Vitenskapskomiteen for mattrygghet
Norwegian Scientific Committee for Food Safety

Pest risk assessment of *Phytophthora fragariae* in Norway

Opinion of the Panel on Plant Health
of the Norwegian Scientific Committee for Food Safety
14.09.2010

ISBN 978-82-8259-003-7

VKM Report 2010: 26

Pest risk assessment of *Phytophthora fragariae* in Norway

Leif Sundheim

Arild Sletten

Trond Rafoss

Arne Stensvand

Citation: Sundheim, L., Sletten, A., Rafoss, T., Stensvand, A. (2010). Pest risk assessment of *Phytophthora fragariae* in Norway. Opinion of the Plant Health Panel of the Scientific Committee for Food Safety, 09/905-2_final, ISBN 978-82-8259-003-7 (Electronic edition). 54 pp. VKM, Oslo, Norway.

SUMMARY

The pathogen *Phytophthora fragariae* Hickman, causal agent of the red core disease of strawberry has been known to be present in a few limited areas in Norway since 1995. Surveys in recent years have revealed previously unknown infected places of production. In order to limit introduction and spread of the pathogen, import of strawberry plants is prohibited, plants to be traded must be tested and found to be free from the pathogen, and places of production where the pathogen has been detected are under strict regulations.

The Norwegian Food Safety Authority (Mattilsynet) considers a revision of the phytosanitary measures and priorities related to red core, and has requested a pest risk assessment of *P. fragariae* from the Norwegian Scientific Committee on Food Safety (VKM) according to the international standard ISPM No. 11. The pest risk assessment was adopted by VKMs Panel on Plant Health in a meeting on 12th August 2010.

VKMs Panel on Plant Health gives the following main conclusions of the pest risk assessment:

1) The pest of concern is the oomycete *Phytohthora fragariae* Hickman. The PRA area is Norway. *P. fragariae* is present in at least five limited regions of the PRA area. These regions are located in the counties of i) Hedmark, ii) Aust-Agder and Vest-Agder, iii) Hordaland and Rogaland, iv) Vestfold, and v) Møre og Romsdal. It is probable that the pathogen is present at some places of production without having been detected yet. The pathogen is regulated as a quarantine pest in the PRA area.

2) With the current import regulations there is a medium probability of introduction of *P. fragariae* through import of infected *Rubus* plants for planting and a low probability of introduction through import of other consignments. However, there is little updated information available on the presence of the pathogen in different production systems, and there is only very limited evidence that the pathogen can spread by other means than strawberry plants. The level of uncertainty is therefore high.

3) Without the current import regulations there would be a very high probability of introduction through the import of non-certified strawberry plants. The level of uncertainty of this assessment is low. The probability of introduction through import of certified strawberry plants is considered low, but without detailed information on the presence/absence of the pathogen in such material the level of uncertainty is high.

4) With the current pest management procedures the probability of spread within the PRA area is medium for raspberry plants and machinery, other farm implements, footwear and animals. The probability of spread through other pathways ranges from low (legally traded, non-certified strawberry plants, seed potatoes, surface water, waterways and irrigation systems) to very low (remaining pathways). The level of uncertainty is low for certified strawberry plants and medium for legally traded, non-certified strawberry plants. Due to limited knowledge on the spread and survival of the pathogen, the level of uncertainty is high for all other pathways.

5) Without the current pest management procedures the probability of spread with strawberry plants within the PRA area would be very high. The probability of spread with raspberry plants would be high and the probability of spread with seed potatoes, machinery, other farm implements, footwear, animals, surface water, waterways and irrigation systems would be medium. The probability of spread through other pathways would range from low to very low. The level of uncertainty is low for strawberry plants, but due to limited

knowledge on the spread and survival of the pathogen, the level of uncertainty is generally high for all other pathways.

6) All strawberry-growing areas in the whole PRA area are considered endangered areas.

KEY WORDS

Pest Risk Analysis (PRA), pest risk assessment, *Phytophthora fragariae*, red core, red stele, strawberry

CONTRIBUTORS

Persons working for the Norwegian Scientific Committee for Food Safety (Vitenskapskomiteen for mattrygghet, VKM), either as appointed members of the Committee or as *ad hoc*-experts, do this by virtue of their scientific expertise, not as representatives for their employers. The Civil Services Act instructions on legal competence apply for all work prepared by VKM.

Acknowledgements

An *ad hoc*-group consisting of both VKM members and external experts was appointed by the Panel on plant health on November 3, 2009. The ad-hoc group has prepared a draft for final preparation by the panel. The members of the working group are acknowledged for their valuable work with the pest risk assessment.

The members of the *ad hoc*-group are:

Leif Sundheim (chair), Panel on Plant Health

Trond Rafoss, Panel on Plant Health and Norwegian Institute of Agricultural and Environmental Research (Bioforsk), Ås, Norway

Arild Sletten, Panel on Plant Health and Norwegian Institute of Agricultural and Environmental Research (Bioforsk), Ås, Norway

Arne Stensvand, Norwegian Institute of Agricultural and Environmental Research (Bioforsk) Ås, Norway

Assessed by

Panel on Plant Health (Panel 9):

Leif Sundheim (chair), Trond Hofsvang, Christer Magnusson, Trond Rafoss, Brita Toppe, Anne Marte Tronsmo, Bjørn Økland, Halvor Solheim and Arild Sletten.

Scientific coordinator from the secretariat: Elin Thingnæs Lid (before March 2010) and Åshild Ergon (from March 2010)

CONTENTS

1. BACKGROUND

The pathogen *Phytophthora fragariae* Hickman, causal agent of the red core disease of strawberry (*Fragaria* spp., including the cultivated strawberry *Fragaria* × *ananassa* L.H. Bailey), was detected in Norway at places of strawberry production in the counties of Hedmark, Aust-Agder and Vest-Agder during a survey in 1995. Further contaminated places of production were discovered in these counties and in Hordaland and Rogaland Counties in 1996 and 1997. No new cases were detected during the years 1998-2005. Surveys in recent years revealed previously unknown infected places of production in Vest-Agder, and new infections were detected in Vestfold and Møre og Romsdal counties.

Eradication of the pathogen was the aim following the detection of the first cases in 1995. Since 1997 the strategy has been to prevent new introductions and to stop further spread of *P. fragariae* to new places of production and ensure the availability of disease-free plants for strawberry production.

Under the present phytosanitary measures growers with fields contaminated by *P. fragariae* frequently have problems maintaining their strawberry production, not only because of the direct damage caused by the disease, but also due to the phytosanitary measures implemented. Phytosanitary measures limit other activities than the strawberry production on the farm. Furthermore, the establishment of buffer zones around contaminated fields, which is included among the phytosanitary measures, is very demanding. Thus the Norwegian Food Safety Authority (Mattilsynet) considers a revision of the phytosanitary measures and priorities related to red core. The Norwegian Food Safety Authority, in a letter of 30th November 2009, requested a pest risk assessment of *P. fragariae* from the Norwegian Scientific Committee for Food Safety (Vitenskapskomiteen for mattrygghet, VKM). The current document is VKM's answer to this request, and was adopted by VKM's Panel on Plant Health on a meeting 12th August 2010.

Be aware that the current document is a pest risk assessment, and not a Pest Risk Analysis (PRA). A PRA consists of both a risk assessment and a risk management part. VKM performs purely the risk assessment, whereas Mattilsynet is responsible for the risk management. However, since this pest risk assessment is part of a PRA process, the current document refers to the PRA term in several contexts, like the identification of the PRA area and referrals to former PRAs. This is in accordance with the international standard ISPM No. 11 (FAO 2004).

2. TERMS OF REFERENCE

In a letter of 30th November 2009 to the Norwegian Scientific Committee for Food Safety, the Norwegian Food Safety Authority announced a possible revision of the current phytosanitary management policy and requested a pest risk assessment of *P. fragariae* in accordance with the international standard ISPM No. 11 (FAO 2004). The Norwegian Food Safety Authority particularly requested the following issues to be considered:

1. The probability that the pathogen has been spread to parts of the PRA area where it has not yet been discovered.
2. The importance of sampling time, sampling density and sampling frequency for successful detection of the pathogen in different certified strawberry plant production systems.
3. Description and importance of pathways of dispersal from infected places of production, including how dispersal is affected by: cultivation method, machinery, topography, distance, vegetation/host plants, season/climate, soil type/drainage and speed of water movement in rivers and streams.
4. Consequences of the establishment of *P. fragariae* in natural vegetation for maintenance of inoculum potential at and around present or future places of strawberry production.
5. Evaluation of management options to the current phytosanitary measures:

   - elimination of the requirement of buffer zones to neighbours and waterways

   - permission for field production and trade of plant material other than strawberry, e.g. nursery plants, raspberry plants, seed potato, turf

   - elimination of the requirement for washing machinery and tools between contaminated and non-contaminated sites

   - concentrate the phytosanitary measures on strawberry plant production and not on berry production.

   - change the management by moving *P. fragariae* from Annex 1 to Annex 2 in "Regulations relating to plants and measures against pests" in the Act of 19 December 2003 No. 124 relating to Food production and safety (Matloven)".

   - removal of the ban on import of *Fragaria* L. (plants for planting except seed).

3. INITIATION

3.1. Initiation points

3.1.1. PRA initiated by the review of phytosanitary policies and priorities

This assessment was initiated by the Norwegian Food Safety Authority as a basis for a review and possible revision of its policy on management of *P. fragariae.*

3.2. Identification of PRA area

The PRA area is Norway.

3.3. Information

Information sources utilised for this pest risk assessment are published material available in international scientific journals, books and reports, as well as personal communications with persons involved in the area, geographical data, unpublished results, and information from the Norwegian Food Safety Authority that have been made available to the risk assessors. Where these information sources have been used, this is indicated in the text by references enclosed in brackets.

The current pest risk assessment largely follows the international standard ISPM No. 11 (FAO 2004).

3.3.1. Previous PRAs

Commissioned by the Norwegian Agricultural Inspection Service, the Norwegian Crop Research Institute (Planteforsk, since 2006 Bioforsk) in 1995 did a pest risk assessment of *P. fragariae* in Norway (Stensvand 1996). The pest risk assessment contained information on symptoms, diagnosis, biology, epidemiology and control of *P. fragariae* as causal agent for red core of strawberry. The potential for introduction and spread and the potential economic consequences of introduction were also discussed. The research on *P. fragariae* and red core of strawberry has been very limited since 1995, and most of the conclusions in the pest risk assessment from 1996 are still considered valid. However, *P. fragariae* is now present in several other areas in Norway, and the pest risk assessment therefore needs to be revised in light of this.

3.4. Conclusion of initiation

The pest of concern is the Oomycete *Phytophthora fragariae*. The pest risk assessment was initiated by the Norwegian Food Safety Authority, and the initiation point is a review of phytosanitary policy and priorities. A PRA for *P. fragariae* in the PRA area conducted in 1995-1996 is still largely valid, but there is a need to perform a new PRA in light of the altered status of the pest in the PRA area, the high costs of the control measures and the need to know more about the efficiency of the control measures. Thus the PRA will continue.

4. PEST RISK ASSESSMENT

4.1 Pest categorization

4.1.1. Identity of pest

4.1.1.1 Scientific name

Phytophthora fragariae Hickman

4.1.1.2 Synonym

Phytophthora fragariae Hickman var. *fragariae*

4.1.1.3 Common names of the disease

Rød marg (Norway)

Rødmarv (Denmark)

Röd rotröta (Sweden)

Red core (United Kingdom)

Red stele (USA)

Rote Würzelfäule (Germany)

Rood wortelroot (The Netherlands)

4.1.1.4 Taxonomic position

Chromista; Oomycota; Oomycetes; Peronosporales; Peronosporaceae; *Phytophthora*

The pathogen *P. fragariae* is closely related to *P. rubi*, which causes root rot in raspberries. They were previously considered varieties of the same species by Wilcox et al. (1993). However, Man in 't Veld (2007) recently provided evidence that the two taxa are reproductively isolated and the original description of *P. fragariae* as a distinct species has therefore been readopted (Index Fungorum 2008).

4.1.1.5 Symptoms and methods of detection

P. fragariae is a biotrophic soilborne pathogen that infects the roots of strawberry plants. Infection starts at the root tips, the secondary roots disintegrate, leaving behind characteristic "rat-tail" primary roots. Infected roots have a red-brown stele. The pathogen causes reduced growth, less tillers, small and dry berries and reduced berry yield. Young leaves can take on a blue-green colour and older leaves can become red, yellow and brown. A more detailed description of life cycle and symptoms, as well as descriptions of methods of detection and diagnostic characters are given by Stensvand (1996). Several molecular methods for species identification have been developed since then (e.g. Bonants et al. 2000, Ioos et al. 2006).

4.1.2 Presence or absence in PRA area

Statistics on strawberry production in the PRA area is given in Table 1 and 2. The geographical location of counties is given in Annex 1. At present *P. fragariae* has been found in five limited regions within the PRA area as described in Table 1. A total of 22 commericial places of production have been found to be infected with *P. fragariae*, while more than 80 commercial places of production are considered to be infected due to sharing of machinery and lease of land for strawberry production (Table 1). This equals 3 % and 12 %, respectively, of the total number of commercial places of production in the PRA area. A more detailed description of the presence of *P. fragariae* in the PRA area is given by Mattilsynet (2009a,b,2010). A discussion on the spread of *P. fragariae* in the PRA area is given in section 4.2.3.

Table 1. Strawberry production in Norwegian counties where *Phytophthora fragariae* has been shown to occur (Mattilsynet 2009a, b, 2010, *pers. comm.* with K. Romstad, Norwegian Food Safety Authority).

Contaminated region	**County**	**Postal zones where *P. fragariae* has been detected**	**Total area of commercial strawberry production in the county (hectare) in 2007**	**Total number of commercial places of strawberry production[1] in the county in 2007**	**Number of commercial places of strawberry production in the county where *P. fragariae* has been found**
1	Hedmark	Furnes, Vallset, Åsvang, Nes	148,1	48	7
2	Aust-Agder	Grimstad, Nedenes, His	46,8	18	3
	Vest-Agder	Søgne, Kristiansand	69,3	32	5
3	Hordaland	Etne	9,2	32	1
	Rogaland	Skjold	55,7	34	2
4	Vestfold	Sande	244,8	67	2
5	Møre og Romsdal	Molde	131,6	46	2

[1] Place of production: Any premises or collection of fields operated as a single production or farming unit, including leased land.

Table 2. Strawberry production in Norwegian counties where *Phytophthora fragariae* is not known to occur (Mattilsynet 2009a).

County	**Total area of commercial strawberry production (hectare) in 2007**	**Total number of places of commercial strawberry production[1] in 2007**
Akershus/Oslo	138.0	22
Østfold	154.9	33
Oppland	148.4	28
Buskerud	177.1	32
Telemark	46.1	22
Sogn og Fjordane	62.2	74
Sør-Trøndelag	51.2	26
Nord-Trøndelag	115.4	40
Nordland	15.9	36
Troms	11.1	46
Finnmark	0.9	6

[1] Place of production: Any premises or collection of fields operated as a single production or farming unit, including leased land.

4.1.3 Regulatory status

P. fragariae is currently regulated as a quarantine pest in Norway and is listed in Annex 1 in "Regulations relating to plants and measures against pests" (Landbruks- og Matdepartementet 2000) in the Act of 19 December 2003 No. 124 relating to Food production and safety (Matloven). EPPO has placed the pathogen on its A2 list and thereby recommended its member countries to regulate it as a quarantine pest (EPPO 2009). In the EU the pathogen is regulated as a quarantine pest and listed in Annex II/A2 of the "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" (EC 2000).

4.1.4 Potential for establishment and spread in PRA area

The previous PRA conducted by Stensvand (1996) argued that the climatic conditions for establishment of *P. fragariae* (temperature and precipitation) are suitable in most parts of the PRA area where strawberries are grown. This was subsequently demonstrated by the fact that the pathogen was able to establish in some regions in the PRA area. The pathogen can easily be spread with infected plant material and is also thought to be able to spread with soil and soil

particles on plant roots, machinery and footwear, and by surface or drainage water. Without control measures the potential both for entry and for spread in the PRA area is high.

4.1.5 Potential for economic consequences in PRA area

In the PRA area *P. fragariae* has since its first detection in 1995 caused considerable economic damage both due to reduced strawberry production and due to direct and indirect costs related to the control measures that had to be implemented. The compensation paid to growers by the Norwegian Agricultural Authority due to the recent pathogen detections amounted to approximately 1.5 mill NOK in 2007 and 350 000 NOK in 2009 (no compensations paid in 2008) (Statens Landbruksforvaltning 2010).

4.1.6 Conclusion of pest categorization

P. fragariae is present in at least five geographically separated and limited regions of the PRA area. These regions are located within the counties of i) Hedmark, ii) Aust-Agder and Vest-Agder, iii) Hordaland and Rogaland, iv) Vestfold, and v) Møre og Romsdal. The pathogen is regulated as a quarantine pest in the PRA area.

Due to the availability of hosts and a suitable climate, there is a potential for further spread of *P. fragariae* in the PRA area as well as for new introductions by plants for planting from countries where the disease occur.

The pest has caused significant losses in the PRA area, and has the potential to cause more losses if spread to new areas. The current control measures may imply high costs for the grower in spite of the current compensation scheme.

Thus, the current pest risk assessment is continued.

4.2. Assessment of the probability of introduction and spread

4.2.1 Probability of entry of the pest from outside the PRA area

4.2.1.1 Identification of pathways

Pathways:

A. Import of strawberry plants for planting - with or without roots.
B. Import of plants of other host species for planting – with or without roots.
C. Import of non-host plants for planting, including seed potato, bulbs, rootstocks etc.
D. Import of soil and other organic growth media.
E. Import of root vegetables and potatoes not intended for planting.

Other pathways, such as spread with animals, machinery, other farm implements and footwear, movement of surface water in fields and through ditches, streams, rivers and irrigation systems, and airborne movement of soil particles, have been assessed to be non-significant.

4.2.1.2 Probability of the pest being associated with the pathway at origin

Pathway A

According to EPPOs PQR database (EPPO 2010) the pathogen is widespread in England and in the United States, while it is present in many European countries and also in some countries in Africa, America and Oceania. In spite of the presence of the pathogen in many European countries, *P. fragariae* appears not to be considered a serious problem, and available information on its distribution and abundance has therefore not been updated. Unlike the situation in Norway, where strawberry is grown as a perennial crop, strawberry is grown as an annual crop in most Western European countries, with new disease-free plants being planted each year. The pathogen has the ability to survive in soil, and the symptoms appear less frequently under summer conditions than under late autumn conditions. It is therefore not unlikely that *P. fragariae* may be present without being detected in fields where strawberry is grown as an annual crop. Strawberry growers in the PRA area are expressing interests in importing plants, and if it was allowed, the number of imported plants would probably become quite significant. For these reasons the probability of the pathogen being associated with imported non-certified strawberry plants (in the absence of an import ban) is considered to be high. The uncertainty level of this assessment is medium.

Official certification programs for the production of strawberry plants for planting exist in many European countries (EPPO 1984), and EPPO (1994) has developed its own certification scheme. The probability of the pathogen to be associated with imported certified strawberry plants (in the absence of an import ban) is considered to be low. However, without detailed documentation of the absence of the pathogen in certified material the uncertainty level of this assessment is high.

P. fragariae is a root pathogen and is mainly present in the roots. In severely diseased plants the pathogen also invades the rhizome and in some susceptible varieties it can spread into the vascular tissue of the petioles as far as their junction with the laminae (Hickman 1940). The probability of the pathogen being associated with imported rootless strawberry plants at origin (in the absence of an import ban) is considered to be high for non-certified plants and low for certified plants. The uncertainty level of these assessments is high.

Pathway B

The main host of the pathogen is cultivated strawberry. The pathogen can cause disease in other *Fragaria* species, and incidentally in loganberry (*Rubus loganobaccus* Duch.) (EPPO 2010). Several other species in the *Rosaceae* have been infected experimentally, including species in the *Dryas, Geum, Potentilla* and *Rubus* genera (reviewed by Stensvand 1996). It cannot be ruled out that *P. fragariae* is able to also infect other species in the *Rosaceae*, but it seems unlikely that species in other plant families might be infected, since this has never been reported. A host plant (other than strawberry) originating from a *P. fragariae*-contaminated field is likely to carry propagules of the pathogen. Most raspberry (*R. idaeus*) plants being planted in the PRA area are also produced within the PRA area, but some are imported, possibly around 10% (*pers. comm.* Asle Michael Fremgård, Norwegian Food Safety Authority). Raspberry plants for planting are usually not produced at the same places of production as strawberry plants for planting in European countries (*pers. comm.*, Simen Myhrene, Gartnerhallen). Most other imported host plants would probably not be originating from such fields either. The overall probability of the pathogen being associated with imported host plants at origin is considered to be low. The uncertainty level of this assessment is high.

Pathway C, D and E

Soil or other growth media originating from fields where the pathogen is present may contain propagules of the pathogen. Non-host plants for planting may be imported in containers with soil, and root vegetables and potatoes may carry soil particles. Soil particles, soil and other organic growth media originating from fields contaminated with *P. fragariae* are likely to carry propagules of the pathogen. However, most consignments would probably not originate from such fields, and the overall probability of the pathogen being associated with pathway C-E at origin is therefore considered to be low. The uncertainty level of this assessment is medium.

4.2.1.3 Probability of survival and multiplication during transport or storage

P. fragariae is a soilborne pathogen that is not able to develop outside host tissue. Oospores that are produced in the stele of infected roots are released into the soil when the roots disintegrate. The oospores of the pathogen can survive in soil without host plants for at least 12 years (Newton et al. 2010), whereas hyphae and other structures persist for a few months only (Alcock and Howells 1936, Montgomerie 1951, Fulton 1959, Duncan and Cowan 1980, Duncan 1980).

The probability of survival and multiplication of the pathogen in living host plant material (pathway A and B) is very high. The uncertainty level of this assessment is low.

The probability of survival of oospores in plants, soil particles, soil or other organic growth media (pathway C-E) is very high. The uncertainty level of this assessment is low. *P. fragariae* cannot multiply without living host tissue. The uncertainty level of this assessment is low.

4.2.1.4 Probability of pest surviving existing pest management procedures

Import of *Fragaria* spp. plants to Norway is prohibited. Import licences for a limited number of plants for breeding purposes are issued by The Norwegian Food Safety Authority (Statens Landbrukstilsyn 2003). There are strict requirements regarding the place of production, quarantine facilities, growing and handling of plants, inspections, and laboratory testing for possible presence of *P. fragariae*. These regulations are mainly in accordance with EPPO Standards for phytosanitary procedures for *P. fragariae*, PM 3/22(1) (EPPO 1998) and Certification scheme for strawberry, PM 4/11(2) (EPPO 2008). The probability that *Fragaria* spp. plants imported through this scheme may carry *P. fragariae* is considered to be low. The uncertainty level of this assessment is medium. The probability of the pathogen surviving illegal import however, would be very high with low uncertainty.

Import of plants of other species - with roots and grown in the field, as well as soil and other organic growth media, is only permitted when it is officially stated that *P. fragariae* is not known to be present at the place of production (Landbruks- og Matdepartementet 2000). Import of potatoes and vegetables not intended for planting is not regulated with regard to *P. fragariae.* However, industries handling imported potatoes and vegetables are obliged to have routines to prevent spread of soilborne pathogens with e.g. washing water (Landbruks- og Matdepartementet 2000). As discussed in section 4.2.1.2 (see pathway A), *P. fragariae* may be prevalent in agricultural fields of many countries without being detected. In addition, infection with *P. fragariae* does not produce symptoms in other host plants than *Fragaria* spp., except incidentally in *R. loganobaccus.* The regulation of import of host plants other than *Fragaria* spp., non-host plants for planting, vegetables, potatoes, soil or other organic growth media gives a low level of protection, as no testing is involved. The probability that propagules of *P.*

fragariae transported through these pathways will survive pest management procedures is therefore considered to be high. The uncertainty level of this assessment is medium.

4.2.1.5. Probability of transfer to a suitable host

The probability of transfer from an infected strawberry plant to other strawberry plants is very high. The uncertainty level of this assessment is low.

Stensvand (1996) reviewed the literature and concluded that species in the *Dryas, Geum, Potentilla* and *Rubus* genera, in addition to *Fragaria,* can pose a risk to strawberry plantings when transferred as planting material from contaminated soil to non-contaminated soil that is later planted with strawberries. The probability of transfer is high if the plants are planted in soil where strawberries will be planted within the next 10-15 years. Strawberry growers in the western counties of the PRA area also commonly grow raspberry, but it is unlikely that they will import other host plants. If the pathogen is present in soil particles on vegetables and potatoes it may spread with washing water from private households or from industries with non-satisfactory routines, but although strawberry fields in dry parts of the PRA area are irrigated, it is unlikely that the pathogen will be transferred to host plants with washing water. The probability of transfer to strawberry plants is therefore considered to be medium for import of raspberry plants, and low for import of other plants as well as vegetables, potatoes, soil and other organic growth media. The uncertainty level of these assessments is high

Direct transfer to wild host plants is unlikely. Indirect transfer to such plants will be discussed in section 4.2.3.

4.2.1.6 Summarised probability of entry for each pathway

The components of probability of entry for each of the identified pathways described above, is given in Table 3. Under the current import regulations, there is a low probability of entry through import of strawberry plants, a medium probability of entry with import of raspberry plants, and a low probability of entry through the other pathways. Without the current import regulations, the probability of entry would be very high for non-certified plants, and low for the other pathways. The level of uncertainty is considered to be low for the assessments of import of non-certified strawberry plants and high for the assessments of other commodities.

Table 3. Probability of entry of *Phytophthora fragariae* by the identified pathways. A high (H), medium (M) or low (L) uncertainty level is indicated in brackets.

<table>
<tr><th>Pathway</th><th>Probability of association with pathway at origin</th><th>Probability of survival and multiplication during transport or storage</th><th>Probability of survival of existing pest management procedures</th><th>Probability of transfer to cultivated strawberry</th></tr>
<tr><td>A. Strawberry plants</td><td>Non-certified plants: High (M)
Certified plants: Low (H)</td><td rowspan="2">Very high (L)</td><td>Low (M)</td><td>Very high (L)</td></tr>
<tr><td>B. Other host plants</td><td>Low (H)</td><td rowspan="4">High (M)</td><td>From raspberry: Medium (H)
From other species: Low (H)</td></tr>
<tr><td>C. Non-host plants for planting</td><td rowspan="3">Low (M)</td><td rowspan="3">Survival: Very high (L)
Multiplication: Nil (L)</td><td rowspan="3">Low (H)</td></tr>
<tr><td>D. Soil and other organic growth media</td></tr>
<tr><td>E. Potatoes and root vegetables not intended for planting</td></tr>
</table>

[1]Probability of entry through pathway B-E is only considered under the current import regulations.

4.2.2 Probability of establishment

4.2.2.1 Availability of suitable hosts and alternate hosts in the PRA area

Strawberry is by far the most important fruit crop in Norway, and is grown in all 19 counties of the country. The total area of strawberry production in 2007 was 1627 hectares (Mattilsynet 2009a).

The range of alternate hosts is described in section 4.2.1.2. Among these, raspberry is commonly cultivated by strawberry growers. Several of the species are cultivated as horticultural crops.

There are four *Fragaria* species native or naturalized in the PRA area; *F. vesca* L., *F. viridis* Weston, *F. moschata* Weston and *F. virginiana* Mill. (Elven et al. 2005). In closely related genera, one *Dryas*, 5 *Geum*, 18 *Potentilla*, 1 *Comarum*, 1 *Drymocallis*, 1 *Dasiphora*, and 43 *Rubus* species are present in the PRA area. Of the four *Fragaria* species native to Norway, *F. vesca* is the most common. It grows all over the country, up to the alpine border (Elven et al. 2005).

4.2.2.2 Suitability of environment

Environmental requirements of the pathogen

Hickman (1940) found the optimum mycelial growth in vitro of *P. fragariae* to be 20°C. The pathogen produces sporangia containing zoospores that are released and can swim a few millimeter in free water in the soil or may be passively spread with the movement of water in or on the soil. The zoospores are responsible for infection of new plants. The temperature optimum for sporangial production for different isolates appears to vary between 10 and 20ºC (Bain and Demaree 1945, McKeen 1958a, Wynn 1967, Law and Millholland 1992). Duncan and Kennedy (1995) found that zoospore production was greater at temperatures below than above 10°C, and that zoospores produced at lower temperatures remained motile for longer time than zoospores produced at temperatures above 10°C.

A high soil moisture level is necessary for development of red core. The disease will therefore more easily establish if drainage is poor (Alcock et al. 1930, Anderson 1935, Hickman 1940, Reid 1941, Hickman and English 1951). The disease may be serious in any soil when annual precipitation is 1 000 mm or more, but it may be equally serious when annual precipitation is around 500 mm if the soils are heavy, compacted, or poorly drained (Montgomerie 1984b).

Climate in the strawberry growing regions in the PRA area

The mean monthly temperature and precipitation during the period 1961-1990 for various locations within or close to important strawberry growing areas are given in Table 1-15 in Annex 2, together with observations on soil temperatures from 10 cm soil depth in the 1990's. Table 16 shows data for air temperature and precipitation at three locations in western Norway where data for soil temperature does not exist. In Southern Norway strawberries are grown up to 4-500 m above sea level, but most of the production takes place below 300 m. In Northern Norway strawberries are grown close to the sea level only. Approximately 70% of the strawberry production area in the country is in South-Eastern and Southern Norway, including the counties of Østfold, Akershus, Oslo, Hedmark, Oppland, Buskerud, Vestfold, Telemark, Aust-Agder, and Vest-Agder. Strawberry growing areas in the counties of Østfold, Hedmark, Oppland and most parts of Akershus and Buskerud, representing approximately 45% of the total strawberry production area, have an annual precipitation of

500-1 000 mm. During summer, the soil temperature exceeds 15°C for 1-3 months. During winter, soil temperature can get below freezing for 3-5 months in the inland and for 1-3 months closer to the coast. Some years there are no frost in the ground along the coast. In strawberry growing areas close to the coast of Vestfold, Telemark, Aust-Agder and Vest- Agder, the precipitation is above 1 000 mm. In these coastal regions, winters are mild, usually with soil temperatures above 0°C. During summer, soil temperature might exceed 15°C for 2-3 months. In strawberry growing areas further inland in these counties, winter temperatures are lower, while summer temperatures are often higher. Annual precipitation here will vary much according to the topography and proximity to the coast. As with much of the agricultural production, most of the strawberry production in the rest of the country is located in close proximity to the sea. In these counties there are remarkable differences in annual precipitation from the inner parts of the sea inlets (fjords) to the coast. For instance along the Sognefjord, it varies from less than 500 mm to above 3 500 mm. However, in most of the strawberry growing areas from Rogaland to Finnmark, annual precipitation is above 1 000 mm, and in some areas even above 2 000 mm. The precipitation is usually highest during autumn and early winter. Except from the northernmost part of the country, the strawberry growing areas in these counties are characterized by mild winters, with soil temperatures often above freezing. Furthermore, summers are often cool, especially close to the coast, with soil temperatures above 15°C only for short periods of time. From the above information it can be concluded that perhaps as much as 40-50% of the Norwegian strawberry production is in areas with an annual precipitation of more than 1 000 mm. In addition, these areas often have wet autumns and mild winters with soil temperatures favourable for the red core disease.

4.2.2.3 Cultural practices and control measures

Strawberry is grown as a perennial crop in Norway. The plants are commonly grown for 2-4 years before the field is being planted with another crop in the rotation. The presence of *P. fragariae* in the field is likely to build up and cause more damage under perennial cultivation systems than under annual cultivation systems. In the case of a transfer from perennial to annual cultivation systems, *P. fragariae* would possibly cause less damage, provided that disease-free plants were used for planting.

Reduction in red core disease has been achieved by growing plants on ridges or raised beds (Montgomerie and Kennedy 1982). Cultivation of strawberry in high plastic tunnels appears to reduce problems with red core, possibly due to avoidance of excessive precipitation. Heiberg (1995) in Norway obtained good control of *P. rubi* in raspberries with raised beds when combined with efficient chemicals. However, the use of raised beds in perennial strawberry production the PRA area is problematic as the plants become more exposed to frost during the winter.

Crop has a limited effect since the resting spores of the pathogen can remain viable in the soil for many years without host plants and since the small size of many Norwegian farms would not allow long crop rotation.

Some fungicides, such as metalaxyl and fosetyl-aluminium can decrease the level of red core (McIntyre and Walton 1981, Lauber et al. 1984, Montgomerie 1984a, Seemüller 1984, Duncan 1985, Stensvand 1996). The only fungicide currently registered against red core in the PRA area is Aliette (fosetyl-aluminium).

There is genetic variation among strawberry genotypes in their resistance resistance to red core (Hickman 1940, Reid 1949, Montgomerie 1984a). Van de Weg (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 avirulence genes. 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.

1989). Both in Europe, Canada and USA there are a number of red core-resistant varieties being grown (Milholland 1994). The main strawberry varieties grown in Norway in recent years are 'Korona', 'Polka', 'Florence', 'Senga Sengana', and 'Frida'. 'Sonata' is a new variety which has become popular the past two years. Korona' and 'Senga Sengana' have been found to be highly susceptible (Elema et al. 1985, Sakshaug 1990, Seemüller 1984). All the other varieties grown in Norway are also regarded as susceptible.

4.2.2.4 Conclusion on establishment potential

Soil temperatures between 0° and 10-15°C and excessive water caused by frequent rain and/or impeded drainage in the soil favours development of *P. fragariae*. Around 40-50% of the strawberry growing areas in Norway have an annual precipitation of more than 1 000 mm, while the rest have 500-1 000 mm. The red core disease may be serious in any soil when annual precipitation is 1 000 mm or more, but it might be equally serious when annual precipitation is around 500 mm if soils are heavy, compacted, or poorly drained. Heavy soils are e.g. found in certain strawberry growing areas close the coast in eastern Norway where the annual precipitation is less than 1 000 mm. However, compacted and poorly drained fields can be found all over the country. Furthermore, much of the areas in Norway with an annual percipitation of more than 1 000 mm are characterized by relatively mild winters and many days with rain during fall and winter, being ideal for establishment and development of *P. fragariae*. The relatively cool summers in the regions along the coast could further favour disease development during that time of the year. Finally, all of the important varieties grown presently in Norway are highly susceptible to the red core disease. The fact that the disease has established in five regions in the PRA area demonstrates the suitability of the climate. Once the pathogen is present in a field, it is difficult to eradicate by any other means than keeping the field free from host plants for more than 12 years. The probability of establishment upon an entry is very high with low uncertainty.

4.2.3 Probability of spread after establishment

Surveys in 1995 revealed that the pathogen was present in strawberry fields in three distinct regions: Hedmark, Aust-Agder/Vest-Agder, and Hordaland/Rogaland (Stensvand and Herrero 1997, Mattilsynet 2009a). No new cases were detected during the years 1998-2005, but in recent years previously unknown contaminated places of production in Vest-Agder, as well as in Vestfold and Møre og Romsdal have been identified (Mattilsynet 2009a,b). Section 4.1.2., table 1, gives an overview of the distribution of *P. fragariae* in the PRA area. It is not known whether the new cases are results of new entries from abroad or results of spread within the PRA area. In some cases the pathogen appears to have been present for some years before being detected. During this time it may have spread to new places of strawberry production.

4.2.3.1 Identification of pathways for spread within the PRA

Pathways:

A. Movement of strawberry plants for planting - with or without roots.

B. Movement of plants of other host species for planting – with or without roots.

C. Movement of non-host plants for planting, including seed potato, bulbs, rootstocks etc.

D. Movement of soil and other organic growth media.
E. Movement of root vegetables and potatoes not intended for planting.
F. Spread with machinery, other farm implements, footwear and animals.
G. Movement of surface water in fields and through waterways and irrigation systems.
H. Airborne movement of soil particles.

The pathogen may spread through these pathways both within a field and between fields at one place of production. However, only spread between places of production is considered here.

4.2.3.2 Probability of the pest being associated with the pathway at origin

Descriptions of the probability of the pest being associated with the pathways A-F at origin outside the PRA area are given in section 4.2.1.2. For these pathways only additional comments relevant for spread within the PRA area are given here.

Pathway A

Among the approximately 12 million strawberry plants being planted in the PRA area yearly, approximately 25-30 % are certified plants, 5-10 % are non-certified, but tested, and 60-70% are produced on the farm (*pers. comm*., Simen Myhrene, Gartnerhallen).

The guidelines for certified production of horticultural crops describe the requirements for production of certified strawberry plants for planting in the PRA area (Statens Landbrukstilsyn 2001). The original plant material must be produced in Norway, or it must have been under quarantine and subsequently found to be free from *P. fragariae* using certain specified methods. Strawberry fields for certified plant production must have a distance to fields with berry production of at least 50 m (within the place of production) or 100 m (fields at neighbouring places of production). Berry fields within the same place of production can be maintained for a maximum of 3 years (Southern and Middle Norway) or 4 years (Northern Norway) and ”Pick your own operations” must not occur. The nuclear stock used for certified plant production must be tested and found to be free from *P. fragariae.*

With the current certification scheme the probability of the pathogen being associated with the pathway of certified strawberry plants (with or without roots) is considered to be very low. The uncertainty of this assessment is low.

Trade with non-certified strawberry plants is permitted if the following conditions are fulfilled: 1) It must be officially stated that *P. fragariae* is not known to occur at the place of production, 2) plants at the place of production must have been tested for *P. fragariae* during the last finished growth period and 3) it can be documented that the plant material is of Norwegian origin or, if not, that the original material has undergone quarantine treatment and has been tested and found to be free from *P. fragariae* (and other quarantine diseases) (Landbruks og Matdepartementet 2000). In the survey program in 2008 the places of production (berry production only) were sampled at a rate of about 25% (Mattilsynet 2009a). The sampling was partly concentrated around risk areas, and partly randomized. Samples were taken from all counties in spring (up to 3 weeks after soil thawing) or in September/October and analysed with Duncans root-tip bait test (Duncan 1980b, 1984). One to three samples, each consisting of 20 plants, were taken from each tested place of production. Plants with an unhealthy appearance

and plants located in badly drained parts of the fields were preferred. Five out of 170 tested places of production (3%) were found to be contaminated (four in a county that was already contaminated, and one in a county previously regarded as non-infected). This suggests that more contaminated places of production may have been found if they had all been tested. The testing of non-certified plants for planting is also done using Duncans root-tip bait test. In this testing program, fields with mother plants are sampled yearly. Several samples, each consisting of 20 plants, are taken in spring or in autumn. The number of samples depends on the area, e.g. 4 samples are taken from a field of 5000 plants (approximately 0.1 hectare) and 11 samples are taken from a field of 600 000 plants. Plants are sampled across the field, but if there are plants with an unhealthy appearance in the field these must be included in the sample (Mattilsynet 2006). According to Duncan (1984) the root-tip bait test is sensitive and can detect one infected plant in five hundred. Even if the sampling is partly directed to unhealthy-looking plants, there might still be escapes, particularly if the infection level is low. There will probably be a higher rate of escapes if the samples are taken too late in spring or too early in autumn. According to Lauber et al. (1984) and Howell and Rankin (1984) symptoms do not appear until late September in Switzerland and in Scotland.

The probability of the pathogen being associated with the pathway of legally traded strawberry plants (with or without roots) originating from non-certified plant production in the PRA area is considered to be low. The uncertainty level of this assessment is medium.

It cannot be ruled out that illegal production and trade might occur, or that other forms of transportation of strawberry plants occur (e.g. gifts between private garden owners). In these cases the probability of association with the pathway would be medium, with a high level of uncertainty.

Pathway B

Raspberry is commonly grown by strawberry growers, particularly in the Western Counties of the PRA area. This is, at present, not the case for other host plants. Most of the traded raspberry plants for planting are certified plants. For contaminated places of production the probability of the pathogen being associated with pathway B is therefore considered to be medium for raspberry plants and low for other host plants. For places of production assumed not to be contaminated the probabilities are considered to be low and very low for raspberry plants and other host plants, respectively. The uncertainty level of these assessments is medium.

Pathway C, D and E

Potatoes are commonly grown in crop rotation with strawberries. To our knowledge, production of non-host plants for planting, soil and other organic growth media and other root vegetables than potato are not commonly associated with the same fields as strawberry production. At contaminated places of production the probability of the pathogen being associated with the pathway is therefore considered to be medium for seed potatoes and very low for other non-host plants for planting, as well as for pathway D and E. At places of production not assumed to be contaminated the probabilities are considered to be low for seed potato and very low for the other pathways. The uncertainty level of these assessments is medium.

Pathway F

Sharing of machines and land lease are common practices among strawberry growers in the PRA area. The probability of the pathogen being associated with pathway F at origin is therefore considered to be high for contaminated places of production, while it is considered to be low for places of production assumed not to be contaminated. There are no published results to support these assumptions, and the uncertainty level is therefore high.

Pathway G

Irrigation of strawberry fields is common practice in many places in the PRA area. In Washington, USA, other *Phytophthora* species can survive in rivers, spread with irrigation and cause sprinkler rot of pear and apple (Covey and Harris 1990, Yamak et al. 2002). Zoospores can also travel in surface water runoff (Duniway 1983), and spread of *P. fragaria* down slopes is often observed in strawberry fields (Hickman 1940). At a contaminated place of production the probability of the pathogen being associated with pathway G is therefore considered to be high to low, depending on the extent of artificial irrigation and topography. At places of production not known to be contaminated the probability is considered to be low. The uncertainty level is medium.

Pathway H

Soil particles carrying propagules of the pathogen may be carried by air movements. However, the volumes of soil translocated from one field to another in this way are very small. The probability of the pathogen being associated with pathway H at origin is therefore considered to be very low, except in the situation where a non-contaminated field is not separated from an adjacent contaminated field by trees or a similar barrier. In such cases the probability of the pathogen being associated with pathway H at origin is considered to be medium. There are no published results supporting these assessments, and the uncertainty level is therefore high.

4.2.3.3 Probability of survival and multiplication during transport or storage

The probability of survival and multiplication during transport or storage for pathway A-E is described in section 4.2.1.3.

Pathway F, G and H

Oospores can survive in soil for at least up to 12 years (Newton et al. 2010). There is a high probability that oospores are able to survive transportation with machines, farm equipment, footwear, water and wind for a considerable length of time, but this has, to our knowledge, never been studied. The uncertainty of this assessment is therefore high. *P. fragariae* is not able to multiply in the absence of a host.

4.2.3.4 Probability of pest surviving existing pest management procedures

The phytosanitary measures to control spread of *P. fragariae* within the PRA area include certified production of strawberry plants for planting, compulsory testing of non-certified strawberry plants to be traded, field surveys, and a number of measures implemented at those places of production where the pathogen is detected. The probability of the pest “surviving”

certified production and testing of non-certified plants to be traded has been covered in section 4.2.3.2, and will not be dealt with here. When *P. fragariae* is detected at a place of production, the Norwegian Food Safety Authority determines control measures in each case (*pers. comm.* K. Romstad, Norwegian Food Safety Authority). These measures are meant to limit further spread and normally imply that:

- trade with plants or transplants of strawberry or crosses with other *Fragaria* species from the place of production is prohibited
- trade with other field grown plant material with roots is prohibited
- trade with soil and other organic growth media is prohibited
- potatoes and root vegetables to be used as food can only be traded under conditions where spread of contaminated soil to new places of production is prevented
- machines, tools and equipment can only be shared with other growers if properly cleaned
- a buffer zone where strawberry production is prohibited is set up around the place of production and next to watercourses passing through. The area of the buffer zone is determined by topography, soil type and climate.

A contaminated property is regarded as contaminated for 15 years after the last year of strawberry production. Contaminated properties are monitored regularly.

Although the probability of *P. fragariae* surviving the strict measures applied upon detection at a place of production is low for pathway A, B, C and D, surveys of the presence of *P. fragariae* in the whole PRA area are not performed on a regular basis, and, in addition, some contaminated fields that are tested may escape detection. This is expected to be the case for up to a few percent of apparently non-contaminated places of production (see section 4.2.3.2). For this reason, the overall probability of the pathogen surviving pest management procedures is considered to be medium for pathway A, B, C and D. The uncertainty level of this assessment is medium.

It is difficult to ensure that routines for preventing spread with traded potatoes and vegetables and cleaning routines for machinery are adequate. There are no regulations preventing spread with footwear, and spread may be facilitated by domestic and wild animals as well. In addition, it is likely that some contaminated places of production exist without being detected, as described above. The overall probability of the pathogen surviving the pest management procedures is therefore considered to be low for pathway E, G and H and medium for pathway F. There are no research results that support these assessments, and the uncertainty level is therefore high.

4.2.3.5 Probability of transfer to a suitable host

Descriptions of the probability of transfer to a suitable host with the pathways A-E are given in section 4.2.1.5.

The pathogen can spread through pathway F-H and infect both cultivated host plants and wild host plants, particularly species of *Fragaria* and *Rubus*, some of which are common in strawberry growing areas. Infected wild plants may then constitute a reservoir of inoculum. The probability of transfer to a suitable host (cultivated or wild) is considered to be medium, low

and very low for pathway F, G and H, respectively. There are no published results to support these assessments and the level of uncertainty is therefore high.

If *P. fragariae* establishes in wild host plant populations surrounding agricultural fields, these populations may maintain the inoculum indefinitely. Inoculum may spread back into strawberry fields, particularly in parts of the PRA area where strawberry fields are commonly irrigated. However, the potential for maintenance of the pathogen in wild populations and further spread from these have not been studied and no assessments of the probabilities can be made.

4.2.3.6 Summarised probability of spread within the PRA area

The components of probability of spread within the PRA area for each of the identified pathways described above are given in Table 4.

With all the current pest management procedures the probability of spread of *P. fragariae* with certified strawberry plants and legally traded, non-certified strawberry plants is considered to be very low and low with a low and medium level of uncertainty, respectively. The probability of spread with raspberry plants, machinery, farm implements, footwear and animals is medium, with a high uncertainty level. The probability of spread with other host plants for planting than strawberry and raspberry, seed potatoes, surface water, waterways and irrigation systems is considered to be low, with a high uncertainty level. The probability of spread with other non-host plants for planting than seed potatoes, soil, other organic growth media and airborne soil particles is considered to be very low, with a high uncertainty level. The probability of spread with potatoes and root vegetables not intended for planting is considered to be very low, with a medium level of uncertainty.

Without the current pest management procedures, the probability of spread of *P. fragariae* with strawberry plants is considered to be very high, with low uncertainty. The probability of spread is considered to be high for raspberry plants, medium for, seed potatoes, animals, machinery, farm implements, footwear, surface water, waterways and irrigation systems, and low for other plants for planting than strawberry, raspberry and seed potatoes, soil, other organic growth media and airborne soil particles. The uncertainty level of these assessments is high. The probability of spread with potatoes and root vegetables not intended for planting is considered to be very low, with a medium level of uncertainty.

Table 4. Probability of spread of *Phytophthora fragariae* within the PRA area by the identified pathways. A high (H), medium (M) or low (L) uncertainty level is indicated in brackets.

<table>
<tr><th>Pathway</th><th>Association with pathway at origin</th><th>Survival and multiplication during transport or storage</th><th>Survival of pest under existing pest management procedures[1]</th><th>Transfer to suitable host (cultivated or wild)</th></tr>
<tr><td>A. Strawberry plants</td><td>Certified plants: Very low (L)
Non-certified plants: Low (M)</td><td rowspan="2">Very high (L)</td><td rowspan="4">Medium (M)</td><td>Very high (L)</td></tr>
<tr><td>B. Other host plants</td><td>Raspberry: Medium to low[2] (M)
Other host plants: Low to very low[2] (M)</td><td>From raspberry: Medium (H)
From other species: Low (H)</td></tr>
<tr><td>C. Non-host plants for planting</td><td>Seed potato: Medium to low[2] (M)
Other plants: Very low (M)</td><td rowspan="3">Survival: Very high (L)
Multiplication: Nil (L)</td><td rowspan="3">Low (H)</td></tr>
<tr><td>D. Soil and other organic growth media</td><td rowspan="2">Very low (M)</td></tr>
<tr><td>E. Potatoes and root vegetables not intended for planting</td><td>Low (H)</td></tr>
<tr><td>F. Machinery, other farm implements, footwear and animals.</td><td>High to low[2] (H)</td><td rowspan="3">Survival: High (H)
Multiplication: Nil (L)</td><td>Medium (H)</td><td>Medium (H)</td></tr>
<tr><td>G. Surface water, waterways and irrigation systems</td><td>High to low[2] (M)</td><td rowspan="2">Low (H)</td><td>Low (H)</td></tr>
<tr><td>H. Airborne soil particles.</td><td>Medium to very low[2] (H)</td><td>Very low (H)</td></tr>
</table>

[1]The pest management procedures considered in this column include surveys and the measures implemented at the places of strawberry production where *P. fragariae* has been detected.

[2]Depending on whether the place of production, or the region, is contaminated or not, and other factors, see section 4.2.3.2.

4.2.4 Conclusion on the probability of introduction and spread

Probability of entry

Under the current import regulations, there is a medium probability of entry with import of raspberry plants and a low probability of entry with all the other identified pathways. The uncertainty levels of these assessments are high. Without the current import regulations, there is a very high probability of entry through import of non-certified strawberry plants (low uncertainty) and a low probability of entry through the other pathways (high uncertainty).

Probability of establishment

Environmental conditions in most strawberry growing areas are suitable for the establishment and development of *P. fragariae*. The probability of establishment upon an entry of the pathogen is therefore very high with a low level of uncertainty.

Probability of spread

With the current pest management procedures, the probability of spread with raspberry plants and with pathway F (machinery etc.) is medium with a high level of uncertainty. The probability of spread with legally traded, non-certified strawberry plants, seed potatoes and with pathway G (water) is low while the probability of spread of the remaining identified pathways is very low. The level of uncertainty is low for certified strawberry plants, medium for legally traded, non-certified strawberry plants, and high for the remaining pathways.

Without the current pest management procedures, the probability of spread with strawberry plants is very high with a low level of uncertainty. The probability of spread with raspberry plants is high with a high level of uncertainty. The probability of spread with seed potatoes and with pathway F (machinery etc.) and G (water) is medium with a high level of uncertainty. The probability of spread with plants for planting than strawberry, raspberry and seed potatoes and with pathway D (soil) and H (air) is low with a high level of uncertainty. The probability of spread with root vegetables and potatoes not intended for planting is very low with a medium level of uncertainty.

4.3 Endangered area

Endangered areas are all strawberry-growing areas in the whole PRA area.

5. CONCLUSION OF THE PEST RISK ASSESSMENT

Pest status of the PRA area

The pest of concern in this pest risk assessment is the oomycete *Phytohthora fragariae* Hickman, the causal agent of red core in strawberry. The PRA area is Norway. *P. fragariae* is present in at least five geographically separated and limited regions of the PRA area. These regions are located in the counties of i) Hedmark, ii) Aust-Agder and Vest-Agder, iii) Hordaland and Rogaland, iv) Vestfold, and v) Møre og Romsdal. It is probable that the pathogen is present at some places of production without having been detected yet. The pathogen is regulated a quarantine pest in the PRA area.

Probability of introduction and spread

With the current import regulations there is a medium probability of introduction of *P. fragariae* through import of infected *Rubus* plants for planting and a low probability of introduction through import of other consignments. However, there is little updated information available on the presence of the pathogen in different production systems, and there is only very limited evidence for that the pathogen can actually spread by other means than strawberry plants. The level of uncertainty is therefore high.

Without the current import regulations there would be a very high probability of introduction through the import of non-certified strawberry plants. The level of uncertainty of this assessment is low. The probability of introduction through import of certified strawberry plants is considered low, but without detailed information on the presence/absence of the pathogen in such material the level of uncertainty is high.

With the current pest management procedures the probability of spread within the PRA area is medium for raspberry plants and machinery, other farm implements, footwear and animals. The probability of spread through remaining pathways ranges from low (legally traded, non-certified strawberry plants, seed potatoes, surface water, waterways and irrigation systems) to very low (remaining pathways). The level of uncertainty is low for certified strawberry plants and medium for legally traded, non-certified strawberry plants. Due to limited knowledge on the spread and survival of the pathogen, the level of uncertainty is high for all other pathways.

Without the current pest management procedures the probability of spread with strawberry plants would be very high with a low level of uncertainty. The probability of spread with raspberry plants would be high and the probability of spread with seed potatoes, machinery, other farm implements, footwear, animals, surface water, waterways and irrigation water would be medium. The probability of spread through remaining pathways would range from low to very low. The level of uncertainty is low for strawberry plants, but due to limited knowledge on the spread and survival of the pathogen, the level of uncertainty is generally high for all other pathways.

Conclusion regarding endangered areas

Endangered areas are all strawberry-growing areas in the whole PRA area.

6. ANSWERS TO SPECIFIC ISSUES MENTIONED IN TERMS OF REFERENCE

The Norwegian Food Safety Authority requested that the following issues were considered in particular (see chapter 2):

1. The probability that the pathogen has been spread to parts of the PRA area were it has not yet been discovered.

As described in section 4.2.3.2, there is high probability that some of the places of production that have not yet been tested may be contaminated. Since the sampling in the surveys has been partly targeted it is not possible to estimate the frequency of contaminated places accurately, but it is likely to fall in the range of 0-3% of non-tested places, possibly more if the detection methods involve a high proportion of false negatives. A place of production within one of the contaminated regions (Table 1) is more likely to be contaminated than a place of production in a non-contaminated area (Table 2). However the discoveries of contaminated places of production in new regions in recent years (Vestfold and Møre og Romsdal) and the general environmental suitability for *P. fragariae* in the strawberry growing regions across the whole PRA area (see section 4.2.2.2) indicates that the pathogen may be present in any part of the PRA area.

2. The importance of sampling time, sampling density and sampling frequency for successful detection of the pathogen in different certified strawberry plant production systems.

As described in section 4.2.3.2, the test being used (Duncans root-tip bait test) has been shown to be sensitive (Duncan 1984). Symptoms are much more severe in late autumn, winter and early spring than during the rest of the year. Some recommendations on testing for *P. fragariae* in certified plant production systems is given in the EPPO certification scheme for pathogen-tested strawberry (EPPO 1994).

3. Description and importance of pathways of dispersal from infected places of production, including how dispersal is affected by: cultivation method, machinery, topography, distance, vegetation/host plants, season/climate, soil type/drainage and speed of water movement in rivers and streams.

A description of pathways for spread within the PRA area, including assessments of their importance is given in section 4.2.3 and summarised in 4.2.3.6.

4. Consequences of the establishment of *P. fragariae* in natural vegetation for maintenance of inoculum potential at and around present or future places of strawberry production.

If *P. fragariae* establishes in wild host plant populations surrounding agricultural fields, these populations may maintain the inoculum indefinitely. To our knowledge, however, such a mechanism of maintenance and spread has never been studied and scientific evidence is therefore not available on this matter.

5. Evaluation of management options to the current phytosanitary measures:

- elimination of the requirement of buffer zones to neighbours and waterways

The buffer zones may limit spread of the pathogen through movement of water, airborne soil particles and mobile soil-inhabiting organisms. An elimination of buffer zones is likely to cause increased risk of spread with surface water moving down slopes, via watercourses and with artificial irrigation. In cases where such spread is not relevant and adjacent fields are separated by trees or a similar barrier, an elimination of buffer zones will have little effect on the spread of the pathogen.

- permission for field production and trade of plant material other than strawberry, e.g. nursery plants, raspberry plants, seed potato, turf

Permitting strawberry growers with *P. fragariae*-contaminated fields to produce raspberry plants in the field and distribute them further will result in a high probability of spread of the pathogen. Permission for field production and trade of other plants will imply a slightly increased probability of spread of the pathogen.

- elimination of the requirement for washing machinery and tools between contaminated and non-contaminated sites

An elimination of the requirement for washing machinery and tools between usage at contaminated and non-contaminated sites would imply a strong increase in probability for spread of the pathogen.

- concentrate the phytosanitary measures on strawberry plant production and not on berry production.

The effects of putting more phytosanitary efforts into strawberry plant production at the cost of phytosanitary efforts in berry production depends on the prevalence of the pathogen and on the production systems used. The more common the pathogen is the more important are measures relating to plant production. And in an annual strawberry production system, spread through other pathways than transport of strawberry plants are likely to have less consequence than in a perennial production system.

At present, raspberry plants for planting, machinery, other farm implements, footwear and animals are regarded as the most important source of spread to new fields (see section 4.2.3.6). It therefore appears that more focus on plant production at the cost of berry production will not have positive effects.

- change the management by moving *P. fragariae* from Annex 1 to Annex 2 “Regulations relating to plants and measures against pests” in the Act of 19 December 2003 No. 124 relating to Food production and safety (Matloven)”.

Moving *P. fragariae* from annex 1 to annex 2 will imply that prohibition of introduction and spread of *P. fragariae* will not be general, but limited to situations were the pathogen is present in certain plants or other regulated articles. The effect of moving *P. fragariae* from annex 1 to annex 2 would therefore depend on which plants and articles would be listed in annex 2. If import and spread of *P. fragariae* was prohibited when present on *Fragaria* and *Rubus* plants, the two potentially most important pathways of introduction and spread would be controlled (low level of uncertainty).

However, the probability of spread with seed potatoes, animals, machinery, other farm implements and footwear, as well as with surface water, ditches, streams, rivers and irrigation water would increase (high level of uncertainty).

- removal of the prohibition on import of *Fragaria* plants and transplants for propagation.

A removal of the prohibition on import of *Fragaria* plants and transplants for propagation would imply a very high probability of introduction with non-certified plants (low uncertainty) and a low probability of introduction with certified plants (high uncertainty).

Based on current knowledge, many of the questions asked by the Norwegian Food Safety Authority cannot be answered properly. New scientific evidence through major research efforts are required to be able to provide more exact and certain answers.

7. REFERENCES

Alcock, N.L., Howells, D.V., Foister, C.E. 1930. Strawberry disease in Lanarkshire. The Scottish Journal of Agriculture 13:242-251.

Alcock, N.L., Howells, D.V. 1936. The *Phytophthora* disease of strawberry. Scientific Horticulture 4:52-58.

Anderson, H.W. 1935. Black stele root rot of strawberry. Phytopathology 25:5.

Bain, H.F., Demaree, J.B. 1945. Red stele root disease of the strawberry caused by *Phytophthora fragariae*. Journal of Agricultural Research 70:11-30.

Bonants, P.J.M., van Bentzx-Peltzer, M.P.E., Hagenaar-de Weerdt, M. 2000. Characterization and detection of *Phytophthora fragaria* in plant, water and soil by molecular methods. OEPP/EPPO Bulletin 30:525-531.

Covey, R. P., Harris, D.C. 1990. *Phytophthora* fruit rots of pear and apple. In: A Compendium of Apple and Pear Diseases. The American Phytopathological Society, St. Paul, MN. p. 30-31.

Duncan, J.M. 1980a. Persistence of mycelium of *Phytophthora fragariae* in soil. Transactions of the British Mycological Society 75:383-387.

Duncan, J.M. 1980b. A technique for detecting red stele (*Phytophthora fragariae*) infection of strawberry stocks before planting. Plant Disease 64:1023-1025.

Duncan, J.M., Cowan, J.B. 1980. Effect of temperature and soil moisture content on persistence of infectivity of *Phytophthora fragariae* in naturally infested field soil. Transactions of the British Mycological Society 75:133-139.

Duncan, J.M. 1984. III. Current systems for detection, certification and control in United Kingdom: Detection and identification of red core disease of strawberries. EPPO Bulletin 14:106-107.

Duncan, J.M. 1985. Effect of fungicides on survival, infectivity and germination of *Phytophthora fragariae* oospores. Transactions of the British Mycological Society 85:585-593.

Duncan, J.M., D.M. Kennedy. 1995. Effect of temperature and host genotype on the production of inoculum by *Phytophthora fragariae* var. *fragariae* from the roots of infected strawberry plants. Plant Pathology 44:10-21.

Duniway J.M. 1983. Role of physical factors in the development of *Phytophthora* diseases. In Erwin DC, Bartnicki-Garcia S, Tsao PH, eds. *Phytophthora*: Its biology, Taxonomy, Ecology, and Pathology. St. Paul, MN, USA: APS Press, p. 175-187.

EC 2000. 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. Official Journal of the European Union. L169. 10.7.2000. p. 1-112.

http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2000:169:0001:0112:EN:PDF

Elema, R.K., Hijink, M.J., Elzenga, G., Groot, A., Hogenboom, N.G, Rijkenbarg**,** G.J.H., Stadhouders, P.J. 1985. 17e Rassenlijst voor Fruitgewassen. (Wageningen). Leiter-Nypels, Maastricht, The Netherlands. 201 pp.

Elven, R., Lid, D.T., Lid, J. 2005. Norsk Flora, 7. utg. Det Norske Samlaget, Oslo. ISBN 9788252160291

EPPO 1984. International discussion meeting on red core disease of strawberries. EPPO Bulletin 14:97-117.

EPPO 1994. Certification scheme, pathogen-tested strawberry. EPPO Bulletin 24:875-889.

EPPO 1998. Phytosanitary procedure. *Phytophthora fragariae*. Inspection and test methods. Eppo Standards PM3/22(1).

http://archives.eppo.org/EPPOStandards/PM3_PROCEDURES/pm3-22-e.doc

EPPO 2008. Certification scheme for strawberry. EPPO Bulletin 38:430–437

EPPO 2009. EPPO A2 List of pests recommended for regulation as quarantine pests. Version 2009-09.

http://www.eppo.org/QUARANTINE/listA2.htm

EPPO 2010. Plant Protection Thesaurus, http://eppt.eppo.org/search.php). Accessed 13.04.2010

EPPO Quarantine Data Retrieval System 2010, http://www.eppo.org/DATABASES/pqr/pqr.htm)

FAO 2004. ISPM No. 11. Pest risk analysis for quarantine pets including analyses of environmental risks and living modified organisms. Food and Agricultural Organization of the United Nations, Rome.

https://www.ippc.int/file_uploaded/1146658377367_ISPM11.pdf

Fulton, R.H. 1959. Spread of strawberry red stele rot, *Phytophthora fragariae*, by resistant varieties and the survival period of the organism. Plant Disease Reporter 43:270-271.

Heiberg, N. 1995. Control of root rot of red raspberries caused by *Phytophthora fragariae* var. *rubi*. Plant Pathology 44: 153-159.

Hickman, C.J. 1940. The red core root disease of the strawberry caused by *Phytophthora fragariae n.sp.* Journal *of* Pomology and Horticultural Science 18:89-118.

Hickman, C.J., English, M.P. 1951. Factors influencing the development of red core in strawberries. Transactions of the British Mycological Society 34:223-236.

Howell, P.J., Rankin, P.A. 1984. Red core of strawberry; Certification in Scotland. EPPO Bulletin 14:110-113

Index Fungorum Partnership 2008. The Dictionary of the Fungi, 10th edition, accessed 26. May 2010.

http://www.indexfungorum.org/,

Ioos, R., Laugustin, L., Schenck, N., Rose, S., Husson, C., Frey, P. 2006. Usefulness of singel copy genes containing introns in *Phytophthora* for the development of detection tools for the regulated species *P. ramorum* and *P. fragariae*. European Journal of Plant Pathology 116:171-176.

Landbruks- og matdepartementet 2000. Regulations relating to plants and measures against pests

http://www.mattilsynet.no/mattilsynet/multimedia/archive/00056/Regulations_relating_56195a.pdf

Lauber, H.P., Pelet, F., Miauton, P. 1984. Switzerland. I. Importance of red core disease in EPPO countries: Switzerland. EPPO Bulletin 14:105-106.

Law, T.F., Milholland, R.D. 1992. Susceptibility of strawberry genotypes to infection and colonization by *races* of *Phytophthora fragariae* and the growth responses of inoculated genotypes. Plant Disease 76:335-339.

Maas, J.L., Galletta, G.J., Draper, A.D. 1989. Resistance in strawberry to races of *Phytophthora* fragariae and to isolates of Verticillium from North America. Acta Horticulturae 265:521-526.

Man in 't Veld, W.A. 2007. Gene flow analysis demonstrates that *Phytophthora fragariae* var. *rubi* constitutes a distinct species, *Phytophthora rubi* comb. nov. Mycologia 99:222-226.

Mattilsynet 2006. Retningslinje. Prøveuttak for undersøkelse av rød marg (*Phytophthora fragariae* var. *fragariae*) i planteproduksjon av jordbær. Intern retningslinje. 2006/764-5.

Mattilsynet. 2009a. Rød marg i jordbærproduksjon. Rapport fra kartleggingsundersøkelse 2008.

http://www.mattilsynet.no/planter/plantehelse/overvakning_kontroll/resultater/rapport_fra_kartleggingsunders_kelse_for_r_d_marg_i_norsk_jordb_rproduksjon_2008_70487

Mattilsynet. 2009b. Raud marg påvist hos jordbærprodusent i Norge.

http://www.mattilsynet.no/smittevern_og_bekjempelse/planter/hendelser/raud_marg_p_vist_hos_jordb_rprodusent_i_molde__72211

Mattilsynet 2010. Funn av rød marg i jordbæråker i Vestfold.

http://www.mattilsynet.no/smittevern_og_bekjempelse/planter/hendelser/funn_av_r_d_marg_i_jordb_r_ker_i_vestfold_81751

McIntyre, J.L., Walton, G.S. 1981. Control of strawberry red stele caused by Phytophthora fragariae. Plant Disease 65:835-836.

McKeen, W.E. 1958a. Red stele disease of the loganberry and strawberry caused by *Phytophthora fragariae*. Phytopathology 48:129-132.

McKeen, W.E. 1958b. Races and resistance to *Phytophthora fragariae*. Plant Disease Reporter 42:768-771.

Milholland, R.D. 1994. A monograph of Phytophthora fragariae and the red stele disease of strawberry. North Carolina Agricultural Research Service, North Carolina State University, Technical Bulletin 306. 35 pp.

Montgomerie, I.G. 1951. Studies of red core root disease of the strawberry caused by *Phytophthora fragariae* Hickman. Ph.D. thesis, Edinburgh University.

Statens landbrukstilsyn (Mattilsynet) 2001. Retningslinjer for sertifisert produksjon av Hagebruksvekster.

http://www.mattilsynet.no/mattilsynet/multimedia/archive/00012/Retningslinjer_for_s_12619a.pdf

Montgomerie, I.G., Kennedy, D.M. 1982. The effects of dazomet, fenaminosulf, and soil ridges on red core disease of strawberry. Annals of Applied Biology 100:443-455.

Montgomerie, I.G. 1984a. Control of red core (*Phytophthora fragariae*) in strawberries. EPPO Bulletin 14:115-116.

Montgomerie, I.G. 1984b. Red stele root rot. *pp. 79-83 In:* J.L. Maas (ed.). Compendium of strawberry diseases. APS Press. 138 pp.

Moore, J.N., Scott, D.H., Converse, R.H. 1964. Pathogenicity of *Phytophthora fragariae* to certain Potentilla species. Phytopathology 54:173-176.

Newton, A.C., Duncan, J.M., Augustin, N.H., Guy, D.C., Cooke, D.E.L. 2010. Survival, distribution and genetic variability of inoculum of the red cores pathogen, *Phytophthora fragariae* var. *fragariae*, in soil. Plant Pathology 59:472-479.

Reid, R.D. 1941. Red core disease of the strawberry. The Scottish Journal of Agriculture 23:264-272.

Reid, R.D. 1949. Breeding strawberries for disease resistance. Agriculture 55:476-482.

Sakshaug, K. Rödröteresistenta jordgubbssorter i forsak. Frukt- och Bärodling 32:52-54.

Scott, D.H., Maas, J.L., Draper, A.D. 1975. Screening strawberries for resistance to *Phytophthora fragariae* with single versus a composite of races of the fungus. Plant Disease Reporter 59:207-209.

Scott, D.H., Draper, A.D., Maas, J.L. 1976. Mass screening of young strawberry seedlings for resistance to *Phytophthora fragariae* Hickman. HortScience 11:257-258.

Seemüller, E. 1984. I. Importance of red core disease in EPPO countries: Federal Republic of Germany (FRG). EPPO Bulletin 14:99-100.

Statens Landbrukstilsyn 2001. Retningslinjer for sertifisert produksjon av hagebruksvekster.

http://www.mattilsynet.no/mattilsynet/multimedia/archive/00012/Retningslinjer_for_s_12619a.pdf

Statens landbrukstilsyn 2003. Karantenebestemmelser for planter og plantemateriale m.m. som er forbudt å innføre til Norge.

http://www.mattilsynet.no/mattilsynet/multimedia/archive/00008/Karantenebestemmelser_8258a.pdf

Statens Landbruksforvaltning 2010. Erstatning etter offentlig pålegg som følge av planteskadegjørere.

http://www.slf.dep.no/portal/page?_pageid=53,424051&_dad=portal&_schema=PORTAL&p_d_i=-201&p_d_c=&p_d_v=2306&p_d_i=-181&p_d_c=&p_d_v=2306&p_d_i=-301&p_d_c=&p_d_v=2188&p_d_i=-283&p_d_c=&p_d_v=2188

Stensvand, A. 1996. Pest risk assessment for Norway of the red stele disease in strawberries, caused by *Phyotophthora fragariae* var. *fragariae*. Planteforsk.

http://www.mattilsynet.no/planter/plantehelse/skadegjorere/fakta_om_planteskadegjorere/r_d_marg__i_phytophthora_fragariae__i__var___i_fragariae_i____fakta_om_58174

Stensvand, A., Herrero, M.L. 1997. Presence of *Phytophthora fragariae* var. *fragariae* in Norway. EPPO Bulletin 27:243-248.

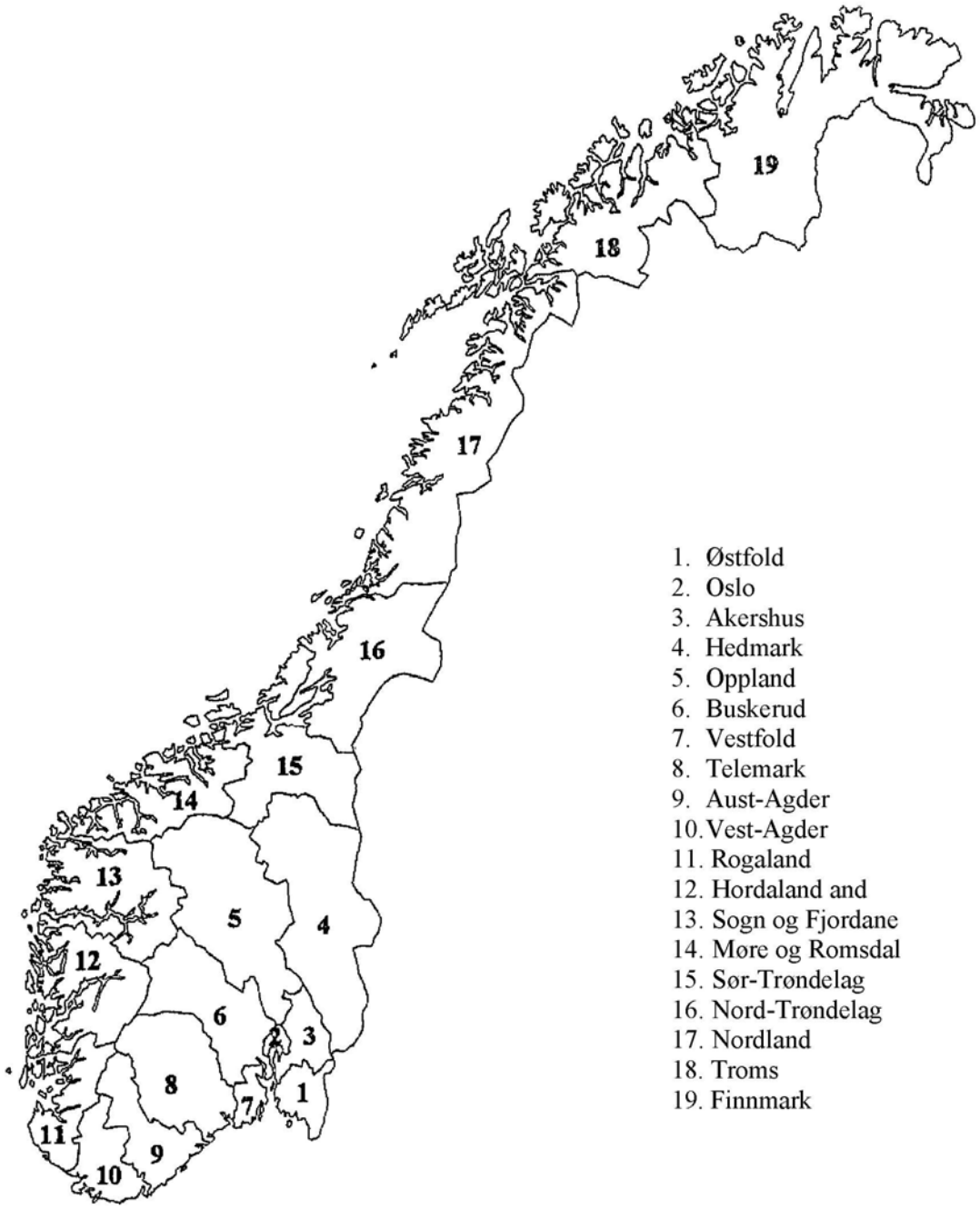
Van de Weg, W.E. 1997. A gene-for-gene modell to explain interactions between cultivars of strawberry and races of *Phytophthora fragariae* var. *fragariae*. Theoretical and Applied Genetics 94:445-451.

Wilcox, W.F., Scott, P.H., Hamm, P.B., Kennedy, D.M., Duncan, J.M., Brasier, C.M., Hansen, E.M. 1993. Identity of a *Phytophthora* species attacking raspberry in Europe and North America. Mycological Research 97:817-831.

Wynn, W.K. 1967. A defined method for the laboratory study of red stele of strawberries. (Abstract). Phytopathology 57:837

Yamak, F., Peever, T.L., Grove, G.G., Boal, R.J. 2002. Occurrence and identification of *Phytophthora* spp. Pathogenic to pear fruit in irrigation water in the Wenatchee river valley of Washington State. Phytopathology 92:1210-1217.

ANNEX 1. MAP OF NORWEGIAN COUNTIES.



ANNEX 2. CLIMATE DATA.

Table 1. Tomb, Østfold County.

Climatological normals for the period 1961-1990 for mean air temperature (°C) and amount of precipitation (mm) provided by the Norwegian Meteorological Institute; soil temperature (°C) 10 cm below ground for the period 1991-1995 provided by the Agro-Meteorological Service at Bioforsk - Norwegian Institute of Environmental and Agricultural Research.

	Climatological normals		Soil temperature				
Month	Temp.	Precip.	1991	1992	1993	1994	1995
January	-4.8	59	-0.3	0.4	0.3	0.1	1.2
February	-4.6	44	-2.6	-0.4	-0.1	0.1	0.8
March	-0.8	54	0.2	2.0	0.3	0.0	1.6
April	4.2	42	5.4	4.1	4.1	4.7	4.8
May	10.3	57	9.5	9.4	12.0	9.3	8.5
June	14.7	66	12.4	15.3	13.6	10.8	14.4
July	16.1	72	15.9	16.2	14.6	16.4	15.8
August	15.0	74	16.7	14.6	13.3	16.0	17.1
September	10.6	92	12.4	11.7	9.1	11.9	13.2
October	6.0	83	7.6	6.0	6.0	7.1	10.7
November	0.6	90	3.5	2.6	2.3	4.2	3.4
December	-3.0	64	1.3	1.7	0.3	2.6	0.9

Table 2. Ås, Akershus County.

Climatological normals for the period 1961-1990 for mean air temperature (°C) and amount of precipitation (mm) provided by the Norwegian Meteorological Institute; soil temperature (°C) 10 cm below ground for the period 1991-1995 provided by the Agro-Meteorological Service at Bioforsk - Norwegian Institute of Environmental and Agricultural Research.

	Climatological normals		Soil temperature				
Month	Temp.	Precip.	1991	1992	1993	1994	1995
January	-4.8	49	0.2	-0.4	-0.2	0.0	0.4
February	-4.8	35	-1.0	-0.9	-0.3	0.2	0.3
March	-0.7	48	-0.1	0.2	-0.2	0.1	0.3
April	4.1	39	4.4	4.1	2.8	4.0	3.1
May	10.3	60	9.0	11.0	11.4	9.7	8.7
June	14.8	68	13.0	17.1	14.4	13.3	15.0
July	16.1	81	17.7	-	15.9	18.2	16.9
August	14.9	83	16.6	15.2	14.4	16.5	17.5
September	10.6	90	12.1	12.4	10.2	11.6	12.4
October	6.2	100	7.3	6.1	5.8	6.1	9.7
November	0.4	79	2.6	1.7	2.0	2.7	1.9
December	-3.4	53	0.6	0.9	0.3	0.7	0.4

Table 3. Kise, Hedmark County.

Climatological normals for the period 1961-1990 for mean air temperature (°C) and amount of precipitation (mm) provided by the Norwegian Meteorological Institute; soil temperature (°C) 10 cm below ground for the period 1991-1995 provided by the Agro-Meteorological Service at Bioforsk - Norwegian Institute of Environmental and Agricultural Research.

	Climatological normals		Soil temperature		
Month	Temp.	Precip.	1993	1994	1995
January	-7.4	36	-2.2	-1.2	-1.2
February	-8.1	29	-	-1.1	-1.8
March	-3.1	27	-1.4	-0.9	-1.3
April	2.2	34	3.0	1.6	1.5
May	8.5	44	10.3	8.4	7.7
June	13.6	59	13.4	12.0	13.4
July	15.2	66	15.6	17.9	15.2
August	14.0	76	13.6	15.1	15.4
September	9.6	64	8.8	9.8	10.4
October	5.1	63	4.3	4.3	6.5
November	-0.8	50	0.5	2.0	-1.6
December	-5.3	37	-	-0.9	-4.9

Table 4. Apelsvoll, Oppland County.

Climatological normals for the period 1961-1990 for mean air temperature (°C) and amount of precipitation (mm) provided by the Norwegian Meteorological Institute; soil temperature (°C) 10 cm below ground for the period 1991-1995 provided by the Agro-Meteorological Service at Bioforsk - Norwegian Institute of Environmental and Agricultural Research.

	Climatological normals		Soil temperature				
Month	Temp.	Precip.	1991	1992	1993	1994	1995
January	-7.4	37	-0.3	-0.2	-1.3	0.4	-0.3
February	-7.0	26	-0.5	-0.6	-1.7	-0.1	-0.1
March	-2.5	29	-0.2	-0.1	-0.7	0.0	-0.1
April	2.3	32	3.1	1.8	1.3	1.2	0.2
May	9.0	44	9.7	11.5	10.9	9.2	8.0
June	13.7	60	13.8	18.0	14.3	12.8	13.7
July	14.8	77	18.3	16.9	15.9	18.3	16.1
August	13.5	72	16.8	14.4	-	15.6	16.6
September	9.1	66	11.1	10.7	9.6	10.4	11.1
October	4.6	64	6.2	5.1	4.8	4.6	7.4
November	-1.3	53	1.9	2.0	1.3	2.3	0.3
December	-5.3	40	0.2	-0.1	0.8	0.0	-0.6

Table 5. Lier, Buskerud County.

Climatological normals for the period 1961-1990 for mean air temperature (°C) and amount of precipitation (mm) provided by the Norwegian Meteorological Institute; soil temperature (°C) 10 cm below ground for the period 1991-1995 provided by the Agro-Meteorological Service at Bioforsk - Norwegian Institute of Environmental and Agricultural Research.

	Climatological normals		Soil temperature				
Month	Temp.	Precip.	1991	1992	1993	1994	1995
January	-5.5	70		-1.3	-0.3	0.1	0.2
February	-5.0	52		-1.3	-0.4	0.5	0.1
March	-0.4	60		1.0	-0.3	0.5	0.1
April	4.8	50		4.8	3.9	3.6	2.5
May	11.0	70		13.1	11.2	8.9	7.7
June	15.7	70		19.2	12.8	11.9	13.2
July	17.1	85		17.8	14.3	16.4	15.0
August	15.7	105		15.1	13.4	15.4	15.6
September	11.3	108		11.7	9.6	11.2	11.9
October	6.6	115	4.8	5.6	5.8	6.0	9.1
November	0.6	95	1.2	1.4	2.3	3.4	2.6
December	-3.5	70	-0.6	0.6	0.5	0.8	0.3

Table 6. Ramnes, Vestfold County.

Climatological normals for the period 1961-1990 for mean air temperature (°C) and amount of precipitation (mm) provided by the Norwegian Meteorological Institute; soil temperature (°C) 10 cm below ground for the period 1991-1995 provided by the Agro-Meteorological Service at Bioforsk - Norwegian Institute of Environmental and Agricultural Research.

	Climatological normals		Soil temperature				
Month	Temp.	Precip.	1991	1992	1993	1994	1995
January	-4.5	85	0.0	0.0	0.8	0.0	0.4
February	-4.5	60	-0.2	-0.3	-0.2	0.0	0.4
March	-0.3	68	0.1	0.5	-0.2	-	0.1
April	4.0	55	5.2	4.0	3.1	-	2.2
May	10.2	75	10.4	11.7	12.3	10.6	8.7
June	14.5	67	13.4	17.8	15.2	14.1	15.2
July	15.5	87	17.7	-	16.3	18.5	17.3
August	14.4	106	16.5	15.0	14.6	16.7	17.8
September	10.3	116	11.9	11.7	10.2	11.8	12.8
October	6.2	132	7.0	6.0	6.1	6.4	9.6
November	1.0	122	2.5	1.7	1.9	3.5	1.5
December	-3.0	87	0.5	0.7	0.4	0.8	0.1

Table 7. Bø, Telemark County.

Climatological normals for the period 1961-1990 for mean air temperature (°C) and amount of precipitation (mm) provided by the Norwegian Meteorological Institute; soil temperature (°C) 10 cm below ground for the period 1991-1995 provided by the Agro-Meteorological Service at Bioforsk - Norwegian Institute of Environmental and Agricultural Research.

	Climatological normals		Soil temperature				
Month	Temp.	Precip.	1991	1992	1993	1994	1995
January	-6.5	50	-	-	-	-	-0.3
February	-5.5	35	-	-	-	-	-0.2
March	-0.5	45	-	0.0	-	0.5	-0.1
April	4.3	40	-	3.4	4.9	3.5	1.9
May	10.4	65	-	12.0	11.9	9.8	8.1
June	14.8	65	-	18.2	15.1	13.2	14.7
July	16.0	75	-	-	16.1	16.8	16.4
August	14.5	95	-	15.2	14.2	15.7	16.8
September	9.8	95	-	12.1	10.2	10.4	11.3
October	5.5	95	5.1	4.9	7.2	4.7	8.0
November	-0.2	75	1.1	0.5	-	2.3	2.3
December	-4.5	55	-0.8	0.2	-	0.1	1.2

Table 8. Landvik, Aust-Agder County.

Climatological normals for the period 1961-1990 for mean air temperature (°C) and amount of precipitation (mm) provided by the Norwegian Meteorological Institute; soil temperature (°C) 10 cm below ground for the period 1991-1995 provided by the Agro-Meteorological Service at Bioforsk - Norwegian Institute of Environmental and Agricultural Research.

	Climatological normals		Soil temperature				
Month	Temp.	Precip.	1991	1992	1993	1994	1995
January	-1.6	113	0.2	0.6	0.5	0.7	0.1
February	-1.9	73	-0.7	-	0.3	0.4	0.0
March	1.0	85	1.0	3.4	2.1	0.7	1.1
April	5.1	58	6.2	5.4	5.7	5.9	5.4
May	10.4	82	12.0	12.0	12.3	10.8	9.5
June	14.7	71	14.0	17.9	15.7	14.2	15.2
July	16.2	92	19.1	17.4	15.7	18.1	17.3
August	15.4	113	17.8	15.4	14.4	16.8	17.9
September	11.8	136	13.4	12.9	11.0	12.1	13.0
October	7.9	162	7.8	6.6	6.8	7.4	9.9
November	3.2	143	3.7	2.6	3.0	3.9	3.4
December	0.2	102	0.9	1.8	0.9	1.6	0.2

Table 9. Særheim, Rogaland County.

Climatological normals for the period 1961-1990 for mean air temperature (°C) and amount of precipitation (mm) provided by the Norwegian Meteorological Institute; soil temperature (°C) 10 cm below ground for the period 1991-1995 provided by the Agro-Meteorological Service at Bioforsk - Norwegian Institute of Environmental and Agricultural Research.

	Climatological normals		Soil temperature				
Month	Temp.	Precip.	1991	1992	1993	1994	1995
January	0.5	105	1.9	3.3	2.2	0.8	2.2
February	0.4	75	-0.5	3.3	2.7	0.1	2.5
March	2.4	80	3.6	4.0	2.7	1.3	2.5
April	5.1	60	6.4	6.1	6.5	5.9	5.7
May	9.5	70	9.6	12.1	12.3	10.5	9.0
June	12.5	75	12.0	16.4	13.8	12.2	13.7
July	13.9	95	16.8	15.8	13.8	16.4	15.5
August	14.1	125	14.4	14.0	15.2	15.5	15.5
September	11.5	160	12.2	12.4	10.8	12.1	12.7
October	8.6	160	8.2	6.6	7.3	7.7	10.1
November	4.4	150	4.7	3.9	2.8	6.3	4.7
December	2.0	125	3.5	2.8	1.0	4.3	1.3

Table 10. Njøs, Sogn og Fjordane County.

Climatological normals for the period 1961-1990 for mean air temperature (°C) and amount of precipitation (mm) provided by the Norwegian Meteorological Institute; soil temperature (°C) 10 cm below ground for the period 1991-1995 provided by the Agro-Meteorological Service at Bioforsk - Norwegian Institute of Environmental and Agricultural Research.

	Climatological normals		Soil temperature				
Month	Temp.	Precip.	1991	1992	1993	1994	1995
January	- 0.8	97	-	1.3	0.5	-0.6	0.6
February	- 0.5	63	-	0.5	0.3	-0.5	0.3
March	1.6	69	-	2.2	1.1	-0.6	1.6
April	5.0	36	6.7	5.6	5.9	3.5	5.3
May	10.3	38	11.1	12.1	12.2	10.0	10.9
June	13.8	50	14.7	18.2	15.5	12.0	16.1
July	14.9	57	19.7	-	15.7	18.4	16.5
August	14.2	75	17.0	14.8	14.5	17.3	17.2
September	10.3	130	12.0	12.2	11.1	12.7	13.2
October	7.0	128	-	5.5	6.9	7.3	8.9
November	2.6	118	2.2	2.0	1.9	4.5	2.2
December	0.3	119	1.1	1.1	- 0.3	1.9	-0.1

Table 11. Furuneset, Sogn og Fjordane County.

Climatological normals for the period 1961-1990 for mean air temperature (°C) and amount of precipitation (mm) provided by the Norwegian Meteorological Institute; soil temperature (°C) 10 cm below ground for the period 1991-1995 provided by the Agro-Meteorological Service at Bioforsk - Norwegian Institute of Environmental and Agricultural Research.

	Climatological normals		Soil temperature		
Month	Temp.	Precip.	1993	1994	1995
January	1.5	179	2.9	0.6	2.7
February	1.2	146	2.9	0.4	2.3
March	2.7	151	2.7	0.2	2.1
April	5.0	102	5.3	4.5	4.2
May	9.3	87	10.7	8.9	8.4
June	12.0	109	12.6	10.8	13.2
July	13.2	127	13.6	15.1	14.7
August	13.2	158	13.3	15.3	15.7
September	10.5	252	10.8	12.1	13.0
October	8.0	250	7.6	7.5	9.5
November	4.5	231	3.6	5.9	4.3
December	2.5	218	1.2	3.7	2.0

Table 12. Surnadal, Møre og Romsdal County.

Climatological normals for the period 1961-1990 for mean air temperature (°C) and amount of precipitation (mm) provided by the Norwegian Meteorological Institute; soil temperature (°C) 10 cm below ground for the period 1991-1995 provided by the Agro-Meteorological Service at Bioforsk - Norwegian Institute of Environmental and Agricultural Research.

	Climatological normals		Soil temperature			
Month	Temp.	Precip.	1992	1993	1994	1995
January	-2.5	116		-0.8	-1.0	-0.6
February	-1.5	95		-0.3	-0.9	-0.6
March	1.0	99		-0.3	-0.7	-0.5
April	3.7	83		0.8	-0.5	-0.5
May	9.0	64		10.7	7.7	6.8
June	12.0	86		12.7	11.1	13.3
July	13.5	117		16.0	16.5	13.9
August	13.2	120		14.3	15.2	14.2
September	9.4	173		9.1	10.1	10.5
October	6.2	157	1.9	4.0	3.2	6.3
November	1.7	131	-1.4	-1.0	0.1	0.3
December	-1.0	154	-1.4	-1.5	-0.5	-0.5

Table 13. Rissa, Sør-Trøndelag County.

Climatological normals for the period 1961-1990 for mean air temperature (°C) and amount of precipitation (mm) provided by the Norwegian Meteorological Institute; soil temperature (°C) 10 cm below ground for the period 1991-1995 provided by the Agro-Meteorological Service at Bioforsk - Norwegian Institute of Environmental and Agricultural Research.

	Climatological normals		Soil temperature			
Month	Temp.	Precip.	1992	1993	1994	1995
January	-4.5	162		-0.5	-0.5	-0.3
February	-3.5	132		0.5	-0.4	-0.3
March	-1.0	123		0.3	-0.4	-0.2
April	2.5	115		5.7	3.7	1.6
May	8.0	78		10.7	8.5	7.6
June	11.5	89		11.9	10.6	12.5
July	13.0	110		14.4	15.6	12.7
August	13.0	110		13.0	14.7	12.5
September	9.0	204		9.0	10.5	10.2
October	6.0	199	2.3	4.5	4.1	6.8
November	1.0	162	-0.5	0.0	1.8	1.2
December	-2.5	201	-0.7	-0.7	0.6	0.5

Table 14. Frosta, Nord-Trøndelag County.

Climatological normals for the period 1961-1990 for mean air temperature (°C) and amount of precipitation (mm) provided by the Norwegian Meteorological Institute; soil temperature (°C) 10 cm below ground for the period 1991-1995 provided by the Agro-Meteorological Service at Bioforsk - Norwegian Institute of Environmental and Agricultural Research.

	Climatological normals		Soil temperature				
Month	Temp.	Precip.	1991	1992	1993	1994	1995
January	-1.5	74	-0.3	1.6	-	0.0	-0.1
February	-1.5	64	-1.7	1.1	1.2	-0.2	0.1
March	1.0	58	0.3	2.4	1.0	-0.1	0.1
April	4.0	50	5.5	-	4.2	3.6	2.6
May	8.5	45	8.7	-	9.0	9.3	8.4
June	12.0	60	13.7	14.6	9.9	11.7	13.5
July	13.5	80	17.4	15.0	12.7	16.4	14.3
August	13.0	73	16.2	12.6	12.2	15.0	13.7
September	9.0	105	9.5	10.2	8.8	10.0	10.3
October	6.0	100	5.6	3.9	5.2	4.8	6.6
November	2.0	75	2.4	1.0	0.9	2.2	0.0
December	0.0	86	1.4	0.8	0.0	1.0	-0.3

Table 15. Sortland, Nordland County.

Climatological normals for the period 1961-1990 for mean air temperature (°C) and amount of precipitation (mm) provided by the Norwegian Meteorological Institute; soil temperature (°C) 10 cm below ground for the period 1991-1995 provided by the Agro-Meteorological Service at Bioforsk - Norwegian Institute of Environmental and Agricultural Research.

	Climatological normals		Soil temperature			
Month	Temp.	Precip.	1992	1993	1994	1995
January	-2.0	130		-0.1	-0.3	0.2
February	-2.0	120		-0.1	-0.3	-0.1
March	-1.0	95		0.1	-0.2	-0.1
April	1.9	85	-0.1	0.2	-0.2	0.0
May	6.3	65	6.6	5.7	2.4	1.2
June	10.0	65	13.1	8.8	8.8	9.7
July	12.0	75	12.8	13.4	12.0	11.5
August	12.0	85	12.1	13.1	12.8	11.6
September	8.4	130	8.9	7.6	8.0	8.8
October	4.5	190	3.7	2.5	3.8	4.5
November	0.8	150	0.4	1.3	0.6	1.3
December	-1.4	145	-0.1	-0.1	0.6	0.5

Table 16. Average values for air temperature (°C) and precipitation (mm) for the period 1950-91 in Hjemleland (Rogaland County), for 1962-88 in Ullensvang (Hordaland County), and for 1961-74 in Norddal (Møre og Romsdal County) provided by the Norwegian Meteorological Institute.

	Hjelmeland		Ullensvang		Norddal	
Month	Temp.	Precip.	Temp.	Precip.	Temp.	Precip.
January	1.1	116	-0.2	144	0.8	136
February	0.9	88	-0.4	94	1.0	101
March	2.9	109	1.7	110	2.9	106
April	5.6	63	5.2	51	5.5	75
May	10.1	73	10.2	50	10.2	46
June	13.1	85	13.8	64	13.0	53
July	14.4	105	15.0	75	14.3	75
August	14.4	121	14.1	92	13.9	77
September	11.6	177	10.5	157	10.6	144
October	8.7	181	7.1	181	7.9	149
November	4.6	169	3.1	163	3.7	153
December	2.4	153	0.9	169	1.5	175