Pest risk assessment of *Ralstonia solanacearum* in Norway – limited to the pathway of ware potatoes from the Netherlands

Opinion of the Panel on Plant Health
of the Norwegian Scientific Committee for Food Safety
07.07.2010

Revised 06.12.2010

ISBN 978-82-8259-009-9

VKM Report 2010: 39

Pest risk assessment of *Ralstonia solanacearum* in Norway – limited to the pathway of ware potatoes from the Netherlands

Leif Sundheim

Trond Rafoss

Arild Sletten

Citation: Sundheim, L., Rafoss, T., Sletten, A. (2010). Pest risk assessment of *Ralstonia solanacearum* in Norway – limited to the pathway of ware potatoes from the Netherlands. Opinion of the Plant Health Panel of the Scientific Committee for Food Safety, 09/906-3-final-revised, ISBN 978-82-8259-009-9 (Electronic edition). 53 pp. VKM, Oslo, Norway.

SUMMARY

The Norwegian Food Safety Authority (Mattilsynet), in a letter of January 5, 2010, requested a pest risk assessment regarding potato import from the Netherlands from the Norwegian Scientific Committee for Food Safety (Vitenskapskomiteen for mattrygghet, VKM). The original pest risk assessment was adopted by VKM's Panel on Plant Health at a meeting on June 22, 2010. The revised version was adopted by VKM's Panel on Plant Health at a meeting on November 12, 2010.

The bacterium *Ralstonia solanacearum* is the causal organism of potato brown rot. *R. solanacearum* is a quarantine pest in Norway and has never been reported in the country. Since 1996 there has been an import ban on potatoes from the Netherlands due to a high incidence of the disease in Dutch potato production.

VKM's Panel on Plant Health gives the following main conclusions of the risk assessment: 1) The bacterial wilt bacterium, *R. solanacearum*, is regulated as a quarantine pest, which has never been detected or intercepted in Norway. Import of ware potato from the Netherlands to Norway will open a potential pathway for entry of the pathogen to the PRA area of Norway. 2) Data from field experiments in Sweden and establishment of the bacterium in Sweden, United Kingdom, and The Netherlands indicate that in the best agro-ecological zones of Norway *R. solanacearum* will be able to develop during the growing season and survive winters in groundkeepers, soil, water and weeds. 3) The distribution of the host plants *Solanum dulcamara* and *S. nigrum* in the PRA area is regarded as a key ecological factor in the establishment of the pest. In the model simulation of entry and establishment, the assumption has been made that only potato cropping areas within the distribution limits of *S. dulcamara* are considered endangered areas. 4) Based on published data from the Dutch monitoring program during 2003-2007 the fraction of Dutch potato lots infested with *R. solanacearum* is at least 1 in 100,000. Adjusting the reported statistics by the efficiency of the sampling procedure and the sensitivity of the testing procedure, we can assume that about a maximum of 25% of the infested lots were detected, and thus the number of infested lots that remains undetected in the potato lots for export will on average be three times the number of infested lots detected. 5) Single introductions of *R. solanacearum* to Norway, i.e. entry of the bacterium, establishment on a suitable host, and dissemination of the bacteria downstream the watercourse to the coast, will on average affect 90 hectares of potato growing land. Geographical variation in damage potential has the effect that the consequence of a single introduction of *R. solanacearum* to Norway varies from a worst case of more than 900 hectares potato-cropping land affected, to a best case of less than 90 hectares affected by a single introduction. 6) It is possible to

eradicate *R. solanacearum* from smaller watercourses by removing the host plants *S. dulcamara* and *S. nigrum*, but difficult to impossible to eradicate *R. solanacearum* from large watercourses.

KEY WORDS

import ban, potato brown rot, probability of introduction

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 VKM members was appointed by the Panel on Plant Health on December 10, 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

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)

Revision

In the original version (09/906_3_final), the term “risk of introduction” in chapter 5 was meant to encompass both the probability of introduction and the consequences of introduction. Since the term “risk of introduction” can be misinterpreted as “probability of introduction”, the conclusion in chapter 5 has been reformulated in this revised version (09/906_3_final_revised).

CONTENTS

1. BACKGROUND

The Norwegian Food Safety Authority (Mattilsynet), in a letter of January 5, 2010, requested a pest risk assessment regarding potato import from the Netherlands from the Norwegian Scientific Committee for Food Safety (Vitenskapskomiteen for mattrygghet, VKM). The current document was adopted by VKM's Panel on Plant Health on a meeting on June 22, 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

The Norwegian Food Safety Authority (Mattilsynet), in the letter of January 5, 2010, requested an assessment of:

1. Probability of entry and establishment of *Ralstonia solanacearum* in Norway if the current import ban on potatoes from the Netherlands is abolished, and import of ware potatoes is allowed.
2. Whether the conclusions related to consequences of a possible establishment of *R. solanacearum* in Norway according to the report VKM report entitled "Assessment of plant health risk regarding potato brown rot and ware potato import from Egypt" from 2005 still are valid or whether new information has become available that indicates any changes in the level of risk.

3. INITIATION

3.1. Initiation point

3.1.1. PRA initiated by the review or revision of a policy

The current pest risk assessment (and the corresponding PRA) was initiated by the Norwegian Food Safety Authority as a basis for a review and possible revision of its policy concerning potato brown rot (*Ralstonia solanacearum)* and potato import from the Netherlands.

This pest risk assessment is limited to the single pathway of import of ware potatoes grown in the Netherlands to Norway.

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, and unpublished results that have been made available to the risk assessors. This includes the letter from the Dutch Plant Protection Service of 10th of July 2009 responding to a number of questions from the Norwegian Food Safety Authority in their letter dated April 30th 2009. Where these information sources have been used, this is indicated in the text by references enclosed in brackets.

The current pest risk assessment is made according to the international standard ISPM No. 11 (FAO 2004).

3.3.1. Previous PRAs

There exist five previous publications which comprise either partial or full PRAs for *R. solanacearum* for the PRA area of Norway. The first one (Sletten, 1998), represents primarily a “Pest categorization” of *R. solanacearum* for the PRA area of Norway according to ISPM No. 11 terminology. The second one, Sletten (2004), is an update of Sletten (1998) taking into account the new knowledge and relevant information for *R. solanacearum* that had accumulated until that time. The third publication, Rafoss & Sletten (2004), is a full PRA for the risk of introduction of *R. solanacearum* to Norway for the pathway of ware potato imports from Egypt. The fourth publication (Rafoss, 2005) represents an addendum and update to Rafoss & Sletten (2004) considering new and additional information about the situation of *R. solanacearum* in Egypt and an assessment of the effect of adding an import control testing procedure in the importing country according to the procedure described by Anonymous (1998). In 2005, VKM’s Panel of Plant Health adopted a pest risk assessment based on the contributions of Rafoss and Sletten (2004) and Rafoss (2005) (VKM 2005).

The information available in these previous publications, with the exception of Rafoss (2005) which is irrelevant due to the fact that its content is specific to another pathway for entry, are included in this PRA and updated where necessary. The obvious and major difference between the present PRA and the previous PRAs is related to the different pathways considered for entry of *R. solanacearum* to the PRA area and the situation of the pest organism at the pathway origin.

3.4. Conclusion of initiation

The pest of concern is the potato brown rot bacterium *Ralstonia solanacearum*. The pest risk assessment was initiated by the Norwegian Food Safety Authority, and the initiation point is a review and possible revision of its policy concerning potato brown rot (*R. solanacearum)* and potato import from the Netherlands. Previous PRAs are concerned with other pathways. 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

Ralstonia solanacearum (Smith) Yabuuchi et. al.

4.1.1.2 Synonyms

Bacterium solanacearum (Smith) Chester
Burkholderia solanacearum (Smith) Yabuuchi et. al.
Pseudomonas solanacearum (Smith) Smith

4.1.1.3 Common names

Potato brown rot (English)
Pourriture brune de la pomme de terre (French)
Braunfäule, Schleimkrankheit der Kartoffel (German)
Mørk ringråte på potet (Norwegian)

4.1.1.4 Taxonomic position

Bacteria: Gracilicutes

4.1.1.5 Biological information

Interaction pathogen/host

Ralstonia solanacearum enters into plants by way of injured roots, stem wounds or through stomata. Within the plant, the bacteria move in the vascular bundles, a process which is accelerated by higher temperature. Speed of movement is also dependent on the plant part colonized. Blocking of the vessels by bacteria is the major cause of wilting (EPPO 1997a). The disease is most severe at 24-35 °C. It is seldom found in temperate climates where the mean air temperature for any winter month falls below 10 °C. There are distinct temperature requirements for optimum disease development and reproduction for the different races (biovars) (Swanepol 1990). High soil moisture and periods of humid weather or rainy seasons are associated with high disease severity. Soil moisture is also one of the major factors affecting reproduction and survival of the pathogen (Nesmith & Jenkins 1985).

Dissemination and dispersal

The natural spread of *R. solanacearum* is usually limited and slow. Root-to-root spread of the bacterium has been recorded (Kelman & Sequeira 1965), but there is little evidence of long-distance spread from field to field. However, race 2 is known to be transmitted by insects and has a high potential for natural spread. Race 3 biovar 2 has been shown to be spread over long distances with surface water when infected *Solanum dulcamara* grows with its roots floating in water, e.g. on riverbanks. When contaminated surface water is used for irrigation, the bacterium may subsequently be spread to other hosts, such as potato. A likely source of primary infection of *S. dulcamara* is sewage effluents from potato processing industries and households using infected ware potatoes (Olsson 1976, Stead *et al.* 1996). In Norway there are regulations in place requiring potato processing plants to have internal controls for safe handling of effluent water to prevent spread of plant pathogens and pests. Nevertheless, this source of primary infection remains as a possible pathway for dispersal as there are no such regulations for private households.

R. solanacearum can be carried over very long distances in symptomless, infected vegetative propagating material. Examples of well-documented cases of long-range dispersal are the use of infected ginger rhizomes as planting material within China, Indonesia and Malaysia (Lum 1973), tomato transplants in U.S.A. and Canada, and latently infected potato tubers being spread locally and internationally (Hayward 1991, Olsson 1976, Turco & Saccardi 1997).

Substantial evidence of spread by infected true seed has so far not been given. Neither is there evidence that *R. solanacearum* survives as an epiphyte on leaf and other plant surfaces, as do some pathovars of *P. syringae* (Kelman *et al.*1994).

Survival

R. solanacearum may survive in soil, but probably only in relatively short periods on its own (Sequeira 1994). Survival is strongly influenced by a number of interacting physical, chemical and biological factors. It is known that *R. solanacearum* persists longest when it is protected from desiccation and antagonism by other microorganisms, and in sheltered environments such as alternative crop and weed hosts, self-sown volunteer potatoes, host debris or in deeper soil layers down to at least 75 cm (Graham *et al.* 1979). It may also survive in the rhizosphere of non-hosts (Sequeira 1994). The range and variety of weed hosts is very extensive, but their significance also varies greatly in different environments and cropping systems (Kelman 1953). Some are symptomless carriers (Hayward 1991). Soil type is an important factor affecting survival (Moffet *et al*. 1983), and different soils may be conducive or suppressive to pathogen survival and subsequent disease development (Nesmith & Jenkins 1985). Soil moisture affects pathogen persistence (Moffet *et al.* 1983). It tends to be longest in moist, well-drained soil, but persistence is reduced by desiccation or flooding (Hayward 1991). Different strains and races of the pathogen vary in their ability to survive in soil. Race 1 may persist in the same soil for many years, while race 2 and 3 disappear rapidly after a disease outbreak when weed hosts are eliminated (Sequeira 1994). Survival of race 3 biovar 2 in soil in cool climates seems to be restricted to one or two years after harvest of potato crops infected by brown rot. The bacterium may also persist in groundkeepers for the same length of time. Long-term survival in perennial weed hosts, like *S. dulcamara,* has been an important means of persistence and subsequent spread in several countries of Northern Europe (Olsson 1976, Elphinstone 1996).

R. solanacearum may survive in tap water for 25 days at room temperature (Olsson 1976), and in ditch water the pathogen survives up to 33 days at 4 °C (Janse 1996). In sterile distilled water the bacterium may survive for many years and even multiply (Wakimoto *et al.* 1982). van Elsas *et al.* (2000) monitored the fate of race 3 biovar 2 after outbreaks of potato brown rot in three different fields in the Netherlands. The population densities declined progressively over time to low levels. In two fields the pathogen persisted for periods of 10 to 12 months. There were indications of occurrence of viable but non-culturable cells (VBNC) of *R. solanacearum* in soil. However, the potential of such cells to revert to healthy and possibly infective cells is unknown.

Adaptability

R. solanacearum race 3 biovar 2 is homogenous and in contrast to the other races very well defined genetically and epidemiologically (Gillings & Fahy 1994). The bacterium has a growth optimum (27 °C), better adapted to more temperate and cooler climates than the other races. It is presumed to originate in South America and has been disseminated to other parts of the world in seed potato tubers (Hayward 1991). Following the recent introduction of race 3 biovar 2 in Northern Europe no report has so far been presented regarding changes in host range, epidemiology or damage potential.

4.1.2 Presence or absence in PRA area

R. solanacearum is not known to occur in Norway, and the pathogen has never been detected or intercepted in the country (Perminow and Borowski 2004, Perminow et al. 2010). Each year since 1998 seed and ware potatoes grown in different parts of Norway have been tested for the presence of *R. solanacearum* with the methods described in EU Council Directive 98/57EC (EU 1998). During the years 1999-2008 around 2300 seed potato lots have been tested. In addition, surveys of water, liquid waste and solanaceous weeds have been carried out in Norway since 2003 to detect *R. solanacearum*. During the years 2003-2009 altogether 293 samples of river water and liquid waste from potato processing companies, and 40 samples of solanaceous and other weeds growing near watercourses have been tested for the presence of *R. solanacearum*.

Distribution of *Ralstonia solanacearum* in Europe

Table 1. European countries where *Ralstonia solanacearum* has been introduced (EPPO 2010a, 2010b)

Country	Year of introduction	Comment
Austria	2009	
Slovakia	2004	
Germany	2001	
Hungary	2000	
Spain	1997	
France	1995	
Turkey	1995	
Belgium	1993	
United Kingdom	1993	
The Netherlands	1993	
Sweden	1976	

4.1.3 Regulatory status

Norway: *R. solanacearum* is a quarantine pest to Norway, regulated by The Food Law, Regulations relating to plants and measures against pests, Royal Ministry of Agriculture 1 December 2000 (Landbruks- og Matdepartementet 2000). There is a temporary ban on import of potatoes from the Netherlands (Landbruks- og Matdepartementet 1996) and restrictions on import of ware potatoes from Egypt (Landbruks- og Matdepartementet 2007).

EPPO: A2 list, No. 58
EU: Annex designation: II/A2

4.1.4 Potential for establishment and spread in PRA area

4.1.4.1 Host plants growing in the PRA area

Potato is one of the major crops in Norway. Tomato is commercially grown only in greenhouses. *Solanum dulcamara* and *S. nigrum* are both common weeds in Norway (Figure 1), but they are not growing further north than the county of Nordland (Lid 1985). *Pelargonium hortorum* is an important plant for the greenhouse industry in Norway. Also, *P. hortorum* is a very popular and common plant in private and public parks and gardens.

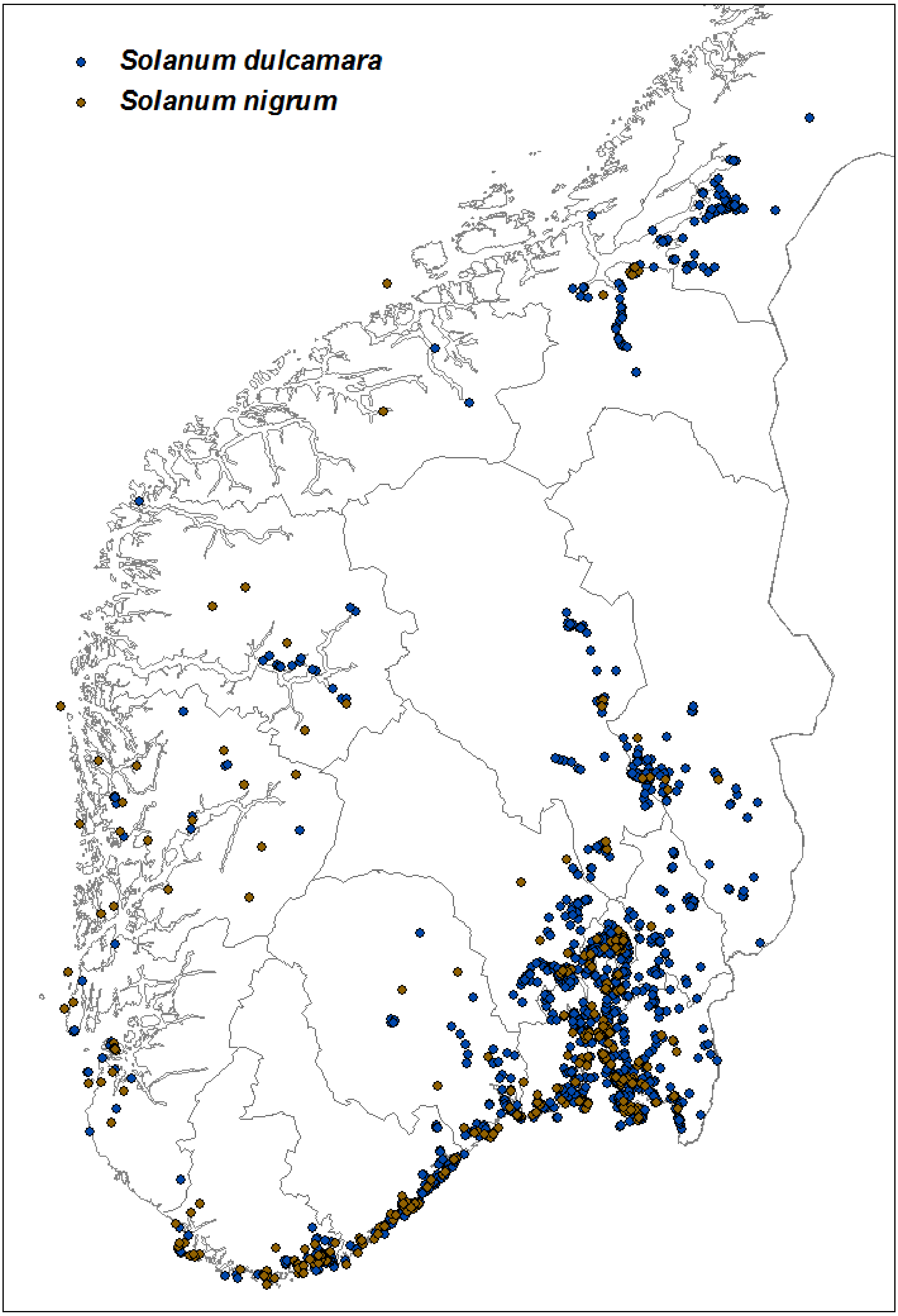


Figure 1. Occurrences of *Solanum dulcamara* and *S. nigrum* in Norway (Data source: http://www.artsdatabanken.no)

4.1.4.2 Climate in the potato growing areas of the PRA area

Potato is grown in every county in Norway, and production of economic importance takes place in the counties of Østfold, Akershus, Hedmark, Oppland, Buskerud, Vestfold, Telemark, Aust-Agder, Rogaland, Møre og Romsdal, Sør-Trøndelag and Nord-Trøndelag, and Nordland. Tables 4-16 (annex 4) give the normal values for mean monthly temperature and precipitation during the years 1961-1990 in these counties. The data were provided by the Norwegian Meteorological Institute (NMI) in Oslo (www.met.no). The tables also include observations on soil temperature 10 cm below ground made by weather stations placed in close vicinity to, or at the NMI stations. The soil temperature data were provided by the Agro Meteorological Service at Bioforsk (http://lmt.bioforsk.no).

4.1.4.3 Climate in areas in Europe where *R. solanacearum* race 3 biovar 2 has been introduced

In the Netherlands, climatic conditions are less favourable for development of disease symptoms and infections generally remain symptomless (Breukers, 2006b). Table 17 gives the normal values for mean monthly temperature and precipitation during the years 1961–1990 in Birmingham in England, De Bilt in The Netherlands and Stockholm in Sweden. Data were provided by the Norwegian Meteorological Institute in Oslo. Brown rot in England has been reported from Oxfordshire region (Stead *et al*. 1996), which is close to Birmingham. The infestation reported in 1976 in Sweden was in Skåne, the very southern part of the country. In connection with investigations concerning the outbreak, successful field infection experiments with *R. solanacearum* were carried out at Solna, which is close to Stockholm (Olsson 1976). This area is located at the latitude of 59°N, which is the same latitude as for Oslo, the capital of Norway, while the natural outbreak of the disease in Sweden was at 55°N, an area that has somewhat higher temperatures.

In two lots of ware potatoes harvested in Sweden in 2009 *R. solanacearum* was detected. These findings followed a notification from the Dutch NPPO, which indicated a clonal link between seed potatoes delivered to Sweden and contaminations found in the Netherlands (EPPO 2010c). A similar detection was reported from United Kingdom (EPPO 2010d). Phytosanitary measures have been taken in both countries to eradicate the pathogen.

4.1.4.4 Comparison of the climate in the PRA-area and in areas where *R. solanacearum* has occurred

Tables 4-17 show the differences in mean temperature and precipitation during the growing season between Norway and three European countries where brown rot has occurred. The climates of the southern parts of Norway will most likely not prevent establishment of the disease. In infection experiments with potato and *R. solanacearum* race 3 biovar 2 in growth chambers with a dark/light temperature of 14/16 °C, Swanepoel (1990) obtained a mean percentage of wilting of 18.3%, and the disease was transmitted to 34.4% of the plants grown from these tubers. At 18/20°C and higher temperatures, the wilting percentage was 100%, and no tubers could be harvested.

Olsson (1976b) has given soil temperatures at Solna, Stockholm for a three-year-period when infection experiments with *R. solanacearum* where carried out. The temperature was below 0°C for about two months during the winter 1974-1975, and somewhat lower the following winter. The bacterium was found to survive in *S. dulcamara* under these conditions. Soil temperatures at several of the localities given in Tables 4-17 are at the same level, in Rogaland County (Table 12) some years considerably higher.

4.1.5 Potential for economic consequences in PRA area

Ralstonia solanacearum causes wilting of plants, with extensive rotting of tubers. Rotted tubers will be rejected for quality reasons. Latent infected tubers detected by laboratory testing will be rejected as seed potatoes because of their potential to transfer disease to future generations of potatoes. *R. solanacearum* is a severe limiting factor in tropical agriculture, where losses up to 75% of the potato crop have occurred in several countries (Cook & Sequeira 1994, Oerke *et al.* 1994). Extensive losses have also been reported from Mediterranean countries. In a model simulation study, Breukers *et al.* (2008) estimated the average yearly costs of brown rot to the Netherlands to be 7.7 million €. This model simulation study was based on the control policy regime in force in 2006. Breukers *et al.* (2008) also simulated the economic impact of reducing the monitoring frequency for brown rot, which accordingly would increase the costs of brown rot in the Netherlands to 12.5 million €, 60% of which would be due to export losses. The model also indicated that, due to potential long-term effects of a strategy, conclusions on cost-effectiveness of a strategy depend on the length of the period over which that strategy is observed.

Potato is one of the major crops in Norway. In 2002 the number of farms growing potatoes at an area of more than 0.5 ha was 7 244, with a total area of 15 118 ha, producing 398 000 tonnes of potatoes at a value of 887 mill NOK (Statistics Norway 2004). A considerable potato production is in addition taking place at a great number of small farms (less than 0.5 ha) and in private gardens. Tomato is commercially grown only in greenhouses. , In 2009 a total of 10 923 tonnes of tomatoes was produced on an area of 32 ha (Statistics Norway 2010).

4.1.6 Conclusion of pest categorization

If *R. solanacearum* was introduced into Norway, the climatic conditions and other factors of importance for the development of the disease will not prevent its establishment and survival in groundkeepers, soil, water and susceptible weeds. Because of the cool climate, the rotting of tubers would probably be of minor importance. But all infected potato lots and related lots would have to be destroyed in order to control the disease, as well as strict measures for hygiene and crop rotation would have to be imposed, to a considerable cost for the affected grower, and the official authorities. The high number of small farms and private gardens where potatoes are grown will make it difficult and expensive to enforce the necessary statutory orders to control the disease. Potential export markets would be lost, and reduced supply of domestically grown potatoes would make the country more dependent on import from other countries. Brown rot has the potential to become a devastating disease for potato growers in Norway. Many of them have small farms, and they depend on potato in their crop rotation schemes. The social impact of a disease outbreak could therefore become considerable. *R. solanacearum* race 3 biovar 2 also has the potential to be established in greenhouses growing tomatoes. In some districts in Norway this is a very important production, and the economic impact of a disease outbreak could be substantial.

4.2. Assessment of the probability of introduction and spread

4.2.1 Probability of entry of the pest

4.2.1.1 Identification of pathways

This pest risk assessment considers only the single pathway of ware potatoes from the Netherlands.

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

The potato brown rot bacterium *R. solanacearum* race 3 biovar 2 was confirmed for the first time in the Netherlands in 1992 (Janse *et al.* 1998). Since 1995 the Dutch potato production has suffered from several outbreaks of brown rot. In 1996 severe control measures were imposed. Since its introduction the eradication policy for *R. solanacearum* in the Netherlands has resulted in a strong decline of brown rot incidence, from more than a hundred annual detections in the late nineties

(Breukers 2006b) to less than ten annually in recent years (Table 2). The current survey for *R. solanacearum* in the Dutch potato production chain includes annual sampling and testing of all seed potato lots of all growers after harvest. All seed potato growers are included in the field inspection procedures. For ware potatoes random samples in the survey are taken of the ware and starch potato lots to monitor the presence or absence of potato brown rot. Samples are also collected to investigate the source of infections found in seed potatoes in earlier years, to identify potato lots that are clonally related to an infected lot and for back and forward tracing of notifications from foreign interceptions in Dutch potato exports. The percentage of tested ware potato growers is about 25% (M. J. Folkers, personal communication). In addition to the random sampling, growing areas that have had its production infected before are always sampled in the annual survey and named "targeted survey". The results from the survey in the years 2003 – 2007 are given in Table 2.

Table 2. Positive samples in the survey for *Ralstonia solanacearum* in Dutch potato production during the last 5 years (Refer to Dutch documents)

Year	Total number of positive samples	Tracing	Ware potato	Starch potato
2003	6	4	1	1
2004	1	1	0	0
2005	1	1	0	0
2006	3	0	2	1
2007	1	1	0	0

The eradication policy has not succeeded in complete eradication of the pathogen, and it is questionable whether this is achievable given the permanent presence of *R. solanacearum* in Dutch waterways (Breukers, 2006b). It remains unclear how these few infections can be prevented (Breukers et al. 2005). A major reason for this is insufficient understanding of the importance of possible risk factors with respect to brown rot prevalence and dispersal in the potato production chain (Breukers et al. 2005). In a comprehensive bio-economic modelling of brown rot in the Dutch potato production chain, summarised by Breukers (2006b), the epidemics of *R. solanacearum* and the effects of the risk management measures imposed were described and analysed with mathematical models. One result from the model study is that the average disease prevalence reaches a plateau at which disease transmission and disease elimination from the chain (as a result of inspection) are in dynamic equilibrium (Breukers *et al.* 2006a). The physical characteristics of all farm and field objects included in the model are based on actual data of all potato farms (n = 11,746) and arable fields (n = 404,773) in the Netherlands (data from 2003), which were provided by the Dutch Agricultural Economics Research Institute (Landbouw Economisch Instituut, LEI). According to Breukers et al. (2006a), there are three different pathways through which a potato lot can become infected with brown rot. First, infections may be caused by irrigation or spraying of potatoes with contaminated surface water, in which brown rot bacteria can occur because of the presence of the weed host *S. dulcamara*. Large parts of the Dutch waterways are contaminated with *R. solanacearum* and serve as a permanent external reservoir of the brown rot bacterium (Figure 2). Infection through surface water (i.e. primary infection) is the only way through which an infection can enter the Dutch potato production chain (Breukers *et al.*, 2006a). The second and third pathways through which a potato lot can become infected with brown rot, horizontal and vertical transmission, respectively, appear once brown rot has entered the potato production chain. By horizontal transmission the pathogen can disperse through the chain by infection of a healthy potato lot from another infected lot, either by direct contact, or indirectly via contaminated machinery or equipment. Vertical transmission, also referred to as infection through clonal relationships, means transmission of the disease from parent to offspring, and occurs with the splitting of an infected but yet undetected seed lot into daughter lots, which are subsequently replanted. As part of the brown rot control policy, the Dutch Plant Protection Service takes samples of the surface water several times during a growing season. Regions in which surface water is found to be contaminated with *R. solanacearum* are designated as ‘‘prohibition areas’’, where the use of surface water for irrigation of potato crop is prohibited (Figure 2). The model developed by Breukers *et al.* (2006a) was applied to simulate *R. solanacearum* dynamics given the brown rot control strategy that prevailed in the Netherlands until 2004. According to Breukers *et al.* (2006a) this strategy, includes a testing frequency of seed potato lots of 100% (as compared to 7% for ware and starch potatoes), and a ban on the use of surface water for potato cultivation in contaminated areas. Breukers *et al.* (2006a) assumed that fields in use by risk-seeking farms have a probability of 1% of being irrigated despite this ban. The simulation was performed for a period of 15 years (i.e. production cycles) and was replicated 100 times with the same initial conditions but a different random number seed.

Figure 2. The shaded areas indicate demarcated zones in the Netherlands where surface water has been found to be infested by *Ralstonia solanacearum* until 2008. In these areas it is forbidden to use surface water in the production of potatoes (map provided by the Dutch Plant Protection Service, 2009)

According to the model simulations (Breukers *et al.*, 2006a) the average yearly number of infected lots is almost 15. The distribution of the number of outbreaks per year is skewed to the right, causing the average yearly number of infections to be greater than the median, which lies around 10 infected lots per year. Due to stochasticity, single model replicates may show large deviations from the average trend. The range of observed number of infections per year is wide, indicating important variability between replicates. Year-to-year variation is also important. On this basis, Breukers *et al.* (2006a) points out that the between-years and between-replications variation in the model results corresponds with the erratic dynamics of *R. solanacearum* observed in practice. Almost all infections that occurred in the model runs occurred in regions with contaminated surface water, and many of them originated through irrigation. Thus, surface water appears to be an important infection source. Also, relatively few infections occur in seed lots, which, is explained by the fact that the probability of a farm being risk-seeking and thus irrigating in a prohibition area, is smaller for farms that produce seed potatoes than for other farms.

In conclusion determination of the probability of the pest being associated with the pathway at origin, an estimate based on the model results can be calculated as follows:

If it is assumed that all yearly infected lots originates from ware potato farms, and 75% is not controlled in the survey, the yearly average of infected lots exported in the ware potato export will be 0.75 x 15 = 11.25 lots. In addition to this number there will be a small probability that some of the 25% of the infected lots undergoing sampling and testing will pass the testing procedure unnoticed, both because of limitations of the sampling procedure and the test sensitivity (see later). Of a total production of 7 million tonnes, 3.5 million tonnes of ware potatoes are exported annually from the Netherlands. Assuming an average size of 20 tonnes per lot, there will be 3.5 million / 20 = 175 000 ware potato lots exported. This gives an average frequency of diseased lots of 11.25 / 175 000 = 0.000064. Relating this to the entry pathway to Norway, the total potato imports in 2009 was 1598 lots (Table 3), with an average lot size of about 22.5 tonnes. This amounts to 36 000 tonnes imported, which is almost 10% of the annual domestic potato production in Norway. If a future Dutch ware potato export to Norway would replace the whole Norwegian potato imports of 1598 lots per year, this would constitute approximately 1% of the Dutch ware potato exports. Using the average number of Dutch ware potato lots infected with *R. solanacearum*, an average number of 0.103 infected lots would be imported to Norway per year. This is approximately one infected ware potato lot each 10 year. If the same calculations is based on the survey results where three infected samples have been detected in the five years from 2003 – 2007 (Table 1), and it is assumed that these three infected samples were from three different lots, it gives an average of 0.6 infected ware potato lots per year detected, which corresponds to a total 2.4 where on average 1.8 infected ware potato lot will escape the sampling procedure. With this number the frequency of diseased lots will be 84% lower, and correspond to approximately one infected ware potato lot each 60 year.

Table 3. Import of ware potatoes to Norway in 2009*

Country of origin	**Number of consignments**
France	618
Denmark	533
Israel	128
United Kingdom	83
Saudi Arabia	73
Cyprus	52
Spain	37
Bosnia Herzegovina	21
Tunis	18
Finland	17
Germany	15
Sweden	2
Italy	1
Total number of consignments	1598

* In the 2010 imports from the same countries of origin appear. Consignment size is not reported, but is assumed to be 20-25 tonnes (*pers. comm.* K. Willumsen, The Norwegian Food Safety Authority.).

Other important findings in the model studies of Breukers (2006b):

- The number of primary infections are independent of infected lots already present in the chain.
- Applying a 100% testing frequency of seed lots leads to an average reduction in brown rot incidence of 40% compared with a 10% testing frequency, while the variability doubles in the reduced testing model runs.
- Model results indicate that most of the on average 15 yearly infected lots in the Dutch potato production chain will be in the ware potato production, because of the fact that the probability of a farm being risk-seeking and thus irrigating in a prohibition area, is smaller for farms that produce seed potatoes than for other farms.

Statistics of sampling and test sensitivity and specificity for *R. solanacearum*

The sensitivity of the test, i.e. the ability to predict presence of the pathogen when it is actually present, varies with infection level. The detection probability of an infected lot, is 95% at an infection level of 1.5%, and increases with increasing infection level. The EU sampling rule of 200 tubers per 25 tons is commonly referred to give an 87% probability of detection at 1% level of infection and a 95% probability of detection at 1.5% infection level.

$$\mathbf{P}_{\mathbf{sampling}} = 1 - (1 - d)^{n}$$

Described in words the above formula says that the probability of the event of missing to sample an infected tuber $(1 - d)$, where d is the level of infection, repeatedly 200 times $(1 - d)^{200}$ is approximately equal to 0.13 or 13%. The other outcome, i.e. the event that the 200 tuber sample will contain one or more infected tubers will be $1 - (1 - 0.1)^{200} = 1 - 0.13 = 0.87$ or 87%. The use of the above formula relies on the assumptions of binomial sampling:

(1) that the population (lot) to be sampled is very much larger than the size of the sample
(2) either that the tubers are randomly distributed in the lot, or that the sample is take randomly throughout the lot

If any of the above assumptions are compromised, the efficiency of the sampling procedure ($\mathbf{P}_{\mathbf{sampling}}$) will be lowered. The effect of aggregation of diseased tubers within the lot, or the heterogeneity of disease incidence, according to the terminology of Madden & Hughes (1999), can be taken account of, but requires data on the degree of aggregation. Unfortunately, to the panel’s knowledge, no studies or data for common levels of aggregation of diseased tubers in potato lots infested with *R. solanacearum* have been published. The test has a specificity of 100%, which means that all tested samples that are found positive are indeed infected with brown rot.

4.2.1.3 Probability of survival and multiplying during transport or storage

According to paragraph 2.1.5.6, transport or storage will not reduce survival of *R. solanacearum* in infested fresh potato export consignments. However, possible development of the brown rot disease in potato tubers with latent infections of *R. solanacearum* at the time of testing in the country of origin may increase the probability of detecting diseased consignments in the import control.

4.2.1.4 Probability of pest surviving existing pest management procedures

No specific treatment is applied to the consignments neither against this or other pests from origin to end-use. However, the phytosanitary procedures of inspection and testing applied to the consignments, both at country of origin and in the importing country, will reduce the probability that the pest will go undetected during export and import.

4.2.1.5. Probability of transfer to a suitable host

Paragraph 4.1.1.5 describes the main dispersal mechanisms for the pest considered. The intended use of the commodity is for fresh consumption. For potatoes, this usually implies the process of peeling and rinsing, whether in industry or in private households, before further processing (e.g. by boiling, deep-frying etc.). Accordingly, the most likely transfer of the pest to a suitable host is by effluent water transporting bacteria released by peeling of diseased potatoes, that either could reach *S. dulcamara* weeds growing downstream the watercourse or by use of contaminated water for irrigation of potato fields. Another way of transfer to a suitable host, is by the unintended use of the ware potatoes as seed potatoes for planting. This is illegal, though not uncommon practice in Norwegian private gardens.

(1) transfer through effluents of potato peeling
(2) transfer through planting as seed potatoes
(3) transfer through waste potato peel

Norwegian regulations require potato processing plants to have internal controls for safe handling of effluent water to prevent spread of plant pathogens and pests.

4.2.2 Probability of establishment

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

The availability of suitable hosts in the PRA area for *R. solanacearum* has been described in paragraph 4.1.4 and Figure 1. Regarding the host plants *S. dulcamara* and *S. nigrum*, their distribution within the PRA area is relatively well known from official field records (Figure 1). Lid (1985), provides a description of the distribution of *S. dulcamara* coinciding with Fægri & Danielsen (1996), with occurrence north to the county of Nordland and vertically up to the altitude of 240 meters above sea level. Regarding its abundance, Lid (1985) describes *S. dulcamara* as common within these geographical distribution limits. A national database of the geographical distribution of vascular plants in Norway is being coordinated by the Norwegian organisation Artsdatabanken (www.artsdatabanken.no). Records of occurrence of *S. dulcamara and S. nigrum* in Norway, available in Artsdatabanken, are shown in Figure 1. The geographical distribution in Figure 1 coincides with the distribution limits described by Lid (1985). Rafoss (2003) developed a method for quantifying establishment and dissemination potential of pathogens based on spatial stochastic simulation. The study by Rafoss (2003) used *R. solanacearum* as model organism and the current PRA area (Norway) as case area. Thus, the results from Rafoss (2003) can be utilised in the present risk assessment. Simulation outputs from Rafoss (2003) were obtained. The dataset contains the distribution of potential natural dissemination area based on simulated release points for *R. solanacearum* in agricultural land. For the purpose of this risk assessment, the simulated dataset is further refined to provide information about potentially affected potato cropping area. The latter operation was done by a spatial join, within a Geographical Information System (GIS), of the dataset from Rafoss (2003) containing spatial data on potentially affected area, with a dataset for Norwegian municipalities percentage of agricultural area utilised for potato cropping (Statistics Norway, 2000). A histogram summary of the potato cropping area potentially affected, based on 1,000 randomly simulated introductions in agricultural fields of *R. solanacearum* is shown in Figure 3.

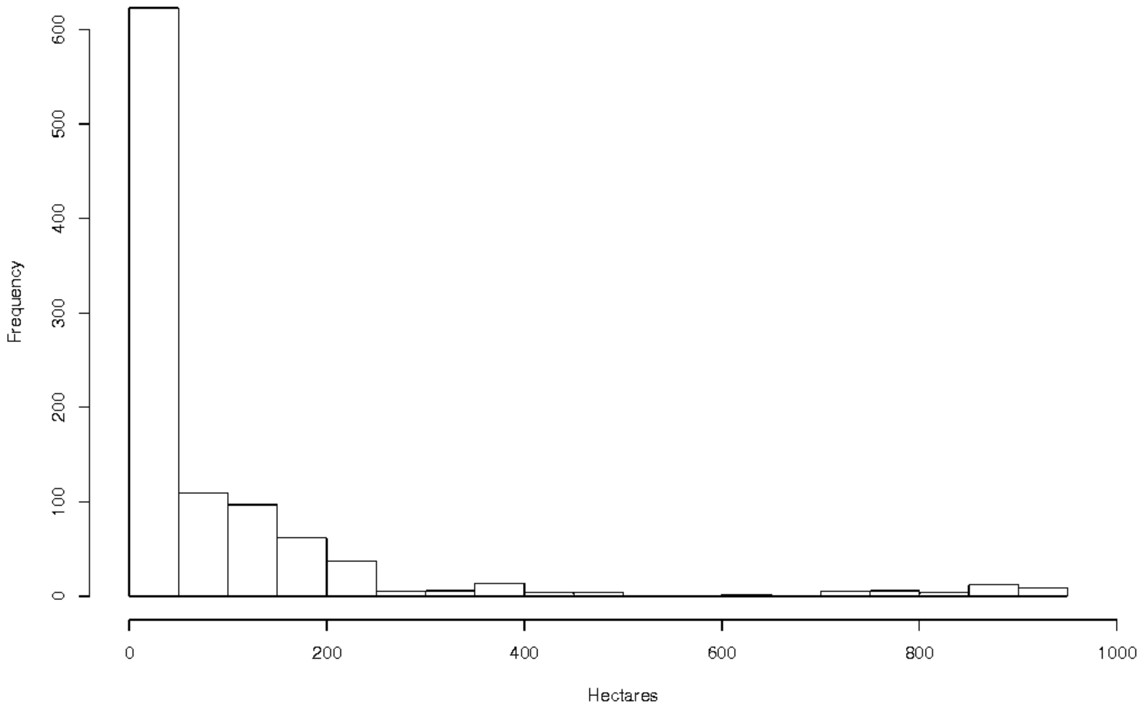


Figure 3. Histogram of potentially affected area (ha) of potato cropping fields, as calculated from the simulation of release of *Ralstonia solanacearum* into agricultural fields, and subsequent spread of the pathogen. The histogram is based on 1,000 simulated releases of the pathogen.

Assumptions underlying model simulations:

- Release or escape of the pathogen into the environment occurs in areas where host plants are present

- Release or escape of the pathogen into the environment occurs in a season where the host is susceptible to infection and/or the pathogen is able to infect its host
- Natural dissemination of the pathogen after entry
- Potato growing land lateral to the infected river or watercourse are affected up to 500 meters away from the riverside (e.g. by means of irrigation etc.)
- Sufficient time to disseminate downstream throughout the watercourse

4.2.2.2 Suitability of environment

The Pest characterization section describes suitability of climate according to the scientific literature, and comparisons of climate data from the PRA area and areas where *R. solanacearum* has been introduced but eradicated, or is known to occur. The conclusion based on these climate comparisons is that the climate of the PRA area will not prevent the establishment of *R. solanacearum*.

4.2.2.3 Cultural practices and control measures

No cultivation practices in the production of host crops in the PRA area are likely to prevent establishment of *R. solanacearum*. Restriction on cultivation practices, such as the prohibition of use of surface water for irrigation, which has been applied in countries where *R. solanacearum* occurs, does not exist for the PRA area.

4.2.2.4 Other characteristics of the pest affecting the probability of establishment

Both the probability of entry of infested consignments (i.e. passing the control), and the probability that they will result in an establishment, will be a function of disease incidence. Disease incidence is here defined as the number of plant units that are diseased relative to the total number assessed (Campbell & Madden 1990, Madden & Hughes 1995). The higher incidence of diseased potato tubers in an infested consignment, the higher the probability for the infestation to be detected, and the consignment rejected for import. On the other hand, the higher incidence, the more inoculum will be available for dissemination of the bacteria in the PRA area. Unfortunately, to our knowledge, no data on incidence levels of *R. solanacearum* infested potato consignments have been documented for other areas where *R. solanacearum* is known to occur. Moreover, aggregation of diseased tubers in infested consignments is another complicating issue. On the scale of potatoes from a single cropping field, patterns of aggregation of diseased tubers (e.g. infection spots in the field originating from diseased seed potatoes) may propagate into potato lots coming from this field due to little mixing during harvest. Or, on the scale of big lots, potatoes coming from diseased fields are not perfectly mixed with potatoes coming from non-diseased fields. The efficiency of the currently employed sampling protocol of 200 tubers per 25 ton of potato assumes perfect random mixing of disease tubers within the lot. The more aggregated eventually diseased tubers occur within an infested lot, the higher is the probability that the sample contain zero diseased tubers.

4.2.3 Probability of spread after establishment

Evidence from areas where *R. solanacearum* is known to occur, or has occurred, but has been successfully eradicated, show that this pest has a high potential for dissemination. However, the rough topography of the PRA area is likely to reduce the dissemination potential of the pest in the PRA area compared to areas with a more even topography. This is because the bacterium by natural means, with few exceptions, only will be disseminated downstream the watercourses of the PRA area. There are no restrictions on use of surface water for irrigation in Norway, and this is a common practice in the Norwegian potato production when needed.

4.2.4 Conclusion on the probability of introduction and spread

Summarising the quantitative information of probability of entry yields:

- Primary infection, that is infection of the potato production by use of contaminated surface water is, despite the ban, an important factor explaining the few infections that still occur in the Dutch potato production chain
- The estimates on the average fraction of Dutch ware potato lots infested with *R. solanacearum* ranges from 0.00001 to 0.00006

Concluding these “on average” considerations, approximately 25% or slightly less of the infested lots will be detected in the sampling and testing survey. Assuming that allowing for import of ware potatoes from the Netherlands will replace the current import volume to Norway, i.e. 1598 lots, one infested lot will enter Norway in the range from one each 10th year to one each 60th year. A lower import volume from the Netherlands will increase the time between entry events.

The above calculations are only done on a per-lot basis. To take the calculation of probability of entry further will require information of the potential size of the import volume and frequency to Norway, in the case of an import permit. This information has not been available so far. Moreover, to calculate the amount of inoculum/propagules that will enter we need to include information on incidence of *R. solanacearum* infected potato tubers in infested potato lots.

If additional risk management measures, like import control, was imposed, it is apparent that only potato lots with a relatively low disease incidence level may pass control and testing. Thus, in addition to the infected lots intercepted by this risk management measure, it will be a side effect that the infected lots that eventually may enter generally will have a lower disease incidence level, than without a control and testing procedure.

The relationship between amount of bacteria that is released (e.g. by effluents from potato peeling) and the probability of transfer to a suitable host on which a successful infection take place, will clearly vary both temporally and spatially. The estimation of this relationship as a function of time of year (e.g. climate conditions, potato cropping stage) and geographical location of point of release (e.g. from data on human population/private households; location of potato industry and the respective level of treatment of effluent water) is a complicated task. As long as this information is not documented, we have to agree on estimates based on expert judgement. Examples of such simplified estimates could be:

- import of one infested lot of average size 25 tons that is distributed to private households will on average lead to an introduction of *R. solanacearum* to Norway in 5 of the 10 cases. The background for this example judgement is that potatoes are normally sold in 2.5 kg packages in Norwegian supermarkets. It is therefore possible that one potato lot sized 25 tons could be distributed to 10,000 different private households in Norway.
- import of one infested lot of average size 25 tons that is distributed to one potato industry plant will on average lead to an introduction of *R. solanacearum* to Norway in 1of the10 cases . For a potato processing plant located close to the coast, and far from potato cropping areas, the probability that bacteria will be transferred to a suitable host will be minimal. However, the majority of the Norwegian potato industry is located in the important potato growing districts. Consequently, processing infested potato lots at the latter industry plants will presumably have a high probability of transfer to a suitable host.

The calculation of the consequence of an introduction is also complicated, but fortunately, more methodology has become available. Calculation of the potential for establishment and consequence of an introduction is described previously. The distribution of potato cropping area potentially affected by one introduction (based on the model) could be read from Figure 3. It is interesting to note that the shape of this distribution is far from the Gaussian (normal) distribution. The distribution in Figure 3 has at least two peaks. The major peak of the distribution is in the left end of the x-axis, indication that an introduction of *R. solanacearum* in most cases will affect a small area of potato cropping land. However, in the right end of the x-axis, also a small peak of the distribution could be identified, indication that introduction of *R. solanacearum* in some areas will affect large areas of potato growing land. The introductions that will give such big impacts are introductions early in the largest watercourses of Southeast Norway. This result could also be read from Figure 4, which depicts the spatial variations in the simulated area of affected arable land dependent of geographical localisation of introductions of *R. solanacearum*. The average area of potato cropping land affected by one introduction (based on the model simulations) is 90 hectares. Standard measures of variability such as standard deviation provide little meaning as long as the frequency distribution is shaped as indicated in Figure 3.

4.2.4.1 Conclusion regarding endangered areas

The geographical distribution of the host plant *S. dulcamara* in the PRA area is regarded as a key ecological factor that favour the establishment of the pest where it occurs. In the model simulations of entry and establishment, the assumption was made that only potato cropping areas within the distribution limits of *S. dulcamara* are being considered endangered areas.

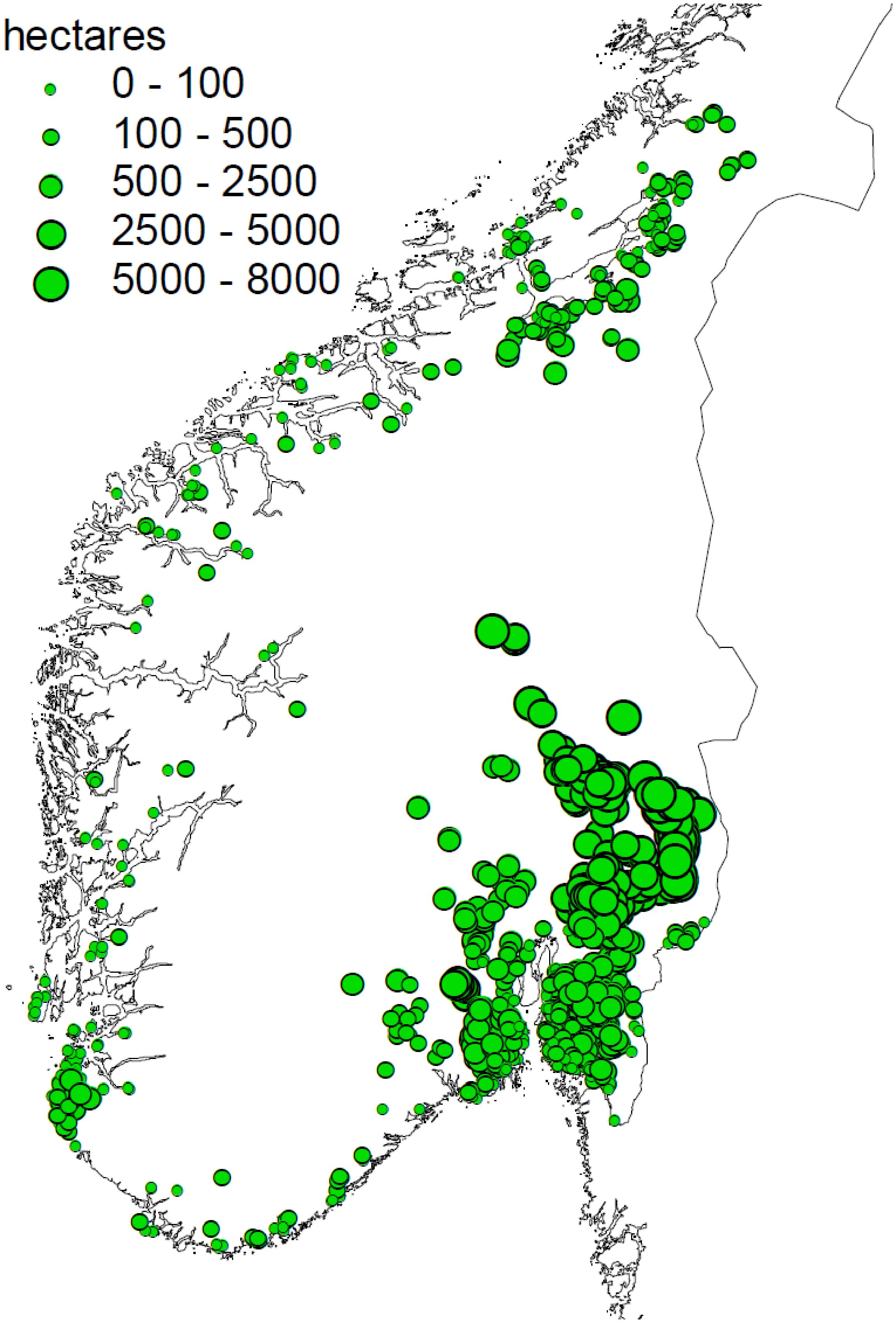


Figure 4. Spatial variations in the simulated area of affected arable land dependent of geographical localisation of introductions of *Ralstonia solanacearum*.

4.3. Assessment of potential economic consequences

4.3.1 Pest effects

4.3.1.1 Direct pest effects

Direct pest effects, such as yield loss from rotting of tubers would probably be of minor importance because of the cool climate in the PRA area.

Ralstonia solanacearum race 3 biovar 2 also has the potential to be established in greenhouses growing tomatoes. Particularly in some districts in Norway this is a very important production, and the economic impact of a disease outbreak could be substantial.

4.3.1.2 Indirect pest effects

In case of an introduction of *R. solanacearum* all infected potato lots and related lots would have to be destroyed in order to control the disease, as well as strict measures for hygiene and crop rotation would have to be put in action, to a considerable cost for the affected grower, and the official authorities. The high number of small farms and private gardens where potatoes are grown will make it difficult and expensive to enforce the necessary statutory orders to control the disease. Many of the small farms have to rely on potato in their crop rotation schemes. The social impact of a disease outbreak could therefore become considerable.

Potential export markets would be lost, and reduced supply of domestically grown potatoes would make the country more dependent on import from other countries.

4.4. Degree of uncertainty

There is a minor uncertainty regarding the prevalence of *R. solanacearum* in the Dutch potato export. The current estimates are based on the results from the Dutch monitoring and testing programme for 2003–2007 and model studies summarised in Breukers (2006b).

The calculations based on model simulations for entry and establishment relies on a number of assumptions. Uncertainty inherent in some of these assumptions has not been accounted for in the current risk assessment estimates. This is either because no documentation has been found available for these factors or because the time and resource constraints of this assessment did not permit the studies necessary to obtain this information.

4.5. Conclusion of the pest risk assessment stage

- The bacterial wilt bacterium, *Ralstonia solanacearum*, is regulated as a quarantine pest, which has never been detected or intercepted by Norway. Import of ware potato from the Netherlands to Norway will open a potential pathway for entry of the pathogen to the PRA area of Norway.
- Data from field experiments in Sweden and establishment of the bacterium in Sweden, United Kingdom, and The Netherlands indicate that in the best agro-ecological zones of Norway *R. solanacearum* will be able to develop during the growing season and survive winters in groundkeepers, soil, water and weeds.
- The distribution of the host plants *Solanum dulcamara* and *S. nigrum* in the PRA area is the key ecological factor in the establishment of the pest. In the model simulation of entry and establishment, the assumption has been made that only potato cropping areas within the distribution limits of *S. dulcamara* are considered endangered areas.
- Based on published data from the Dutch monitoring program during 2003-2007 the fraction of Dutch potato lots infested with *R. solanacearum* is at least 1 in 100,000. Adjusting the reported statistics by the efficiency of the sampling procedure and the sensitivity of the testing procedure, we can assume that about a maximum of 25% of the infested lots were detected, and thus the number of infested lots that remain undetected in the potato lots for export will on average be three times the number of infested lots detected.
- Single introductions of *R. solanacearum* to Norway, i.e. entry of the bacterium, establishment on a suitable host, and dissemination of the bacteria downstream the watercourse to the coast, will on average affect 90 hectares of potato growing land. Geographical variation in damage potential has the effect that the consequence of a single introduction of *R. solanacearum* to Norway varies from a worst case of more than 900 hectares potato-cropping land affected, to a best case of less than 90 hectares affected by a single introduction.
- It is possible to eradicate *R. solanacearum* from smaller watercourses by removing the host plants *S. dulcamara* and *S. nigrum*, but difficult to impossible to eradicate *R. solanacearum* from large watercourses

5. CONCLUSION

The bacterium *R. solanacearum* presents a risk to the PRA area of Norway. This pest risk assessment shows that there is a medium risk associated with *R. solanacearum* in import of ware potato from the Netherlands.

6. ANSWERS TO TERMS OF REFERENCE

1. The probability of introduction of *Ralstonia solanacearum* to Norway by the pathway for entry of ware potatoes for food and industry purposes grown in the Netherlands is expected to occur at a rate of entry in the range from 0.00001 to 0.00006 (1 to 6 per 100 000 lots imported). The probability that one infected lot will result in establishment is not known. On the other hand, in parts of the PRA area there are no known barriers to establishment of the pathogen.
2. The conclusions related to consequences of a possible establishment of *Ralstonia solanacearum* in Norway according to the report VKM report entitled “Assessment of plant health risk regarding potato brown rot and ware potato import from Egypt” from 2005 are still valid. More recent information about the geographical distribution of the *S. dulcamara* and *S. nigrum* in the PRA area has become available. This new information indicates a minor increase in the availability of host plants for the pathogen in the PRA area.

7. REFERENCES

Anonymous. 1998. Council directive 98/57/EC. Off. J. Eur. Communities L-235:1-39.

Breukers, A., Hagenaars, T., van der Werf, W. & Oude Lansink, A. 2005. Modelling of brown rot prevalence in the Dutch potato production chain over time: from state variable to individual-based models. Nonlinear Analysis: Real World Applications 6(4), 797-815.

Breukers, A., Kettenis, D.L., Mourits, M., van der Werf, W. & Lansink, A.O. 2006a. Individual-based models in the analysis of disease transmission in plant production chains: An application to potato brown rot. Agricultural Systems 90, 112-131.

Breukers, A. 2006b. Bio-economic modelling of brown rot in the Dutch potato production chain. PhD-thesis Wageningen University.

Breukers, A., Mourits, M., van der Werf, W., & Lansink, A.O. 2008. Costs and benefits of controlling quarantine diseases: a bio-economic modelling approach. Agricultural Economics 38, 137-149.

Campbell, C. L. and Madden, L. V. 1990. Introduction to Plant Disease Epidemiology. Wiley Interscience, New York.

Cook, D. & Sequeira, L.. 1994. Strain differentiation of *Pseudomonas solanacearum* by molecular genetic methods. In: Bacterial wilt: The disease and its causative agent, *Pseudomonas solanacearum* (Ed. By Hayward, A. C., & G. L. Hartman), pp 77-93. CAB International, UK.

EPPO 1997a. Quarantine Pests for Europe, Second Edition. *Ralstonia solanacearum,* pp 1071-1081 CAB International, UK.

EPPO 2010a. Plant Protection Thesaurus

http://eppt.eppo.org/search.php.

EPPO 2010b. Quarantine Data Retrieval System 2010

http://www.eppo.org/DATABASES/pqr/pqr.htm

EPPO 2010c. *Ralstonia solanacearum* detected in Sweden. EPPO Reporting Service 2010/099.

EPPO 2010d. *Ralstonia solanacearum* detected in the United Kingdom. EPPO Reporting Service 2010/100.

Elphinstone, J. G. 1996. Survival and possibilities for extinction of *Pseudomonas solanacearum* (Smith) Smith in cool climates. Potato Research 39, 403-410.

EU 1998. Council Directive 98/57/EC of 20 July 1998 on the control of *Ralstonia solanacearum*. Annex II-test scheme for the diagnosis, detection and identification of *Ralstonia solanacearum*. Official Journal of the European Communities, No. L235, 8-39.

FAO 2004. Pest Risk Analysis for Quarantine Pests, Including Analysis of Environmental Risks and Living Modified Organisms. International standards for phytosanitary measures (ISPM) No. 11. Food and Agriculture Organisation of the United Nations, Rome.

Fægri, K. and Danielsen, A. 1996. Maps of the distribution of Norwegian vascular plants, The southeastern element. Fagbokforlaget, Bergen.

Gillings, M. R. & P. Fahy. 1994. Genomic fingerprinting: towards a unified view of the *Pseudomonas solanacearum* species complex. . In: Bacterial wilt: The disease and its causative agent, *Pseudomonas solanacearum* (Ed. By Hayward, A. C., & G. L. Hartman), pp 95-112. CAB International, UK.

Graham, J., D.A. Jones & A. B. Lloyd. 1979. Survival of *Pseudomonas solanacearum* race 3 in plant debris and in latently infected potato tubers. Phytopathology 69, 1100-1103.

Hayward, A. C. 1991. Biology and epidemiology of bacterial wilt caused by *Pseudomonas solanacearum*. Annual Review of Phytopathology 29, 65-87.

Janse, J. D. 1996. Potato brown rot in Western Europe – history, present occurrence and some remarks on possible origin, epidemiology and control strategies. EPPO Bulletin **26**, 679-695.

Janse, J.D., Araluppan, F.A.X., Schans, J., Wenneker, M. & Westerhuis, W. 1998. Experiences with Bacterial Brown Rot *Ralstonia solanacearum* Biovar 2, Race 3 in the Netherlands. In: Prior, P.H., Allen, C. & Elphinstone, J. (eds.) Bacterial Wilt Disease: Molecular and Ecological Aspects; report of the Second International Wilt Symposium, Gosier, Guadeloupe, France. Springer, 1998, 443 pp.

Kelman, A. 1953. The bacterial wilt caused by *Pseudomonas solanacearum*. NC Agr. Exp. Sta. Tech. Bull. 99, 194 pp.

Kelman, A. & L. Sequeira. 1965. Root-to-root spread of *Pseudomonas solanacearum*. Phytopathology 55, 304-309.

Kelman, A., G. L. Hartman & A. C. Hayward. 1994. Introduction. . In: Bacterial wilt: The disease and its causative agent, *Pseudomonas solanacearum* (Ed. By Hayward, A. C., & G. L. Hartman), pp 1-7. CAB International, UK.

Landbruks- og Matdepartementet 1996. Forkrift om tiltak mot mørk ringråte i potet.

http://www.lovdata.no/cgi-wift/wiftldles?doc=/app/gratis/www/docroot/for/sf/ld/ld-19960514-0498.html&emne=potet*%20og*%20import*&

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

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

Landbruks- og Matdepartementet 2007. Forskrift om import av matpoteter fra Egypt.

http://www.lovdata.no/cgi-wift/wiftldles?doc=/app/gratis/www/docroot/ltavd1/filer/sf-20071116-1259.html&emne=potet*%20og*%20import*&

Lid, J. 1985. Norsk, svensk, finsk flora. Det Norske Samlaget, Oslo, Norway.

Lum, K. Y. 1973. Cross inoculation studies of *Pseudomonas solanacearum* from ginger. MARDI Res. Bull. 1, 15-21.

Madden, L. V. & Hughes, G. 1995. Plant disease incidence: Distributions, heterogeneity, and temporal analysis. Annual Review of Phytopathology 33:529-564.

Mattilsynet 2010. Moffett, M. L., J. E. Giles & Wood, B.A. 1983. Survival of *Pseudomonas solanacearum* biovars 2 and 3 in soil: effect of moisture and soil type. Soil Biol. Biochem. 15, 587-591.

Nesmith, W.C. & Jenkins, S.F. 1985. Influence of antagonists and controlled matric potential on the survival of *Pseudomonas solanacearum* in four North Carolina soils. Phytopathology 75, 1182-1187.

Report Oerke, E-C., H-W. Dehne, F. Schönbeck & Weber, A. 1994. Crop production and crop protection. Estimated losses in major food and cash crops. Elsevier, Amsterdam 1994.

Olsson, K. 1976. Experience of brown rot caused by *Pseudomonas solanacearum* (Smith) Smith in Sweden. EPPO Bulletin 6, 199-207.

Olsson, K. 1976b. International planning conference and workshop on the ecology and control of bacterial wilt caused by *Pseudomonas solanacearum*. North Carolina State Univ. Raleigh, North Carolina 18-23.7 1976.

Perminow, J. I. S. & Borowski, E. 2004. Analyser av vann for smitte av *Ralstonia solanacearum* (mørk ringråte på potet). (*In Norwegian*) Commissioned by the Norwegian Food Safety Authority.

Perminow, J.I.S., Akselsen, I.-L. & Borowski, E. 2010. Overvåking av *Ralstonia solanacearum* (mørk ringråte) i vann. Bioforsk Rapport 5(48).

http://www.bioforsk.no/ikbViewer/page/tjenester/publikasjoner/publikasjon?p_document_id=66836

Rafoss, T. 2003. Spatial Stochastic Simulation Offers Potential as a Quantitative Method for Pest Risk Analysis. Risk Analysis, 23(4):651-661.

Rafoss, T & Sletten, A. 2004. Quantitative pest risk assessment for the potato brown rot bacterium *Ralstonia solanacearum* (race 3 biovar2) in fresh potato imports to Norway from Egypt. Norwegian Scientific Committee for Food Safety.

Rafoss, T. 2005. Addendum and update to: Quantitative Pest Risk Assessment for the potato brown rot bacterium *Ralstonia solanacearum* (race 3 biovar 2) in fresh potato imports to Norway from Egypt. Report commissioned by the Norwegian Scientific Committee for Food Safety.

Sequeira, L. 1994. Epilogue: Life with a ”mutable and treacherous tribe”. In: Bacterial wilt: The disease and its causative agent, *Pseudomonas solanacearum* (Ed. By Hayward, A. C., & G.L. Hartman), pp 235-247. CAB International, UK.

Sletten, A. 1998. Pest Risk Assessment (PRA) for Norway on *Ralstonia solanacearum*”. Report from the Norwegian Crop Research Institute, commissioned by The Norwegian Agricultural Inspection Service.

Sletten, A. 2004. Pest Risk Assessment (PRA) for Norway on *Ralstonia solanacearum*”. Report from the Norwegian Crop Research Institute, commissioned by The Norwegian Agricultural Inspection Service (Updated October 2004).

Statistics Norway. 2000. Agricultural census 1999.Statistics Norway, Oslo.

Statistics Norway. 2004. Statistics Norway, NOS D 286, Jordbruksstatistikk.

Stead, D. E., J. G. Elphinstone &Pemberton, A. W. 1996. Potato brown rot in Europe. Proceedings, Brighton Crop Protection Conference – Pest & Diseases 1996, pp 1145-1152.

Swanepoel, Anita E. 1990. The effect of temperature on the development of wilting and on progeny tuber infection of potatoes inoculated with South African strains of biovar 2 and 3 of *Pseudomonas solanacearum*. Potato Research 33, 287-290.

Turco, P., Saccardi, A., Piazzi, E., Martini, G., Melegatti, A., Xodo, E. & Gambin, E. 1998. Monitoring of *Pseudomonas solanacearum* in the Veneto region (Italy). EPPO Bulletin 28, 85-92.

van Elsas, J.D., Kastelein, P., van Bekkum, P., van der Wolf, J.M., de Vries, P.M., & van Overbeek, L.S. 2000. Survival of *Ralstonia solanacearum* Biovar 2, the causative agent of potato brown rot, in field and microcosm soils in temperate climates. Phytopathology 90, 1358-1366.

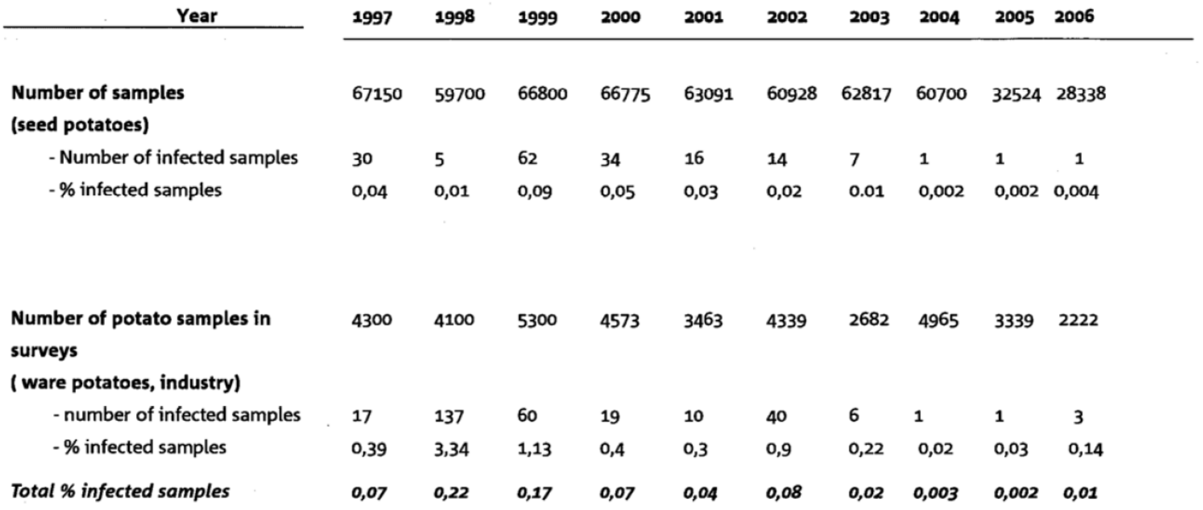
VKM 2005. Assessment of plant health risk regarding potato brown rot and ware potato import from Egypt. Opinion of the Plant Health Panel of the Scientific Committee for Food Safety, 04/201-16-3-*rev2* final. 6 pp. VKM, Oslo, Norway.

http://www.vkm.no/dav/1b834f260a.pdf

Wakimoto, S., I. Utatsu, N. Matsuo & Hayashi, N. 1982. Multiplication of *Pseudomonas solanacearum* in pure water. Ann. Phytopath. Soc. Japan 48, 620-627.

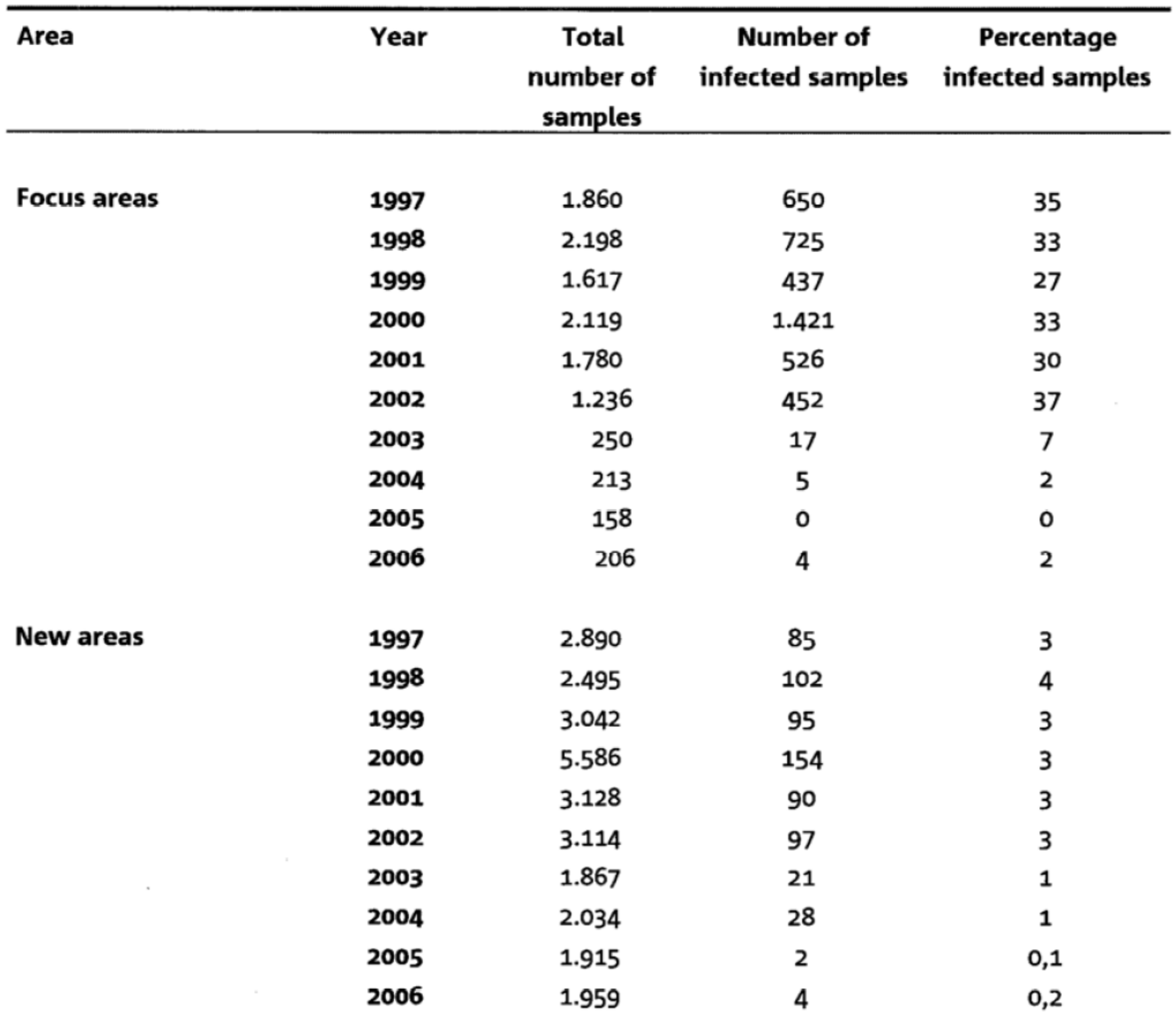
Annex

Annex 1. Number of potato samples tested and infected with *Ralstonia solanacearum* since 1997



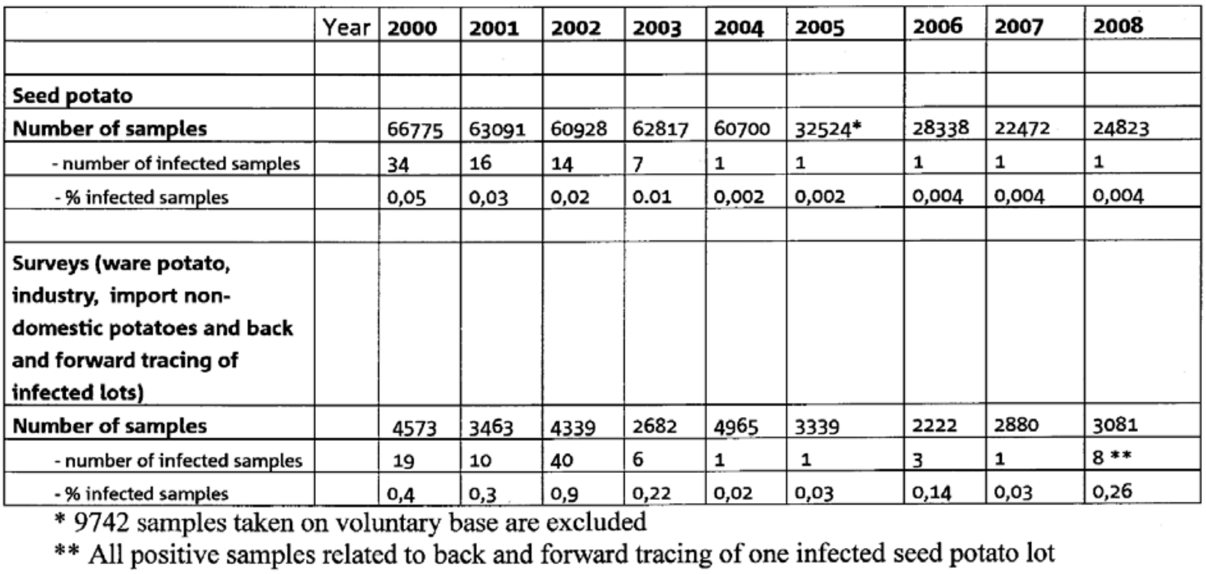
Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Number of samples (seed potatoes)	67150	59700	66800	66775	63091	60928	62817	60700	32524	28338
- Number of infected samples	30	5	62	34	16	14	7	1	1	1
- % infected samples	0,04	0,01	0,09	0,05	0,03	0,02	0.01	0,002	0,002	0,004
Number of potato samples in surveys (ware potatoes, industry)	4300	4100	5300	4573	3463	4339	2682	4965	3339	2222
- number of infected samples	17	137	60	19	10	40	6	1	1	3
- % infected samples	0,39	3,34	1,13	0,4	0,3	0,9	0,22	0,02	0,03	0,14
Total % infected samples	***0,07***	***0,22***	***0,17***	***0,07***	***0,04***	***0,08***	***0,02***	***0,003***	***0,002***	***0,01***

Annex 2. Survey results surface water and *Solanum dulcamara* (bittersweet) on *Ralstonia solanacearum* 1997 - 2006



Area	Year	Total number of samples	Number of infected samples	Percentage infected samples
Focus areas	**1997**	1.860	650	35
	1998	2.198	725	33
	1999	1.617	437	27
	2000	2.119	1.421	33
	2001	1.780	526	30
	2002	1.236	452	37
	2003	250	17	7
	2004	213	5	2
	2005	158	0	0
	2006	206	4	2
New areas	**1997**	2.890	85	3
	1998	2.495	102	4
	1999	3.042	95	3
	2000	5.586	154	3
	2001	3.128	90	3
	2002	3.114	97	3
	2003	1.867	21	1
	2004	2.034	28	1
	2005	1.915	2	0,1
	2006	1.959	4	0,2

Annex 3. Number of potato samples tested and infected with *Ralstonia solanacearum* since 2000.



	Year	2000	2001	2002	2003	2004	2005	2006	2007	2008
Seed potato										
Number of samples		66775	63091	60928	62817	60700	32524*	28338	22472	24823
- number of infected samples		34	16	14	7	1	1	1	1	1
- % infected samples		0,05	0,03	0,02	0.01	0,002	0,002	0,004	0,004	0,004
Surveys (ware potato, industry, import non-domestic potatoes and back and forward tracing of infected lots)										
Number of samples		4573	3463	4339	2682	4965	3339	2222	2880	3081
- number of infected samples		19	10	40	6	1	1	3	1	8 **
- % infected samples		0,4	0,3	0,9	0,22	0,02	0,03	0,14	0,03	0,26

* 9742 samples taken on voluntary base are excluded

** All positive samples related to back and forward tracing of one infected seed potato lot

Annex 4. Climate data.

Table 4. Tomb, Østfold County. Climatological normals for the period 1961-1990 for mean air temperature (°C) and amount of precipitation (mm); soil temperature (°C) 10 cm below ground for the period 1991-1995.

	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 5. Ås, Akershus County. Climatological normals for the period 1961-1990 for mean air temperature (°C) and amount of precipitation (mm); soil temperature (°C) 10 cm below ground for the period 1991-1995.

	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 6. Kise, Hedmark County. Climatological normals for the period 1961-1990 for mean air temperature (°C) and amount of precipitation (mm); soil temperature (°C) 10 cm below ground for the period 1993-1995.

	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 7. Apelsvoll, Oppland County. Climatological normals for the period 1961-1990 for mean air temperature (°C) and amount of precipitation (mm); soil temperature (°C) 10 cm below ground for the period 1991-1995.

	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 8. Lier, Buskerud County. Climatological normals for the period 1961-1990 for mean air temperature (°C) and amount of precipitation (mm); soil temperature (°C) 10 cm below ground for the period 1991-1995.

	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 9. Ramnes, Vestfold County. Climatological normals for the period 1961-1990 for mean air temperature (°C) and amount of precipitation (mm); soil temperature (°C) 10 cm below ground for the period 1991-1995.

	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 10. Bø, Telemark County. Climatological normals for the period 1961-1990 for mean air temperature (°C) and amount of precipitation (mm); soil temperature (°C) 10 cm below ground for the period 1991-1995.

	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 11. Landvik, Aust-Agder County. Climatological normals for the period 1961-1990 for mean air temperature (°C) and amount of precipitation (mm); soil temperature (°C) 10 cm below ground for the period 1991-1995.

	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 12. Særheim, Rogaland County. Climatological normals for the period 1961-1990 for mean air temperature (°C) and amount of precipitation (mm); soil temperature (°C) 10 cm below ground for the period 1991-1995.

	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 13. Surnadal, Møre og Romsdal County. Climatological normals for the period 1961-1990 for mean air temperature (°C) and amount of precipitation (mm); soil temperature (°C) 10 cm below ground for the period 1993-1995.

	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	
December	-1.0	154	-1.4	-1.5	-0.5	

Table 14. Rissa, Sør-Trøndelag County. Climatological normals for the period 1961-1990 for mean air temperature (°C) and amount of precipitation (mm); soil temperature (°C) 10 cm below ground for the period 1992-1995.

	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 15. Frosta, Nord-Trøndelag County. Climatological normals for the period 1961-1990 for mean air temperature (°C) and amount of precipitation (mm); soil temperature (°C) 10 cm below ground for the period 1991-1995.

	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 16. Sortland, Nordland County. Climatological normals for the period 1961-1990 for mean air temperature (°C) and amount of precipitation (mm); soil temperature (°C) 10 cm below ground for the period 1992-1995.

	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 17. Climatological normals for the period 1961-1990 for mean air temperature (°C) and amount of precipitation (mm) for locations in England, the Netherlands and Sweden.

	Birmingham, UK		De Bilt, NL		Stockholm, SE	
Month	Temp.	Precip.	Temp.	Precip.	Temp.	Precip.
January	3.1	57	2.2	69	-2.8	39
February	3.1	48	2.5	49	- 3.0	27
March	5.2	51	5.0	66	0.1	26
April	7.6	49	8.0	53	4.6	30
May	10.6	56	12.3	61	10.7	30
June	14.0	56	15.2	70	15.6	45
July	15.8	46	16.8	76	17.2	72
August	15.4	66	16.7	71	16.2	66
September	13.2	54	14.0	67	11.9	55
October	10.0	52	10.5	75	7.5	50
November	6.0	59	5.9	81	2.6	53
December	4.2	66	3.2	83	-1.0	46