Frankel (2008). The outbreak of sudden oak death in the US prompted EPPO (the European and Mediterranean Plant Protection Organization) to send a questionnaire to member countries, initiating surveys of *P. ramorum* in several countries. Therefore, the first reports of *P. ramorum* in several European countries are from the early 2000's. For example, the first reported detection from Norway was from a batch of imported rhododendron plants in the summer of 2002 (Herrero et al., 2006). The origin of this first introduction is not recorded, but the first reports from the neighboring countries Sweden and Denmark in 2002 were from nursery plants of rhododendron and *Viburnum* originating from Germany and the Netherlands (Herrero et al., 2006). In 2004, Finland reported its first case of *P. ramorum* from imported rhododendron plants into a nursery (Lilja et al., 2007). Norway subsequently reported *P. ramorum* on rhododendron, *Calluna vulgaris, Kalmia* sp., and *Pieris japonica* in 2004, on *Viburnum fragans* in 2005, and on *Vaccinium myrtilis* in 2009 (Redlin et al., 2014).

Surveys of the incidence of *P. ramorum* in Norwegian nurseries, public parks, garden centers, private gardens, etc., have been carried out intermittently from 2006 to 2020 (Herrero et al., 2011; Herrero et al., 2021; Herrero et al., 2017; Herrero et al., 2010; Herrero et al., 2008; Herrero et al., 2007) (Figure 1-3). In 2003 and 2004, most of the samples came from Norwegian nurseries. Starting in 2005, imported plants were examined, and since 2006, the establishment and spread of *P. ramorum* in Norwegian public parks was surveyed (Herrero et al., 2007). The first detection of *P. ramorum* in the wider environment in Norway was on an American oak (*Quercus* sp.) in a park in Bergen in 2008 (Herrero et al., 2010). By 2008, several samples from garden centers, outdoor sites, and import consignments were analyzed using real-time PCR. In 2010, most detections were from nurseries and garden centers in southern Norway (Herrero et al., 2011).

The general pattern emerging from all these surveys (2006, 2008-2009, 2010, 2016, and 2020) is that most detections in nurseries have been from rhododendron. In some years, all detections were from rhododendron. Only a few detections have been made from other plants, such as *Pieris japonica* (Herrero et al., 2021; Herrero et al., 2017). In the two most recent surveys in 2016, *P. ramorum* was found in 6 of 13 sampled import consignments. In samples taken from nurseries and garden centers the pathogen was found in 40 of 98 samples (2016) and in 33 of 171 samples (2020). In samples taken from green outdoor areas (i.e., private gardens and public parks) *P. ramorum* was found in 55 of 234 samples (2016) and in 39 of 131 samples (2020). In most cases, detections in outdoor areas were from sites where *P. ramorum* had been detected previously (Herrero et al., 2011; Herrero et al., 2021; Herrero et al., 2017; Herrero et al., 2010; Herrero et al., 2008; Herrero et al., 2007).

In the US, *P. ramorum* has repeatedly, and from early on, mainly been detected on five ornamental host genera that have emerged as the most common carriers of the pathogen in imported nursery plants. These five genera are *Rhododendron*, *Viburnum*, *Pieris*, *Syringa*, and *Camellia* (Grünwald et al., 2008a). However, the most recent USDA host list has become more extensive and also includes other associated host plants (APHIS, 2023).

1.2 Presence or absence in the PRA area

Phytophthora ramorum is present in the PRA area.

Phytophthora ramorum is mainly present in the southern and western parts of Norway (Figure 3) but has been found as far north as Harstad (in a garden center). Positive detections of *P. ramorum* have been made in the following 58 municipalities: Alver, Arendal, Asker, Askøy, Bergen, Bærum, Bømlo, Drammen, Elverum, Fredrikstad, Færder, Gjøvik, Grimstad, Hamar, Harstad, Haugesund, Holmestrand, Horten, Hustadvika, Karmøy, Klepp, Kongsvinger, Kristiansand, Kristiansund, Kvam, Larvik, Lillehammer, Lillestrøm, Lindesnes, Lærdal, Moss, Nordre Follo, Oslo, Porsgrunn, Rana, Randaberg, Oslo, Ringerike, Ringsaker, Sandefjord, Sandnes, Skien, Sokndal, Sola, Stavanger, Steinkjer, Stjørdal, Stord, Sveio, Time, Trondheim, Tønsberg, Ullensaker, Vestby, Vestnes, Vindafjord, Volda, Ålesund.

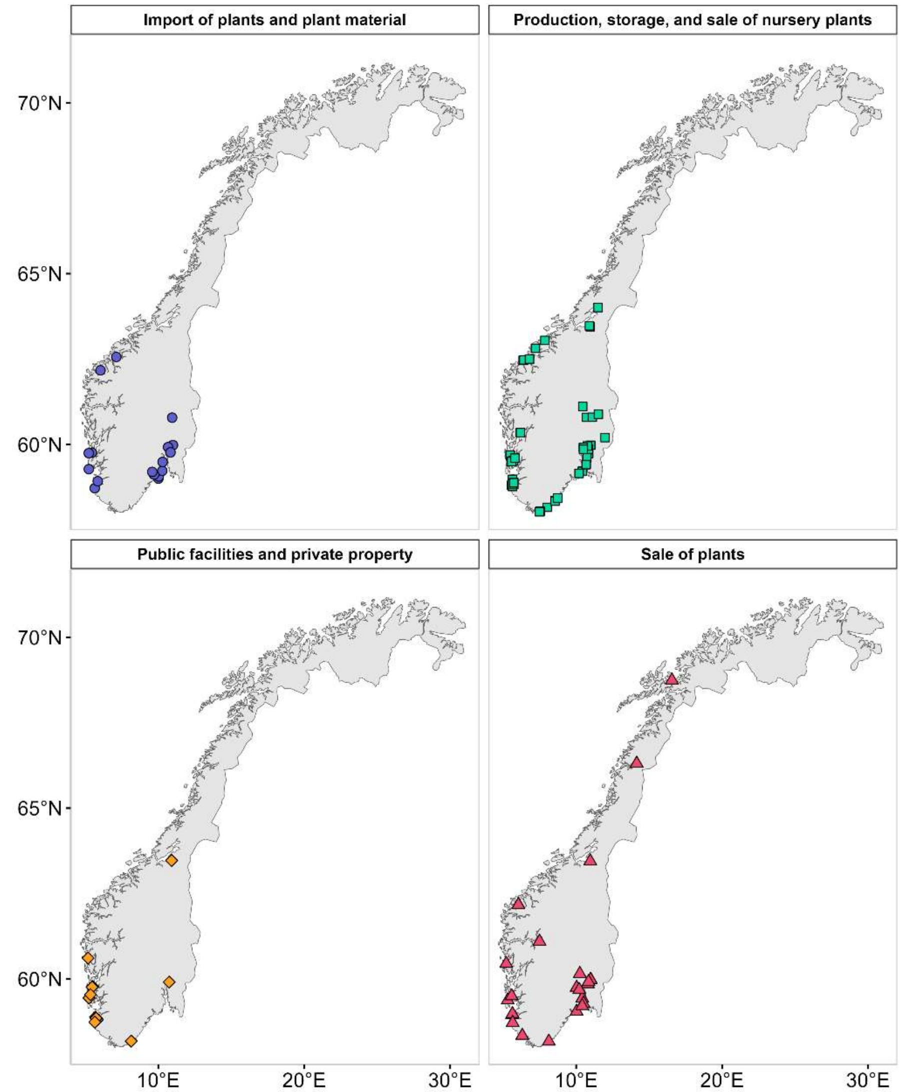

Figure 3. Detection of *Phytophthora ramorum* in Norway since 2004, following surveys carried out by NIBIO on behalf of Mattilsynet. Colored dots indicate the type of activity or site where the pathogen was detected. Orange symbols show detections of *P. ramorum* in the wider environment and illustrate the pathogen's restricted distribution in Norway since 2004. Data from Mattilsynet

1.3 Regulatory status

In Norway, *P. ramorum* is currently regulated in "Regulations 17 March 2003 no. 341 on measures against *P. ramorum*" (Werres et al., 2001), which were laid down as a temporary measure in 2003 under the regulations relating to plants and measures against pests, § 40. No distinction was made between genetic lineages at the time, nor between European and North American isolates.

At present, the European Union distinguishes between EU isolates and non-EU isolates. EU isolates of *P. ramorum* are listed as regulated non-quarantine pests (RNQP) and are included in parts D, E, and J of Annex IV to the Commission Implementing Regulation 2019/2072, with associated measures to prevent the occurrence of the pest (i.e., EU isolates) in plants for planting of the plant categories listed in Annex V to the 2019/2072 regulation. Non-EU isolates are included on the list of EU quarantine pests not known to occur in the Union (Annex II, part A). Specific requirements are set for the introduction of specified plants (Annex VII, point 32.5) and wood (Annex VII, point 111) originating in Canada, the United Kingdom, the US, and Vietnam.

The UK distinguishes between European and non-European isolates in their legislation, rather than between EU- and non-EU isolates. Non-European *P. ramorum* isolates are regulated as a quarantine pest in the Plant Health list of GB quarantine pests, part A ((Pests not known to occur in Great Britain) (Phytosanitary Conditions) (Amendment) (EU Exit) Regulations 2020, Schedule 1/Annex 2). In the same regulations, European isolates of *P. ramorum* are listed in Annex 2A - List of provisional GB quarantine pests.

In addition, *P. ramorum* is listed on the EPPO A2 list since 2013 and on the Swiss A1 list since 2019.

1.4 Potential for establishment and spread in the PRA area

Phytophthora ramorum is established in Norway. However, the exact extent of the current distribution and the potential for further spread and establishment of *P. ramorum* in Norway are not well known.

1.4.1 Hosts

Phytophthora ramorum can live in a very large number of plants (Appendix III and (Sundheim et al., 2009). More than 150 host plants have been recorded throughout the world. On most hosts, symptoms are limited to leaf spots or shoot dieback and the host is not killed. Some plant species infected with *P. ramorum* produce spores that can spread the disease, whereas others do not. It is thus important to distinguish between dead-end (or terminal) hosts that the pathogen can infect but not sporulate on and transmissive (or sporulating) hosts that the pathogen can infect and sporulate on. Transmissive hosts serve as major reservoirs for the further spread and infection of *P. ramorum*. The distinction between dead-end and transmissive hosts is important for management and control of *P. ramorum*. Because transmissive hosts are more likely to spread the disease they should be targeted for e.g. removal. Dead-end hosts, on the other hand, pose a smaller threat and may not require the same level of management. However, some dead-end hosts may still be important reservoirs for the pathogen by allowing it to persist in the environment.

Most major host plants are transmissive hosts and typically display symptoms of shoot dieback and leaf spots (Grünwald et al., 2008a). Dead-end hosts display stem cankers and bleeding, the other major category of symptoms of *P. ramorum*. Dead-end hosts include red oaks (*Quercus falcata, Quercus rubra)* and coast live oak (*Quercus agrifolia*) (Davidson et al., 2005; Garbelotto et al., 2003; Grünwald et al., 2008b). Interestingly, tanoak (*Lithocarpus densiflorus*) displays both categories of symptoms and is a transmissive host (Grünwald et al., 2012; Grünwald et al., 2008a).

Some transmissive hosts have been particularly well studied due to their ability to support high levels of sporulation. A few of these hosts are present in Norway and are listed below. Differences in spore production between host species have been extensively studied to understand the relative importance of different hosts in disease epidemiology in mixed forest stands. For example, the role of tanoak, which supports less sporulation, has been compared with that of California Bay laurel (*Umbellularia californica*), which support more sporulation. As expected, removing a host with profuse sporulation from forest stands was more effective in reducing disease dissemination than removing a host with moderate levels of sporulation (Garbelotto et al., 2017).

Another aspect of disease transmissivity in host plants is that transmissivity does not always correlate with symptom development. *Phytophthora ramorum* has in several studies been observed to sporulate on asymptomatic leaves (Denman et al., 2008; Frankel, 2008; Vettraino et al., 2007). Experimental infection of roots of *Rhododendron macrophyllum* using infested potting media did not result in above-ground symptoms (Parke and Lewis, 2007). The possible presence of infected plants without symptoms has been raised as a concern and an uncertainty in past risk assessments, such as the EFSA Scientific Opinion (PRA) of *P. ramorum* in 2011 (EFSA, 2011).

Some important transmissive hosts of *P. ramorum*, such as *Rhododendron* and *Viburnum*, are present in Norway (Appendix III and Sundheim et al. (2009). Other known transmissive hosts under European conditions are species of *Camellia*, *Larix*, *Pieris*, and *Vaccinium* (EPPO, 2013). In addition, several widely distributed tree species in Norway (Figure 4) are hosts of *P. ramorum* according to the host list in Appendix III. Three of these species have been confirmed to be susceptible through pathogenicity tests on logs (European beech (*Fagus sylvatica*) and pedunculate oak (*Quercus robur*); (Harris et al., 2021) or by observations of secondary infection in forest stands (silver birch (*Betula pendula*) and European beech*;* (APHIS, 2023; Webber et al., 2010).

Of the six tree species illustrated in Figure 4 European beech is most frequently reported with natural infection. These infections are usually a result of heavily infected rhododendrons growing nearby. For the other tree species there are only occasional or single reports of natural infections in forests (Webber et al., 2010; Webber and Rose, 2008). For pedunculate oak we have not been able to find any examples of naturally infested stands.

Even with a complete list of host plants it can be hard to make accurate predictions about host susceptibility, as even phylogenetically related hosts like rhododendron and azalea may contribute differently to disease epidemiology. Also, just because a susceptible host is present in an area does not mean that it has to be targeted for management operations. One example is from the US, where the highly susceptible host western larch (*Larix occidentalis*) does not get infected because the environmental conditions in places where western larch grows are not conducive to disease development (Parke and Peterson, 2019). Another example comes from New Zealand, where a native tree (*Fuchsia excorticata*, commonly known as tree fuchsia or New Zealand fuchsia) has turned out to be more susceptible than rhododendron, the main driver of *P. ramorum* disease epidemiology in Europe. Tree fuchsia is more susceptible when leaves are inoculated with biologically realistic concentrations of *P. ramorum* zoospores (1×10^2 spores/mL) and supports more spore production than rhododendron (Huberli et al., 2008).

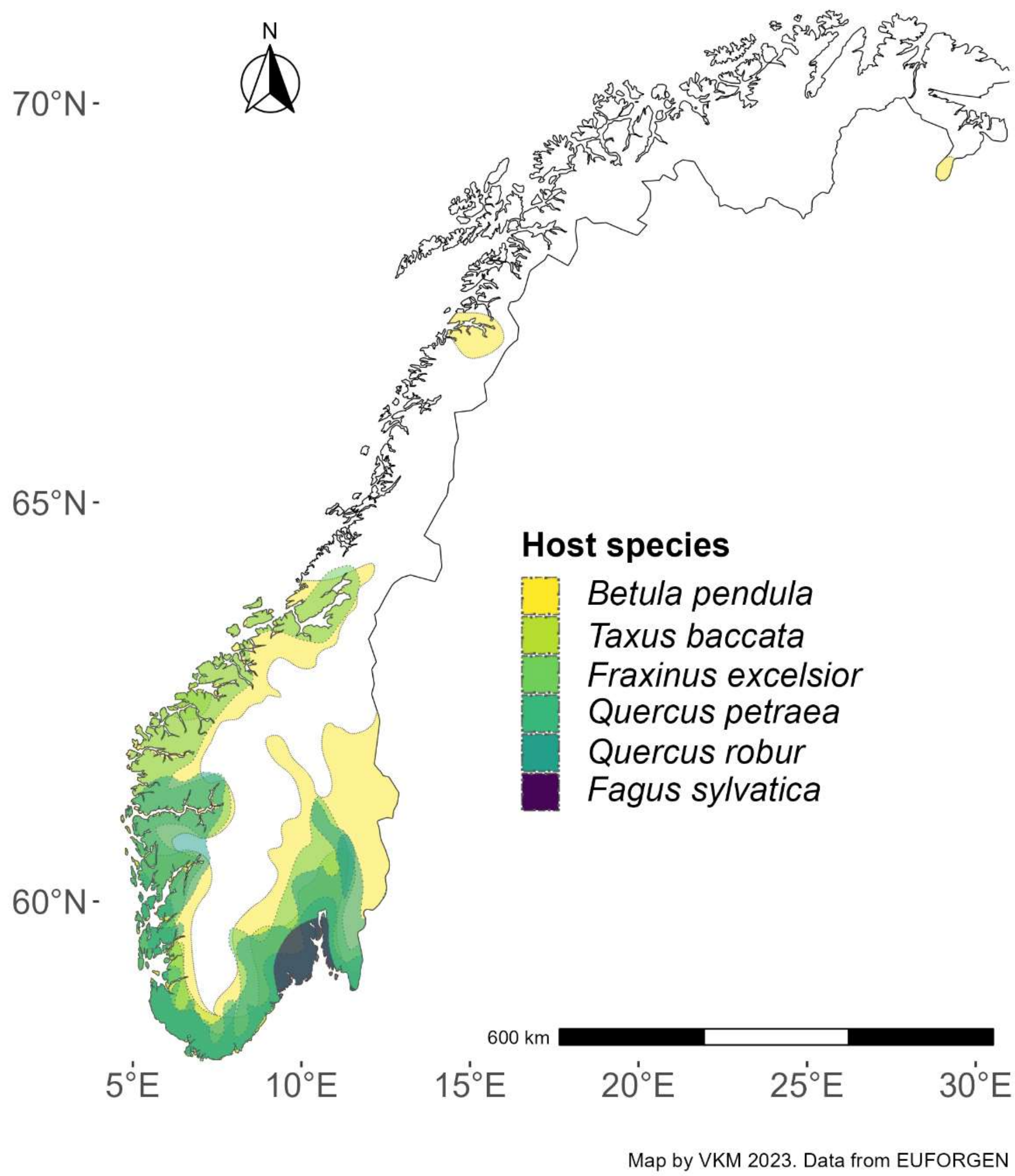

Figure 4. Geographic distribution of tree species that are known hosts of *Phytophthora ramorum* in Norway and where distribution data are available (Caudullo et al., 2023). Unfortunately, there is no data available on the Norwegian distribution of larch (*Larix* spp.), which are important transmissive hosts of *P. ramorum* in the UK.

1.5 Potential for economic consequences in the PRA area

Phytophthora ramorum may cause host symptoms such as stem cankers (dead tissues that are slowly spreading), leaf lesions, and crown dieback. The severity of these symptoms ranges from cosmetic damage to needles or foliage, to death of entire plants or large groups of plants. Given the pathogen's wide host range, the economic losses caused by *P. ramorum* can be substantial. Quantitively, most damage is done to ornamental plants, such as rhododendron, *Viburnum*, and *Pieris*, but the pathogen can also damage economically important production and amenity trees such as beech, oaks (in the red oak-group), and conifers (mainly Douglas fir (*Pseudotsuga menziesii*), Japanese larch (*Larix kaempferi*), and European larch (*L. decidua*)). Trees used in urban environments have a much greater monetary value than forest trees. A *P. ramorum* epidemic in a city planted with many susceptible tree species could thus have great financial consequences. *Phytophthora ramorum* has undergone large host shifts in the past, as when it suddenly appeared as a severe pathogen on larch trees in SW England and Wales in 2009. The possibility that such host shifts may happen again makes it difficult to predict the full damage potential of *P. ramorum*.

Damage by *P. ramorum* can occur in natural settings, parks and gardens, or plant nurseries. Many host trees become naturally infected when heavily infected rhododendron or other highly sporulating hosts grow nearby. This is also true for ornamental tree hosts, such as horse chestnut (*Aesculus hippocastanum*), sycamore (*Acer pseudoplatanus*), Japanese evergreen oak (*Quercus acuta*), Austrian oak (*Quercus cerris*), Spanish oak (*Quercus falcata*), American red oak (*Quercus rubra*) (Webber, 2008), and several other tree species listed in Appendix III. These trees have a scattered and limited distribution in Norway, so the potential for economic impact in production forests is minor. However, this can change with climate change, since the susceptibility and sporulation potential of host trees is temperature dependent (Garbelotto and Frankel, 2020). Bilberry (*Vaccinium myrtillus*), an ecologically very important and widespread species in Norwegian forests, can also be infected by *P. ramorum* in the wild. Damage to bilberry may have both economic effects (e.g. due to reduced berry picking) and ecosystem effects, since bilberry is an important food source for birds and other animals. The potential ramifications of *P. ramorum* infection in bilberry forests are hard to predict but are likely to be minor in most areas. Heather (*Calluna vulgaris*), another common forest plant, is not considered to be a major host of *P. ramorum* at present. Infection of heather by *P. ramorum* was reported from a plant nursery in Poland in 2004 (Orlikowski and Szkuta, 2004), but *P. ramorum* could not be isolated from heather or other forest plants in adjacent forests over the next years. This suggests that the original infection was a rare event and/or was contained and did not spread from the nursery (Orlikowski et al., 2007).

2 Assessment of the probability of introduction and spread

The probability that a pest will be introduced in a new area depends on the probabilities that it will enter and become established. Since *P. ramorum* has been detected repeatedly in Norway following its first discovery in 2002, we know that the pathogen can be introduced and established. In this chapter we present the main entry pathways of *P. ramorum*, based on information provided in the previous PRA of this pest in Norway (Sundheim et al., 2009).

2.1 Probability of entry of a pest

Since the first detection of *P. ramorum* in Norway in 2002 the pathogen has been detected many times. Between 2008 and 2012 it was detected 416 times in imported consignments of plants for planting, in Norwegian nurseries, in parks, and in gardens (Figure 9). Thus, the pathogen clearly has a relatively high probability of entry. The probability differs between different entry pathways (Chapter 2.2) and different geographical origins of imported commodities. In general, the overall probability of entry is a function of the probability that the pathogen is associated with the pathway at the origin, the probability that it will survive and even multiply during transport and storage, and the probability that it will be able to transfer to a suitable host plant after arriving in Norway. Each of these probabilities are discussed in the following paragraphs, following a brief presentation of the main entry pathways. We assess the probability of entry for each pathway following a fixed five-level scale: very unlikely, unlikely, moderately likely, likely, very likely (Appendix I, Table A1-1). Levels of uncertainty are rated following a fixed three-level scale: low, medium, high (Appendix I, Table A1-3).

2.2 Identification of entry pathways

The 2009 PRA evaluated eight different entry pathways (see chapter 4 in Sundheim et al. (2009)). We consider that those eight pathways still are the most important ones for entry of *P. ramorum* into Norway, with plants for planting being the most important. Furthermore, as in the 2009 PRA, we consider all the pathways to be important for entry of both European and non-European isolates. Entry pathways can be either direct or indirect, with direct pathways representing the highest probability for establishment. For direct pathways the consignment itself is either a host plant or is placed in direct contact with host plants at its destination. For indirect pathways the consignment is not placed in direct contact with host plants at its destination and infection of host plants may happen through e.g. compost of imported biomass. Below we summarize the information from Sundheim et al. (2009), updated with recommendations from the revised PRA on *P. ramorum* by EPPO in 2021 (EPPO, 2013). We also provide new and updated estimates of the likelihood of entry and the uncertainty for each pathway. The eight pathways listed in Table 3 constitute all the pathways that are considered important. There is no evidence that natural spread (by water, wind or animals) is an important entry pathway into Norway.

Table 3. Eight entry pathways for *Phytophthora ramorum* to Norway (from Sundheim et al. (2009)). All pathways are relevant for import of both European and non-European *P. ramorum* isolates and lineages. Estimates of likelihood of entry and associated uncertainties are updated in this PRA. Direct pathways are pathways where the end-use of the commodity is to be placed in direct contact with host plants in a suitable habitat (parentheses indicate that the pathway sometimes may be direct).

Pathway	Likelihood	Uncertainty	Nature	Phytosanitary regulation	Key pathway components
Plants for planting of known hosts	Very likely	Low	Direct	Yes	Rhododendron, Viburnum, Pieris
Plants for planting of non-host species accompanied by contaminated, attached growing media	Likely	Medium	(Direct)	Yes	Many possible species
Soil/growing media (with organic matter) as a commodity	Moderatly likely	High	(Direct)	Yes	Import is banned from outside Europe
Soil as a contaminant (e.g. on footwear, machinery, vehicles etc.)	Unlikely	Medium	(Direct)	No	Hiking footwear, mountain bikes, forestry machinery etc.
Foliage and cut branches (for ornamental purposes) of foliar hosts	Very unlikely	Low	Indirect	No	Acer, Camellia, Kalmia, many others
Seeds and fruits of host plants	Very unlikely	High	(Direct)	No	
uropeBark from host plants	Very unlikely	Low	Direct	Yes	Both conifers and deciduous trees
Wood from host plants	Very unlikely	Low	Indirect	Yes	Wood from Europe

2.2.1 Plants for planting of known hosts

We consider the probability of entry of *P. ramorum* to Norway with plants for planting of known hosts to be **very likely**, with a **low** level of uncertainty.

Sundheim et al. (2009) rated plants for planting of known host as the most likely pathway for entry of *P. ramorum* into Norway (likelihood 'high', uncertainty 'low', according to the scales they used). The reasons for the high probability of entry are that suitable host plants are imported in high volumes and that the pathogen has been detected numerous times in imported plants (Table 3 and Figure 5). Plants for planting are a direct entry pathway since the pathway's end-use is to plant known host plants in a suitable habitat.

As *P. ramorum* has a very wide host range and is present in many countries in Europe and elsewhere, the pathogen can be present on many imported plant species. The potential for introducing non-European isolates or mating types depends on the geographical origin of the imported host plants. Most detections in Norway have been made on imported rhododendron but there have also been numerous detections on *Viburnum* and some on *Pieris japonica* (Table 4). Among the numerous host plants of *P. ramorum*, transmissive hosts represent a much higher probability for establishment of *P. ramorum* in the environment than dead-end hosts. Rhododendron is a major transmissive host of *P. ramorum* and during the last 30+ years almost all imports of rhododendron to Norway (99%; Figure 6 have come from five European countries. However, the plants may originate from third countries.

Table 4. Number of interceptions of *Phytophthora ramorum* from different plant genera. Numbers are from the EPPO Global Database and show the number of interception events, not the number of imported plants. All interceptions are from plants for planting, potted plants or cuttings.

Genus	Interceptions	Frequency
Rhododendron	231	0.724
Viburnum	60	0.189
Pieris	13	0.040
Camellia	3	0.009
Leucothoe	3	0.009
Magnolia	2	0.006
Photinia	2	0.006
Vaccinium	2	0.006
Aucuba	1	0.003
Hamamelis	1	0.003
Laurus	1	0.003

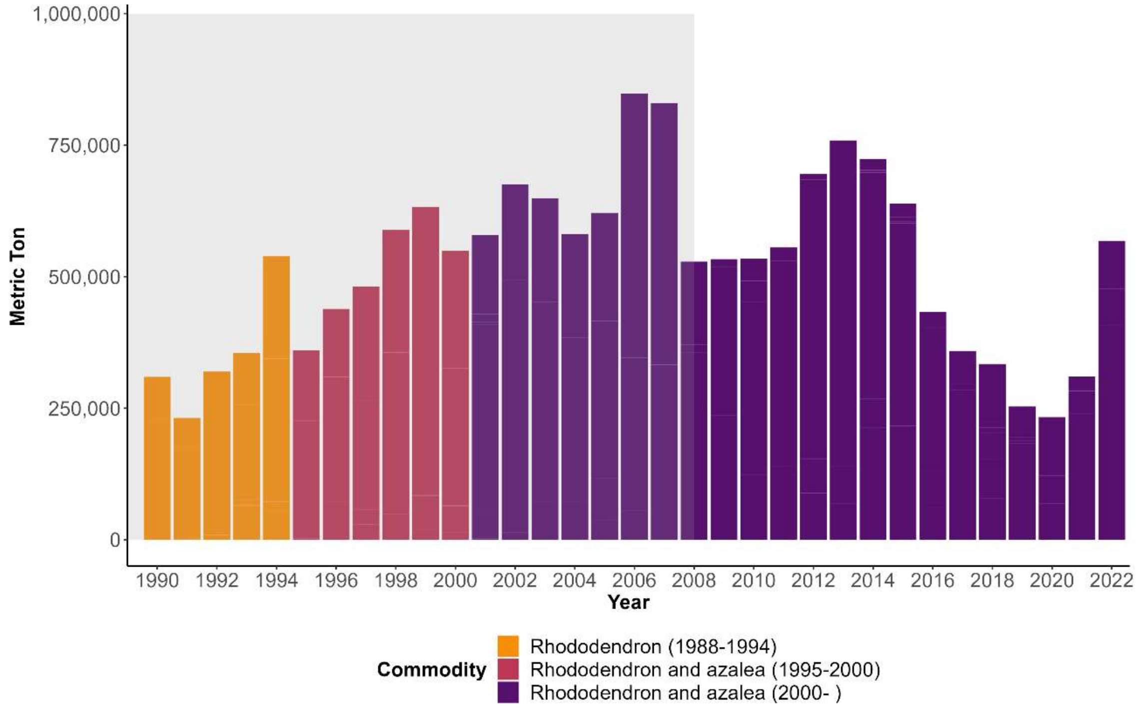

Figure 5. All imports of rhododendron and azalea (import codes 06023009, 06023090, 06023090) to Norway from 1990 to 2022. The shaded area delimits the years covered by the previous PRA of *Phytophthora ramorum* in Norway (Sundheim et al., 2009). Data is from Statistics Norway (SSB).

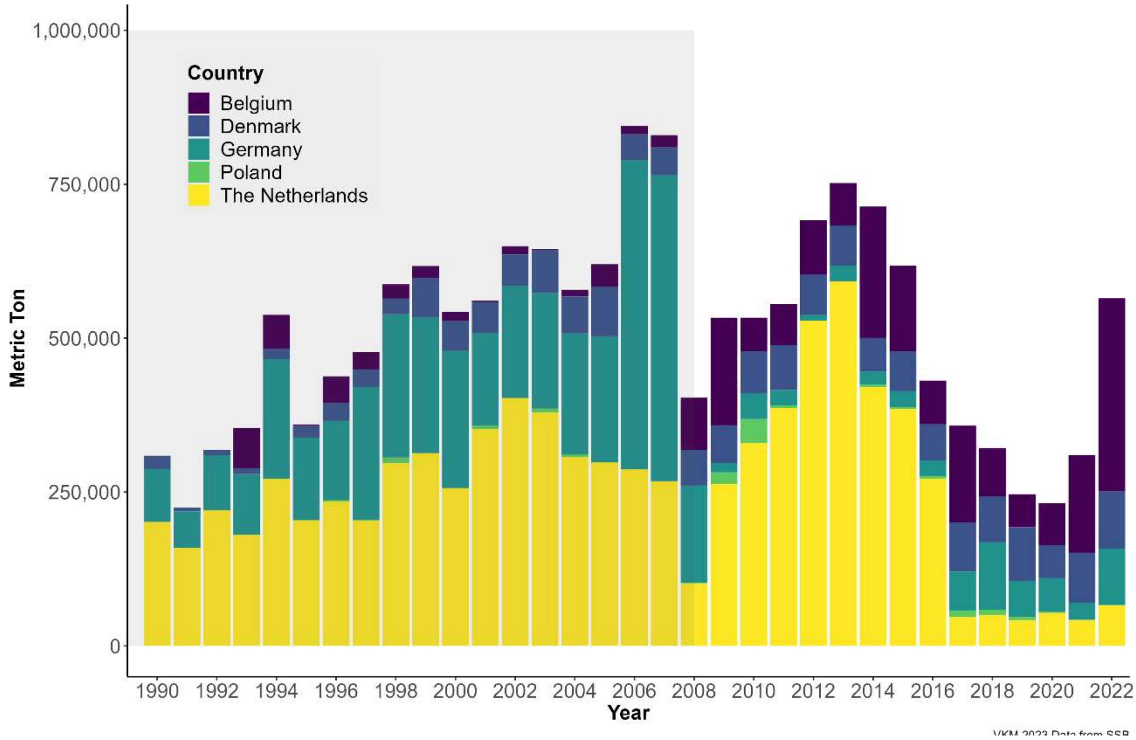

Figure 6. Imports of rhododendron and azalea to Norway from 1990 to 2022 per exporting country. Five countries (The Netherlands, Belgium, Denmark, Germany, and Poland) constitute 99% of all imports to Norway both before and after 2008 (the year when the previous Norwegian PRA on *Phytophthora ramorum* was written (Sundheim et al., 2009)). The shaded area delimits the years covered by Sundheim et al. (2009). Data is from Statistics Norway (SSB).

2.2.2 Plants for planting of non-host species accompanied by contaminated, attached growing media

We consider the probability of entry of *P. ramorum* to Norway with plants for planting of non-host species accompanied by contaminated, attached growing media to be **likely**, with a **medium** level of uncertainty.

Sundheim et al. (2009) rated this pathway as representing a medium likelihood for entry of *P. ramorum* into Norway, with high uncertainty. Non-host plants may introduce *P. ramorum* into Norway if the plants are accompanied by contaminated growing media or infested plant debris. If such plants are planted in areas where host plants of *P. ramorum* occur, such imports can be a direct pathway. Studies have shown that *P. ramorum* can survive in contaminated growing media for more than a year (Linderman and Davis, 2008). Depending on the geographical origin of imported non-host plants there is a potential for also introducing non-European isolates or mating types through this pathway. However, it is unknown to what extent *P. ramorum* is present in growing media of imported non-host plants.

2.2.3 Soil or growing media

We consider the probability of entry of *P. ramorum* to Norway with soil or growing media to be **moderately likely**, with a **high** level of uncertainty.

Sundheim et al. (2009) rated this pathway as representing a medium likelihood for entry of *P. ramorum* into Norway, with high uncertainty. Experimental evidence shows that sporangia and chlamydospores of *P. ramorum* can survive for up to 6 and 12 months, respectively, in different growing media components (references in Sundheim et al. (2009)). As for non-host plants for planting, soil/growing media can be a direct pathway if such media are used when planting host species of *P. ramorum* or other plants near host plants. Like the entry pathways discussed above, soil/growing media has the potential for also introducing non-European isolates or mating types. Import of soil and organic growing media into Norway is not allowed from countries outside Europe. For import from within Europe, a phytosanitary certificate must follow the consignment.

2.2.4 Soil as a contaminant

We consider the probability of entry of *P. ramorum* to Norway with soil as a contaminant to be **unlikely**, with a **medium** level of uncertainty.

Phytophthora ramorum can be introduced with contaminated soil attached to boots, vehicles or other objects. Since it is difficult to quantify the magnitude of such imports, Sundheim et al. (2009) rated this introduction pathway as representing a low likelihood for entry of *P. ramorum* into Norway, with high uncertainty (their Table 7). We largely concur with these ratings of likelihood and uncertainty, using the scales defined in Appendix I. Contaminated soil can be a direct pathway if e.g. contaminated footwear is later used in areas with host plants of *P. ramorum*. Studies have shown that the pathogen can survive on contaminated footwear that is not cleaned and where the attached soil remains moist (Cushman et al., 2008; Davidson et al., 2005). As for the other entry pathways listed above, this pathway could introduce European as well as non-European isolates or mating types, depending on the geographic origin of the contaminated soil.

2.2.5 Foliage and cut branches of foliar hosts

We consider the probability of entry of *P. ramorum* to Norway with foliage and cut branches of foliar hosts to be **very unlikely**, with a **low** level of uncertainty.

Sundheim et al. (2009) rated this pathway as representing a low likelihood for entry of *P. ramorum* into Norway, with high uncertainty. The high uncertainty was due to the lack of information about import of foliage and cut flowers, even though several hosts of *P. ramorum* are popular for cut flower production and are being imported to Norway. There is no requirement for a phytosanitary certificate when importing foliage and cut branches, hence no specific phytosanitary controls are in place. Christmas trees constitute a potential entry pathway with relatively high import volumes (Sundheim et al., 2009). Different conifers, including some commonly used Christmas tree species, are recorded as natural hosts of *P. ramorum* in the US (Colorado fir (*Abies concolor*), grand fir (*A. grandis*), red fir (*A. magnifica*), and Douglas fir (*Pseudotsuga menziesii*); (Sundheim et al., 2009)). Foliage and cut branches are an indirect, low-likelihood pathway, operating through compost of imported biomass. As for the other entry pathways described above, this pathway could introduce European as well as non-European isolates or mating types.

2.2.6 Seeds and fruits of host plants

We consider the probability of entry of *P. ramorum* to Norway with seeds and fruits of host plants to be **very unlikely**, with a **high** level of uncertainty.

Sundheim et al. (2009) rated this pathway as representing a low likelihood for entry of *P. ramorum* into Norway, with high uncertainty. This pathway has the potential for introducing also non-European isolates or mating types. Import of seeds and fruits of host plants of *P. ramorum* can be a direct entry pathway if imported seeds are used for planting. Little information is available on the volume of such imports and to what extent they constitute an important pathway (Sundheim et al., 2009).

2.2.7 Bark from host plants

We consider the probability of entry of *P. ramorum* to Norway with bark from host plants to be **very unlikely**, with a **low** level of uncertainty.

Sundheim et al. (2009) rated this pathway as representing a low likelihood for entry of *P. ramorum* into Norway, with high uncertainty. If e.g. conifer bark is used for mulching in nurseries, parks or gardens, such imports may constitute a direct pathway, since it will place the pathogen in direct contact with host plants. Import of conifer bark to Norway is prohibited from Portugal and all non-European countries, reducing the risk associated with this pathway. Import of bark of certain deciduous trees from the US to Norway is also prohibited as a phytosanitary regulation against *P. ramorum*. EPPO's PRA on *P. ramorum* suggests that import restrictions should apply to bark from all tree hosts that display symptoms of bark cankers (EPPO, 2013). Host trees displaying canker symptoms are listed in the publication.

2.2.8 Wood from host plants

We consider the probability of entry of *P. ramorum* to Norway with wood from host plants to be **very unlikely**, with a **low** level of uncertainty.

Sundheim et al. (2009) rated this pathway as representing a medium likelihood for entry of *P. ramorum* into Norway, with high uncertainty. Both hyphae and chlamydospores of *P. ramorum* can colonize the outer wood of host plants. Import of wood will usually be an indirect pathway since wood is rarely placed in direct contact with host plants for *P. ramorum*. There are phytosanitary restrictions on importing wood from host plants in areas where *P. ramorum* is known to occur (Sundheim et al., 2009). The current likelihood of wood imports resulting in entry of *P. ramorum* into Norway is probably lower than it was in 2009, since the planned massive import of wood chips from North America to Norway described in the 2009 report has been discontinued (see Sundheim et al. (2009)).

2.2.9 Summary of entry pathways

Overall, we consider the probability of entry of *P. ramorum* to Norway to be **very likely**, with a **low** level of uncertainty.

The experience with entry of *P. ramorum* into Norway in the 14 years since the previous PRA confirms the importance of plants for planting of known hosts (2.2.1) as the major entry pathway. Among known host plants imported into Norway in considerable volumes, several species of rhododendron comprise most of the known introductions of *P. ramorum* (Table). Since rhododendron is a transmissive host, rhododendron import is the entry pathway constituting the highest risk for Norway.

The revised EPPO PRA on *P. ramorum* (EPPO, 2013) suggests that regulatory measures should focus on 'high-risk plants', which they define as highly susceptible and highly sporulating plants, particularly those that are traded in high volumes. Examples of high-risk plant genera are *Rhododendron*, *Viburnum, Pieris*, *Camellia*, *Larix*, and *Vaccinium* (EPPO, 2013). One particular rhododendron species, *R. ponticum*, has become invasive and facilitated spread of *P. ramorum* in the UK. Import of host plants that promote *P. ramorum* infection and spread, such as tanoak (*Lithocarpus densiflorus*) and California Bay laurel (*Umbellularia californica*), should be avoided.

2.3 Distribution of *Phytophthora ramorum*

Phytophthora ramorum is widely distributed across multiple continents: North and South America, Europe, and Asia. In the US, *P. ramorum* was first detected in California in 2001 and is now established in the wider environment in several states and has been registered in nurseries in 41 states. *Phytophthora ramorum* is also registered in Argentina (Sansford,

2009) Canada, and 20 European countries, primarily in commercial nurseries. The EPPO Global Database (EPPO, 2023a) and the CABI compendium (CABI, 2023) provide updated summaries of the global distribution of *P. ramorum*.

2.4 Probabilities of *Phytophthora ramorum* being associated with pathways at their origin

We consider the overall probability of *P. ramorum* being associated with important entry pathways at the origin of shipment to be **very likely**, with a **low** level of uncertainty.

For some entry pathways and geographical origins, it is very likely that *P. ramorum* will be associated with the pathway at the origin. The probability is highest for plants for planting from infested areas in the US, Europe, and the less known area of origin of the pathogen in Asia. Table 7 in Sundheim et al. (2009) presents the probability and uncertainty of association for different entry pathways and geographical origins. Most of these estimates are probably still valid today. *Phytophthora ramorum* is present in many European nurseries that export plants to Norway, so import of plants for planting of known host plants of *P. ramorum* from Europe remains the most likely entry pathway into Norway. Since both mycelium and spores of *P. ramorum* can be associated with infected plants, there is a high probability that viable pathogen propagules will be associated with imported plants.

2.5 Probability of survival during transport or storage

For all relevant entry pathways, we consider it **very likely** that *P. ramorum* will survive and multiply during transport and storage, with a **low** level of uncertainty.

For plants for planting the high probability of survival during transport or storage is confirmed by the repeated detections of the pathogen in consignments of rhododendron and other host plants. Spores of *P. ramorum* are generally formed inside host tissue and are known to survive and remain viable for several months during transportation and storage along all relevant pathways.

2.6 Probability of pest surviving existing pest management procedures

We consider the overall probability of *P. ramorum* surviving existing pest management procedures to be **very likely**, with a **low** level of uncertainty.

The probability of *P. ramorum* surviving existing pest management procedures depends on the commodity/pathway and the phytosanitary measures that are applied. VKM (2009) provides a detailed presentation of the probability for each major entry pathway. Challenges associated with detection and eradication of *P. ramorum* combine to increase the likelihood of the pest surviving existing pest management procedures. Pest detection success during inspections is influenced by several factors, such as the inspection method used, the experience of the inspector, the sampling approach, and the methods used for symptom identification. Several factors can make it challenging to detect *P. ramorum* during inspections. Because leaf, shoot or stem symptoms are not unique to *P. ramorum* it can be difficult to reliably identify the pathogen. Infected plants might be overlooked since similar symptoms can be caused by other plant pathogens or physiological conditions. Infected rhododendron leaves are for example easily overlooked and not always easily observable. Plants may also be carrying the disease without displaying obvious symptoms. Such latent infections are usually not detected during inspections. Spores of *P. ramorum* have been found in apparently healthy rhododendron, and sporulation from naturally infected but asymptomatic foliage has been reported.

Asymptomatic plants are a major problem when monitoring for *P. ramorum* in order to carry out eradication or other management steps. In addition, successful eradication is made difficult by the ability of *P. ramorum* to survive in soil, compost, and other media following the removal of diseased plants.

2.7 Probability of transfer to a suitable host

We consider the overall probability of *P. ramorum* being transferred to suitable hosts to be **very likely,** with a **low** level of uncertainty. The probability varies across different pathways.

Phytophthora ramorum has been consistently detected within the nursery trade in Norway and Europe. We consider it very likely that Norwegian nurseries and garden centers will continue to facilitate entry and spread of the pathogen in Norway. Upon sale to consumers, transfer to suitable environments such as parks and private gardens is very likely, especially along the west coast of Norway where the pathogen is present on rhododendron many places.

The transfer of *P. ramorum* from plants for planting to host plants in natural environments is also very likely. The pathogen has been found outside nurseries primarily along the west coast of Norway, with Bergen being a hotspot. Potential sources for transfer to the environment are infected plants for planting or dispersal of inoculum through natural spread or human activity. Factors influencing the probability of transfer include the type of commodity, proximity of nurseries to suitable hosts in the environment, presence and susceptibility of local host plants, human activity, and climatic factors, especially the amount of rain. Many of these factors or conditions are met along the west coast of Norway, including widespread planting of rhododendron, and this increases the likelihood of transfer to the environment. Transfer from contaminated soil/growing media is moderately likely if hosts are planted in contaminated material.

We consider it highly unlikely that *P. ramorum* can be transferred to suitable hosts through other means such as fruits, infected timber, or wood chips.

2.8 Probability of establishment

We consider it **very likely** that *P. ramorum* will eventually establish in or spread to new areas in Norway, with a **low** level of uncertainty, especially if efforts to prevent import of infected plants and to eradicate *P. ramorum* infestations are discontinued.

This conclusion is based on numerous detections of the pathogen since 2002 (Figure 9), the presence of transmissive hosts, especially rhododendron, the suitability of the environment, the biological characteristics of the pest, and current pest management practices. Planting of infected rhododendrons in parks and gardens can spread the pathogen from nurseries to the surrounding environment. Subsequent natural spread is expected to be slow due to the limited dispersal capacity of the pathogen. However, in areas with favorable climatic conditions and abundant hosts, the pest is very likely to establish.

2.9 Availability of suitable hosts in the PRA area

Phytophthora ramorum has a very broad host range and has been detected on more than 150 plant species across a wide range of genera. There is an abundance of suitable hosts in the PRA area (Appendix III). VKM (2009) lists 27 host plants that are common trees, shrubs or ornamentals in Norway and seven of these have been naturally infected by *P. ramorum* in Norway.

Different rhododendron species are the predominant host species of *P. ramorum* in Norway, being common ornamentals in private gardens and public parks throughout Norway. Rhododendron species are particularly widely distributed and abundant along the southwestern coast.

2.10 Suitability of environment

2.10.1 Köppen-Geiger climate classification

The Köppen-Geiger climate classification of world regions where *P. ramorum* occurs is illustrated for the present climate in Figure 7. *Phytophthora ramorum* already occurs in very diverse climates but according to our data it is most frequent in the climate class Dfc (subarctic climate) with several detections from southeastern Norway. Climate class Dfc is characterized by all months having an average temperature below 10 °C and four or more months having an average temperature above 0 °C. The pathogen is also common in the very different BWh climate class (desert climate, USA), characterized by an annual average temperature above 18 °C and an annual precipitation below 250 mm. Such dry conditions are not optimal for *P. ramorum*, and the high occurrence of the pathogen in desert climate might be a result of the coarse spatial resolution (1×1 km) of the Köppen-Geiger climate classification. This means that pockets of humid coastal forests in e.g. southern California may be classified as BWh if that climate class dominates within a 1 km^2 pixel.

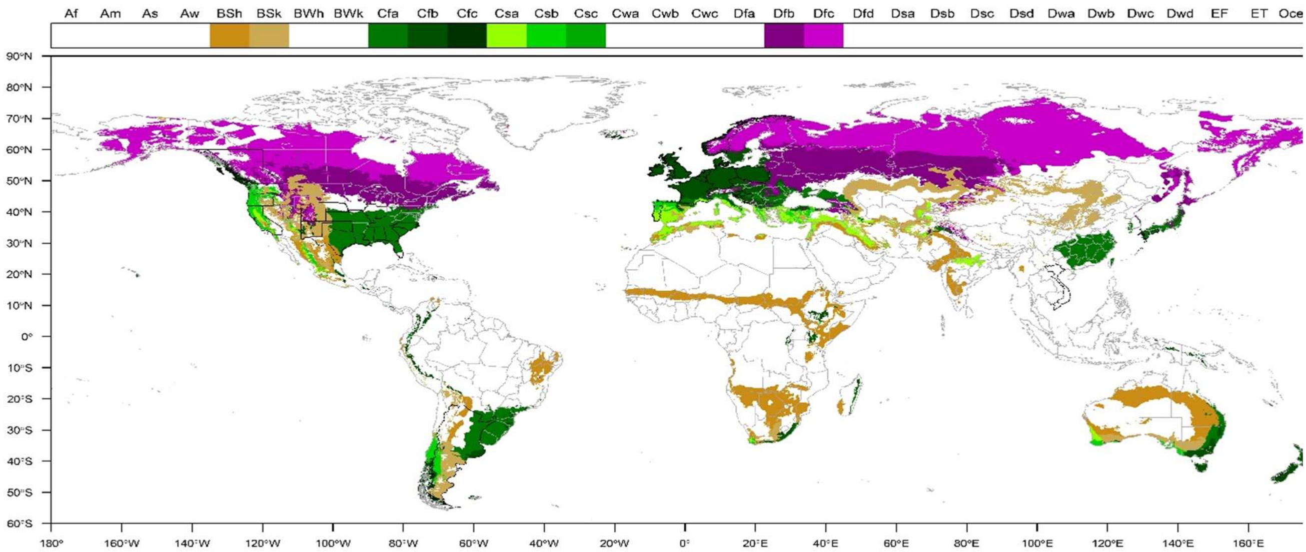

Figure 7. Köppen-Geiger climate classification world map. The map shows the distribution of the different climate classifications from where *P. ramorum* has been documented. Each distinct color corresponds to a different climate category.

Ireland et al. (2013) modeled the potential geographical distribution of *P. ramorum* using the CLIMEX software (Figure 8). Their model result is largely in agreement with the CLIMEX model published by Sundheim et al. (2009), predicting a high ecoclimatic suitability along the coast of Norway from Østfold to as far north as Nordland. Because the Ireland et al. (2013) model is better parameterized and includes threshold values it is less likely than Sundheim et al. (2009) to overestimate the distribution of *P. ramorum* in Norway. The VKM model predicted a moderately high climatic suitability across most of the PRA area, including alpine areas. Ireland et al. (2013) set a lower temperature threshold for *P. ramorum* growth at 0 °C and a minimum soil moisture threshold of 0.2 (the soil moisture threshold is the proportion of total soil moisture holding capacity, also known as field capacity, remaining in the soil 2-3 days after saturation when free drainage has ceased (O'Geen, 2013)). Soil moisture holding capacity is strongly dependent on the soil type. Norway, and especially the west coast, is characterized by very steep altitudinal gradients from sea level to alpine areas. This also gives steep gradients in temperature and soil properties. Up to 300 meters above sea level the soil is fertile, but above 300 meters there are usually nutrient-poor soils that support only sparse vegetation, such as coniferous forests and shrubs. At higher elevations, above 800-900 meters, the soil layer is often very thin or non-existing, giving zero probability of establishment of host plants of *P. ramorum*. According to our data, in Norway *P. ramorum* has been recorded from sea level to 551 meters (25% of the records are from below 20 m, 50% are from below 43 m, and 75% are from below 74 m).

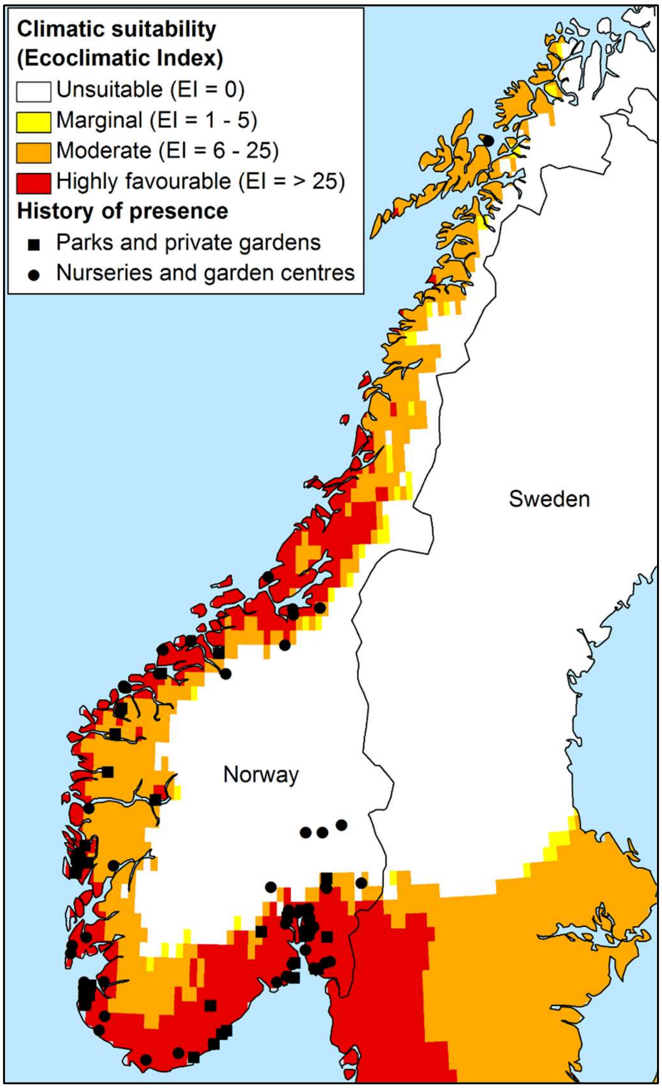

Figure 8. Modelled eco-climatic suitability and known detections of *Phytophthora ramorum* in Norway, as per 2013. Eco-climatic suitability is projected using 1961–1990 climate normals and the CLIMEX modelling tool. The map is an excerpt from Figure 2 in Ireland et al. (2013).

2.11 Probability of spread after establishment

We consider the overall probability of spread of *P. ramorum* in Norway after establishment to be **moderately likely**, with a **medium** level of uncertainty.

2.11.1 Natural spread

The literature published the last 14 years agrees with the description in Sundheim et al. (2009) of the natural spread of *P. ramorum*. The pathogen has been shown to spread to new hosts mostly less than 200 meters away (Webber, 2022) and has very limited dispersal capacity in dry environments (Pastalka et al., 2017). *Phytophthora ramorum* can spread short distances by for example wind during extreme weather events. It can also be spread by wind-driven rain and with water in runoff and along rivers (Goss et al., 2011). The probability of favorable dispersal events is influenced by the frequency of storms, the number of infected plants at the source, and the availability of host plants in the area. The relatively high abundance of rhododendron, combined with high precipitation, increases the probability of natural spread in southwestern Norway. Spread of *P. ramorum* will vary from year to year in response to favorable climatic events.

2.11.2 Human-mediated spread

International and national human-mediated spread with traded plants is well-documented for many pests and pathogens, including *Phytophthora*. In the US and Canada, long-distance spread of *P. ramorum* is primarily attributed to human-mediated movement of infected plants, soil, or other contaminated materials. Such movement has, for example, been responsible for the spread of the NA1 and NA2 mating types in California and Oregon (Goss et al., 2011). Also in Europe, spread of *P. ramorum* is primarily attributed to human-mediated movement (EFSA, 2011). Transmission from nurseries to the wider environment has been slow, as *P. ramorum* normally disperses only a few meters by natural means (Pastalka et al., 2017) and rarely more than 200 meters (Webber, 2022). The main cause of human-mediated spread of *P. ramorum* in Norway is planting of infected and often symptomless rhododendron plants in parks and private gardens.

2.12 Conclusion on the probability of introduction and spread

We consider the overall probability of introduction and spread of *P. ramorum* in Norway to be **likely**, with a **low** level of uncertainty.

Factors that increase the likelihood of entry are the presence of multiple entry pathways, relatively high import volumes, a high likelihood of the pest being associated with the pathway at its origin, and a high likelihood for pest survival during transport or storage.

Additionally, the probability of transfer to suitable hosts after arrival contributes to the relatively high likelihood of establishment.

Once established, the probability of spread within the PRA area is rated as likely. The primary mode of spread is through trade of infected host plants for planting, with a low level of uncertainty. However, natural spread is expected to be slow due to the predominant short-distance spread of the pathogen. Nevertheless, natural spread could be more rapid in areas with favorable climate conditions and abundant host plants.

Phytophthora ramorum can probably establish itself in all Norwegian counties except Innlandet and Finnmark. It will probably be most abundant in coastal areas from Viken as far north as Nordland. It is uncertain how high above sea level *P. ramorum* can establish itself, but it will probably not be abundant at higher elevation. The pathogen has usually been found below 250 meters.

2.13 Direct and indirect pest effects

Most of the direct pest effects of *P. ramorum* concern consequences for infected host plants. High inoculum pressures may result in death of susceptible hosts. Plant mortality has mainly been observed in the western US in tanoak and coast live oak forests, in western UK on larch, and on rhododendron all over Europe. Species of beech and oak may also die if they are surrounded by infected rhododendron. A particular concern in Norway might be the potential establishment and spread of *P. ramorum* in wild bilberry (*Vaccinium* sp.), as this could impact associated nature types as well as berry collection.

Indirect pest effects are often associated with imposed restrictions on plant trade and movement to prevent further pathogen spread. Mandated eradication measures also have economic consequences due to direct costs and loss of infected plants, whether in nurseries, garden centers or in the wider environment.

2.14 Conclusion of the pest risk assessment

Overall, we consider the probability of entry of *P. ramorum* to Norway to be **very likely**, with a **low** level of uncertainty.

The experience with entry of *P. ramorum* into Norway in the 14 years since the previous PRA confirms the importance of plants for planting of known hosts (chapter 2.2.1) as the major entry pathway. The likelihood of entry is increased by the presence of multiple entry pathways, considerable import volumes, a high likelihood of the pest being associated with the pathway at its origin, and a high likelihood for survival during transport or storage.

We consider the overall probability of introduction and spread of *P. ramorum* to be **likely,** with a **low** level of uncertainty.

The likelihood of entry is increased by the presence of multiple entry pathways, considerable import volumes, a high likelihood of the pest being associated with the pathway at its origin, and a high likelihood for survival during transport or storage.

Once established, the probability of spread within the PRA area is rated as **likely**. The primary mode of spread is through trade of infected host plants for planting, with a **low** level of uncertainty.

3 Pest Risk Management

Effective management of the threat posed by *P. ramorum* or any other phytopathogenic *Phytophthora* species requires correct pathogen detection and identification. Detection of *Phytophthora* species has traditionally been done by isolation from symptomatic plant material or via baiting from soil or water with subsequent isolation from the bait material. *Phytophthora ramorum* can be found in soil and water courses in close vicinity to infected plants, but in contrast to most other *Phytophthora* species, its main infection pathway seems to be above-ground parts of the plant rather than fine roots. Thus, typical symptoms on rhododendron are necroses on leaves and shoots, and on larch, dead shoots indicate the possible presence of the disease. Some tree species, such as beech, are usually infected only when they are surrounded by infected rhododendrons. On these tree species symptoms include discolored bark (slime flux) at the base of the trunk and can be indistinguishable from signs of attack by other *Phytophthora* species.

Phytophthora ramorum is considered an invasive species in Europe, and until recently all lineages and isolate groups were classified as a quarantine pest in the EU (see chapter 1.3). Because it has been mandatory to attempt to eradicate *P. ramorum*, reliable detection and identification of this species is important, especially in nurseries. The normal procedure for detecting and identifying *P. ramorum* would typically be:

- Inspection of host plants at import sites or in nurseries (mainly species of *Rhododendron*, but also *Kalmia*, *Pieris*, *Viburnum*, and other known ornamental host plants).
- Symptomatic plant parts are tested using the Pocket Diagnostic Kit for *Phytophthora*, to quickly determine whether *Phytophthora* is present or not.
- In case of a positive test, samples are sent to a laboratory for isolation and identification at the species level.
- Identification of *P. ramorum* is made using morphological traits of pure cultures or molecular methods.

Outside nurseries, *P. ramorum* is usually detected using bark samples of symptomatic trees or baiting of soil samples and waterways with rhododendron leaves. However, foliar samples can also be used for trees and shrubs with symptomatic leaves or shoots, such as *Larix*, *Taxus*, and *Syringae*. Leaves used as baits are inspected for leaf spots that could indicate possible *Phytophthora* infection. Subsequent isolation and identification follow the steps listed above.

Rapid identification of *P. ramorum* is important to deal effectively with infected plants and cases where the pathogen has become established in the environment, and this has sparked the development of various molecular tools. At first, the aim was to distinguish and identify

P. ramorum to species level, but as different lineages and mating types became known more specific tests were developed. These diagnostic tools are described below. In Norway, the main focus has been to identify *P. ramorum* to species, but testing of mating type, lineage, and genotype has also been done. Only mating type A1 and lineage EU1 have been found in isolates from Norway, and of the seven genotypes found EU1MLG1 was the most common (Timmermann et al., 2018).

3.1 Diagnostic tools for differentiating lineages and mating types of *Phytophthora ramorum*

Accurate identification of the lineage and mating type of *P. ramorum* can be essential for disease management and quarantine regulations. Various diagnostic tools have been developed for this purpose. In Table 5 we present an overview of methods to detect *P. ramorum* and to distinguish between different lineages (geographical origin),mating types (A1, A2), and isolate groups.

3.1.1 Molecular diagnostic tools

Several molecular diagnostic tools have been developed to differentiate *P. ramorum* lineages and mating types. Polymerase chain reaction (PCR) is a common molecular diagnostic tool that amplifies DNA sequences specific to *P. ramorum*. Specific PCR primers have been developed for each lineage and mating type, allowing for the accurate identification of *P. ramorum* isolates. Lineage identification can also be done using amplified fragment length polymorphism and microsatellites (Ivors et al., 2006; Ivors et al., 2004), PCR-RFLP (Elliott et al., 2009; Van Poucke et al., 2012), single-nucleotide polymorphisms (Kroon et al., 2004), ISSR-PCR (Wiejacha et al., 2007), and real-time PCR using genes unique to each lineage (Feau et al., 2018; Feau et al., 2019).

3.1.2 Other diagnostic tools

Other diagnostic techniques have also been developed to differentiate between *P. ramorum* lineages and mating types. One example is the use of differential growth media to differentiate between lineages based on colony morphology (Jung et al., 2021).

3.1.3 New developments

Recent studies have explored new diagnostic tools for *P. ramorum* identification. Capron et al. (2023) have recently developed a suite of new multiplex real-time PCR tools (SODplex) to streamline the detection and identification of all four linages present in North America and Europe. SODplex-base, one of four multiplex assays, combines primers and probes for sensitive and accurate detection of *P. ramorum* and *Phytophthora* to genus level. SODplex-ITS and SODplex-mito offer single-step identification of *P. ramorum* and the EU1, NA1, and NA2 lineages present in North America. SODplex-lin targets each of the four *P. ramorum* lineages present in Europe and North America in a single reaction. Capron et al. (2023) Overall, the methods developed by Capron et al. (2023) provides reliable and efficient tools to identify *P. ramorum* and can aid in disease control and prevention efforts.

Table 5. Overview of methods to detect *Phytophthora ramorum* and to distinguish between different lineages (geographical origin), the two known mating types (A1, A2), and groups of isolates. In most cases, a pure culture of *P. ramorum* is required to use the methods, but the PCR tests can be used on plant materials.

	Methods	References
P. ramorum	Conventional PCR Conventional Duplex PCR	EPPO (2023b); Ivors et al. (2006); Ivors et al. (2004); Kroon et al. (2004); Schlenzig (2011)
	Real-time PCR	EPPO (2023b); Hughes et al. (2006); Schena et al. (2008)
Lineages	Real-time PCR	EPPO (2023b); Feau et al. (2019); Jung et al. (2021)
Mating types	Pairing with known mating types Real-time PCR	O'Hanlon et al. (2016); Vercauteren et al. (2010); Werres and Kaminski (2005); Jung et al. (2021); Feau et al. (2019)
Isolate groups	Multilocus genotypes based on microsatellites Phenotypes based on cultural characteristics	Harris et al. (2018); Yuzon et al. (2020); Elliott et al. (2018b); Jung et al. (2021); Kasuga et al. (2012)

3.2 Options for preventing or reducing introduction and establishment of *Phytophthora ramorum*

Given the difficulties to eradicate *P. ramorum* once the pathogen has arrived at a site, the focus is usually on options to prevent introduction and establishment. Since infected plants are the main pathway for both entry and infestation of the environment, efforts in the EU and Norway have been made to reduce the risks associated with mainly rhododendron, but also other host plants for planting.

Measures fall in three broad categories:

- Regulations and recommendations aimed at production places, including plant health inspections.
- Regulations and recommendations aimed at importers and plant distributors, such as nurseries and garden centres.
- Testing symptomatic plants for the presence of *P. ramorum* and destroying infected specimens (and other host plants in the vicinity).

For the past 15 years, *P. ramorum* has probably been one of the most regulated and monitored plant pathogens in Europe. The costs have been huge both for the companies involved in plant production and distribution and for plant health authorities. On one hand, these efforts have not eradicated the pathogen from nurseries, as is evident from the fact that *P. ramorum* can still be found in imported rhododendrons (Figure 9). In addition, the EU decision to partly deregulate the pathogen (the EU1 lineage) means relaxed demands for plant health inspections and eradication of host plants and indicates that complete control of *P. ramorum* is considered impossible. However, non-EU isolates of *P. ramorum* are still regulated as quarantine pests in the EU. This includes not only NA1, NA2, EU2, and all Asian lineages, but also EU1 isolates from USA and non-EU countries such as the UK and Norway. On the other hand, without the regulations and monitoring efforts that have been in place, which forced especially European rhododendron producers to deal with the *Phytophthora* problem, the present situation might have been much worse. It must also be noted that *P. ramorum* isolates from within EU are still considered as RNQPs, i.e. regulated non-quarantine pests/pathogens.

In Norway, the main measures taken by the plant health authorities (Mattilsynet) have been to fund monitoring and testing carried out by NIBIO and to adjust regulations for import of host plants (mainly rhododendron) to Norway according to the results from import control. The latter means that German and Dutch nurseries can only export host plants to Norway if their production is certified according to specific descriptions from Mattilsynet. One effect of these regulation adjustments is clearly seen in the import of rhododendron and azalea to Norway (Figure 6), which decreased markedly from Germany and the Netherlands after stricter demands were imposed. It should be noted that the reduction in numbers of *P. ramorum*-infected plants from Germany and the Netherlands also might be related to a large overall decrease in import volume, and not only better plant hygiene in approved nurseries. In addition, there are no regulations preventing other EU countries from buying plants from non-approved nurseries in Germany and the Netherlands and exporting them to Norway. If a shift in main export country, currently to Belgium (Figure 6) is followed by an increase in *P. ramorum* positive plants from this country, it might be prudent to demand certification for all producers of rhododendron and other main amenity host plants of *P. ramorum*.

The monitoring efforts and reports from NIBIO have provided essential documentation of the current *P. ramorum* situation in Norway. The impact of other Norwegian management measures seems more uncertain, including the obligation to report any knowledge or suspicions of possible infections by *P. ramorum* and the option for Mattilsynet to require actions aimed at preventing the spread of the pathogen. The PRA from 2009 (Sundheim et al., 2009) pointed out the difficulty of eradicating *P. ramorum* in nurseries and the wider environment, and many studies and experiments, especially in the US and UK, have come to similar conclusions (Daniels et al., 2022; Hansen et al., 2019; Shishkoff, 2007; Swain and

Garbelotto, 2015; Tjosvold et al., 2009; Tjosvold et al., 2008; Yakabe and MacDonald, 2010).

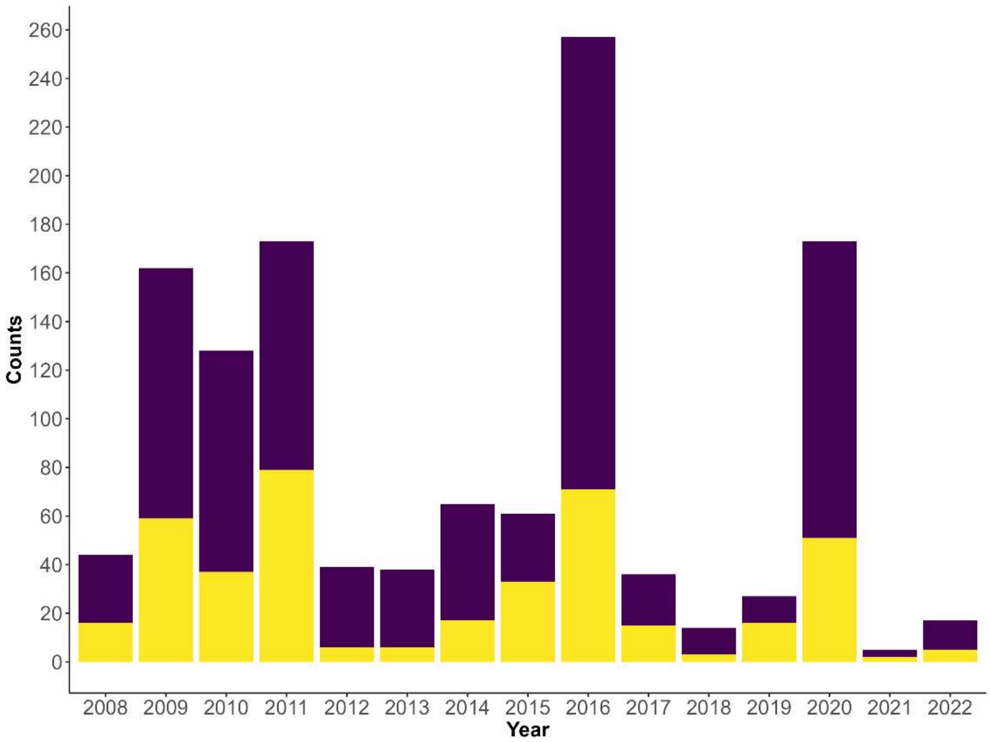

Figure 9. Results of monitoring plants in Norway (mainly rhododendrons) for the presence of *Phytophthora ramorum* from 2008 to 2022. Yellow and purple bars show the number of positive and negative tests, respectively. Exact numbers from 2005 to 2007 could not be included in the graph, but the number of positive tests in those years were high according to the reports from NIBIO. Tighter regulations for import of rhododendron to Norway were introduced in 2008 and 2017, mainly aimed at specific countries from which a high number of infected plants had been detected in the previous years.

Options for preventing the introduction, establishment, and spread of *P. ramorum* in Norway in the future are similar to those that have been implemented in the past. Plants for planting should remain the main focus, but another measure could be to inform the public about the risks associated with bringing plant material and soil (intentionally or unintentionally) from abroad, in particular from other continents (Asia and North America). Possible options for preventing introduction, establishment, and spread of *P. ramorum* are:

- Monitoring imported rhododendron for presence of *P. ramorum*.
- Monitoring imports of other main ornamental hosts (*Viburnum, Pieris, Syringa*, and *Camellia*) for presence of *P. ramorum*.
- Inspecting Norwegian nurseries with rhododendron (and other important hosts) for symptomatic plants and testing those found.

- Testing asymptomatic host plants imported from, produced at, or growing in places with a history of *P. ramorum* detections.
- Establish buffer zones around infested areas and monitor host plants for symptoms, both to document local spread and to reduce or eradicate *P. ramorum* presence.
- Removing and destroying *P. ramorum*-infected rhododendron, mainly from nurseries, but also parks, gardens, and other places where the pathogen is established.
- Provide guidelines for the safe removal or destruction of infected plants, including how to avoid spreading *Phytophthora* via soil on equipment and footgear.
- Discouraging or prohibiting planting of rhododendron in nature areas and close to streams and rivers, especially in southwestern Norway.
- Create awareness about the risk associated with moving rhododendrons between private gardens, especially in areas with known presence of the pathogen.
- Encourage travelers from abroad to clean footgear and other items that have been in contact with soil before they enter Norway, and to not bring host plants into Norway.
- Encourage visitors to areas in Norway with documented and persistent *P. ramorum* infections (e.g. Bergen) to clean footgear and other items which have been in contact with soil before they leave the area.

Furthermore, the PRA on *P. ramorum* from EPPO ((EPPO, 2013), revised in 2021) proposes buffer zones that separate sites of plant production from sporulating hosts. Buffer zones are especially important for tall sporulating hosts, such as larch trees, that can spread inoculum (at low levels) as far as 1 km. The recommended minimum distance from plant production sites to tall sporulating hosts is 100 m. For *Rhododendron* (and other shrub hosts), at least 10 m distance is recommended (EPPO, 2013).

3.3 Conclusion of pest risk management

Pest risk management of *P. ramorum* mainly consists of preventing entry and establishment of the pathogen in Norway via infected plants. Thus, most management options are focused on import, plant nurseries, and other distributors of host plants, and are aimed at detecting the presence of *P. ramorum* before the plants enter Norway or are planted in the wider environment. For the few locations where *P. ramorum* has been introduced and persists, management should aim to prevent spread of the pathogen. This mainly involves removal of infected plants, but other options should also be considered, such as creating buffer zones, imposing restrictions on movement of plants and soil, and avoiding planting of susceptible host plants. Eradication of new occurrences (recent introductions) in parks and other green spaces should be a priority, to prevent spread of *P. ramorum* to other hosts or environments.

4 Uncertainties

The most critical uncertainty concerning *P. ramorum* is the limited knowledge of the genetic background of previous *P. ramorum* infestations in Norway. There are also missing genetic links to the geographic origin of the lineages that prevail in Europe and North America. The importance of sexual reproduction for the development of new, more aggressive *P. ramorum* hybrids with new pathogenic potential is also not clear.

5 Conclusions (with answers to the terms of reference)

1. Description of lineages, mating types, and isolate groups of *Phytophthora ramorum*, as well as updated knowledge of their occurrence in Norway, the rest of Europe, and elsewhere in the world. The report should also provide information on the total distribution and establishment of *P. ramorum* in Norway.

Phytophthora ramorum is present in Norway but has a restricted distribution. The pathogen is mainly present in the southern and southwestern parts of Norway but has been found as far north as Harstad (in a garden centre). The pathogen has been detected in 58 municipalities, and the distribution and establishment of *P. ramorum* in Norway are described more in details in Chapter 1.2.

The only *P. ramorum* lineage considered to be present in Norway is EU1, with mating type A1. The other lineage in Europe, EU2, has so far mainly been documented from the UK, but does not seem to play a major role in disease outbreaks there. The most widely distributed multilocus genotype in Europe is EU1MLG1, which became dominant in Europe (including Norway) after 2008. In North America, the known lineages are NA1, NA2, and EU1 from both nurseries and forests. NA1 and NA2 are the opposite mating type (A2) of European lineages. Several other lineages and genotypes have been documented in Asia, where both mating types are found. The main threats concerning future problems with *P. ramorum* are entry and establishment of non-European isolates (of all lineages), as well as emergence of new genotypes in European *P. ramorum* populations.

2. Overview of diagnostic possibilities for distinguishing different lineages, mating types, and isolate groups of *Phytophthora ramorum*.

There are several options for diagnosing *P. ramorum* to species and lineage (mainly EU1, EU2, NA1, NA2). From a management perspective it is more important to distinguish these entities than mating type and isolate groups (genotypes). The latter are mainly relevant for research purposes or in cases of unexpected disease developments, such as occurrence on new hosts, increased spread or more severe symptoms on known hosts. However, for more detailed regulation, monitoring, and management of *P. ramorum* it could be useful to identify genotypes, i.e. to distinguish EU1MLG1 from other genotypes. These diagnostic possibilities are described in Chapter 3.1.

3. Updated information on host plants for *Phytophthora ramorum*.

Rhododendron remains the most important host plant for *P. ramorum* in Norway, both in terms of imported plants and detections, mainly in nurseries, garden centres, and public parks). Species in other ornamental plant genera, such as *Viburnum*, *Pieris*, and *Kalmia,* are also listed as major hosts in Europe, and *P. ramorum* has been detected at least once on species in all these genera in Norway. In the US, *Rhododendron*, *Viburnum*, *Pieris*, *Syringa*, and *Camellia* are considered to be the main ornamental hosts. In Norway, there has been one documented detection of *P. ramorum* on *Syringa*. *Vaccinium* and several tree species are potential hosts for Norway in the wider environment in Norway (Appendix III), but these hosts are most likely to be infected on sites where rhododendron is affected by *P. ramorum*. So far in Scandinavia, no infections have been found on larch, which is another transmissive (sporulating) host in Europe (mainly Japanese larch in the UK). Efforts to prevent introduction, establishment, and spread of *P. ramorum* should focus on transmissive hosts, of which rhododendron is the most common in Norway. An updated list of host plants worldwide can be found in the EPPO Database and on the USDA homepage, and the most important hosts for Norway are listed in Appendix III.

4. Updated assessment of possible pathways for introduction of *Phytophthora ramorum*, including which host plants and other articles that, when imported, will entail a particularly high risk of introducing the pest to Norway, as well as differences in risk when importing from different countries or regions.

We consider the probability of entry of *P. ramorum* to Norway to be very likely, with a low level of uncertainty.

Plants for planting, in particular *Rhododendron* and other ornamental hosts, remain the most important entry pathway for *P. ramorum*, as described in chapter 2. Due to the high import volumes to Norway, nurseries in the EU are still the main sources of infected plants. Recurring detection of infected plants via import control has led to tighter restrictions for nurseries in two EU countries (Germany, the Netherlands) and this has reduced the volume of imported host plants (mainly rhododendron) and thus the potential for introductions of *P. ramorum*. However, other EU countries may increase their export to Norway, and if their plant production has the same problems with *P. ramorum* the risk of importing the disease remains in spite of regulation efforts. In addition to import from EU, the risks associated with plant import from the UK, North America, and Asia should also be considered. Import from these areas may lead to the introduction of new mating types, lineages, and genetic variants, with unpredictable results.

5. Updated knowledge of the future potential for establishment and spread of *Phytophthora ramorum* in Norway, particularly in those areas of the country where so far few or no detections have been made in parks/gardens or in natural vegetation.

If the efforts to prevent import of infected plants and to eradicate *P. ramorum* infestations are discontinued, we consider it very likely that the pathogen will eventually establish in or spread to new areas in Norway. There is high potential for establishment and spread of *P. ramorum* along the southwestern and southern coast of Norway, where climatic conditions are favourable for the pathogen and rhododendrons and other hosts are common.

We consider the overall probability of spread of *P. ramorum* in Norway after establishment to be moderately likely, with a medium level of uncertainty. Despite several and repeated detections of the pathogen in some locations, further spread seems to be local and limited. New sites with *P. ramorum* outbreaks have been rare in the last decade. It is difficult to determine whether this is due to import regulations, eradication efforts (removal of infected plants) or other factors. The potential for persisting infections and spread in areas with a conducive climate (high precipitation) cannot be ignored.

6. Pest categorization of *Phytophthora ramorum* against criteria for what characterizes a potential quarantine pest or a potential regulated non-quarantine pest for Norway. If there are differences in the assessment for different lineages, mating types or isolate groups this should be described in more detail.

Phytophthora ramorum still meets the criteria of being regulated as a potential quarantine pest. This is true for at least all other lineages than EU1 - thought to be the only lineage present in Norway. For the EU1 lineage, a possible categorization for European isolates is ‘regulated non-quarantine pest’, whereas non-European EU1 isolates fulfil the criteria of being a quarantine pest. Within the EU1 lineage there are different isolate groups, and new genotypes may arise. If the genotype of EU1 isolates present in imported plant materials differ from isolates that are already present in Norway, European EU1 isolates also fit the category ‘quarantine pest’.

7. Assessment of effects if *Phytophthora ramorum* is further spread to areas in Norway where few or no detections have been recorded to date, including the consequences of the possible establishment of new lineages, mating types, and isolate groups. This includes the potential for damage to various types of cultivated plants, forests, and uncultivated plants, as well as any other economic and environmental effects in the short and long term. In addition, a corresponding assessment should be made of the effects for parts of the country where the pest has been found repeatedly.

The potential effect of introducing new lineages, mating types or isolate groups is considered to be similar for new areas in Norway and areas where *P. ramorum* is already present. If the pathogen becomes widely spread and/or more genotypically diverse, the potential for damage is considered to be high, due to the possibility of shifts in host plants and disease development. In addition to preventing new introductions, it is important to limit domestic spread of the pathogen from known infestations and, if possible, to eradicate *P. ramorum* from those sites. The longer *P. ramorum* is present at a site, and the more widespread the pathogen becomes, the higher is the risk that the pathogen will adapt to (new) local hosts and environmental factors.

8. Identification of relevant risk-reducing options and evaluation of their effectiveness and feasibility:

a) in connection with imports, domestic plant production, and plant sales

Monitoring host plants for symptoms, testing for the presence of *P. ramorum*, especially on imported plants, and destroying infected plants remain the best risk-reducing options. These measures can be effective, as long as the pathogen is not widespread in Norway. The feasibility of these measures is good, since they are already in place. It can also be useful to run public awareness campaigns about the importance of cleaning soil from footgear and other items after visiting areas where *P. ramorum* is present, as well as other risk-reducing options for private gardens.

b) when found in a parks/gardens and in natural vegetation, including an assessment of the possibility of eradication or containment of the pest where it has already been detected and possibly established in Norway.

Prompt removal and destruction of infected ornamental hosts, in particular rhododendron, and to not replant with susceptible plant species, are effective risk-reducing options, at least as long as the pathogen has a patchy distribution in Norway. For infected trees, the best management measures depend on the situation, but infected larch trees should always be removed and destructed. For non-transmissive tree species such as beech the risk of inadvertently spreading the pathogen during felling operations should be weighed against the risk associated with leaving an infected tree on site.

6 Data gaps

Phytophthora ramorum has a complex reproductive system that involves different mating types and genetic variation within these types. Further research is needed to fully understand the distribution and prevalence of different mating types and how they impact disease management strategies.

The possible relationship between *P. ramorum* virulence and evolutionary fitness of the progeny needs further research. Local infection pressures following establishment in an area are important to monitor but this has not yet been done in Norway. Uncontrolled proliferation and dissemination can provide the pathogen an opportunity to develop multilocus genotypes with new pathogenic potential on susceptible plant hosts, as demonstrated by the outbreaks of ramorum dieback on Japanese larch in the UK. It is important to continuously update the list of *P. ramorum* host plants, since new host plants probably will appear. Because *Phytophthora ramorum* is an invasive pest native European plants have, unfortunately, not developed resistance over a long coevolutionary time span.

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8 Appendices

Appendix I

Table A1-1: Rating of probability of entry of a pest.

Probability	The likelihood of entry would be:
Very unlikely	• Is not, or is only very rarely, associated with the pathway at the origin. • Has no import volume. • May not survive during transport or storage. • Cannot survive the current pest management procedures existing in the risk assessment area. • May not transfer to suitable habitat in the risk assessment area.
Unlikely	• Is rarely associated with the pathway at the origin. • Has very low import volume. • Survives at a very low rate during transport or storage. • Is strongly limited by the current pest management procedures existing in the risk assessment area. • Has considerable limitations for transfer to a suitable habitat/crop in the risk assessment area.
Moderately likely	• Is frequently associated with the pathway at the origin. • Has moderate import volume. • Survives at a low rate during transport or storage. • Is affected by the current pest management procedures existing in the risk assessment area. • Has some limitations for transfer to a suitable habitat/crop in the risk assessment area
Likely	• Is regularly associated with the pathway at the origin. • Has high import volume. • Mostly survives during transport or storage. • Is partially affected by the current pest management procedures existing in the risk assessment area. • Has very few limitations for transfer to a suitable habitat/crop in the risk assessment area.

Probability	The likelihood of entry would be:
Very likely	• Is usually associated with the pathway at the origin. • Has a very high import volume. • Survives during transport or storage. • Is not affected by the current pest management procedures existing in the risk assessment area • Has no limitations for transfer to a suitable habitat/crop in the risk assessment area.

Table A1-2: Rating of probability of establishment of a pest.

Probability	The likelihood of establishment would be
Very unlikely	• There is an absence or very limited availability of suitable habitat/crop • The environmental conditions are unsuitable. • There are other considerable obstacles preventing the establishment.
Unlikely	• There is limited availability of suitable habitats/crops. • The environmental conditions are unsuitable over the majority of the risk assessment area. • There are other obstacles preventing establishment.
Moderately likely	• Suitable habitats/crops are abundant in a few areas of the risk assessment area • Environmental conditions are suitable in a few areas of the risk assessment area. • No obstacles to establishment occur.
Likely	• Suitable habitats/crops are widely distributed in some areas of the risk assessment area • Environmental conditions are suitable in some areas of the risk assessment area. • No obstacles to establishment occur • Alternatively, the pest has already established in some areas of the risk assessment area.
Very likely	• Host plants are widely distributed. • Environmental conditions are suitable over the majority of the risk assessment area. • No obstacles to establishment occur • Alternatively, the pest has already been established in the risk assessment area.

Table A1-3: Ratings for describing levels of uncertainty for entry or establishment of a pest.

Uncertainty	The Uncertainty of establishment would be
Low	• No or little information is missing. • No or few data are missing, incomplete, inconsistent, or conflicting. • No subjective judgment is introduced. • No unpublished data are used.
Medium	• Some information is missing. • Some data are missing, incomplete, inconsistent, or conflicting. • Subjective judgment is introduced with supporting evidence. • Unpublished data are sometimes used.
High	• Most information is missing. • Most data are missing, incomplete, inconsistent, or conflicting. • Subjective judgment may be introduced without supporting evidence. • Unpublished data are frequently used.

Appendix II

Literature search for "*Phytophthora ramorum*" between 2008 until week 50 2022.

Phytophthora ramorum

Kontaktperson:	Per Hans Micael Wendell
Søk:	Bente Foss/ Hovedbibliotekar, Bibliotek for helseforvaltningen FHI
Dublettsjekk i EndNote:	Før dublett kontroll: 2018 Etter dublettkontroll: 916

Database: **Ovid MEDLINE(R) and Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Daily and Versions(R) <1946 to December 19, 2022>**
Dato: 20.12.22
Antall treff: 193

1	"Phytophthora ramorum?".tw,kf.	283
2	limit 1 to yr="2008- Current"	193

Database: **Embase**
Dato: 20.12.22
Antall treff: 149

1	"Phytophthora ramorum?".tw,kf.	197
2	limit 1 to yr="2008- Current"	149

Database: **Web of Science**
Dato: 20.12.22
Antall treff: 598

# 1	598	TS="Phytophthora ramorum$" Indexes=SCI-EXPANDED, SSCI, A&HCI, ESCI Timespan=2008-2022

Database: **Scopus**

Dato: 20.12.22
Antall treff: 476

1	TITLE-ABS-KEY ("Phytophthora ramorum*") AND PUBYEAR > 2007 AND PUBYEAR < 2023	476 document results

Database: **Cinahl**
Dato: 20.12.22
Antall treff: 0

S1	TI ("Phytophthora ramorum#") OR AB ("Phytophthora ramorum#")	0

Database: **Cochrane Database of Systematic Reviews**
Issue 12 of 12, December 2022
Cochrane Central Register of Controlled Trials
Issue 11 of 12, November 2022
Dato: 20.12.22
Antall treff: 0

#1	"Phytophthora ramorum" or "Phytophthora ramorums"::ti,ab	0

Database: **Epistemonikos**
Dato: 20.12.22
Antall treff: 9

1	"Phytophthora ramorum*" AND year (2008-2022)	9

Database: **CAB Abstracts <1973 to 2022 Week 50>**
Dato: 20.12.22
Antall treff: 593

1	"Phytophthora ramorum?".tw.	945
	limit 1 to yr="2008 -Current"	593

Appendix III

Known *Phytophthora ramorum* host plants globally, their importance/host status according to EPPO (Type), and their occurrence in Norway according to Lids flora (Lids 2004). Data from EPPO EPPO (2023a).

Host plant	Type	Norway
Kalmia **(whole genus)**	Major host	No
Kalmia latifolia	Major host	No
Larix decidua	Major host	Yes
Larix kaempferi	Major host	Yes
Notholithocarpus densiflorus	Major host	No
Pieris	Major host	Yes
Quercus agrifolia	Major host	No
Rhododendron (whole genus)	Major host	Yes
Rhododendron arboreum	Major host	No
Rhododendron catawbiense	Major host	Yes
Rhododendron macrophyllum	Major host	No
Rhododendron ponticum	Major host	No
Rhododendron yakushimanum	Major host	No
Syringa vulgaris	Major host	Yes
Viburnum (whole genus)	Major host	Yes
Arctostaphylos (whole genus)	Wild/Weed	No
Chamerion angustifolium	Wild/Weed	No
Epilobium ciliatum	Wild/Weed	Yes
Pteris cretica	Wild/Weed	No
Abies alba	Host	Yes
Abies concolor	Host	Yes
Abies grandis	Host	No
Abies magnifica	Host	No
Abies procera	Host	Yes
Acer circinatum	Host	No
Acer davidii	Host	No
Acer laevigatum	Host	No
Acer macrophyllum	Host	No
Acer pseudoplatanus	Host	Yes
Adiantum aleuticum	Host	No
Adiantum jordanii	Host	No
Aesculus californica	Host	No

Host plant	Type	Norway
Aesculus hippocastanum	Host	Yes
Alnus cordata	Host	No
Arbutus menziesii	Host	No
Arbutus unedo	Host	No
Arctostaphylos canescens	Host	No
Arctostaphylos columbiana	Host	No
Arctostaphylos glauca	Host	No
Arctostaphylos manzanita	Host	No
Arctostaphylos pumila	Host	No
Arctostaphylos sensitiva	Host	No
Arctostaphylos uva-ursi	Host	Yes
Arctostaphylos virgata	Host	No
Arctostaphylos viridissima	Host	No
Ardisia japonica	Host	No
Berberis aquifolium	Host	No
Betula pendula	Host	Yes
Calluna vulgaris	Host	Yes
Calycanthus occidentalis	Host	No
Camellia (whole genus)	Host	No
Camellia japonica	Host	No
Camellia sasanqua	Host	No
Castanea sativa	Host	Yes
Castanopsis orthacantha	Host	No
Ceanothus thyrsiflorus	Host	No
Cercis chinensis	Host	No
Chamaecyparis lawsoniana	Host	Yes
Choisya (whole genus)	Host	No
Choisya ternata	Host	No
Chrysolepis chrysophylla	Host	No
Cinnamomum camphora	Host	No
Clintonia andrewsiana	Host	No
Cornus capitata	Host	No
Cornus hybrids	Host	No
Cornus kousa	Host	No
Corylopsis spicata	Host	No
Corylus cornuta	Host	No
Cryptomeria (whole genus)	Host	No
Daphniphyllum glaucescens	Host	No
Distylium myricoides	Host	No

Host plant	Type	Norway
Drimys winteri	Host	No
Dryopteris arguta	Host	No
Eucalyptus haemastoma	Host	No
Euonymus kiautschovicus	Host	No
Fagus sylvatica	Host	Yes
Frangula californica	Host	No
Frangula purshiana	Host	No
Fraxinus excelsior	Host	Yes
Fraxinus latifolia	Host	No
Garrya elliptica	Host	No
Gaultheria procumbens	Host	No
Gaultheria shallon	Host	No
Griselinia littoralis	Host	No
Hamamelis mollis	Host	No
Hamamelis virginiana	Host	No
Hamamelis x intermedia	Host	No
Heteromeles arbutifolia	Host	No
Ilex aquifolium	Host	Yes
Ilex chinensis	Host	No
Ilex latifolia	Host	No
Kalmia angustifolia	Host	No
Larix x eurolepis	Host	No
Laurus nobilis	Host	No
Leucothoe axillaris	Host	No
Leucothoe fontanesiana	Host	No
Lithocarpus glaber	Host	No
Lonicera hispidula	Host	No
Lophostemon confertus	Host	No
Loropetalum chinense	Host	No
Magnolia (whole genus)	Host	No
Magnolia acuminata	Host	No
Magnolia cavaleriei	Host	No
Magnolia delavayi	Host	No
Magnolia denudata	Host	No
Magnolia doltsopa	Host	No
Magnolia figo	Host	No
Magnolia foveolata	Host	No
Magnolia grandiflora	Host	No
Magnolia insignis	Host	No

Host plant	Type	Norway
Magnolia kobus	Host	No
Magnolia liliiflora	Host	No
Magnolia lotungensis	Host	No
Magnolia maudiae	Host	No
Magnolia salicifolia	Host	No
Magnolia stellata	Host	No
Magnolia wilsonii	Host	No
Magnolia x loebneri	Host	No
Magnolia x soulangeana	Host	No
Magnolia x thompsoniana	Host	No
Maianthemum racemosum	Host	No
Nerium oleander	Host	No
Nothofagus obliqua	Host	No
Osmanthus (whole genus)	Host	No
Osmanthus decorus	Host	No
Osmanthus delavayi	Host	No
Osmanthus fragrans	Host	No
Osmanthus heterophyllus	Host	No
Osmorhiza berteroi	Host	No
Parrotia persica	Host	No
Phoradendron leucarpum	Host	No
Photinia x fraseri	Host	No
Physocarpus opulifolius	Host	Yes
Picea sitchensis	Host	Yes
Pickeringia montana	Host	No
Pieris formosa	Host	No
Pieris hybrids	Host	No
Pieris japonica	Host	No
Pittosporum undulatum	Host	No
Prunus laurocerasus	Host	No
Prunus lusitanica	Host	No
Pseudotsuga menziesii	Host	Yes
Pyracantha koidzumii	Host	No
Quercus (whole genus)	Host	No
Quercus acuta	Host	No
Quercus cerris	Host	No
Quercus chrysolepis	Host	No
Quercus falcata	Host	No
Quercus ilex	Host	No

Host plant	Type	Norway
Quercus kelloggii	Host	No
Quercus parvula var. shrevei	Host	No
Quercus petraea	Host	Yes
Quercus phillyreoides	Host	No
Quercus robur	Host	Yes
Quercus rubra	Host	Yes
Ribes laurifolium	Host	No
Rosa (whole genus)	Host	No
Rosa gymnocarpa	Host	No
Rosa rugosa	Host	Yes
Rubus spectabilis	Host	Yes
Salix caprea	Host	Yes
Sarcococca (whole genus)	Host	No
Schima argentea	Host	No
Schima wallichii	Host	No
Sequoia sempervirens	Host	No
Taxus baccata	Host	Yes
Taxus brevifolia	Host	No
Taxus x media	Host	No
Torreya californica	Host	No
Toxicodendron diversilobum	Host	No
Trientalis latifolia	Host	No
Tsuga heterophylla	Host	Yes
Umbellularia californica *	Host	No
Vaccinium intermedium	Host	No
Vaccinium myrtillus	Host	Yes
Vaccinium ovatum	Host	No
Vaccinium parvifolium	Host	No
Vaccinium vitis-idaea	Host	Yes
Vancouveria planipetala	Host	No
Viburnum davidii	Host	No
Viburnum hillieri	Host	No
Viburnum plicatum var. tomentosum	Host	No
Viburnum tinus	Host	No
Viburnum x bodnantense	Host	No
Vinca minor	Host	Yes

* California bay laurel is a major sporulating host in USA.