SCIENTIFIC OPINION

Scientific Opinion on the risks to plant health posed by *Phytophthora fragariae* Hickman var. *fragariae* in the EU territory, with the identification and evaluation of risk reduction options[1]

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ABSTRACT

The Panel on Plant Health assessed the risk to plant health from *Phytophthora fragariae* for the European Union and evaluated the current EU legislation and possible risk reduction options. The pest is present in most areas of Europe except southern Mediterranean regions. Entry through the plants for planting, but not seeds, pathway, is assessed as a major pathway, with the probability of entry rated as unlikely and the uncertainty as high. The probability of establishment is likely in the absence of existing disease control practices with low uncertainty. The probability of spread in the absence of a scheme for the production of certified plants for planting is considered to be very likely. With certification, spread is considered to be unlikely to moderately likely, depending on the inclusion of testing for the pathogen as part of certification. These ratings have medium uncertainty. Potential impact is rated as minor with medium uncertainty. The Panel evaluated the effectiveness of current EU legislation regarding the introduction and spread of *P. fragariae*. According to the regulation the import of *Fragaria* plants for planting, other than seeds, is prohibited from specified countries, whereas for import of these plants from other countries and for movement of these plants within the EU special requirements with respect to *P. fragariae* must be fulfilled. If the current legislation specific to *P. fragariae* were removed, no major consequences would be expected, unless the industry simultaneously ceased its voluntary certification activity. This is largely because of the important level of protection afforded to the industry by the widely used certification schemes for *Fragaria*, which significantly reduce the risks of entry, establishment, spread and impact. Certification schemes for the movement of *Fragaria* plants for planting offer the greatest efficiency and feasibility and the least uncertainty, especially if effective detection is incorporated into them.

KEY WORDS

Phytophthora fragariae, red core, red stele, pest risk assessment, risk reduction options, strawberry, *Fragaria* × *ananassa*

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SUMMARY

Following a request from the European Commission (EC), the EFSA Panel on Plant Health (PLH) was asked to deliver a scientific opinion on the pest risk of *Phytophthora fragariae* Hickman var. *fragariae* for the European Union (EU) territory and to identify risk reduction options and evaluate their effectiveness in reducing the risk to plant health posed by the organism. In particular, the Panel was asked to provide an opinion on the effectiveness of the current EU requirements against this organism, which are laid down in Council Directive 2000/29/EC, in reducing the risk of introduction of this pest into, and its spread within, the EU territory.

The Panel conducted the pest risk assessment following the general principles of the "Guidance on a harmonised framework for pest risk assessment and the identification and evaluation of pest risk management options" (EFSA PLH Panel, 2010) and of the "Guidance on evaluation of risk reduction options" (EFSA PLH Panel, 2012). As *Phytophthora fragariae* Hickman var. *fragariae* is already present in some EU Member States and has been regulated by the EU for many years, the Panel conducted the pest risk assessment taking into account the current EU plant health legislation.

After consideration of the evidence, the Panel reached the following conclusions:

With regard to the assessment of the risk to plant health of *P*. *fragariae* for the EU territory:

The widespread cultivation of strawberry means that the endangered area includes the whole of the EU. *P*. *fragariae* is present in most areas except the southern Mediterranean regions, and, while it has been eradicated from some Member States, there is a continued threat of spread, both naturally and by human assistance.

With regards to entry, the Panel concludes that pathway strawberry plants for planting (including plants in tissue culture (*microplants*), "frigo" plants (*young plants after cold storage*) and green plants (*runners*)) is the major pathway for entry of the pathogen into the risk assessment area from non-Member States. This pathway was the only one chosen for further assessment. The overall rating for entry is unlikely. Very little trade in strawberry plants for planting has been reported from non-Member States. Detection methods, if used as intended, are effective in eliminating infected plants for planting. The uncertainty is high owing to lack of information on trade and the quality and frequency of inspection data across Member States.

With regards to establishment, the Panel notes that strawberries are grown throughout the EU. A small number of wild species are present in the EU, but these are unlikely to play any important role in the further establishment of the disease following new entry of the pathogen or spread within the EU. It is reasonable to conclude that the climate in the majority of the Member States is suitable for the disease: it is probably most conducive in the western part of northern Europe, with a temperate, oceanic climate, and least so in the southern Mediterranean regions, where high soil temperatures would inhibit pathogen establishment and disease development. Given the climatic conditions throughout much of the strawberry-producing areas, the probability of establishment following a new entry of the pathogen or spread within the EU is rated as likely, in the absence of existing disease control practices, with low uncertainty. Different cultural practices and control measures may be applied in attempts to eradicate the pathogen once it is present in a field; however, as oospores of *P*. *fragariae* may survive for many years in plant debris and soil, eradication could be very difficult.

With regards to spread, the Panel concluded that by definition this also means establishment in a new area where the pest was previously absent. As noted under establishment, cultivated strawberries are widespread and climatic conditions are suitable in the risk assessment area. The pathways for spread within the EU territory are the same as those for entry into the EU. A distinction is made between spread by natural means and that occurring through human assistance, with the latter being considered much more important. The main pathway for spread over all scales of distance is the movement of infected plants for planting through the extensive intra-EU trade. In the absence of certification, spread

is considered to be very likely. With certification, spread is considered to be unlikely to moderately likely. Certification, where supported by appropriate methods, is effective in containment and prevention of further spread. These ratings are associated with a medium uncertainty.

With regards to the magnitude of impact, the Panel concluded that pest effects can be partitioned into yield losses and control costs. Crop yields have been reduced by as much as two-thirds in untreated plantations. Disease control costs in strawberry are not available. Even so, fungicide treatments are only partially effective and might not mitigate the disease fully in the absence of phytosanitary measures. Importantly, the existence of regulation and voluntary certification schemes for strawberry ensures healthy planting materials for fruit producers. In addition, significantly shorter cycles in modern strawberry cultivation practices (one to two seasons) contribute to a reduction in the impact of disease.

Disease outbreaks are as far is known reported only from commercial strawberry production. However, to some extent strawberries are also grown in private gardens, and they may also become infected. It is thus likely that the pathogen may occur in amenity land but only to a very limited extent.

Overall the consequences were assessed as minor. By comparison with other strawberry pests and pathogens, under the current regulatory regime the pest effects and the environmental effects are likely to have little impact. Under this regime and with pest management practices the level of the disease remains manageable. The uncertainty is rated as medium.

With regard to risk reduction options, the Panel evaluated the phytosanitary measures formulated in Council Directive 2000/29/EC and identified additional risk reduction options where relevant.

The Panel evaluated the phytosanitary measures against the introduction and spread of *P. fragariae* listed in Council Directive 2000/29/EC, explored the possible consequences if these measures were to be removed and identified additional risk reduction options to enhance the current measures.

The Panel concludes that the special requirements for introduction of *Fragaria* plants for planting, specified by 2000/29/EC, Annex IV, Part A, Section I (19.2), and for movement of *Fragaria* plants within the EU specified by 2000/29/EC, Annex IV, Part A, Section II (12), are not fully effective in preventing the introduction into and spread within the EU of *P. fragariae*.

None of the risk reduction options explored were considered to have a major effect on their own in reducing these risks. Options were, however, identified with moderate to high effectiveness and feasibility that would reduce the magnitude of consequent impacts.

The Panel considered that, at the present level of trade into the EU, removal of *P. fragariae* from Annex IIAII would have only a marginal effect on the risk of its introduction into and spread within the EU and on its impact, because of the remaining legislation for the introduction into and movement within the EU of *Fragaria* plants for planting, the important level of protection by the widely used certification scheme for *Fragaria*, which significantly reduces the risks of entry, establishment, spread and impact, and the currently available pest management practices.

The effectiveness of risk reduction options that could further reduce the risk of introduction and spread was evaluated. None of the risk reduction options explored were considered to have a very high effectiveness in reducing the risk of introduction. Concerning entry, the two most important risk reduction options are inspections and surveillance, and certification, especially if supported by effective detection tests (root tip and bioassay and/or DNA tests). Effective maintenance of these two risk reduction options can prevent the entry of *P. fragariae*.

If, however, the current regulation was to be discarded along with simultaneous removal of the widely used certification schemes for *Fragaria*, there would be major consequences for the potential impact of *P. fragariae*. This is largely because of the important level of protection afforded to the industry by the widely used certification schemes for *Fragaria*, which significantly reduce the risks of entry, establishment, spread and impact. Certification schemes for the movement of strawberry plants for planting offer the greatest efficiency and feasibility and the least uncertainty, especially if effective detection is incorporated into them.

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BACKGROUND AS PROVIDED BY THE EUROPEAN COMMISSION

The current European Union plant health regime is established by Council Directive 2000/29/EC on protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community (OJ L 169, 10.7.2000, p. l).

The Directive lays down, amongst others, the technical phytosanitary provisions to be met by plants and plant products and the control checks to be carried out at the place of origin on plants and plant products destined for the Union or to be moved within the Union, the list of harmful organisms whose introduction into or spread within the Union is prohibited and the control measures to be carried out at the outer border of the Union on arrival of plants and plant products.

Arabic mosaic virus, Tomato black ring virus, Raspberry ringspot virus, Strawberry latent ringspot virus, Strawberry crinkle virus, Strawberry mild yellow edge virus, *Daktulosphaira vitifoliae* (Fitch), *Eutetranychus orientalis* Klein, *Parasaissetia nigra* (Nietner), *Clavibacter michiganensis* spp. *michiganensis* (Smith) Davis *et al*., *Xanthomonas campestris* pv. *vesicatoria* (Doidge) Dye, *Didymella ligulicola* (Baker, Dimock and Davis) v. Arx, and *Phytophthora fragariae* Hickman var. *fragariae* are regulated harmful organisms in the EU. They are all listed in Annex II, Part A, Section II of Council Directive 2000/29/EC, which means that they are organisms known to occur in the EU and whose introduction into and spread within the EU is banned if they are found present on certain plants or plant products.

Given the fact that these organisms are already locally present in the EU territory and that they are regulated in the EU since a long time, it is considered to be appropriate to evaluate whether these organisms still deserve to remain regulated under Council Directive 2000/29/EC, or whether, if appropriate, they should be regulated in the context of the marketing of plant propagation material, or be deregulated. In order to carry out this evaluation a recent pest risk analysis is needed which takes into account the latest scientific and technical knowledge on these organisms, including data on their agronomic and environmental impact, as well as their present distribution in the EU territory.

The revision of the regulatory status of these organisms is also in line with the outcome of the recent evaluation of the EU Plant Health Regime, which called for a modernisation of the system through more focus on prevention and better risk targeting (prioritisation).

TERMS OF REFERENCE AS PROVIDED BY THE EUROPEAN COMMISSION

EFSA is requested, pursuant to Article 29(1) and Article 22(5) of Regulation (EC) No 178/2002, to provide a pest risk assessment of Arabic mosaic virus, Tomato black ring virus, Raspberry ringspot virus, Strawberry latent ringspot virus, Strawberry crinkle virus, Strawberry mild yellow edge virus, *Daktulosphaira vitifoliae* (Fitch), *Eutetranychus orientalis* Klein, *Parasaissetia nigra* (Nietner), *Clavibacter michiganensis* spp. *michiganensis* (Smith) Davis *et al*., *Xanthomonas campestris* pv. *vesicatoria* (Doidge) Dye, *Didymella ligulicola* (Baker, Dimock and Davis) v. Arx, and *Phytophthora fragariae* Hickman var. *fragariae*, for the EU territory.

For each organism EFSA is asked to identify risk management options and to evaluate their effectiveness in reducing the risk to plant health posed by the organism. EFSA is also requested to provide an opinion on the effectiveness of the present EU requirements against those organisms, which are laid down in Council Directive 2000/29/EC, in reducing the risk of introduction of these pests into, and their spread within, the EU territory.

Even though a full risk assessment is requested for each organism, in order to target its level of detail to the needs of the risk manager, and thereby to rationalise the resources used for its preparation and to speed up its delivery, EFSA is requested to concentrate in particular on the analysis of the present spread of the organism in comparison with the endangered area, the analysis of the observed and potential impacts of the organism as well as the availability of effective and sustainable control methods.

ASSESSMENT

1. Introduction

1.1. Purpose

This document presents a pest risk assessment prepared by the Panel on Plant Health (PLH; hereinafter referred to as the Panel) for *Phytophthora fragariae* Hickman var. *fragariae*, in response to a request from the European Commission. The scientific opinion includes the identification and evaluation of risk reduction options in terms of their effectiveness and technical feasibility in reducing the risk posed by the organism.

1.2. Scope

The scope of the opinion is to assess the risks posed by *P. fragariae* var. *fragariae* to the risk assessment area and to identify and evaluate risk reduction options. The Panel considers in its opinion the current European Union legislation and the existing industry certification system. The pest risk assessment area is the EU territory.

2. Methodology and data

2.1. Methodology

2.1.1. The guidance documents

The risk assessment was conducted in line with the principles described in the document "Guidance on a harmonised framework for pest risk assessment and the identification and evaluation of pest risk management options" (EFSA PLH Panel, 2010).

The detailed questions in the EFSA-adapted European and Mediterranean Plant Protection Organization (EPPO) risk assessment scheme, presented in the above-mentioned guidance document, were used as a checklist to ensure that all relevant elements were included. However, as the terms of reference require the opinion to "concentrate in particular on the analysis of the present spread of the organism in comparison with the endangered area, the analysis of the observed and potential impacts of the organism as well as the availability of effective and sustainable control methods", the opinion provides only a limited assessment of entry and establishment. The entry section (Section 3.2) examines the different pathways that have been found to transport the pest species and assesses the effectiveness of the current measures in Council Directive 2000/29/EC in terms of preventing entry. The establishment section (Section 3.3) focuses on determining: (i) the areas of potential establishment outdoors and in protected crops; and (ii) the extent to which there are still significant areas suitable for establishment where the pest is not present.

The evaluation of risk reduction options was conducted in line with the principles described in the above-mentioned guidance document (EFSA PLH Panel, 2010), as well as with those in "Guidance on methodology for evaluation of the effectiveness of options to reduce the risk of introduction and spread of organisms harmful to plant health in the EU territory" (EFSA PLH Panel, 2012).

In order to follow the principle of transparency, as described under Section 3.1 of the guidance document on the harmonised framework for risk assessment (EFSA PLH Panel, 2010)—"… Transparency requires that the scoring system to be used is described in advance. This includes the number of ratings, the description of each rating … the Panel recognises the need for further development …"—the Plant Health Panel developed rating descriptors to provide clear justification when a rating was given, which are presented in Appendix A of this opinion.

2.1.2. Methods used for conducting the risk assessment

As *P. fragariae* var. *fragariae* is already present in the EU territory and has been regulated for a long time (Annex IIAII of Council Directive 2000/29/EC[4]), the Panel not only took into account the existing legislation when conducting the pest risk assessment but also discussed the situation that might arise if these regulations were lifted.

The assessment of the probability of entry (Section 3.2) focused on the potential for further entry of *P. fragariae* var. *fragariae* from non-EU European countries into the risk assessment area, i.e. the EU, whereas the assessment of the probability of spread (Section 3.4) was conducted with regard to further spread of the pest within and between the EU Member States. The Panel took into account the existing legislation when conducting the pest risk assessment.

The conclusions for entry, establishment, spread and impact are presented separately. The descriptors used to assign qualitative ratings are provided in Appendix A.

2.1.3. Methods used for evaluating the risk reduction options

The Panel identified potential risk reduction options and evaluated them with respect to their effectiveness and technical feasibility, i.e. consideration of the technical aspects that influence their practical application. The sustainability of the options was considered, based on the definition of "sustainable agriculture" as "capable of being continued with minimal long-term effect on the environment/capable of being maintained at a steady level without exhausting natural resources or causing severe ecological damage" [5]. The evaluation of the efficiency of management options in terms of the potential cost-effectiveness of measures and their implementation is not within the scope of the Panel's evaluation.

The descriptors used to assign qualitative ratings for the evaluation of the effectiveness and technical feasibility of management options are shown in Appendix A.

2.1.4. Level of uncertainty

For the risk assessment conclusions on entry, establishment, spread and impact and for the evaluation of the effectiveness of the management options, the levels of uncertainty were rated separately. The descriptors used to assign qualitative ratings to the level of uncertainty are shown in Appendix A.

2.2. Data

2.2.1. Literature search

An extensive literature search on *P. fragariae* var. *fragariae* was conducted at the beginning of the mandate. The literature search follows the first three steps (preparation of protocols and questions, search, selection of studies) of the EFSA guidance on systematic review methodologies (EFSA, 2010). Further references and information were obtained from external experts and from citations within the references found.

2.2.2. Data collection

In seeking data and information concerning the current situation of the pest, its distribution, the damage caused to plants and management, the PLH Panel undertook the following actions:

[4] Council Directive 2000/29/EC of 8 May 2000 on protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community. OJ L 169, 10.7.2000, p. 1-112.

[5] Dictionary.com, "sustainable", in Collins English Dictionary—Complete and Unabridged 10th Edition. Source location: HarperCollins Publishers. http://dictionary.reference.com/browse/sustainable. Available: http://dictionary.reference.com. Accessed 2 March 2013.

1. The National Plant Protection Organisation (NPPO) contacts of all EU Member States were requested to confirm or update the current status of the organism in their territory (contacted on 24 January 2013, with answers received up to 21 March 2013). The NPPOs' replies are provided in Table 3.

2. A hearing of technical experts from the small fruit sector was organised in order to obtain data and information on the production in trade, propagation, certification and disease management in Europe of strawberry and raspberry plant propagation material. The meeting took place in Parma on 22 May 2013, and a technical report of the data and information received from the industry experts was published (EFSA, 2014).

3. When expert judgement and/or personal communications were used, justification and evidence have been provided to support the statements. Personal communications were considered only when provided in written form and when other sources of information were not publicly available.

For the evaluation of the probability of entry, the EUROPHYT database was consulted, searching for pest-specific notifications on interceptions. EUROPHYT is a web-based network launched by the Directorate General for Health and Consumers (DG SANCO), and is a sub-project of PHYSAN (Phyto-Sanitary Controls) specifically concerned with plant health information. The EUROPHYT database manages notifications of interceptions of plants or plant products that do not comply with EU legislation.

3. Pest risk assessment

3.1. Pest categorisation

3.1.1. Identity of the pest

P. fragariae is a single taxonomic entity and can be adequately distinguished from other species of the same genus.

3.1.1.1. Taxonomy

Scientific name: *Phytophthora fragariae* Hickman

Taxonomic position:

Kingdom Chromista

Phylum Oomycota

Class Oomycetes

Order Peronosporales

Family Peronosporaceae

Genus *Phytophthora*

Species *Phytophthora fragariae* Hickman

Common names of the disease caused by the pathogen: red core, red stele, Lanarkshire disease.

P. fragariae was first described by Hickman (1940) as the organism causing red core of strawberry. It stood unaltered until Wilcox et al. (1993) split it into two varieties: var. *fragariae*, which causes red core of strawberry; and var. *rubi*, which causes root rot of red raspberry. The original separation into two varieties accommodated differences in whole protein electrophoretic patterns, morphology (quite minor) and host range: var. *fragariae* effectively caused only red core of strawberry (see below); and var. *rubi* caused only root rot of raspberry.

In 1997 var. *rubi* was properly separated from *P. fragariae* by its elevation to a new species *P. rubi* on the basis of gene flow analysis (Man in't Veld, 1997). The elimination of varieties within *P. fragariae* meant that the original description of Hickman was re-applied automatically only to the *Phytophthora* causing red core of strawberry. *P. fragariae* and *P. rubi* are undoubtedly more closely related to one another than to any other *Phytophthora* sp. discovered to date and have been located in the same clade within *Phytophthora*, along with *P. cambivora*, *P. europaea*, *P. uliginosa*, *P. alni* subsp. *alni* and *P. alni* subsp. *uniformis*.[6] Hickman (1940) had already noted the morphological similarity of *P. fragariae* to *P. cambivora*.

All isolates of *P. fragariae* so far tested have very similar whole protein electrophoretic patterns not shared by *P. rubi* or *P. cambivora* (Duncan et al., 1991), indicating that it is a well-defined species. Furthermore, in pathogenicity tests, all isolates with this protein profile, or very slight variants thereof, produced typical red core symptoms when inoculated on to strawberry plants. In contrast, the same isolates caused only 1–2 mm browning at the tips of some white roots (probably a hypersensitive reaction) upon inoculation of red raspberry plants (*Rubus idaeus* L.). The exact reverse was the case with isolates of *P. rubi*: they caused extensive root rot on red raspberry but did not cause any symptoms on strawberry apart from browning of root tips.

The uniformity of isolates of *P. fragariae* in terms of morphology, cultural characteristics, molecular markers and pathogenicity, indicates a well-defined species; moreover, the members examined appear to have one common phylogenetic ancestor: in other words *P. fragariae* is a monophyletic taxon (Duncan et al., 1991).

3.1.1.2. Detection and identification

Identification

Symptoms

Red core disease has a characteristic symptomatology that makes its diagnosis relatively straightforward and unambiguous. This was described fully by Hickman (1940) and Bain and Demaree (1945). Briefly, affected plants fail to develop or do so only slowly in the spring, with new foliage stunted and often bluish in colour. In warm spells in late spring and early summer diseased plants wilt badly and often die. Above-ground symptoms are a consequence of poor and badly rotted root systems comprising main roots, with few if any fibrous laterals that are rotted away. The main roots rot from the tips upwards: the grey–brown rotting and lack of laterals gives affected roots a very characteristic appearance, aptly named "rat's tail". Slicing open the roots longitudinally reveals wine red discolouration of their steles, hence the common European and American names for the disease of red core and red stele respectively. The discolouration of the stele can reach well above the rotted part of the root well into the white and apparently healthy part of the root as far as the crown. Thick-walled oospores (~32 µm diam.) of *P. fragariae* are produced in abundance in and around the stele.

In summer it becomes very difficult to isolate the fungus, and it is thought that the pathogen becomes quiescent, depending for survival upon oospores left in rotted roots (Hickman, 1940; Bain and Demaree, 1945).

P. fragariae can be readily isolated from infected roots (Montgomerie and Kennedy, 1983).

6 See Phylogram of Clade 7a of *Phytophthora* species at: http://www.phytophthoradb.org/species_new.html

Cultural characteristics

These are well described by both Hickman (1940) and Bain and Demaree (1945). Hyphal form and dimensions are not usually very good discriminatory characters in *Phytophthora* identification. Colony form and growth rate are more useful. As with most species in molecular clade 7, cultures of *P. fragariae* on French bean agar form quite large amounts of evenly fluffy aerial mycelium but grow more slowly than any other species, even *P. rubi*.

Like all species in Clade 7a, *P. fragariae* produces fairly large non-papillate sporangia (on average 50 × 30 µm) (Bain and Demaree, 1945) that can undergo internal proliferation: the sporangiophore continues growing through the base of an earlier sporangium, which has already discharged its contents as zoospores, to produce another sporangium. Sometimes the new sporangium is formed inside the remnants of the old sporangium, in which case it is described as nested. Several successions of nested sporangia can often be found. A sporangiophore can also grow sympodially from just below the base of a sporangium to produce new sporangia. However, most if not all of these features of sporangia can also be found in other Clade 7a species.

Although single-zoospore isolates of *P. fragariae* readily form oospores in abundance in the roots of their strawberry host, they do not do so in culture. In French bean agar cultures, oospores, often misshapen with deeply pigmented oogonial envelopes, can be found but invariably embedded in pieces of bean, usually starch grains (Hickman, 1940). In contrast, *P. rubi* forms oospores fairly readily in culture, and they are neither misshapen nor with highly coloured oogonial envelopes. (J.M. Duncan, personal communication, April 2013).

Molecular techniques

Various molecular markers have been used to discriminate among *P. fragariae* and closely related species starting with the internal transcriber spacer (ITS) regions of ribosomal DNA. This is still a good target for routine identification (and detection, see below) of *P. fragariae*, although alone it cannot distinguish *P. fragariae* from *P. rubi*. The early use of discernible bands in gels has been superseded by direct sequencing of polymerase chain reaction (PCR) products obtained with genus- and species-specific primers. Other markers are now available, including nuclear and mitochondrial DNA markers, and the number is growing.

Analysis of a combination of the cytochrome c oxidase (cox) gene, a mitochondrial gene, and ITS sequence (Robideau et al., 2011) should separate unequivocally *P. fragariae* and *P. rubi* (D.E. Ll. Cooke, The James Hutton Institute, Dundee, personal communication, October 2013). The number of such markers can only grow, as will the number of *Phytophthora* species to which they will be applied, making possible precise fingerprinting not only of species but also of strains within species.

Pathogenicity

Finally, although pathogenicity is not considered a taxonomic character, it does often define species in practical terms, and therefore with red core of strawberry the pathogenicity of isolates recovered from red core outbreaks should be a consideration in determining identity (Duncan et al., 1991).

<u>Detection</u>

In soil

Susceptible *Fragaria* spp. have been used to detect *P. fragariae* in the field and in soil samples. The spread of *P. fragariae* from an infested strawberry field across an adjacent field that had never before grown a strawberry crop was studied using plants of “Baron Solemacher”, a landrace of the alpine strawberry, *Fragaria vesca* var. *alpina* (Duncan, 1979).

This and other landraces of alpine strawberry make ideal bait plants because the plants do not runner and are grown from commercially available seed, thereby eliminating the risk of contamination by the pathogen. In addition, preliminary experiments demonstrated that three landraces, including "Baron Solemacher", were highly susceptible to all available races of *P. fragariae* (Duncan, 1979).

"Baron Solemacher" was also used to demonstrate that *P. fragariae* can survive in an infested site for 10 years after a diseased strawberry crop (Newton et al., 2010). The non-runnering nature of the plants allowed them to be planted on a grid without the risk of their spreading and intermingling across the site.

Runnering clones of the woodland strawberry, *F. vesca*, are as susceptible to all races of *P. fragariae* as alpine strawberry and as useful as a bait plant, if care is taken to ensure that plants are not exposed to infection with the pathogen before use.

Duncan (1976) used plants of the clone VS1 to detect and estimate levels of the pathogen in soil samples from an infested site. Mixing the soil with soilless compost improved the sensitivity of detection by the bait plants. In controlled inoculation with a range of zoospore suspensions, the bait test detected zoospore numbers similar to the number released on the germination of single oospores (8–16) (Duncan, 1975).

Clone VS1 was also used to study survival of the pathogen in naturally infested soil samples stored under a range of soil moisture levels and at a range of temperatures (Duncan and Cowan, 1980). The fungus persisted in the soil for the length of the experiment (approximately three years) at temperatures of 15 ºC and below but declined rapidly at 30 ºC. Persistence was also best at intermediate levels of moisture.

In plant material

However useful *in situ* field baiting and baiting of soil samples under controlled conditions were in experimental studies, they were of little value in the practical matter of preventing further spread in commerce. In particular, *P. fragariae* was never detected in soil samples from fields that had never previously grown a strawberry crop, despite many attempts across the east of Scotland (J.M. Duncan, unpublished results): either the pathogen was not present or it was not present at levels detectable by a test necessarily restricted by the practicalities of collecting and handling large amounts of soil.

Adapting the soil bait test by replacing the soil component in soil/soilless compost mixtures with strawberry root tips and then baiting with alpine strawberry "Baron Solemacher" immediately yielded results. The first test of the method on a commercial stock of runner plants supplied to a commercial fruit grower detected infection of the stock. A few root tips were cut from every fifth bundle of 25 plants as they were removed from the clean paper sacks in which they had been supplied from the runner plant producer. Within three to five weeks symptoms of red core were observed in some of the trial pots but not in control pots containing only soilless compost. In experiments in which diseased roots were mixed with healthy roots, the root tip bait test (as it was subsequently known) detected 10 out of 10 samples containing 1 % infected roots (Duncan, 1980). All aspects of this test, from sampling regimes for collecting root tips to the sensitivity of the test itself, were examined in an EU COST programme from which a number of protocols emerged (Duncan, 2001).

The root tip bait test, with variations, was soon taken up by plant health inspectorates in Scotland and in England and Wales and was applied (and still is) to various grades of planting stocks entered for plant health certification. It was also used in Germany and other countries. In the Netherlands, the technique was adapted by suspending the roots of the bait plants in water containing the root tip samples. This technique may be slightly more sensitive than the original use of root tip compost mixtures. DNA testing of the water from the Dutch test has also been shown to be effective (Duncan, 2001).

DNA-based detection

Specific primers, based on the ITS sequences of ribosomal DNA (Cooke et al., 2000) (see Section 3.1.1.2 above on identification) have been used to detect *P. fragariae* and *P. rubi* in nested (two-round) PCR and single-round PCR assays. The root tip bait test (or variations thereof) was modified and combined with PCR testing to yield a range of testing protocols for red core relevant to the needs and equipment of individual laboratories. For large samples of roots, water from the bait test developed in the Netherlands was tested by PCR, whereas PCR was used directly on root material from smaller samples. Rapid PCR product detection protocols were also developed (Bonants et al., 2004). The validation of both the protocols and the procedures was tested via a ring test involving nine EU-based laboratories. The results across the various laboratories were consistent and feedback positive (Duncan, 2001).

More generally, fast and reliable methods have been developed for DNA extraction from soil and zoospores trapped from water on filters making it possible to follow the activity and spread of *Phytophthora* species throughout the year.

3.1.1.3. Biology and life cycle

P. fragariae can persist in soil for years as thick-walled sexual spores—oospores. Survival for more than 10 years has been recorded in controlled experiments in the field (Newton et al., 2010). In all probability, few oospores survive for this long, but the polycyclic nature of the disease means that low levels of inoculum can soon spread and cause severe disease. Typically, when outbreaks occur, either as a result of soil inoculum or by introduction on infected plants, visible damage and symptoms do not become obvious until the second year after planting (See Figure 1).

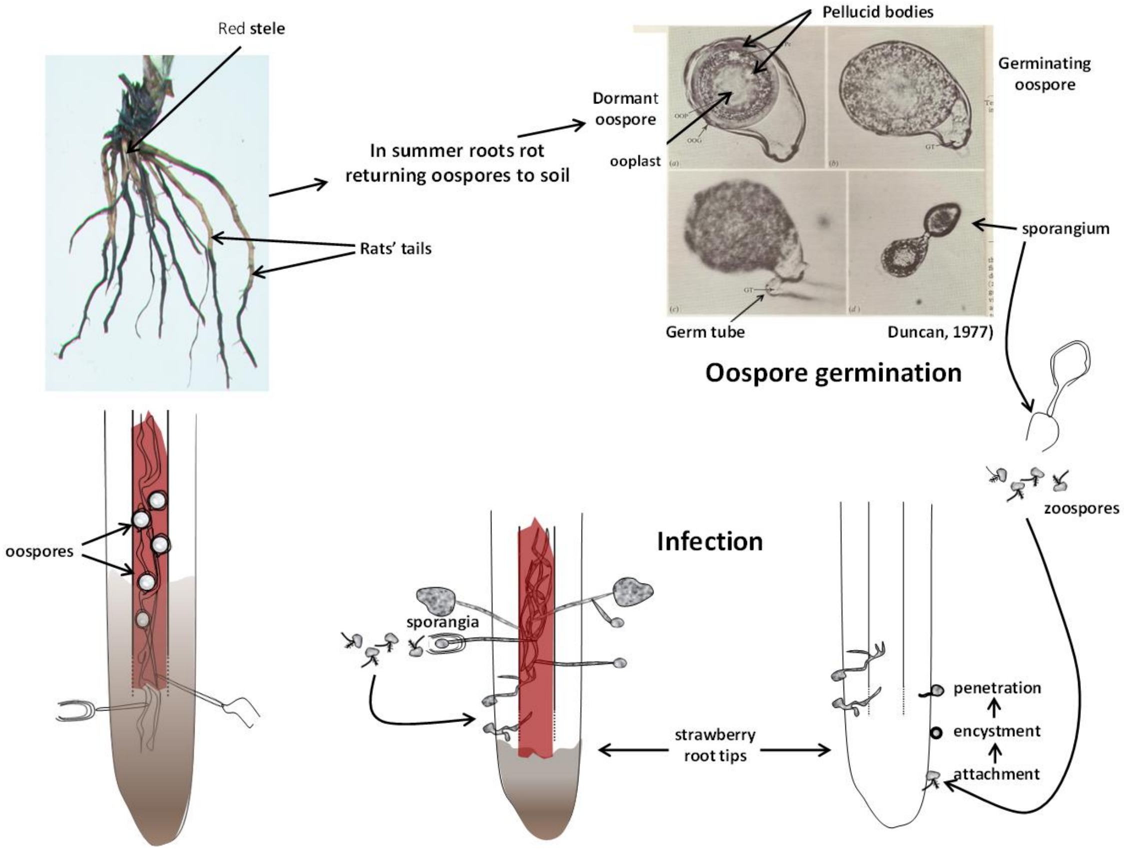

Figure 1: Diagrammatic life cycle of *Phytophthora fragariae*, based mainly on Hickman (1940) and Bain and Demaree (1945)

External conditions that initiate oospore germination are not known, but significant levels of germination can occur when oospores extracted from infected roots are placed in water or 1 % distilled water agar. Oospore germination occurs within one to three days of the first indication of activity (Duncan, 1977). Changes in the internal structure and erosion of the inner wall are followed by the swelling of the oospore and the production of a germ tube that forms a sporangium, sometimes several: these resemble in every aspect the sporangia produced asexually on infected roots.

Oospore germination proceeds most rapidly at about 15–20 ºC, but above 20 ºC fewer oospores germinate, and none at all germinate at 30 ºC: at this temperature they appear to die within a few weeks (Duncan, 1985a). Below 15 ºC, germination proceeds more slowly, ceasing altogether at 5 ºC. However, the numbers of germinating spores remains overall the same as at 15 °C, and spores kept at 5 ºC for several weeks have much the same level and speed of germination when returned to 15 ºC. Low temperatures slow and, if low enough, stop germination but do not kill the oospores (Duncan, 1985a). Thus oospores are most probably aestivation structures allowing them to survive warmer (but not too warm) and dry summers when conditions are unfavourable for infection.

In water, sporangia from oospores are small and release 8–16 zoospores (Duncan, 1975); larger sporangia (on average 50 × 30 µm (Bain and Demaree, 1945)) are produced on infected roots and can release 40–50 zoospores, perhaps more. Zoospores are chemotactically attracted to root tips (Halsall, 1976) and to points where lateral roots are about to emerge: on root tips they attach and encyst mainly in the zone of elongation just behind the root cap. Germ tubes from the encysted spores then penetrate the root tissue. Within two to three days, new sporangia form on the outside of the roots, again around root tips and where lateral roots are about to emerge from larger roots. Sporangia can be produced on roots in high numbers (Bain and Demareee, 1945). In turn they release more zoospores to spread the infection to nearby roots and plants. Zoospores are negatively geotactic (Cameron and Carlile, 1977), i.e. they swim upwards in water—a behaviour that ensures their accumulation near the surface of the soil where they are more easily washed away by mass movement of water down slopes. Thus, red core outbreaks typically spread downhill very rapidly: in strawberry plants planted in rows the disease can spread quite a distance down one row before “jumping” to a neighbouring row.

The production of sporangia is favoured by low temperatures. *In vitro*, their formation and subsequent release of zoospores is promoted by irrigating discs cut from the margins of actively growing colonies, firstly with dilute mineral solutions (Montgomerie and Kennedy, 1975) and then with distilled water usually at 5–10 ºC. Water extracts of soil have an even greater stimulatory effect on the formation of sporangia (Duncan, 1985a; Kennedy et al., 1986) and it is probable that microorganisms and their products can stimulate zoosporangial production.

Zoospores quickly loose motility and encyst at temperatures > 15 ºC but keep swimming for much longer periods below 10 ºC, up to one to two days. In the laboratory, they have been observed swimming very actively just below the frozen surface of water (Bain and Demaree, 1945).

Zoospores can also infect at very low temperatures. Inoculated plants showed few visible symptoms of infection when kept at 5 ºC or lower but kept releasing large amounts of inoculum in drainage water, presumably in the form of zoospores, for weeks after the initial inoculation, as assessed with a sensitive bioassay (Duncan and Kennedy, 1994). In contrast at 15 ºC the production of secondary inoculum started much sooner and peaked much earlier than in plants kept at the lower temperatures.

After penetration of the roots, the pathogen then proceeds to grow upwards, primarily in the central cylinder or stele (Hickman, 1940). As it does so, the stele turns a deep wine red colour, hence the name of the disease: red stele or red core. The roots begin to rot with much of the fibrous root disappearing leaving a root system comprising mainly primary roots which have a very characteristic “rat’s tail” appearance. As the fungus moves up the root, it forms abundant oospores in or around the stele. The location, abundance, size and appearance of the oospores are very characteristic of red core: the oospores of *P. cactorum* have been observed in roots but in the cortex and not the stele (J.M. Duncan, unpublished observations).

As spring turns to summer, affected plants wilt, often irreversibly. At this time, it becomes very difficult to isolate the fungus (Hickman, 1940; Bain and Demaree, 1945). The fungus almost certainly persists until the cooler, wetter autumn months as oospores within rotted roots and fragments of rotted roots that have disintegrated in the soil. Thereafter, the cycle in plants and roots is repeated.

Pathogenicity

Hickman (1940) inoculated a number of common fruits and vegetables, e.g. tomato, with *P. fragariae* but did not manage to infect any of them. He also examined plants of a number of common UK weed species collected from the middle of severe outbreaks of red core but never found signs of infection with *Phytophthora*. Likewise, Bain and Demaree (1945) tried to infect a wide range of plant material but failed, apart from one ripe apple fruit, into which *P. fragariae* grew a short distance. They also noted that one of three clones of *F. chiloensis* did not become infected upon inoculation: all other *Fragaria* species were susceptible, although some varieties of cultivated strawberry were highly resistant.

Fragaria is a member of the tribe Potentilleae in the family Rosaceae, and other genera within the tribe and family were susceptible upon inoculation with *P. fragariae*. Five *Potentilla* spp. out of 19 tested were susceptible to one race of *P. fragariae*: red steles were present, in one case right to the crown of the plant, as well as typical oospores, although numbers per millimetre of root were lower in all five *Potentilla* spp. than in a susceptible strawberry plant (Moore et al., 1964). In a wider study that included European and Asian species of *Potentilla* and *Geum*, as well as North American species, only *P. glandulosa*, 1 of 16 North American species and subspecies, was susceptible to four races of *P. fragariae* (Converse and Moore, 1966). In contrast, 6 of 11 European and Asiatic species and subspecies were susceptible to two races of the pathogen. The susceptibility of *P. glandulosa* prompted the following comment: “No reports are known of the natural occurrence of *Phytophthora fragariae* on *Potentilla* or on other *Potentilla* species anywhere. However, it is possible that *Potentilla glandulosa* may be associated with the natural occurrence of *Phytophthora fragariae* in western USA” (Converse and Moore, 1966).

Two *Geum* and one *Dryas* species, eight species and subspecies of *Potentilla*, *R. parviflorus* and 14 varieties and selections of red raspberry (*R. idaeus* var. *idaeus*) were susceptible when inoculated with various races of *P. fragariae* (Pepin, 1967). However, the symptoms generally were not severe: in the case of raspberry, the most severe symptom was red steles for about one-quarter the length of a root. However, the author did not consider red stele disease to be detrimental to raspberry as it rarely involved more than a few rootlets. Oospores were noted in red raspberry but their small size (26.4 µm diameter) must raise suspicion that another *Phytophthora* species might have been involved. *P. idaei* is almost ubiquitous in raspberry plants, even in stocks of high health status (Kennedy and Duncan, 1994), and has oospores about the same size.

P. fragariae has been reported only once from a non-*Fragaria* host in nature, when it was isolated from an unthrifty loganberry plantation in Vancouver Island, Canada (McKeen, 1958a). The isolate was in morphology, culture and pathology a typical isolate of *P. fragariae* (Duncan et al., 1991): it caused typical red core symptoms on strawberry but failed to infect red raspberry, *R. idaeus* var. *idaeus*, but was not tested on loganberry.

Table 1: A recent study lists species of *Fragaria* that occur in Europe (Hummer et al., 2011)

***Fragaria* species**	**Global occurrence**
F. vesca L.	Europe, Asia west of the Urals, disjunct in North America
F. viridis Duch.	Europe and Asia
Fragaria × *bifera*	France, Germany. Natural hybrid of *F. vesca* and *F. viridis*
Fragaria × *ananassa* Duch. ex Lamarck	Cultivated strawberry
F. moschata Duch.	Euro-Siberia
Fragaria × *vescana* R. Bauer and A. Bauer	Cultivated in Europe, artificial hybrid of *F. vesca* and *Fragaria* × *ananassa*

Pathogenicity is intimately related to resistance in the host. There are no known reports of resistance within the wild species *F. vesca* and *F. Moschata* (see Table 1). The latter is unlikely to have been tested as widely as *F. vesca*. Nothing appears to be known about the susceptibility of *F. viridis* or of its hybrid with *F. vesca*, *Fragaria* × *bifera*, likewise of the hybrid *F. vescana* between *F. vesca* and the cultivated strawberry *Fragaria* × *ananassa*, which is grown commercially within Europe. However, given the highly susceptible nature of all *F. vesca* clones tested to date, it might be safe to assume that its hybrids are susceptible.

The cultivated strawberry *(Fragaria × ananassa)* has some resistance to the disease depending on the cultivar and the race of *P. fragariae* with which it is challenged. Resistance to specific races of the pathogen is present in both putative parents of the cultivated strawberry: *F. chiloensis* (female parent) and *F. virginiana* (male parent) (Hancock, 1999, as cited in Hummer et al., 2011). *F chiloensis* exists as four subspecies two of which concentrated on sand dunes down the west coast of North America and another in coastal mountains of South America, with the forth restricted to the Hawaiian Islands. *F. virginiana* is found in all parts of North America. Of 25 parents identified as effective in the transfer of resistance to races of *P. fragariae* (Daubeny, 1964), the most effective was cv. "Yaquina" a clone of *F. chiloensis*. Other effective parents included a number of commercial cultivars of the cultivated strawberry; the "Del Norte" clone of *F. chiloensis* and "Sheldon" clone of *F. virginiana*

A "gene-for-gene" model for the resistance of strawberry to *P. fragariae*, proposed by Van de Weg (1997), is now widely accepted by strawberry breeders and geneticists. Up to 10 genes for resistance to *P. fragariae*, R_{pf} genes, have been recognised (five of which have been published in the literature; E. Van de Weg, Wageningen University and Research Centre, The Netherlands, personal communication, July 2013), and several of these have been closely linked to molecular markers, one of which is published in the literature (Haymes et al., 2000). The method of selection of strawberry seedlings, used in the United States Department of Agriculture strawberry breeding programme, was to expose strawberry seedlings to zoospores of mixtures of different isolates. This programme has resulted in a number of cultivars which possess three variable combinations of three different resistance genes ($R_{Pf2,}$ R_{Pf3}, which always include R_{Pf1}). No cultivar with such a combination has yet succumbed to red core in commercial production in the USA or in experimental studies in Europe. Given the liability of more complex races of the pathogen, i.e. that which can overcome a combination of these three resistance genes (Kennedy and Duncan, 1993), it is possible that resistance conferred by the possession of three or more R_{pf} genes would not break down readily in the field if cultivars possessing them were grown widely in commerce (E. van de Weg, Wageningen University and Research Centre, the Netherlands, personal communication, July 2013). Durability of this resistance could be further sustained by practices that decrease the spread of new, highly virulent races.

3.1.2. Current distribution

3.1.2.1. Global distribution

The disease was first recorded in 1920 in Scotland, UK (Alcock et al., 1930)—now part of the EU territory. Since then it has been reported in many countries where strawberry is grown. The recorded global distribution is shown in Figure 2.

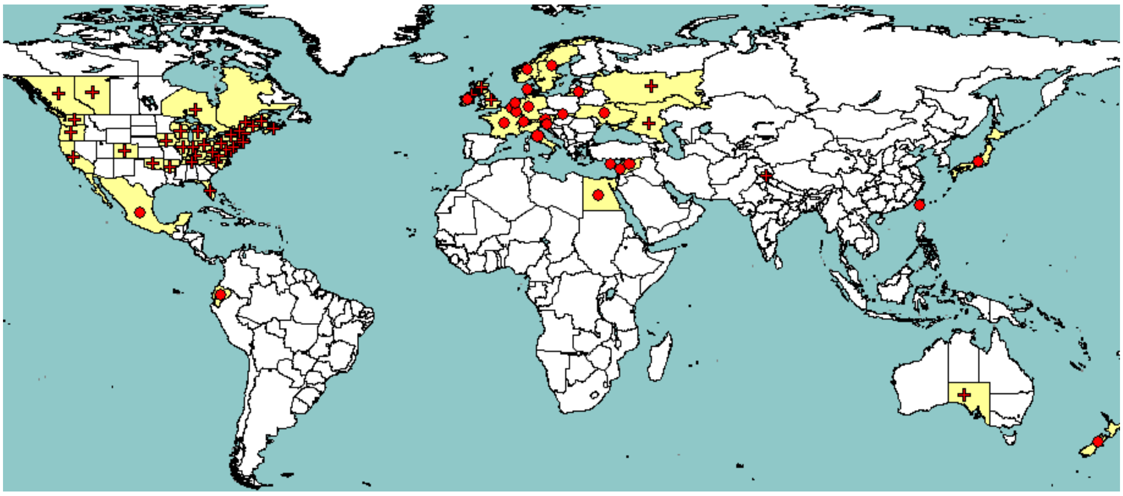

Figure 2: Global distribution of *P. fragariae* extracted from EPPO PQR (version 5.0, assessed in February 2013). Red circles represent pest presence as national records and red crosses pest presence as sub-national records (Note that this figure combines information from different dates, some of which could be out of date).

Table 2 summarises information on the current distribution of the pest updated with data from the EPPO Plant Quarantine Data Retrieval System (PQR).

Table 2: Status of *P. fragariae* outside the EU

Continent	Country	Pest status EPPO PQR 2013 (date of information indicated in brackets)
Africa	Egypt	Present, no details (1992)
America	Canada	Present, restricted distribution (1993)
	Ecuador	Present, restricted distribution (1992)
	Mexico	Present, restricted distribution (1993)
	USA	Present, widespread (1994)
Asia	India	Present, restricted distribution (2000)
	Japan	Present, no details (1992)
	Lebanon	Present, no details (1992)
	Syria	Present, no details (1997)
	Taiwan	Present, few occurrences (1992)
Oceania	Australia	Present, restricted distribution (1993)
	New Zealand	Present, few occurrences (1993)
Europe (non-EU)	Norway	Present, restricted distribution
	Switzerland	Present, restricted distribution
	Russia	Present, restricted distribution (1992)
	Ukraine	Present, restricted distribution (1998)

There have been only three interceptions from Third countries into the EU—two from Switzerland, and one from Poland pre-accession (EUROPHYT, 2013).

3.1.2.2. Occurrence in the risk assessment area

The pathogen is present in many countries in the risk assessment area. Table 3 and Figure 3 summarise the most up-to-date information on the current distribution of the pest, considering the official answers received from the Member States and data from the EPPO PQR database.

P. fragariae has been reported in 16 Member States and is not reported in seven, with no information available from three. In two Member States (Hungary, Lithuania) *P. fragariae* is reported to have been eradicated.

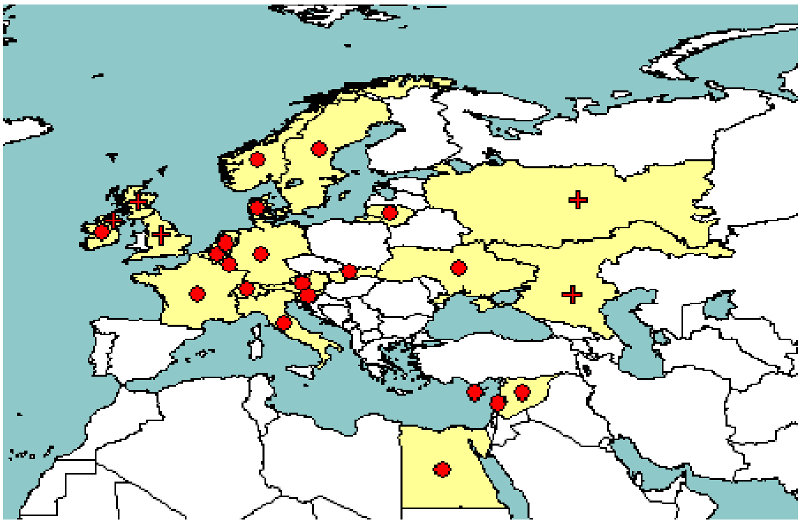

Figure 3: Distribution of *P. fragariae* in Europe and neighbouring countries extracted from EPPO PQR (version 5.0, 2013). Red circles represent pest presence as national records and red crosses pest presence as sub-national records).

Table 3: The current distribution of *P. fragariae* in the risk assessment area based on responses to the EFSA questionnaire (official answers given by the NPPOs) and the EPPO PQR database

Member State	Pest status in EPPO PQR 2013	Pest status in EFSA questionnaire (2013)
Austria	Present, restricted distribution	Present, restricted distribution
Belgium	Present, restricted distribution	Present, restricted distribution
Bulgaria	Absent, pest no longer present	Absent, pest no longer present
Croatia	–	No data. Possibly, great losses in strawberry production
Cyprus	Present, restricted distribution	Absent (no records)
Czech Republic	Absent, invalid record	Absent, invalid record
Denmark	Present, restricted distribution	Present, only in some areas
Estonia	Absent, confirmed by survey	Absent, confirmed by survey
Finland	–	Present, only in some areas where host crops are grown
France	Present, restricted distribution	Present, restricted distribution

Member State	Pest status in EPPO PQR 2013	Pest status in EFSA questionnaire (2013)
Germany	Present, restricted distribution	Present, restricted distribution
Greece	–	Absent , not known to occur
Hungary	Absent, pest eradicated	Absent, pest eradicated
Ireland	Present, restricted distribution	Present, restricted distribution
Italy	Present, few occurrences	Present, few occurrences
Latvia	–	
Lithuania	Present, restricted distribution	Absent, pest eradicated
Luxembourg	Present, restricted distribution	
Malta	–	Not known to occur
The Netherlands	Present, restricted distribution	Present, restricted distribution
Poland	–	Present, restricted distribution (confirmed by surveys)
Portugal	–	Absent, latest detection in 1994
Romania	–	Absent, confirmed by survey
Slovakia	Present, restricted distribution	Present, restricted distribution
Slovenia	Present, restricted distribution	Absent, pest record invalid
Spain	Absent, unreliable record	
Sweden	Present, restricted distribution	Absent: pest no longer present (the pest was recorded in 1979, 1982 and 1996 The pest has not been recorded since 1996)
UK	United Kingdom: present, restricted distribution Channel Islands: absent, pest no longer present England: present, widespread Northern Ireland: present, no details	England, Scotland and Wales: present, widespread Northern Ireland, Channel Islands and Isle of Man: absent, pest no longer present

3.1.3. Regulatory status in the risk assessment area

P. fragariae is a regulated harmful organism in the EU and is listed in Council Directive 2000/29/EC in the following sections:

Annex II, Part A—Harmful organisms the introduction of which into, and spread within, all Member States shall be banned if they are present on certain plants or plant products.

Section II—Harmful organisms known to occur in the EU and their introduction into and spread within the EU is banned if they are found present on certain plants or plant products.

(c) Fungi

Species	Subject of contamination
7. *Phytophthora fragariae* Hickman var. *fragariae*	Plants of *Fragaria* L. and *Rubus* L., intended for planting, other than seeds

Annex IV, Part A—Special requirements which must be laid down by all Member States for the introduction and movement of plants, plant products and other objects into and within all Member States

Section I—Plants, plant products and other objects originating outside the Community

Plant products and other objects	Special requirements
19.2. Plants of … *Fragaria* L., … intended for planting, other than seeds, originating in countries where the relevant harmful organisms are known to occur on the genera concerned The relevant harmful organisms are—on *Fragaria* L.: *Phytophthora fragariae* Hickman, var. *fragariae*	Without prejudice to the provisions applicable to the plants where appropriate listed in Annex III (A)(9) and (18), and Annex IV(A)(I)(15) and (17), official statement that no symptoms of diseases caused by the relevant harmful organisms have been observed on the plants at the place of production since the beginning of the last complete cycle of vegetation

Section II—Plants, plant products and other objects originating in the Community

Plant products and other objects	Special requirements
12. Plants of *Fragaria* L., …., intended for planting, other than seeds	Official statement that: (a) the plants originate in areas known to be free from the relevant harmful organisms; or (b) no symptoms of diseases caused by the relevant harmful organisms have been observed on plants at the place of production since the beginning of the last complete cycle of vegetation The relevant harmful organisms are: —on *Fragaria* L: *Phytophthora fragariae* Hickman var. *fragariae*

Elements of Annexes III and V of 2000/29/EC are also relevant to the prevention of entry of the pest.

Annex III—Member States shall ban the introduction into their territory of the plants or plant products

Part A—Plants, plant products and other objects the introduction of which shall be prohibited in all member states.

Description	Country of origin
18. Plants of *Fragaria* L., intended for planting, other than seeds	Without prejudice to the prohibitions applicable to the plants listed in Annex III A (9), where appropriate, non-European countries, other than Mediterranean countries, Australia, New Zealand, Canada, the continental states of the USA

Annex V lists plants, plant products and other objects which must be subject to a plant health inspection before being permitted to enter the community or being moved within the community. According to Annex V, Part A, Section I, plants intended for planting other than seeds of *Fragaria*, originating in the EU, must be accompanied by a plant passport. According to Annex V, Part B, Section I, *Fragaria* plants intended for planting, other than seeds, imported into the EU must be accompanied by a phytosanitary certificate and be subject to documentary, identity and plant health checks on import. These checks may be carried out at an approved place of inspection elsewhere in the EU, subject to agreement between the relevant competent authorities.

Commission Decisions 2011/74/EC amending Commission Decision 2003/248/EC[7] and 2011/75/EC amending Commission Decision 2003/249/EC[8] provide temporary derogations from the import prohibition specified in Annex III, point 18, for *Fragaria* plants for planting other than seeds originating in Argentina and Chile, respectively. These derogations concern not only *P. fragariae* but cover all harmful organisms, in particular those listed in Annex I and II of 2000/29/EC. Detailed requirements for these imports of *Fragaria* plants for planting are specified in Annex I of Commission Decisions 2003/248/EC and 2003/249/EC, and they are far more stringent than the requirements of 2000/29/EC, Annex IV, Part A, Section I (19.2), e.g.:

- Import of these plants is allowed only from 1 June to 30 September.
- The plants shall have been produced exclusively from mother plants, which were imported from a Member State and certified under an approved certification scheme of a Member State.
- The land on which the plants are produced must meet specific conditions.
- The plants must be officially inspected by the respective Plant Protection Services of Argentina and Chile, at least three times during the growing season and again prior to export for the presence of the harmful organisms.

In addition to Council Directive 2000/29/EC, *Fragaria* L. is further regulated in Council Directive 2008/90/EC[9] on the marketing of fruit plant propagating material and fruit plants intended for fruit production.

3.1.4. Potential for establishment and spread in the risk assessment area

P. fragariae was reported in the EU. It is present in many European countries (see Table 3), having been reported in 16 countries. Only in two Member States has it been reported as eradicated. Therefore we conclude that *P. fragariae* is established and can potentially spread in the pest risk assessment area.

3.1.4.1. Host range of *P. fragariae*

As described in Section 3.1.1.3, the main host of the pathogen is *Fragaria* × *ananassa*. The pathogen can also cause limited disease in a small number of other genera within the Rosaceae, e.g. *Potentilla* (McKeen, 1958a; Pepin, 1967; Duncan and Kennedy, 1994). Other wild *Fragaria* species are also susceptible, including *F. vesca*, which is used in the root tip bait test for *P. fragariae* (Duncan, 1980; EPPO, 2008a). *R. loganobaccus* has been recorded on one occasion as a host plant in Canada (McKeen, 1958a).

3.1.4.2. Strawberry production in Europe

Europe grows approximately 100 000 ha of strawberry each year (see Table 4) using a variety of growing systems, within which the crop can be grown as an annual or a perennial crop. Outside of the Mediterranean region, the crop is usually managed as a perennial. However, the number of years a crop is grown has shortened in recent decades, largely because plantations give a higher proportion of larger fruit in the early years of production and perhaps because shorter rotations reduce pest and disease problems. This trend is likely to continue in future "increasing the demand for high quality, disease-free planting material" (EFSA, 2014). In perennial systems, planting takes place in spring or

[7] COMMISSION DECISION of 2 February 2011 amending Decision 2003/248/EC as regards the extension of the duration of temporary derogations from certain provisions of Council Directive 2000/29/EC in respect of plants of strawberry (*Fragaria* L.), intended for planting, other than seeds, originating in Argentina. OJ L 29, 3.2.2011, p. 32.

[8] COMMISSION DECISION of 2 February amending Decision 2003/249/EC as regards the extension of the duration of temporary derogations from certain provisions of Council Directive 2000/29/EC in respect of plants of strawberry (*Fragaria* L.), intended for planting, other than seeds, originating in Chile. OJ L 29, 3.2.2011, p. 33.

[9] Council Directive 2008/90/EC of 29 September 2008 on the marketing of fruit plant propagating material and fruit plants intended for fruit production. OJ L 267, 8.10.2008, p. 8–22.

summer, and plantations are maintained thereafter for several years. Traditionally, production has been in open fields either as matted row or hill (raised) beds, the two major planting methods for strawberries worldwide. Matted rows are popular in northern Europe, e.g. the Nordic countries, as they offer some protection against cold winters (Davik et al., 2000).

In the Mediterranean region, the large fruit size and yields justify the cost of fresh planting each year. Planting may take place in the autumn or spring with plants destroyed the following summer after harvest.

Whether grown as an annual or a perennial, all over Europe the strawberry is being grown increasingly under cover, most commonly in polythene or Spanish tunnels. Plants can be grown in the ground in tunnels, but very often they are grown on tables in inert substrates, such as peat or coir, with drip irrigation providing required fertilisers and crop protectants. Apart from freeing farmers from the operational constraints imposed by weather, fruit quality is greatly improved in such systems compared with fruit produced in open fields and yields are more consistent (Demchak, 2009). Most diseases, including red core, are also less troublesome in protected growing systems: two notable exceptions are powdery mildew and crown rot (*P. cactorum*).

The status of sustainable strawberry production in Europe has been surveyed (Steffek et al., 2004), and by 2004 in some countries organic strawberry production had reached a level of 4–6 %. How organic growers cope with damaging diseases such as red core and crown rot is not known.

Strawberry growers require a reliable supply of quality plants for planting to maintain their industry and, with 100 000 ha of production to be replanted annually or every two or three years, strawberry propagation is itself an important industry. Because growers, especially smaller ones, often produce their own plants for planting, accurate figures for annual production within the EU are not readily available. In Belgium, for example, “most growers prefer to grow their own plants to be sure about plant quality” (EFSA, 2014). However, using estimates of the average life of a plantation of three years and a common planting density of 25 000 plants per hectare yields an annual requirement for the EU as a whole of 730 million plants for planting. Reducing the average life of a plantation from three to two years would increase this figure to 1 200 million. Even more plants for planting will be required in future as it has been forecast that “Plants for planting will be used for only one growing cycle/season” (EFSA, 2014). Major producers of strawberry plants are Spain, Poland, France, Italy, the Netherlands and the UK (EFSA, 2014). “In general there is no production outside the EU that will return to the EU” (EFSA, 2014).The value of healthy strawberry plants for planting to the strawberry industry historically has been recognised by growers and national governments, and many countries have long-established certification schemes for ensuring the health of planting material. Increasingly, *in vitro* micropropagation is used initially to produce plants each year (Bourrain, 2009) from mother plants of high health status held under glass at government research stations or by growers’ organisations (such as the Nuclear Stock Association in the UK) and monitored continuously for “trueness to type” and absence of pests and diseases. These plants are then “bulked up” in successive years of propagation in which, because of the increasing amounts of material, propagation in the field becomes increasingly important. A typical series in this process, taken from the FERA scheme in England and Wales (UK), would be from Foundation (mother plants) to Super-Elite, Elite, A, and Approved Health Grades (Anonymous, 1984). Commercial fruit producers generally plant A or Approved Health plants; some prefer Elite (FERA PHPS, 2013). All strawberry propagation schemes in Europe have a zero tolerance for *P. fragariae* in accordance with EPPO’s scheme (EPPO, 2008a).

Table 4: Production of strawberry in Europe expressed in 1 000 hectares in 2010 and 2011 (source: FAOSTAT databases, data extracted in April 2013)

Country	Area harvested (1 000 ha)	
	2010	**2011**
Austria	1.254	1.267

Country	Area harvested (1 000 ha)	
	2010	**2011**
Belgium	1.550	1.550
Bulgaria	0.690	1.011
Cyprus	0.032	0.036
Croatia	0.201	0.158
Czech Republic	0.495	0.509
Denmark	0.980	1.010
Estonia	0.589	0.3
Finland	3.311	3.599
France	2.875	3.102
Germany	13.644	13.848
Greece	1.241	1.153
Hungary	0.578	0.505
Ireland	0.100	0.101
Italy	5.991	6.000
Latvia	0.368	0.255
Lithuania	1.1.92	1.201
Luxembourg	0.002	0.002
Malta	0.013	0.013
Netherlands	1.632	1.652
Poland	37.122	50.522
Portugal	1.650	1.647
Romania	2.664	2.645
Slovakia	0.225	0.236
Slovenia	0.102	0.09
Spain	6.988	6.857
Sweden	1.900	1.790
United Kingdom	4.968	4.972
Norway	1.330	1.350
Switzerland	0.425	0.444

The data for 2012 are not yet available.

3.1.4.3. Climatic conditions

Cultivated strawberry is grown in every Member State and the pathogen occurs or has occurred in the majority of Member States. Therefore current climatic conditions in the majority of Member States are conducive for the disease. In particular the maritime temperate climate appears highly conducive for symptom development, which makes detection in the field easier than in a warmer and drier Mediterranean area. The impact of climate change will probably be seen in changes in the production system (e.g. irrigation) in the Mediterranean climate, which may exacerbate the disease.

3.1.5. Potential for consequences in the risk assessment area

Consequences in the risk assessment area are determined by the scale and type of strawberry production, as detailed in the previous section (see Section 3.1.4). Impact, in terms of yield loss, has been well documented. Other studies outside of the risk assessment area, e.g. North America and Australia, have reported similar findings.

Red stele caused by *P. fragariae* causes serious economic losses in cool, wet strawberry production areas (McIntyre and Walton, 1981; Montgomerie and Kennedy, 1982; Wicks, 1983; Paulus, 1990; Harris, 1991; Pinkerton et al., 2002). A specific estimate–of loss was made by Montgomerie and Kennedy (1982), who stated that the relationship between red core disease incidence/severity and yield was highly significant and negatively correlated. Yield loss of strawberry caused by *P. fragariae* was also given by Wicks (1983), who reported that 30–50 % of strawberry plants were wilted and collapsed on several commercial strawberry plantings in South Australia in the early summer of 1980. The causal agent of the disease was identified as *P. fragariae* (Wicks and Lee, 1982).

Fungicide and soil sterilants demonstrate potential yield loss caused by *P. fragariae*. In several studies, yield losses were obtained by comparing disease reduction and yield increase on treated and control (untreated) plots (Montgomerie and Turner, 1979; McIntyre and Walton, 1981; Montgomerie and Kennedy, 1982; Wicks, 1983; Harris, 1991). In a fungicide trial only metalaxyl out of three fungicides tested gave satisfactory control of red core disease (McIntyre and Walton, 1981). Metalaxyl-treated plants had 137 % more flowers than the untreated control, with the corresponding fruit yield 161 % higher. The rating of infected plants averaged over three readings made over 12 months on a 0–5 scale (0, none; 1, 20 %; 2, 40 %; 3, 60 %; 4, 80 % plants showing symptoms; and 5, all plants dead) was 2.9 for the controls and 1.25 for the metalaxyl treatment, a highly significant difference. In a comparison of several fungicide treatments (Montgomerie and Kennedy, 1982) red core severity ranged from 5 % in treated plots to 52 % in the water control, while marketable yield ranged from 3.11 kg to 1.55 kg per 25 m^2 plot respectively. Disease severity and yield correlated negatively on a linear regression scale, and the relationship between the two was significant at $p \leq 0.05$. A single application of fosetyl aluminium gave significant red core disease control and yield increase compared with untreated plots (O'Neill and Griffin, 1987). A half-dose spray of fosetyl aluminium plus a half-dose drench of captafol applied after picking and in spring also gave significant disease control and a significantly better yield than untreated plots. The timing of fungicide application had no effect on the level of red core incidence or fruit yield. The increased yield using fosetyl aluminium and captafol was mainly due to a decrease in red core disease but may also have been partly due to control of non-specific root rots.

In all the above studies no treatment gave complete control of the disease. Therefore the yield increases that correlated with disease reduction almost certainly were lower than what could be achieved with complete control of the disease or in its absence. Thus estimates of yield reductions of two-thirds in the absence of any treatments to control red core disease are realistic. They are echoed in responses from the present-day industry, even with ready recourse to fungicides. In Belgium, the disease is serious "in a cold and humid spring or in fields with bad drainage …. *Phytophthora fragariae* can cause damage from 10 to 20–30 %." and "*Phytophthora* (*P. cactorum* and *P. fragariae*) are causing significant losses regularly" (EFSA, 2014).

However, there are potential environmental consequences arising from the use of fungicides. Moreover, the need to control this disease creates the risk of selecting fungicide-resistant strains of the pathogen. Metalaxyl-resistant strains of *P. fragariae* have been reported from Germany (Seemüller and Sun, 1989).

3.1.6. Conclusion on the pest categorisation

P. fragariae is present and widely distributed in the risk assessment area. It has the potential to cause considerable yield loss, especially in cooler, more temperate regions of the Community. In order of importance, current disease control strategies are based on quarantine measures, avoidance of the disease based on certification schemes, chemical control and, to a lesser extent, resistance and on-farm sanitation. Its widespread distribution in the EU implies that spread has occurred principally through infected planting material.

Based on the above, it may be concluded that *P. fragariae* continues to present a risk to strawberry crops grown in the risk assessment area.

3.2. Probability of entry

The risk assessment area is the EU territory. Because *P. fragariae* occurs in many Member States (but not all) within the EU (Section 3.1.2), the assessment of the probability of entry focuses on the potential for further entry into the risk assessment area.

Owing to the scarcity of interception records, the assessment of the significance of the pathways and their analyses are based on a thorough literature search, expert knowledge and information on the host range and biology of *P. fragariae*.

3.2.1. Identification of pathways

Under the current EU legislation, the Panel identified the following pathways for entry of *P. fragariae* from infested areas into the risk assessment area:

1. Strawberry plants for planting (including plants in tissue culture (*microplants*), “frigo” plants (*young plants after cold storage*) and green plants (*runners*)—hereafter, just “plants for planting), but not seeds;

2. Plants of other host species for planting;

3. Non-host plants for planting, including seed potatoes, bulbs, rootstocks, etc.;

4. Soil and other organic growth media;

5. Root vegetables and potatoes not intended for planting;

6. Pathogens adhering to machinery, other farm implements and footwear;

7. Movement of surface water in fields and through ditches, streams and rivers.

<u>Plant-related pathways</u>

1—Strawberry plants for planting

Strawberry is the main host of *P. fragariae*. The pathogen is mainly present in the roots, but in severely diseased plants it can also invade the rootstock and in some susceptible varieties spread into the vascular tissue of the petioles as far as their junction with the laminae (Hickman, 1940).Thus the probability of the pathogen being associated with strawberry plants if the production site is infested with *P. fragariae* is rated as very likely. The uncertainty is low.

P. fragariae has never been observed on fruit on diseased plants in the field and never been isolated from such fruit. Thus the likelihood of entry into the EU and subsequent establishment and spread within the EU on *Fragaria* seed can be rated as very unlikely. The uncertainty is very low.

2—Plants of other host species for planting

The pathogen can also cause disease in other *Fragaria* species (see Section 3.1.1.3) and has done so in one reported case in *R. loganobaccus*; however, this is considered to be a minor pathway (the level of production in Europe is not well known). Wild *Fragaria* species, notably *F. vesca*, grow in many countries in Europe, but there are no reports that these species could represent a pathway for the pathogen. Several other species in the Rosaceae family have been infected experimentally, including species in the genera *Dryas*, *Geum*, *Potentilla* and *Rubus* (EPPO, 1998). If the field from which an imported host plant other than strawberry originates is infected with *P. fragariae*, the probability of the pathogen being associated with the pathway at origin is rated as very unlikely. The uncertainty is medium to high.

<u>Soil-related pathways</u>

3—Non-host plants for planting, including seed potato, bulbs, rootstocks, etc.

4—Soil and other organic growth media

5—Root vegetables and potatoes not intended for planting

6—Pathogens adhering to machinery, other farm implements and footwear

The common feature of these pathways is soil. Soil or other growth media may contain oospores of the pathogen. Non-host plants for planting may be imported in containers with soil, and root vegetables and potatoes may carry soil particles. If the field where the plant, soil or other organic growth media originates is infested with *P*. *fragariae*, and strawberry plants have been grown, viable oospores may be present (Newton et al., 2010). Oospores can also be moved by soil on implements and machinery (EPPO, 1998) that may be imported into the risk assessment area. The probability of the pathogen being associated with the pathway at origin is rated as unlikely. The uncertainty is high.

Water-related pathway

7—Movement of surface water in fields and through ditches, streams and rivers

P. *fragariae* can spread by zoospores in surface or soil water, or contaminated irrigation water. There is no report about the viability of zoospores of *P*. *fragariae*, but it is generally known that zoospores, which have a thin cell wall, have a short life span, possibly two to three days at most. However, for the pathogen to enter into the EU by such a pathway would require very specific circumstances such as river catchments common to EU and non-EU countries. The probability of the pathogen being associated with this pathway is rated as very unlikely with high uncertainty.

3.2.1.1. Selection of the most important pathways

The selection of the most important pathways from those listed above for further assessment was based on the EFSA guidance on a harmonised framework for pest risk assessment and the identification and evaluation of pest risk management options (EFSA PLH Panel, 2010). The guidance states that: the most relevant pathways should be selected using expert judgement and, where there are different origins and end uses, it is sufficient to consider only realistic worst-case pathways.

The Panel concludes that pathway 1—Strawberry plants for planting—is the major pathway for entry of the pathogen into the risk assessment area from third countries for the reasons given above. This pathway is the only one chosen for further assessment.

3.2.2. Pathway 1—strawberry plants for planting

3.2.2.1. Probability of association with the pathway at origin

If the production site outside the EU from which an imported strawberry plant originates is infected with *P*. *fragariae* (see Table 2 for country listings), the probability of the pathogen being associated with the pathway at origin is very likely. Other than visual inspection or testing at the place of production there are no known treatments that eliminate the pathogen without damaging the plant. In such a circumstance the only way to prevent entry of infected plants is the same inspection and testing procedures as are used in the certification schemes practised within the EU, where *Fragaria*, as well as a range of other host plants intended for planting, are produced under strict certification schemes.

The trade volumes and frequency of imports from countries where *P*. *fragariae* is present and the effectiveness of implementation of regulations/inspections will determine the likelihood of entry. EUROSTAT data on the movement of plants for planting along the pathway from third countries to the EU is not available as it is aggregated in the category of “vegetable and strawberry plants”. As indicated by the hearing of industry experts (EFSA, 2014), the vast majority of *Fragaria* plants for planting material used in the pest risk assessment area are produced within Europe, although some international trade of material between California and Canada and Europe has been reported and presents a potential risk.

3.2.2.2. Probability of survival during transport or storage

Conditions during transport and storage would normally be controlled to avoid damage to plants for planting. It is unlikely that such conditions would have a deleterious effect on the pathogen. As noted in Section 3.1.1.3, oospores can survive at low temperatures and only start to lose viability above 20 °C. Thus the probability of survival during transport and storage is rated as very likely. The uncertainty is low.

3.2.2.3. Probability of survival of existing pest management procedures for entry

All strawberry plants for planting imported into the EU are subject to inspection and issue of a plant passport (see Section 3.1.3; import-related provision and passport provisions).

However, host plants may not show symptoms if they are not heavily infected. Thus they may not be detected by inspections made in connection with the issuing of plant passports. If present, symptoms are unequivocal and not to be confused with those caused by other pathogens. Where symptoms are not present, there are reliable and validated detection methods involving root tip bioassay or direct DNA testing. It is not known how widespread use of these methods is across EU Member States.

Chemical control is not applicable at this stage because of (a) masking of symptom expression and (b) emergence of resistant strains (Seemüller and Sun, 1989).

If the detection methods are used as intended, then the probability of eliminating infected plants for planting is rated as very likely with low uncertainty. If the detection methods are not used as intended, then the probability is rated as unlikely with medium uncertainty.

3.2.2.4. Probability of transfer to a suitable host

The probability of an infected plant for planting transferring inoculum to a healthy plant at the time of planting is rated as very unlikely: the roots of infected plants are unlikely to be wet enough during storage and transport for zoosporangia to form on their surfaces. Uncertainty is rated as low to medium.

However, once planted, oospores present in infected plants for planting may germinate and produce sporangia and zoospores that can subsequently infect healthy plants. If this is considered part of transfer, then this subsequent infection process is rated as likely with medium uncertainty, depending on the length of season and soil environmental suitability. Furthermore, these subsequent infections may lead to oospores being produced and persisting in soil, providing a source of inoculum for future plantings.

3.2.3. Conclusions on the probability of entry

Rating	Justification
Unlikely	If red core exists at the same frequency in the country of origin as it does in the EU, then the likelihood of association at the place of production would be the same as for the spread of the pathogen within the EU Very little trade in strawberry plants for planting is reported from third countries Detection methods if used as intended are effective in eliminating infected plants for planting Purely visual inspection is inadequate for detection

3.2.4. Uncertainties on the probability of entry

Rating	Justification
High	There is a lack of information on the quality and frequency of trade volume data There is a lack of information on the quality and frequency of inspection data and how this varies across Member States

3.3. Probability of establishment

3.3.1. Availability of suitable hosts in the risk assessment area

Strawberries are commercially grown throughout the EU, as detailed in Table 4 in Section 3.1.4. A small number of wild species are present in the EU (see Table 1), but these are unlikely to play any important part in the further establishment of the disease following new entry of the pathogen or spread within the EU. There are few alternate hosts for the pathogen, which in effect is specific to *Fragaria*.

3.3.2. Suitability of the environment

Cultivated strawberry is grown in every Member State, and the pathogen occurs or has occurred in the majority of them. Thus it is reasonable to conclude that the natural environment in the majority of Member States is conducive for the disease. However, the pathogen is largely absent from the southern Mediterranean regions. As discussed below (Section 3.3.2.1), controlled experimental studies have shown that zoospore germination, dispersal and infection is favoured by low temperatures, < 15 °C. Zoospore production occurs from infected strawberry roots in the field, and hence soil temperature is likely to be a limiting environmental factor. Soil temperatures in the rooting zone of strawberry in southern Mediterranean regions exceed 15 °C for some 50–70 % of days (Figure 4).

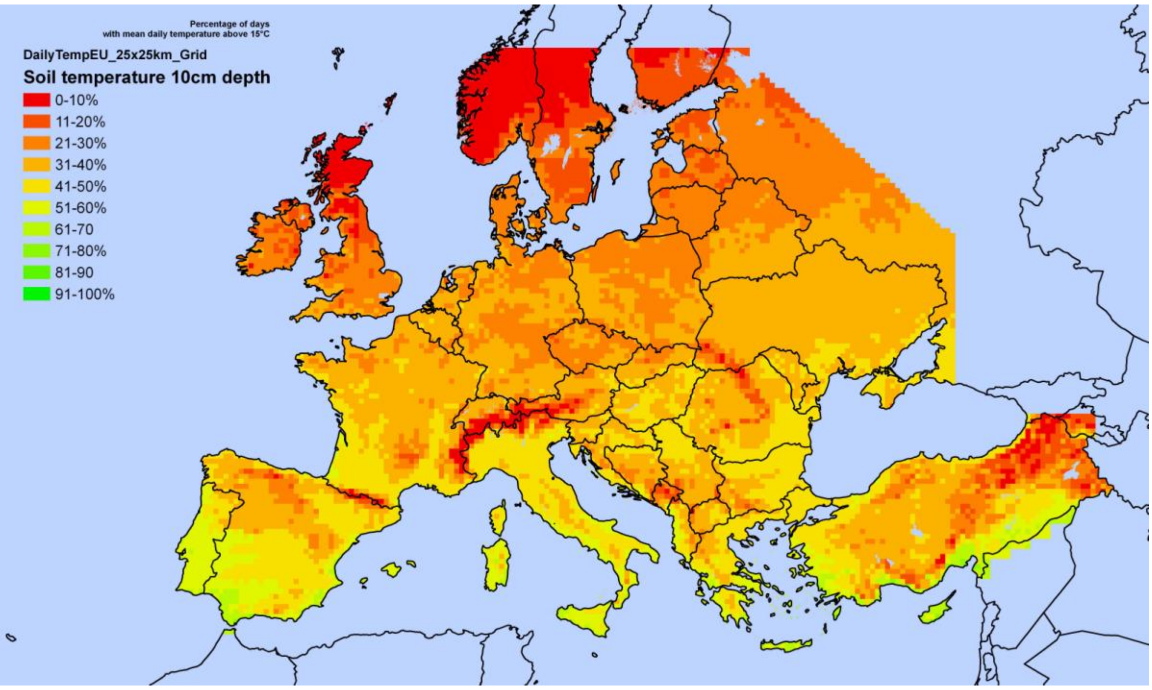

Figure 4: Percentage of days with mean temperature of the soil in the rooting zone above 15 °C. Estimated for interpolated weather data from 2008 to 2012 (JRC-MARS), soil data (JRC-ESDB) and proxy crop similar to strawberries (JRC-CGMS) by Ceglar et al. (2013).

In the UK, *P. fragariae* continues to be highly damaging when imported on planting material, and the importance of certification schemes in restricting the importation of the disease is recognised and much appreciated. By contrast, the disease is considered to be of occasional importance in France and very little in Spain (EFSA, 2013), thereby highlighting the effect of climate in decreasing the importance of the disease in the southern part of Europe, particularly in the Mediterranean region. The threshold temperature conditions which inhibit both oospore germination (> 20 °C) and zoospore activity (> 15 °C) may be important factors in soils at production sites in these regions. Further information on climatic and edaphic factors is summarised below.

3.3.2.1. Temperature

Mycelium

According to (Hickman, 1940) optimum mycelial growth *in vitro* of *P. fragariae* is at 20 °C, with fair growth at 10 °C and none at 30 °C. Ho and Jong (1988) described very slight growth at 5 °C and no growth at 30 °C.

Sporangia and zoospore

Bain and Demaree (1945) reported the most vigorous and abundant *in vitro* sporangia production at 14 °C, only slightly less at 18 °C, fairly abundant at 10 °C and 22 °C, and occasional at 25 °C. McKeen (1958b) had the maximum *in vitro* production of sporangia at 12–17 °C, while Wynn (1967) found 10 °C to be optimal for sporangia production. Optimum temperatures for the production of sporangia of the four races of the pathogen ranged from 12 °C to 20 °C. Production of sporangia by all isolates was reduced at 4 °C and 24 °C, and no sporangia were produced by any isolate at 28 °C.

In a study under controlled conditions, Duncan and Kennedy (1994) investigated the effect of temperature on the zoospore production by *P. fragariae* from the roots of infected strawberry plants. Drainage water from diseased plants was more infective and also infective over a much longer period of time at 2 °C or 8 °C than that from plants at 14 °C or 20 °C, and no infection ever occurred with water from plants held at 26 °C. Although *P. fragariae* sometimes produced similar amounts of secondary inoculum at 8 °C and 14 °C, production was generally greater at temperatures below than at those above 10 °C. The results were consistent with observations on the effect of temperature on zoospore production from agar discs and on zoospore motility: more zoospores were produced at lower temperatures, and they remained motile for longer. Soil conditions are generally favourable for infection in eastern Scotland between the months of October and March, when soil temperatures of 10 °C are rarely exceeded and when there is an excess of rainfall over evapotranspiration (Duncan and Kennedy, 1994).

3.3.2.2. Precipitation

Because free water in the soil is necessary for the dispersal of zoospores, either by self-propulsion or in moving rain water, the disease may be serious in any soil when annual precipitation is 1 000 mm or more, but it can be equally serious when annual precipitation is around 500 mm if soils are heavy, compacted, or poorly drained (Montgomerie, 1984a). The frequency of winter rainfall days in Scotland had a major impact on the incidence and damage caused by the disease (Reid, 1949). In Germany elevated areas with high precipitation and a long dormant season (as in southern Bavaria) are particularly prone to damage by red core (Seemüller, 1984).The disease was of little importance on various sites in the upper Rhine valley where there is less rain and the soils are well drained.

3.3.2.3. Soil moisture

Alcock et al. (1930) reported from Scotland that red core occurred on both light and heavy soils at one farm, on a sandy peat at a second and on a gravelly soil at a third farm. Usually diseased plants occurred in the lowest part of the field, and the disease would spread from this area. However, a centre of infection could occur at the top of a slope and spread downhill. Anderson (1935) observed in Illinois, USA, that red core usually appeared for the first time at places where the water-carrying capacity of the soil was high, but later on it could spread to well-drained loam soil. Hickman (1940) reported that in England red core was most damaging in places where soil drainage was poor, but it could also occur where the soil was apparently well drained. Bad drainage is, however, not a necessary factor, as the disease may occur over a wide range of soil conditions.

Hickman and English (1951) reported that the disease would progress as long as there was a gradient of soil moisture sufficient to ensure the production and dispersal of zoospores, whether the drainage was free or impeded. Such conditions would result from a combination of moderate rainfall with impeded drainage or from heavy rainfall on relatively freely draining soil. When combining watering frequency with free drainage, more frequent watering produced highly significant increases in the amount of infection. Frequency of watering combined with waterlogging showed the same effect, but at each level of watering there was more disease in the waterlogged series than in the freely drained series. They concluded that waterlogging provides permanent rather than periodic conditions (as with free drainage) favourable for zoospore production. With soil held at a range of field capacity (40–90 %), red core developed only at higher levels.

3.3.2.4. Soil alkalinity

Hickman (1940) suggested that red core could be checked by soil alkalinity. Determination of the pH values of soil samples from the diseased areas gave an average value of 6.1, at the junction of diseased with healthy areas 7.0, and in the healthy areas 7.9. Hickman and English (1951) studied the relationship between soil pH and red core *in vitro* and under controlled conditions in the greenhouse. Usually there was a clear decrease in disease development at high pH (above 7.0), but the results were not straightforward, since high disease levels were also found where alkalinity was high.

3.3.3. Cultural practices and control measures

Different cultural practices and control measures may be applied in order to eradicate the pathogen once it is present in a field. However, since oospores of *P. fragariae* may survive for many years in plant debris and soil (see Section 3.1.1.3 above), eradication could be very difficult depending on the extent of previous infestation and the time elapsed since its presence is reported. It is likely that eradication cannot be confirmed until there has been at least 10 years of reported absence. The different options are considered in detail below.

3.3.3.1. Certified plants

There are many reports of the first occurrence of red core in a new area being associated with the import of infected planting material (Alcock et al., 1930; Anderson, 1935; Alcock and Howells, 1936; Hickman, 1940; Reid, 1941; Gråberg, 1984; Seemüller, 1984). It is thus very important to prevent the spread of infected planting material by maintaining strict legislative restrictions on production and distribution of strawberry plants.

In the UK, legislative attempts to control red core began as early as 1947 with the Sale of Strawberry Plants and Black Currant Bushes Orders, which prohibited the sale of uncertified strawberry and blackcurrant plants (Steer, 1984; Howell and Rankin, 1984; Duncan et al., 1986). In Scotland, this order prohibits the sale of uncertified strawberry plants for planting from England, Wales and Eire (Duncan et al., 1986). The certification programme in North Carolina, USA, has been very successful according to Milholland (1994). Based upon the EPPO recommendations in 1994 (EPPO, 2008a), national official certification schemes have been developed in many European countries. In later years micropropagation schemes based on indexed plants for planting have shown to be successful for mass production of disease-free certified strawberry plants in several countries (Bourrain, 2009).

3.3.3.2. Cultural practices

Soil drainage has been mentioned above as an important factor affecting the development of red core (Alcock et al., 1930; Anderson, 1935; Hickman, 1940; Reid, 1941; Hickman and English, 1951). In problem areas, drainage should be improved and soil compaction should be avoided (Montgomerie, 1984a). Good results have been achieved by growing plants on ridges or raised beds. Montgomerie and Kennedy (1982) reduced the attack of *P. fragariae* in strawberries significantly by growing plants on 305-mm-high ridges. As separate treatments, raised beds and metalaxyl had approximately the same effect. Hickman (1940) suggested that a very long rotation with other crops may be necessary before it would be safe to grow strawberries in infested fields again. In practice, this is difficult since the resting spores of the fungus can remain viable in the soil for many years without host plants.

3.3.3.3. Chemical control

Reports of chemical control of red core can be traced almost as far back as the original description of the disease. Thus, in the description below many of the fungicides and treatments, in particular soil fumigation, are no longer approved in the EU and many other countries.

Soil fumigation is used in some countries to control soilborne diseases and weeds in strawberry plantings. However in the USA, despite the use of methyl bromide, other disease management strategies, such as the use of pathogen-free propagation and planting stock, chemical control and resistant cultivars, were also often required to control red core (Milholland, 1994). In Scotland, pre-planting treatments with dazomet were ineffective (Montgomerie and Kennedy, 1982). Infective propagules can be present in the soil at a depth of more than 60 cm (Hickman, 1940), which would be almost out of reach of any disinfectant treatment. A total eradication of *P. fragariae* from soil is thus impossible.

Phenylamides (e.g. metalaxyl) and fosetyl aluminium, are the fungicides most commonly used against *P. fragariae*. When testing various fungicides in Scotland, Montgomerie (1984b) stated that the most effective material was metalaxyl, followed by fosetyl aluminium. The strategies for chemical control developed in Scotland were based on fungicide application just prior to the majority of new roots being produced in the autumn. In infested fields, one spray applied each year achieved yield and berry size comparable to those from uninfested fields. Failure by some growers to achieve heavy yields was due in some instances to lack of disease control or by incorrect timing of sprays or inhibition of root and plant growth by factors other than red core. McIntyre and Walton (1981) significantly reduced red core with spring and autumn applications of metalaxyl. The second year after planting, metalaxyl-treated plants had a mean of 137 % more flowers and at harvest 161 % more total fruit by weight at harvest than untreated plants. They suggested that metalaxyl used as a transplant drench, in addition to spray applications each spring after bud break and each autumn before dormancy, should enable susceptible strawberry cultivars to be grown in fields infested with *P. fragariae*. Seemüller (1984) reported that a foliar spray with metalaxyl or fosetyl aluminium in the autumn before dormancy was a good control method. Under conditions particularly favouring the disease, an additional application in spring after bud break may be beneficial. In Switzerland, one or two applications of fosetyl aluminium in the autumn were recommended (Lauber et al., 1984). Only fosetyl aluminium, among a range of other tested fungicides, had a visible effect on inactive oospores, and the increased mortality of oospores in roots exposed to it in water was probably a consequence of fosetyl aluminium lowering the pH of the solution (Duncan, 1985b). In media buffered at pH 4.5–6.5 fosetyl aluminium had no effect on oospores in roots or on their subsequent germination or infectivity to strawberry plants. Spores extracted from metalaxyl-treated roots showed reduced germination *in vitro* and reduced infectivity to strawberry plants. The results indicated that none of the fungicides could be expected to kill oospores in soils, although they might prevent or reduce infection by preventing germ tube formation or by antisporulant activity. It was further stated that it is not advisable to treat strawberry nursery stocks with fungicides, because oospores within roots may survive the treatment. Fungicide residues on the root surfaces could suppress spore germination and infection and so give false-negative results when the stocks are tested for red core in root-tip bait tests. Fungicide treatments of strawberry nursery stocks could also enhance the danger of spreading fungicide-resistant strains. Metalaxyl-resistant strains have been found in strawberries in Germany (Seemüller and Sun, 1989).

Information from the industry suggest that metalaxyl-based products continue to be the main chemical control.

3.3.3.4. Resistance in the host

Hickman (1940) observed that different cultivars vary in their susceptibility to red core. Reid (1949) reported a considerable variation in varietal resistance to the disease, ranging from extreme susceptibility to almost complete immunity. He also found that certain varieties may be classed as fairly resistant if grown in the drier parts of the country, while the same varieties could rapidly die if grown in other areas. Seemüller (1984) mentioned that “Senga Sengana” is among the most susceptible varieties grown in Germany. Milholland (1994) discussed the inheritance of resistance to red core. It is controlled by the same genetic principles that determine transfer of other physiological or morphological characteristics. Resistance may be controlled by a single gene pair or it may be quantitatively controlled by two or more genes. Van de Weg (1988, 1997) suggested that resistance of strawberry and virulence of *P. fragariae* behaves according to a gene-for-gene system with at least five race-specific resistance and virulence genes. Currently up to 10 such genes for resistance to *P. fragariae*, R_{pf} genes, are recognised (E. Van de Weg, Wageningen University and Research Centre, The Netherlands, personal communication, July 2013).

There are several reports on breeding strawberries for resistance to *P. fragariae* (Reid 1941, 1949; McKeen, 1958b; Scott et al., 1975, 1976; Maas et al., 1988). In Europe, Canada and the USA there are a number of red core-resistant varieties grown (Milholland, 1994). However, in Europe the resistant varieties have not yet been widely accepted in the market. The variety "Elsanta", commonly grown in Europe, is highly susceptible to red core (Elema et al., 1985). With increasing concern over the use of pesticides and the elimination of methyl bromide, resistant cultivars will continue to be an important disease management strategy to prevent establishment of the pathogen in new plantings.

3.3.4. Other characteristics of the pest affecting the probability of establishment

Since the first report of the pathogen in the UK in 1920 there have been numerous reports throughout the EU but the patterns of introduction have not been well documented. The cardinal temperatures for the pathogen are commensurate with its wide distribution and ready establishment throughout much of the EU and provide some explanation regarding why the pathogen is rarely reported from the Mediterranean regions of the EU. There is limited variability in the species, perhaps owing to its homothallic nature and its soilborne existence. However, despite the limited variation, new physiological races have arisen regularly to frustrate the efforts of breeders seeking disease-resistant cultivars.

3.3.5. Conclusions on the probability of establishment

The probability of establishment following a new entry of the pathogen is no greater (or less) than the probability of establishment following spread within the EU. Given the climatic conditions throughout much of the strawberry-producing areas, the probability of establishment is rated as **likely** in the absence of existing disease control practices with **low uncertainty**.

Rating	Description
Likely	Cultivated strawberry is grown in every Member State and the pathogen occurs or has occurred in the majority of the Member States Host plant(s) are widespread and climatic conditions are suitable in most of the risk assessment area, except in the southern Mediterranean regions where soil temperatures limit establishment The probability of establishment following a new entry of the pathogen is no greater (or less) than the probability of establishment following spread within the EU Different cultural practices and control measures may be applied in order to eradicate the pathogen once it is present in a field; however, since oospores may survive for many years in plant debris and soil, eradication could be very difficult

3.3.6. Uncertainties on the probability of establishment

Rating	Description
Low	Comprehensive data and other information available on the suitability of climate and susceptible hosts in the risk assessment area

3.4. Probability of spread

Since the risk assessment area is the EU and the pest is already established in several countries of the EU (Section 3.1.2), this section assesses the probability of further spread from invaded parts of the EU to areas where the pest is not present. Spread by definition also means establishment in a new area where the pest is not present. As already noted in the establishment section, host plants are widespread and climatic conditions are suitable in the risk assessment area. We consider the pathways for spread within the EU territory as being the same as those for entry into the EU. We first make the distinction between spread by natural means (Section 3.4.1) and that occurring through human assistance (Section 3.4.2). We then consider the pathways important for local spread of the pathogen (Section 3.4.3)

3.4.1. Spread by natural means

3.4.1.1. Long-distance spread

Long-distance spread by wind or vectors such as birds or insects is not known (EPPO, 1998). In some countries (Netherlands, Belgium, Luxembourg, Germany, etc.), there are widely connected river–irrigation ditch systems through which inoculum could spread to regions and countries within the risk assessment area where the disease may be locally absent.

3.4.1.2. Short-distance spread

Short-distance spread does occur with soil within and between farms on farm machinery, implements and footwear, and potentially through wind dispersal of soil particles. Infested soil particles on dirty tools or equipment can also spread the disease from field to field (Goode, 1956; Milholland, 1994).

P. fragariae survives in the soil in the form of oospores for up to at least 10 years (Newton et al., 2010). New infections from germinating oospores in soil are mainly affected by soil water. High soil temperatures (> 20 °C) will inhibit this process. Soil water is therefore a key issue (irrigation, soils that receive lots of steady water from rain, soils with poor water drainage) especially if the soil becomes waterlogged (Duncan and Kennedy, 1989). If soil temperature is also suitable (between 10 °C and 15 °C), then infection takes place quickly and will rapidly spread across a strawberry plantation (Milholland, 1994).

Sporangia of *P. fragariae* germinate in the presence of water to release zoospores, and these zoospores swim in the water to reach the host roots. Without water the zoospores have no way of reaching a host root. Therefore, water is essential in short-range spread (Goode, 1956). The result of infection is a proliferation of new sporangia and further release of zoospores. Zoospores, being negatively geotactic, move upwards in soil and accumulate in surface water run-off (Cameron and Carlile, 1977). Spread of *P. fragariae* down slopes is often observed in strawberry fields (Hickman 1940; Milholland, 1994).

3.4.2. Spread by human assistance

Long-distance spread is clearly related to transport of strawberry planting materials (Pathway 1) (Bain and Demaree, 1945; Duncan and Kennedy, 1994; Milholland, 1994). The role of other non-*Fragaria* hosts (Pathway 2) is likely to be very minor (McKeen, 1958a; Converse and Moore, 1966; Pepin, 1967).

Movement of plant material is believed to be the source of overall spread of the disease within countries and throughout much of Europe (Anonymous, 2012). There is a high probability that much of the spread of red core happened through trade and movement of non-certified strawberry plants. Trade in strawberry plants has effectively spread *P. fragariae* rapidly within countries and worldwide (EPPO, 1998).

3.4.3. Pathways involved in local spread

3.4.3.1. Pathways involving soil

Pathways 3, 4, 5 and 6 each concern soil and are considered of minor importance for long-distance spread but important for local spread

The oospores of the pathogen may survive in soil without host plants for more than 10 years under natural soil conditions, whereas hyphae and other structures persist for only a few months (Alcock and Howells, 1936; Montgomerie, 1951; Fulton, 1959; Duncan, 1980; Duncan and Cowan, 1980; Newton et al., 2010).

The probability of survival of oospores in plants, soil particles, soil or other organic growth media during transport and storage is considered very high. There are no studies on possible multiplication of *P. fragariae* in soil and other plant growth media in the absence of its host, but it is considered very unlikely. There are no reports of multiplication other than on a host plant either alive or in decay. Although oospores can be detected only in the laboratory in roots by microscopy or by baiting technique in soil and water (Duncan 1984), there are no reports of the viability of oospores in soil associated with non-host plantings. Non-host plants, soil and other organic growth media, root vegetables, potatoes, machinery, farm implements and footwear could infest soil with oospores which could subsequently infect a newly planted strawberry crop.

3.4.3.2. Pathways involving water

Spread can occur through movement of surface water across and between fields and in ditches, streams, rivers and irrigation systems (Alcock et al., 1930; Anderson, 1935; Hickman, 1940; Bain and Demaree, 1945; Hickman and English, 1951; Goode, 1956; Duniway, 1983; Milholland, 1994; Duncan, and Kennedy, 1989; Covey and Harris 1990, Yamak et al., 2002; Newton et al., 2010; Anonymous, 2012).

Extensive use of irrigation—even in warmer and drier Mediterranean regions—could potentially contribute to short-distance disease spread and cause a serious outbreak of disease (Anonymous, 2012), as has happened in Sweden (Gråberg, 1984).

3.4.4. Containment of the pest within the risk assessment area

The disease is present in the majority of Member States, but even in individual countries the incidence is variable, with some areas free of disease. In this context the possibility of containment within well-defined boundaries is not feasible. At the individual farm level it may be possible to eradicate the pathogen by moving to novel production systems based on soilless culture. The movement to soilless culture in Trento in northern Italy has accelerated because of the impact of *Phytophthora* (but possibly *P. cactorum* rather than *P. fragariae*) but at a cost estimated to be EUR 1/kg of harvested fruit (EFSA, 2014

Certification schemes, where implemented, would play an important role in containing *P. fragariae* within those areas that it is presently established.

3.4.5. Conclusions on the probability of spread

Rating	Justification
Very likely (in the absence of certification)	One principal mechanism of spread over all scales of distance Environmental conditions are conducive over much of the risk assessment area Host are present throughout the risk assessment area Extensive intra-EU trade in strawberry plants for planting
Unlikely to moderately likely (with certification)	Certification, where supported by appropriate methods, is effective in containment and prevention of further spread

3.4.6. Uncertainties on the probability of spread

Rating	Justification
Medium	Lack of validated information on trade within the EU Lack of information on methods used in certification

3.5. Conclusion regarding endangered areas

The pathogen is already recorded from much of the area of potential establishment in the EU. This area is equivalent to the endangered area since crop damage can occur wherever it is present.

3.6. Assessment of consequences

3.6.1. Pest effects

Pest effects can be partitioned into yield losses and control costs. Disease control costs in strawberry are not available. Even so, fungicide treatments are only partially effective and might not fully mitigate the disease in the absence of phytosanitary measures (Section 3.3.3).

Crop yields have been reduced by as much as two-thirds in untreated plantations (McIntyre and Walton, 1981). Even greater damage can occur: Reid (1949) reported that "Whole plantations can be completely destroyed by this disease in a very short time." As has been noted many times elsewhere in this opinion, conditions are favourable throughout much of the assessment area, but especially in northern Europe, for this pathogen to build up to levels that can cause significant damage in a relatively short time—a year or two. More recent information has been summarised in Section 3.1.5.

Importantly, the existence of regulation and voluntary certification schemes for strawberry ensures healthy planting materials for fruit producers. In addition, significantly shorter cycles in modern strawberry cultivation practice (one to two seasons) (EFSA, 2014) contributes to a reduction in the impact of the disease.

Resistant cultivars (Section 3.3.3) are not generally grown and will not be so, unless they have grower and consumer appeal.

3.6.1.1. Biological control

At the present time commercial biocontrol products specific for *P. fragariae* are not available, although products for a wide range of soilborne pathogens, including unspecified phytophthoras have been promoted previously. A crop biofumigant comprising 100 % oriental mustard seed, *Brassica juncea*, meal is available. Application rates vary from 0.98 to 2.24 metric tonnes in early spring (MPT Mustard Products and Technologies, 2012). There has been extensive research on potential biocontrol agents, but as yet none has been taken up in commercial practice (Hessenmuller and Zeller, 1996; Gulati et al., 1999; Norman and Hooker, 2000; Pinkerton et al., 2002; Millner et al., 2004; Gupta et al., 2005).

3.6.1.2. Other integrated pest management tools

IPM programmes for strawberry production, which include *P. fragariae*, have not been developed in Europe, but the essential elements have been correctly identified in North America; for example in California (UC IPM Pest Management Guidelines, 2013), Minnesota (McCamant, 2007), Ontario (Ontario Crop IPM, 2013), Connecticut (University of Connecticut IPM, 2013) and South Carolina (Louws, 2012).

These elements typically include:

- Choose well-drained sites and do not replant in sites known to have had the disease in the past.
- In high-risk areas, choose resistant varieties where available. There are several races of *P. fragariae*; not all varieties are resistant to all strains of the fungus.
- Obtain plants from a recognised plant certification programme.
- Eliminate spread of contaminated soil to new plantings.

- Planting strawberries on beds raised at least 25 cm high will raise the root system above the water table and prevent high levels of infection with red core.
- Fungicides, where approved, can be applied to prevent spread of the disease.
- Utilise soil solarisation where the climate is suitable.

3.6.2. Environmental consequences

3.6.2.1. Consequences of occurrence of the pest in natural habitats or amenity land

P. fragariae is present and causes disease of the main host *Fragaria* × *ananassa* in many countries in the risk assessment area (see Section 3.2.2). Disease outbreaks are, as far as is known reported only from commercial production of strawberry. However, to some extent strawberries are also grown in private gardens, and they may also become infected. It is thus likely that the pathogen may occur in amenity land but to a very limited extent. Minor hosts of the pathogen are other *Fragaria* species, including *F. vesca*, which grows in the wild. *R. loganobaccus* has been recorded on one occasion as a host plant in Canada (McKeen, 1958a). Several other species in the Rosaceae family have been infected experimentally, including species in the *Dryas*, *Geum*, *Potentilla* and *Rubus* genera (McKeen, 1958a; Pepin, 1967; Duncan and Kennedy, 1994). However, there is no report from the risk assessment area that the pest has caused disease of any of the minor hosts. It is unlikely that the pathogen can cause damage to these plants growing in amenity land.

3.6.2.2. Consequences to the environment arising from the extensive use of fungicides

As described in Section 3.3.3, several fungicides can be used to control *P. fragariae*, but their efficacy varies. When used to a limited extent the consequences to the environment, if any, would be minor. Major disease outbreaks however, may need extensive use of fungicides or soil disinfectants to be controlled, which could have a negative effect on the environment.

3.6.3. Conclusion on the assessment of consequences

Rating	Justification
Minor	By comparison with other strawberry pests and pathogens the pest effects and the environmental effects are likely to have small impact Under current regulation and pest management practices the level of the disease remains manageable The existence of efficient voluntary certification systems for strawberry No recorded case of *P. fragariae* in natural ecosystems The limited environmental consequences

3.6.4. Uncertainties on the assessment of consequences

Rating	Justification
Medium	An absence of information on fungicide use and associated costs There is a paucity of information on disease/crop loss relationships

3.7. Conclusion of the pest risk assessment

The widespread cultivation of strawberry means that the endangered area includes the whole of the EU. *P. fragariae* is present in most areas except for the southern Mediterranean regions, and, while it has been eradicated from some Member States, there is a continued threat of spread, both naturally and by human assistance, with the consequent impact on strawberry production as detailed in the risk assessment sections above.

4. Identification and evaluation of risk reduction options

This section evaluates the current phytosanitary measures and the effectiveness of the present EU requirements against this pest, which are laid down in Council Directive 2000/29/EC.

The structure of this section is as follows: the current regulations to prevent the introduction and spread of *P*. *fragariae* are presented and evaluated in Section 4.1. The consequences of deregulation are discussed in Section 4.2. The phytosanitary measures to prevent the entry of the pest from third countries into the EU are addressed in Section 4.3. Measures to prevent establishment are outlined in Section 4.4. Measures to prevent spread within the EU and those to reduce the impact of the pathogen are outlined in Section 4.5. The conclusions are given in Section 4.6.

4.1. Evaluation of current phytosanitary measures to prevent the introduction and spread of *P*. *fragariae*

Phytosanitary measures to prevent the introduction and spread of *P*. *fragariae* are listed in Annexes II and IV of EU Council Directive 2000/29/EC while requirements for *Fragaria* plants for planting, other than seeds, are formulated in Annexes III and V (Section 3.1.3). In Annex IIAII the pest is listed as known to occur in the Community and relevant for the entire Community, and its introduction into, and spread within, all Member States shall be banned if present in plants of *Fragaria* L. intended for planting, other than seeds. According to Annex III Part A (18) the import of *Fragaria* plants for planting, other than seeds, is prohibited except from those countries mentioned (Section 3.1.3). In addition, Annex III part A (14) bans the import of soil and growing medium as such, which consists in whole or in part of soil or solid organic substances such as parts of plants, humus including peat or bark, other than that composed entirely of peat originating from Turkey, Belarus, Moldavia, Russia, Ukraine and third countries not belonging to continental Europe, other than Egypt, Israel, Libya, Morocco and Tunisia. For origins of strawberry plants for planting excluding seeds, not specified by Annex III Part A (18), Annexes IVAI and IVAII describe special requirements which must be followed by all Member States for the introduction and movement of plants, plant products and other objects into and within all Member States. An official statement is required, to the effect that *Fragaria* L. plants for planting, other than seeds, originate in areas known to be free from *P*. *fragariae*, or no symptoms of disease caused by *P*. *fragariae* have been observed on the plants at the place of production since the beginning of the last complete cycle of vegetation. According to Annex V, Part B, Section I, *Fragaria* plants intended for planting, other than seeds, imported into the EU must be accompanied by a phytosanitary certificate and be subject to documentary, identity and plant health checks on import. These checks may be carried out at an approved place of inspection elsewhere in the EU, subject to agreement between the relevant competent authorities. For subsequent movement within the EU the phytosanitary certificate must be replaced by a plant passport. The plant passport should be issued at the point of entry, or authorised place of inspection, following completion of the plant health checks, although the plant passports are usually issued by the importing nursery. Such a passport would include information on the absence of *P*. *fragariae* outlined in the present opinion, given its listing in Annex IIAII. Strawberry plants for planting other than seeds, originating in the EU, are listed in Annex V, Part A, Section I (2). This means that a plant passport is required for movement within the EU if they are produced by producers whose production and sale is authorised to persons professionally engaged in plant production, that is producers of strawberry plants and fruits. Strawberry plants for planting, prepared and ready for sale to the final consumer (hobby gardeners), do not require a plant passport for movement within the EU, provided that it is ensured by the responsible official bodies of the Member States that their production is clearly separate from that of other products.

The derogations from the import prohibition (Annex III, Part A (18)) for Argentina and Chile, provided by Commission Decision 2003/248/EC (amended by Commission Decision 2011/74/EC) and Commission Decision 2003/249/EC (amended by Commission Decision 2011/75/EC), are subject to strict requirements as specified in Annex I of Commission Decisions 2003/248/EC and 2003/249/EC. These derogations are not specifically formulated for *P*. *fragariae* but are aimed at prevention of all harmful organisms, in particular those listed in Annexes of Commission Decision 2000/29/EC. Not all requirements of the derogations may therefore be relevant for *P*. *fragariae*.

P. *fragariae* is not reported to be present in Argentina and Chile (Section 3.1.2.1), therefore the measures required according to the derogations will not influence the probability of entry of *P*. *fragariae* with *Fragaria* plants for planting from Argentina and Chile.

The Panel's opinion on the effectiveness of the present EU requirements in reducing the risk of introduction of this pest into, and their spread within, the EU territory is based on the analysis of Annexes IIAII, III, IV and V.

The main considerations in this analysis are:

Imports of *Fragaria* L. plants for planting, other than seeds, are prohibited for third (non-EU countries mentioned in Annex III, Part A (18), and are subject to special requirements (Annex IV, Part A, Section I (19.2) for other third countries where the disease may occur (e.g. USA, Canada, Australia and New Zealand).

The special requirements for the derogation of the import prohibition of *Fragaria* for Chile and Argentina are far more stringent than the special requirements of Annex IV, Part A, Section I (19.2), for other third countries, even though *P*. *fragariae* is not reported to be present in Chile and Argentina.

Currently the risks of *P*. *fragariae* are reduced by certification schemes adopted by a well-developed nursery industry, thereby improving the phytosanitary status of *Fragaria* plant material for planting (see Section 3.1.4).

The special requirements for introduction into and movement within the EU of *Fragaria* plants for planting, other than seed, (Annex IV, Part A, Section I (19.2), and Annex IV, Part A, Section II (12), respectively) rely on visual inspections which are not further specified. However, symptoms of red core may be difficult to detect, or not be detected at all, i.e. the infection could be latent. In addition, the testing of plants for the presence of *P*. *fragariae* with recommended, sensitive laboratory methods is only voluntary.

Based on this, the Panel concludes that the special requirements for introduction of *Fragaria* plants for planting, specified by 2000/29/EC, Annex IV, Part A, Section I (19.2), and for movement of *Fragaria* plants within the EU specified by 2000/29/EC, Annex IV, Part A, Section II (12), are not fully effective in preventing the *introduction* into and spread within the EU of *P*. *fragariae*.

4.2. Consequences of removing the pest from Annex IIAII

In the analysis of the consequences of a potential removal of *P*. *fragariae* from Annex II, Part A, Section II, the Panel considered that:

- *P*. *fragariae* is widespread within the EU territory.
- Imports of *Fragaria* plants for planting, other than seeds from non-Member States, into the EU would still be prohibited for countries specified by Annex III, Part A (18).
- Currently, a relevant contribution to reducing the probability of introduction and spread of *P*. *fragariae* is made by certification schemes adopted by the industry to improve the phytosanitary status of *Fragaria* plant material for planting.
- Further protection against the impact of the *P*. *fragariae* is provided by modern crop production practices that are increasingly used (short production cycles, soilless cultivation etc.—see Section 3.6).

In reaching its conclusions, the Panel considered that revoking the IIAII regulation would have consequences for other elements of Council Directive 2000/29/EC, particularly on the specific requirements laid down in Annexes IV and V, and that the mandatory requirements for official statements on pest freedom of production areas, plant inspection activities and freedom from symptoms in traded plants would therefore be correspondingly relaxed.

Fragaria plants for planting, other than seed, are covered by several regulations specified in Annexes of the Directive. Those listings concern other pathogens, viruses and virus-like organisms listed in Annex IAI (non-European viruses and virus-like organisms) and IIAII. Revoking the regulation for *P. fragariae* would not affect the regulations for these other pathogens, which would mean that phytosanitary certificates, plant passports and associated official inspections would still be required for *Fragaria* plants for planting, other than seed.

Plants for planting of the genus *Fragaria* are produced under comprehensive certification schemes voluntarily applied by the industry (e.g. Naktuinbow Elit System, 2013; FERA PHPS, 2013). One of the standards, specified in an EPPO certification scheme for pathogen-tested strawberry (EPPO, 2008a), requires all levels of propagation to be completely free of the presence of *P. fragariae* (a zero tolerance) after random testing for symptomless infection with *P. fragariae*.

It is likely that the industry would continue to adhere to this voluntary standard, not just to comply with Directive 2000/29/EC but to ensure product quality. Given the considerable potential impact of *P. fragariae*, it can be assumed that, even if the current IIAII regulation was lifted, the industry would continue to include it in the present voluntary certification schemes, thereby reducing the probability of introduction and spread.

If the current regulation were to be removed, no major consequences or changes in the potential impact considered here would be expected. This is due largely to the important level of protection afforded to the industry by the widely used certification scheme for *Fragaria* which significantly reduce the risks of entry, establishment, spread and impact, and the currently available pest management practices.

If the current regulation was to be discarded along with simultaneous removal of the widely used certification schemes for *Fragaria*, or if *P. fragariae* was excluded from the list addressed by the voluntary schemes, there would be major adverse consequences for the potential impact of *P. fragariae*.

4.3. Options to reduce the probability of entry

In this section, the options for consignments coming from outside of Europe are addressed. The options to prevent or reduce infestation in the crop are discussed in detail in Section 4.5 (options to reduce the probability of spread and the magnitude of impact) and are not repeated here, although they can be applied also in the country of origin. The 11 interlocking risk reduction options (RROs), identified in Section 4.5 are all pertinent to the production of strawberry crops and strawberry planting material free of *P. fragariae*. Indeed they could all be described as "best practices" for strawberry growing. However, from the point of view of imports into the EU, the two most important to the EU are undoubtedly: (i) inspections and surveillance; and (ii) certification, especially if supported by effective detection tests (root tip and bioassay and/or DNA tests). Effective maintenance of these two RROs will prevent the entry of *P. fragariae* into the EU, even if the exporting country pays little regard to the other nine RROs. The remaining nine RROs are considered in Section 4.5 on spread within the EU.

4.3.1. Prohibition

Prohibition of importation of host plants *from* third countries into the risk assessment area is a possible measure to reduce the risk of entry of the pathogen. Such a measure is already in place for strawberry plants for planting, except for those countries specifically listed in the regulation and the derogation countries (see Section 3.1.3). Checks on consignments from those countries must take place: (i) at the place of production; (ii) prior to shipment; and (iii) inspection at the point of entry.

There is an apparent low rate of detection (see Section 3.1.2) in imported consignments (only three cases in 20 years, each from non-EU European countries), although the number of consignments over this period is unknown. However the visual methods employed may limit detection of infection. If bait test or DNA tests are used, there is a limited probability of entry with such a prohibition regulation.

Effectiveness: The effectiveness of prohibiting the import of host plants is high.

Technical feasibility: The technical feasibility of prohibiting the entry of all strawberry plants is low, given the third countries specifically mentioned in the legislation and subsequent derogations.

Uncertainty: There is low uncertainty in these ratings: there is a single host (strawberry plant) and there is no evidence that entry is possible on other plant species.

4.3.2. Pest freedom, inspection or testing

Currently, the production scheme for strawberry plants for planting includes visual inspection for disease symptoms as well as screening mother plants for disease presence. International Standards for Phytosanitary Measures (ISPM) 31 (IPPC, 2009) provides guidance on appropriate sampling methodologies for inspection or testing of consignments. However, the effectiveness of inspection for *P. fragariae* depends on the ease of visual detection and/or manifestation of symptoms. Sometimes infections remain cryptic, or only mild symptoms on roots are present. Therefore, the Panel considers the effectiveness of visual inspection to be low but its feasibility to be high. Uncertainties associated with these ratings are low.

Plants with visible symptoms and cryptically infected can also be tested for the presence of *P. fragariae* using available techniques such as bioassay and PCR testing. The latter method is highly sensitive and can detect the pathogen at low concentrations (less than 1 % of roots infected) even in asymptomatic hosts. Tests could be performed on roots of all plants in the case of a limited number of plants. However, in the case of large numbers of plants, various forms of structured sampling can be used. The effectiveness of testing is high in the case of root testing of all imported plants. However, with high volumes of material, only a limited amount can be tested, which decreases the effectiveness to moderate. The feasibility of testing a limited number of samples is considered high, but it decreases to moderate/low for large volumes of imported planting material unless a rigorous and validated sampling scheme is used. The uncertainty associated with these ratings is low.

Large numbers of tests can be handled readily with the root tip bait test, as has been demonstrated by Naktuinbouw in the Netherlands. DNA tests are as sensitive as the root tip bait test, but more processing and handling of the samples is required, perhaps, as a result, restricting the throughput of samples for testing. However, DNA testing for *P. fragariae* is in regular use in some laboratories. A particular advantage of the DNA test is that a single sample of DNA can be tested for the presence of other important pathogens, e.g. samples being tested for *P. fragariae* can be tested simultaneously for the presence of *P. cactorum*, causal agent of crown rot of strawberry (Jogendijk et al., 1996).

Effectiveness: high for bait and DNA test; low to moderate for visual symptoms alone.

Technical feasibility: moderate to high depending upon test used.

Uncertainty: low.

4.3.3. Pre-entry or post-entry quarantine systems

Pre- and post-entry quarantine can be very effective for verifying the presence of harmful organisms. EU Member States may impose a post-entry quarantine in the case of a substantiated suspicion that particular consignments may harbour harmful organisms. Quarantine controls can be applied to demonstrate freedom from disease over a period of time allowing plants to grow under strict isolation from other plant material, followed by subsequent inspections and/or tests to ensure the absence of the suspected disease. In case of asymptomatic infection by *P. fragariae* the quarantine period would also allow more time for symptoms to develop.

However, feasibility is low for the large number of plants involved in the late cycles of multiplication, close to commercialisation, since these measures can only be applied to a very limited number of plants. Uncertainty on these ratings is low.

Effectiveness: low if applied only on visual inspection but high if plants were tested for the presence of the pathogen.

Technical feasibility: moderate for a large number of plants involved but high for small number of high-grade runner stocks (Elite and above).

Uncertainty: low.

4.3.4. Phytosanitary certificates and other compliance measures

To confirm that consignments imported into the EU originate from a country, area or place of production that is free from *P. fragariae*, phytosanitary certificates and other documentary guarantees concerning the consignments to be imported can be required from the exporting countries. To fulfil such requirements, exporting countries have to implement inspection at the place of production and inspection of parent plant material prior to propagation.

Nevertheless, ensuring the freedom of the consignments from the pest requires reliable inspection. Where established infestation occurs in the production field, companies importing strawberries can require guarantees, such as those provided by certification schemes, of freedom from *P. fragariae* in their consignments.

All voluntary certification systems require inspection, monitoring, sampling and/or testing (Jogendijk et al., 1996; FERA PHPS, 2013). Such systems have been widely implemented and have been shown to be technically feasible.

In temperate climates, inspection is best done in the cool (but not freezing) autumn and spring months when the soil is more likely to be wet and when symptoms are more easily detected. Sampling and testing are also best done at the same time as the pathogen is likely to be growing actively in the roots of the host. Another consideration in the timing of sampling and testing is that the results of tests should be available as early as possible to growers to allow orderly marketing of their plants. However, uncertainty is rated medium. There is possible variation in the implementation of inspections required for "official statements" in different exporting countries. In the case of voluntary certification systems, there is variation owing to the different standards of the various schemes.

Effectiveness: high, if phytosanitary certificates are based on inspection, monitoring, sampling and testing, otherwise, low.

Technical feasibility: very high, since the measure is already in place.

Uncertainty: the variation in the extent and level of inspection conducted by the exporting country is rated as medium.

4.3.5. Preparation of the consignment and specified treatment of the consignment reducing pest prevalence in the consignment

There are no effective treatments for consignments. (See Section 3.2.2.)

Effectiveness: low.

Technical feasibility: low.

Uncertainty: low.

4.4. Options to reduce the probability of establishment

4.4.1. Eradication

The eradication of *P. fragariae* from production in soil in open or protected fields by the complete destruction of the infected plant material and its removal from the field would be extremely difficult. It would be more feasible in soilless media in protected cultivation.

Effectiveness: very low for production in soil; moderate for soilless production.

Technical feasibility: very low production in soil but moderate for soilless production, especially "table" systems.

Uncertainty: low.

4.5. Options to reduce the probability of spread and the magnitude of impact

The measures to prevent spread within the EU and those to reduce the impact of the pathogens are outlined in Section 3.4.

An important recommendation for preventing the spread of red core on plants for planting would be the incorporation of DNA testing of root tips for the presence of *P. fragariae* into the strawberry certification schemes of Member States. Testing could be applied to all grades of stocks but could be restricted to grades "Elite" and higher, at least initially. Contamination of the highest grade stocks constitutes a greater threat than contamination of lower grades, because they are the source from which all other grades originate. Other strategies for control of red core would be enhanced by a testing regime of the type outlined above: the deployment of fungicides to control the disease; and red core resistant cultivars.

4.5.1. Inspections and surveillance

Data on the spread and epidemiology of *P. fragariae* play a fundamental role in the development of appropriate prevention and control measures. Although *P. fragariae* is already established in many Member States (see Section 3.1.1.5 and Figure 4), information on the proportion of the area or number of fields infested within a Member State is not available. However, the number of interceptions by the root tip bait test is available from the Netherlands: about 20 stocks are rejected each year by the test in the Dutch certification scheme (EFSA, 2014), although the overall number of stocks submitted for certification and testing in the large Dutch strawberry propagation industry is not known.

The Panel concludes that inspection and surveillance are essential measures in reducing the phytosanitary risk of further spread of the pest in the risk assessment area when combined with other risk reduction options. ISPM 6 (IPPC, 1997) provides guidelines for general and specific surveys. Because inspection/testing is always necessary to confirm pest freedom, it is an integral part of several other options such as establishment of pest-free areas (ISPM 4—IPPC, 1995) and places of production (ISPM 10—IPPC, 1999), pre-export checking of consignments (ISPM 31—IPPC, 2008) and pre-entry or post-entry quarantine.

A good inspection and surveillance programme targeted on *P. fragariae* and including root tip testing (bait or DNA) will detect early spread and assist in the development strategies to prevent further spread (ISPM 6—IPPC, 1997; EPPO, 2008b).

Effectiveness: low to moderate for visual inspections of plants alone (symptomless infection is common) and high for bait and DNA testing.

Technical feasibility: high for visual inspection and moderate to high for bait and DNA testing, provided appropriate technical expertise is available.

Uncertainty: low.

4.5.2. Certification scheme

Voluntary certification of *P. fragariae*-free mother plants is an essential part of the nursery supply chain within the EU. Various certification schemes exist (Commission Communication 2010/C 341/04[10]); for example the Dutch industry follows the Naktuinbouw certification system (EFSA, 2014). The certification standard for EPPO for pathogen-tested material of strawberry (EPPO, 2008a) provides detailed guidance on the production of vegetatively propagated plants and includes testing for *P. fragariae* (see Section 4.2).

The Panel concluded that certification schemes as a RRO are highly effective and feasible with low uncertainty.

Effectiveness: high.

Technical feasibility: very high.

Uncertainty: low.

4.5.3. Growing plants under exclusion conditions

Growing strawberry under exclusion conditions may be effective in the management of *P. fragariae* in protected growing environments.

In general, exclusion conditions for growing rank from lower to higher pest risk, and include: (i) growth chamber; (ii) greenhouse; (iii) screen house; and more problematically (iv) field grown in containers. Enclosures provide better opportunities for pest exclusion than does outdoor cultivation (ISPM 36—IPPC, 2012). Strawberry plants for planting are rated as high pest risk commodity as they are plants for planting and propagation (ISPM 32—IPPC, 2009); thus their potential to introduce or spread regulated diseases is high.

Plants intended for production under exclusion conditions should originate from a pest-free production area or pest-free production site and should be grown in soilless medium. In general, use of soil as a growing medium is likely to pose a much greater threat from *P. fragariae*. Sterilisation, pasteurisation or other effective methods for treating the growing medium prior to planting may manage some pest risk (ISPM 36—IPPC, 2012).

However, the main emphasis in protected systems must be on ensuring good separation of high health grade stocks from stocks of lower grade with a "one-way" flow of plants and other material through the system without the opportunity for "short circuits". The best way to achieve this is by good management and training and constant monitoring.

In field production of disease-free plants, prevention of water movement from nearby fields, which might transport zoospores that could infect a disease-free crop, is paramount. Glasshouse production prevents such movement, although careful watering and splash prevention is still important.

Growing plants, originating from appropriately tested pathogen-free stocks, under enclosed exclusion conditions, especially in soilless media, would be highly effective but incur increased production costs.

[10] Commission Communication—EU best practice guidelines for voluntary certification schemes for agricultural products and foodstuffs.

Effectiveness: the effectiveness of growing plants under exclusion conditions is considered high, when growing plants in soilless culture, but negligible when grown in open field containers.

Technical feasibility: the technical feasibility of this RRO is rated as moderate to high.

Uncertainty: the uncertainty is considered low.

4.5.4. Physical and cultural control

Spread of *P. fragariae* does occur within and between farms, in soil on machinery, implements and footwear. These can and should be cleaned and disinfected between operations. Therefore, elimination of this contamination is a practical and useful control element against *P. fragariae*.

Effectiveness: **moderate**.

Technical feasibility: **moderate**

Uncertainty: **medium**

4.5.5. Chemical control

There is a dearth of truly effective fungicides available for the control of red core. There is clearly a case, therefore, for applied research on a wider range of emerging active substances that could be used against red core and the potential for these to be integrated into new disease control strategies (EFSA, 2014).

Until the development of the DNA test, the use of anti-*Phytophthora* fungicides on propagation material was not recommended, as it could lead to false negatives in the root tip test while not eliminating the pathogen from plants. A further concern with the phenylamide fungicides (metalaxyl, mefoxenam) is that their use on runner plants would lead to the emergence of strains of *P. fragariae* resistant to these materials. DNA testing should be unaffected by the presence of fungicides.

Effectiveness: moderate to high.

Technical feasibility: high.

Uncertainty: medium.

4.5.6. Resistance to red core

Disease resistance is an effective strategy for controlling red core, providing it is deployed in cultivars that the industry wishes to grow. However, it is possible that new varieties emerging from the breeding process select and transmit new races of the pathogen throughout the strawberry industry. Such transmission would be prevented or at worst delayed by comprehensive DNA testing of new cultivars. In that way new races would have to emerge *de novo* many times to achieve a wide distribution in commercial strawberry production. The whole key, therefore, to preventing movement of newly emergent races is comprehensive DNA testing of propagation stocks.

Effectiveness: moderate.

Technical feasibility: low owing to the lack of resistance in commercially acceptable varieties.

Uncertainty: medium.

4.5.7. Biological control

There are no commercially available biological agents of proven effectiveness against *P. fragariae*.

Effectiveness: unknown.

Technical feasibility: low.

Uncertainty: low.

4.5.8. IPM tools

IPM is practised in the strawberry industry mainly with respect to insect pests. Guidelines published in the USA are covered in Section 3.6.1.2.

Effectiveness*:* is considered moderate.

Technical feasibility: moderate.

Uncertainty: medium.

4.5.9. Maintaining a pest-free area

A pest-free area is an area in which a specific pest does not occur, as demonstrated by scientific evidence, and in which, where appropriate, this condition is officially maintained. The delimitation of a pest-free area should be relevant to the biology of the pest concerned. In principle, the pest-free area could be established only by applying the criteria for establishing freedom from pests as set out in ISPM 4 (IPPC, 1995). Because inspection is always necessary to confirm pest freedom, it is an integral part of several other options such as establishment of pest-free areas (ISPM 4—IPPC, 1995) and places of production (ISPM 10—IPPC, 1999), pre-export checking of consignments (ISPM 31—IPPC, 2008) and pre-entry or post-entry quarantine.

However, with *P. fragariae,* even with rigorous inspection it would be very difficult to establish a pest-free area in Europe. The production of plants for planting is concentrated in northern Europe, where conditions in that area favour the production of large and numerous runner plants. Unfortunately the same conditions favour the disease, which is more common and damaging than in warmer areas of the EU. There is therefore no suitable pest-free area for propagation that can be identified within the EU, hence the low rating for effectiveness given below.

Effectiveness: low.

Technical feasibility: low.

Uncertainty: low.

4.5.10. Pest-free production site

A pest-free production site is a place of production in which a specific pest does not occur, as demonstrated by scientific evidence, and in which, where appropriate, this condition is being officially maintained for a defined period (ISPM 10—IPPC, 1999). Requirements for the establishment and maintenance of a pest-free production site, as an approved phytosanitary measure by the NPPO, include:

- systems to establish pest freedom;
- systems to maintain pest freedom;
- verification that pest freedom has been attained or maintained;
- product identity and phytosanitary security of the consignment.

Where necessary, a pest-free place of production or a pest-free production site also includes the establishment and maintenance of an appropriate buffer zone. Pre-planting site preparation, combined with the use of healthy planting material, is the key to controlling the pest.

As regards *P. fragariae*, all producers of runner plants strive to select pathogen-free production sites using the criteria as described in EPPO standards and ISPM requirements. Unfortunately, the selection of a clean site cannot be guaranteed with present technology, hence the need for effective bait/DNA testing of runner plants during and after propagation.

Effectiveness: low because of ineffective soil detection methods.

Technical feasibility: very low.

Uncertainty: medium.

4.5.11. Hygiene best practice to control spread by human activities

To implement best practices, there should be training in the use of disposable clothes, the restriction of the movement of equipment and tools, the chemical disinfection of equipment and small tools and limiting the access of people to the place of production of strawberry plants for planting.

Effectiveness: moderate to high depending on the maintenance of hygienic standards.

Technical feasibility: high.

Uncertainty: low.

Table 5: Summary of the risk reduction options identified and evaluated under Section 4

Level of action option (entry, establishment, spread, impact)	Category of options	Type of measure (for details, see EFSA PLH Panel, 2012)	Effectiveness	Technical feasibility	Uncertainty
Entry	Options for consignments	Prohibition	High	Low	Low
Entry		Pest freedom, inspection or testing	Low to moderate (visual inspection) High (testing of planting material)	Moderate to high	Low
Entry		Pre-entry or post-entry quarantine systems	Low to high Depending on visual inspection or testing	Moderate to high Depending on number of plants involved	Low
Entry		Phytosanitary certificates and other compliance measures	High if phytosanitary certificates are based on inspection, monitoring, sampling, otherwise low	Very high	Medium
Entry		Preparation of the consignment and specified treatment of the consignment reducing pest prevalence in the consignment	Low	Low	Low
Establishment		Eradication	Very low for production in soil; moderate for soilless production	Very low for production in soil but moderate for soilless production	Low

Table 5: Continued

Level of action option (entry, establishment, spread, impact)	Category of options	Type of measure (for details, see EFSA PLH Panel, 2012)	Effectiveness	Technical feasibility	Uncertainty
Spread/impact	Options preventing or reducing infestation in the crop	Inspections and surveillance	Low to moderate (visual inspections) High (testing of planting material)	High (visual inspection) Moderate to high (testing)	Low
		Certification scheme	High	Very high	Low
Spread/impact		Growing plants under exclusion conditions (glasshouse, screen, isolation)	High (in soilless culture) Negligible (in open field containers)	Moderate to high	Low
Spread/impact		Physical and cultural control	Moderate	Moderate	Medium
Spread/impact		Chemical control	Moderate to high	High	Medium
Spread/impact		Resistance to red core	Moderate	Low	Medium
Spread/impact		Biological control	Unknown	Low	Low
Spread/impact		IPM tools	Moderate	Moderate	Medium
Spread/impact	Options ensuring that the area, place or site of production or crop is free from the pest	Maintaining a pest-free area	Low	Low	Low
Spread/impact		Pest-free production site	Low	Very low	Medium
Spread/impact		Inspections and surveillance	Low to moderate (visual inspections) High (testing of planting material)	High (visual inspection) Moderate to high (testing)	Low
Spread/impact		Hygiene best practice to control spread by human activities	Moderate to high	High	Low

4.6. Conclusions on the analyses of risk reduction options and on the current phytosanitary measures

The Panel evaluated the phytosanitary measures against the introduction and spread of *P. fragariae* and explored the possible consequences if these measures were to be removed. In addition, the Panel identified and evaluated additional risk reduction options to enhance the current measures.

The Panel concludes that the special requirements for introduction of *Fragaria* plants for planting, specified by 2000/29/EC, Annex IV, Part A, Section I (19.2), and for movement of *Fragaria* plants within the EU specified by 2000/29/EC, Annex IV, Part A, Section II (12), are not fully effective in preventing the *introduction* into and spread within the EU of *P. fragariae*.

The Panel considered that, at the present level of trade into the EU, removal of *P. fragariae* from Annex IIAII would have only a marginal effect on the risk of its introduction into and spread within the EU and on its impact, because of the remaining legislation for the introduction into and movement within the EU of *Fragaria* plants for planting, the important level of protection by the widely used certification scheme for *Fragaria* which significantly reduces the risks of entry, establishment, spread and impact, and the currently available pest management practices. If, however, the current regulation was to be discarded along with simultaneous removal of the widely used certification schemes for Fragaria, there would be major consequences for the potential impact of *P. fragariae*.

In order to identify RROs that could further reduce the risks of spread from established affected areas within the EU, the effectiveness of current measures was evaluated. None of the RROs explored were considered to have much effect on their own in reducing these risks. Options were, however, identified, with moderate to high effectiveness and feasibility that reduce the magnitude of consequent impacts. The option with the greatest efficiency and feasibility and least uncertainty is the use of certification schemes for the movement of strawberry plants for planting, especially if effective detection were incorporated into them.

CONCLUSIONS

After consideration of the evidence, the Panel reached the following conclusions:

With regard to the assessment of the risk to plant health of *P. fragariae* for the EU territory:

The widespread cultivation of strawberry means that the endangered area includes the whole of the EU. *P. fragariae* is present in most areas except for the southern Mediterranean regions, and while it has been eradicated from some Member States, there is a continued threat of spread, both naturally and by human assistance.

With regards to entry the Panel concludes that the pathway strawberry plants for planting (including plants in tissue culture (*microplants*), “frigo” plants (*young plants after cold storage*) and green plants (*runners*)), is the major pathway for entry of the pathogen into the risk assessment area from third countries. This pathway was the only one chosen for further assessment. The overall rating of entry is unlikely. Very little trade in strawberry plants for planting has been reported from third countries. Detection methods if used as intended are effective in eliminating infected plants for planting. The uncertainty is high owing to lack of information on trade and quality and frequency of inspection data across Member States.

With regards to establishment the Panel notes that strawberries are grown throughout the European Union. A small number of wild species are present in the EU but these are unlikely to play any important role in the further establishment of the disease following new entry of the pathogen or spread within the EU. It is reasonable to conclude that the climate in the majority of the Member States is suitable for the disease: it is probably most conducive in the western part of northern Europe, with a temperate, oceanic climate, and least so in the southern Mediterranean regions, where high soil temperatures would inhibit pathogen establishment and disease development. Given the climatic conditions throughout much of the strawberry-producing areas, the probability of establishment following new entry of the pathogen or spread within the EU is rated as likely in the absence of existing disease control practices, with low uncertainty. Different cultural practices and control measures may be applied in attempts to eradicate the pathogen once it is present in a field; however, since oospores of *P. fragariae* may survive for many years in plant debris and soil, eradication could be very difficult.

With regard to spread, the Panel concluded that, by definition, this also means establishment in a new area where the pest was absent. As noted under establishment, cultivated strawberries are widespread and climatic conditions are suitable in the risk assessment area. The pathways for spread within the EU territory are the same as those for entry into the EU. A distinction is made between spread by natural means and that occurring through human assistance, with the latter being considered much more important. The main pathway for spread over all scales of distance is the movement of infected plants for planting through the extensive intra-EU trade. In the absence of certification, spread is considered to be very likely. With certification, spread is considered to be unlikely to moderately likely. Certification, where supported by appropriate methods, is effective in containment and prevention of further spread. These ratings are associated with a medium uncertainty.

With regards to the magnitude of impact, the Panel concluded that pest effects can be partitioned into yield losses and control costs. Crop yields have been reduced by as much as two-thirds in untreated plantations. Disease control costs in strawberry are not available. Even so, fungicide treatments are only partially effective and might not fully mitigate the disease in the absence of phytosanitary measures. Importantly the existence of regulation and voluntary certification schemes for strawberry ensures healthy planting materials for fruit producers. Additionally, significantly shorter cycles in modern strawberry cultivation practice (one to two seasons) contributes to a reduction in the impact of the disease.

Disease outbreaks are, as far is known, reported only from commercial production of strawberry. However, to some extent strawberries are also grown in private gardens, and they may also become infected. It is thus likely that the pathogen may occur in amenity land, but to a very limited extent.

Overall the consequences were assessed as minor. By comparison with other strawberry pests and pathogens under the current regulatory regime, the pest effects and the environmental effects are likely to have little impact. Under this regime, and with pest management practices, the level of the disease remains manageable. The uncertainty is rated as medium.

With regard to risk reduction options, the Panel evaluated the phytosanitary measures formulated in Council Directive 2000/29/EC and identified additional RROs where relevant.

The Panel evaluated the phytosanitary measures against the introduction and spread of *P. fragariae*, listed in Council Directive 2000/29/EC, explored the possible consequences if these measures were to be removed and identified additional RROs to enhance the current measures.

The Panel concludes that the special requirements for introduction of *Fragaria* plants for planting, specified by 2000/29/EC, Annex IV, Part A, Section I (19.2), and for movement of *Fragaria* plants within the EU specified by 2000/29/EC, Annex IV, Part A, Section II (12), are not fully effective in preventing the *introduction* into and spread within the EU of *P. fragariae*.

None of the RROs explored were considered to have a major effect on their own in reducing these risks. Options were, however, identified with moderate to high effectiveness and feasibility that reduce the magnitude of consequent impacts.

The Panel considered that, at the present level of trade into the EU, removal of *P. fragariae* from Annex IIAII would have only a marginal effect on the risk of its introduction into and spread within the EU and on its impact, because of the remaining legislation for the introduction into and movement within the EU of *Fragaria* plants for planting, the important level of protection arising from the widely used certification scheme for *Fragaria*, which significantly reduces the risks of entry, establishment, spread and impact, and the currently available pest management practices

The effectiveness of RROs that could further reduce the risk of introduction and spread was evaluated. None of the RROs explored were considered to have a very high effectiveness in reducing the risk of introduction. Concerning entry, the two most important RROs are inspections and surveillance and certification, especially if supported by effective detection tests (root tip and bioassay and/or DNA tests). Effective maintenance of these two RROs can prevent the entry of *P. fragariae*.

If, however, the current regulation were to be discarded, along with simultaneous removal of the widely used certification schemes for Fragaria, there would be major consequences for the potential impact of *P. fragariae*. This is largely because of the important level of protection afforded to the industry by the widely used certification schemes for *Fragaria*, which significantly reduce the risks of entry, establishment, spread and impact. Certification schemes for the movement of strawberry plants for planting offer the greatest efficiency and feasibility and the least uncertainty, especially if effective detection is incorporated into them.

DOCUMENTATION PROVIDED TO EFSA

1. Request (see Background and Terms of Reference) to provide a scientific opinion on the risks to plant health of Arabis mosaic virus, tomato black ring virus, raspberry ringspot virus, strawberry latent ring spot virus, strawberry crinkle virus, strawberry mild yellow edge virus, *Daktulosphaira vitifoliae* (Fitch), *Eutetranychus orientalis* Klein, *Parasaissetia nigra* (Nietner), *Clavibacter michiganensis* spp. *michiganensis* (Smith) Davis et al., *Xanthomonas campestris* pv. *vesicatoria* (Doidge) Dye, *Didymella ligulicola* (Baker, Dimock and Davis) von Arx, and *Phytophthora fragariae* Hickmann var. *fragariae*, for the EU territory; SANCO.E2 GC/ap (2012) 1011925, 19 July 2012. Submitted by the European Commission, DG SANCO (Directorate General for Health and Consumers).

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APPENDICES

Appendix A. Ratings and descriptors

In order to follow the principle of transparency as described under paragraph 3.1 of the guidance document on the harmonised framework for risk assessment (EFSA, 2010)—"… Transparency requires that the scoring system to be used is described in advance. This includes the number of ratings, the description of each rating … the Panel recognises the need for further development …"—the Plant Health Panel has developed specifically for this opinion rating descriptors to provide clear justification when a rating is given.

1. Ratings used in the conclusion of the pest risk assessment

In this opinion of EFSA's Plant Health Panel for the risk assessment of *P. fragariae* and the evaluation of the effectiveness of the risk reduction options, a rating system of five levels with their corresponding descriptors has been used to formulate separately the conclusions on entry, establishment, spread and impact as described in the following tables.

1.1. Rating of probability of entry

Rating for entry	Descriptors
Very unlikely	The likelihood of entry would be very low because the pest: 1. is not or is only very rarely associated with the pathway at the origin; 2. cannot survive during transport or storage; 3. cannot survive the current pest management procedures existing in the risk assessment area; 4. cannot transfer to a suitable host in the risk assessment area
Unlikely	The likelihood of entry would be low because the pest: 1. is rarely associated with the pathway at the origin; 2. can survive at a very low rate during transport or storage; 3. is strongly limited by the current pest management procedures existing in the risk assessment area; 4. has effective limitations for transfer to a suitable host in the risk assessment area
Moderately likely	The likelihood of entry would be moderate because the pest: 1. is occasionally associated with the pathway at the origin; 2. can survive at a low rate during transport or storage; 3. is limited by the current pest management procedures existing in the risk assessment area; 4. has some limitations for transfer to a suitable host in the risk assessment area
Likely	The likelihood of entry would be high because the pest: 1. is frequently associated with the pathway at the origin; 2. can survive during transport or storage; 3. is unlikely to be limited by the current pest management procedures existing in the risk assessment area; 4. has very few limitations for transfer to a suitable host in the risk assessment area
Very likely	The likelihood of entry would be very high because the pest: 1. is always or almost always associated with the pathway at the origin; 2. always survives during transport or storage; 3. is not limited by the current pest management procedures existing in the risk assessment area; and/or 4. has no limitations for transfer to a suitable host in the risk assessment area

1.2. Rating of probability of establishment

Rating for establishment	Descriptors
Very unlikely	The likelihood of establishment would be very low because of the absence or very limited availability of host plants; the unsuitable environmental conditions; and the occurrence of other considerable obstacles preventing establishment
Unlikely	The likelihood of establishment would be low because of the limited availability of host plants; the unsuitable environmental conditions over the majority of the risk assessment area; and the occurrence of other obstacles preventing establishment
Moderately likely	The likelihood of establishment would be moderate because hosts plants are abundant in few areas of the risk assessment area; environmental conditions are suitable in few areas of the risk assessment area; and no obstacles to establishment occur
Likely	The likelihood of establishment would be high because hosts plants are widely distributed in some areas of the risk assessment area; environmental conditions are suitable in some areas of the risk assessment area; and no obstacles to establishment occur. Alternatively, the pest has already established in some areas of the risk assessment area
Very likely	The likelihood of establishment would be very high because hosts plants are widely distributed; environmental conditions are suitable over the majority of the risk assessment area; and no obstacles to establishment occur. Alternatively, the pest has already established in the risk assessment area

1.3. Rating of probability of spread

Rating for spread	Descriptors
Very unlikely	The likelihood of spread would be very low because: 1. the pest has only one specific way to spread (e.g. a specific vector, specific assisting virus…) which is not present in the risk assessment area; 2. highly effective barriers to spread exist; 3. the hosts are not or very rarely present in the area of possible spread
Unlikely	The likelihood of spread would be low because: 1. the pest has one to few specific ways to spread (e.g. specific vectors, specific assisting virus) and the occurrence of the pest in the risk assessment area is rare; 2. effective barriers to spread exist; 3. the hosts are occasionally present
Moderately likely	The likelihood of spread would be moderate because: 1. the pest has few specific ways to spread (e.g. specific vectors, specific assisting virus) and the occurrence of the pest in the risk assessment area is limited; 2. partially effective barriers to spread exist; 3. the hosts are abundant in few parts of the risk assessment area
Likely	The likelihood of spread would be high because: 1. the pest has some non-specific ways to spread (mechanical transmission…), which occur in the risk assessment area; 2. no effective barriers to spread exist; 3. the hosts are widely present in some parts of the risk assessment area
Very likely	The likelihood of spread would be very high because: 1. the pest has multiple non-specific ways to spread (mechanical transmission…), which all occur in the risk assessment area; 2. no effective barriers to spread exist; 3. the hosts are widely present in the whole risk assessment area

1.4 Rating of magnitude of the potential consequences

Rating of potential consequences	Descriptors
Minimal	Differences in crop production (saleable fruits, tubers, plants for planting, seed, etc.) are within normal day-to-day variation; no additional control measures are required
Minor	Crop production (saleable fruits, tubers, plants for planting, seed, etc.) is rarely reduced or at a limited level; additional control measures are rarely necessary
Moderate	Crop production (saleable fruits, tubers, plants for planting, seed, etc.) is occasionally reduced to a limited extent; additional control measures are occasionally necessary
Major	Crop production (saleable fruits, tubers, plants for planting, seed, etc.) is frequently reduced to a significant extent; additional control measures are frequently necessary
Massive	Crop production (saleable fruits, tubers, plants for planting, seed, etc.) is always or almost always reduced to a very significant extent (severe crop losses that compromise the harvest); additional control measures are always necessary

2. Ratings used for the evaluation of the risk reduction options

The Panel developed the following ratings with their corresponding descriptors for evaluating the effectiveness of the risk reduction options to reduce the level of risk.

2.1. Rating of the effectiveness of risk reduction options

Rating	Descriptors
Negligible	The risk reduction option has no practical effect in reducing the probability of entry, establishment or spread, or the magnitude of potential consequences
Low	The risk reduction option reduces, to a limited extent, the probability of entry, establishment or spread, or the magnitude of potential consequences
Moderate	The risk reduction option reduces, to a substantial extent, the probability of entry, establishment or spread, or the magnitude of potential consequences
High	The risk reduction option reduces the probability of entry, establishment or spread, or the magnitude of potential consequences, by a major extent
Very high	The risk reduction option essentially eliminates the probability of entry, establishment or spread, or any potential consequences

2.2. Rating of the technical feasibility of risk reduction options

Rating	Descriptors
Negligible	The risk reduction option is not in use in the risk assessment area, and the many technical difficulties involved (e.g. changing or abandoning the current practices, implementing new practices and or measures) make their implementation in practice impossible
Low	The risk reduction option is not in use in the risk assessment area, but the many technical difficulties involved (e.g. changing or abandoning the current practices, implementing new practices and or measures) make its implementation in practice very difficult
Moderate	The risk reduction option is not in use in the risk assessment area, but it can be implemented (e.g. changing or abandoning the current practices, implementing new practices and or measures) with some technical difficulties
High	The risk reduction option is not in use in the risk assessment area, but it can be implemented in practice (e.g. changing or abandoning the current practices, implementing new practices and or measures) with limited technical difficulties
Very high	The risk reduction option is already in use in the risk assessment area or can be easily implemented with no technical difficulties

3. Ratings used for describing the level of uncertainty

For the risk assessment chapter—entry, establishment, spread and impact—as well as for the evaluation of the effectiveness of the risk reduction options, the level of uncertainty has been rated separately in coherence with the descriptors that have been defined specifically by the Panel in this opinion.

Rating	Descriptors
Low	No or little information is missing or no or a small number of data are missing, incomplete, inconsistent or conflicting. No subjective judgement is introduced. No unpublished data are used
Medium	Some information is missing or some data are missing, incomplete, inconsistent or conflicting. Subjective judgement is introduced with supporting evidence. Unpublished data are sometimes used
High	Most information is missing or most data are missing, incomplete, inconsistent or conflicting. Subjective judgement may be introduced without supporting evidence. Unpublished data are frequently used