EUROPEAN AND MEDITERRANEAN PLANT PROTECTION ORGANIZATION
ORGANISATION EUROPEENNE ET MEDITERRANEENNE POUR LA PROTECTION DES PLANTES

12-17833

Pest Risk Analysis for

Candidatus Liberibacter solanacearum in Solanaceae

September 2012

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This risk assessment follows the EPPO Standard PM 5/3(4) *Decision-support scheme for quarantine pests* (available at http://archives.eppo.int/EPPOStandards/pra.htm) and uses the terminology defined in ISPM 5 *Glossary of Phytosanitary Terms* (available at https://www.ippc.int/index.php).

This document was first elaborated by an Expert Working Group and then reviewed by core members and by the Panel on Phytosanitary Measures and if relevant other EPPO bodies. It was finally approved by the Council in September 2012.

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Pest Risk Analysis for *Candidatus* Liberibacter solanacearum in Solanaceae

This PRA was conducted following EPPO Standard PM 5/3 (4) *Decision-support scheme PRA for quarantine pests*.

A preliminary draft has been prepared by the EPPO Secretariat. This document has been reviewed by an Expert Working Group that met in the EPPO Headquarters in Paris on 2010-11-30/12-03[1]. A short associated PRA was also prepared to cover the vector of *Ca* L. solanacearum, *Bactericera cockerelli*.

This EWG was composed of:
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Ms Fabienne Grousset – Consultant for EPPO who has prepared the draft PRA.

Core members (Dirk Jan Van der Gaag, Leif Sundheim Gritta Schrader, Nursen Ustun, Françoise Petter) reviewed the PRA in autumn 2011. The risk management part was reviewed by the Panel on Phytosanitary Measures for Potato on 2012-02, and by the Panel on Phytosanitary Measures on 2012-03.

[1] Some additional references were included in this PRA during the consultation phase within the EPPO framework, when new relevant research results appeared. Nevertheless no exhaustive bibliography was conducted.

Content *(you may click on the title to reach the selected section)*

Stage 1: Initiation

General comments on the scope of this PRA:

The elements below are essential to the present PRA:

- This PRA focuses on Solanaceae hosts of *Ca*. L. solanacearum, as the bacterium has been reported to cause serious economic losses in the Americas and also in New Zealand on its Solanaceae hosts. The PRA covers the bacterium itself and the bacterium/*Bactericera cockerelli* complex. *B. cockerelli* is also a pest in its own right, and a separate PRA has also been prepared.
- Although *Ca*. L. solanacearum has recently been identified on carrot in the PRA area (Finland, Norway, Sweden, Spain), to date there does not seem to be a pathway between carrot and solanaceous plants: the vector on carrot is *Trioza apicalis* (and a *Bactericera* sp.), which does not feed on Solanaceae, and there are also no psyllids feeding on both carrot and Solanaceae in this part of the PRA area. Data available for the bacterium on carrot and its vector are found in Annex 1.
- There is a major uncertainty regarding the host range of *Ca*. L. solanacearum, which has now been found outside of Solanaceae, as well as on reservoir plants. For the latter there are uncertainties on whether alternative hosts that are common to the two known vectors (*T. apicalis* and *B. cockerelli*) (e.g. spruce) could act as a source of the bacterium in the case that *B. cockerelli* was introduced (i.e. providing a possible pathway from carrot to Solanaceae in the PRA area).
- There are some major uncertainties regarding vectors: (all details on vectors have been grouped in sections 15a and 15b)
  * to date, it is suspected that the bacterium has more vectors than originally thought
  * whether a psyllid present in the PRA area could both infest carrot and Solanaceae, thereby increasing the risk of introduction and spread if carrots infected with the bacterium would enter areas where such a psyllid occurs (i.e. providing a possible pathway from carrot to Solanaceae in the PRA area). The existence of such a psyllid would drastically change this PRA.
  * some specific features of *B. cockerelli* create a major uncertainty when trying to define the possible zone of establishment of the vector in the field in the PRA area and its impact (detailed in the text). In summary: migration patterns, and occurrence of transient populations; reasons why it does not survive in winter in the northwestern part of its range (e.g. Washington); importance of vertical transmission to the progeny, persistence of the bacterium in *B. cockerelli* populations and factors affecting this, difference between populations of *B. cockerelli* in North America.
- *Ca*. L. solanacearum was identified in 2008 and is the subject of extensive research. Knowledge about this pest and its vectors continues to evolve very rapidly. Some additional references were included in this PRA during the consultation phase within the EPPO framework, when new relevant research results appeared. Nevertheless no exhaustive bibliography was conducted.

Thus, the scope of this PRA is the risk of *Ca*. L. solanacearum for Solanaceae. The risk will be assessed with and without the presence of the known vector on Solanaceae, *B. cockerelli*. A separate PRA has been prepared in which the probability of entry of *B. cockerelli* and the impact of the vector alone has been assessed.

1 - Give the reason for performing the PRA

Identification of a single pest

Justification:

In 2008, a new bacterial species belonging to the genus '*Candidatus* Liberibacter' was found associated with diseases of potato, tomato and other solanaceous crops in the Americas, and the bacterium was also discovered in New Zealand. In particular, it was found associated with a potato disease called 'zebra chip' which has caused significant economic losses, by reducing both yield and quality of potato crops. The pathogen is an unculturable, phloem invading bacterium. It is transmitted by a vector, the leaf psyllid *Bactericera cockerelli* (Hemiptera, Triozidae), which lives among others on plants of the Solanaceae family, especially tomato and potato. The pest and its vector have never been detected in the PRA area, and the EPPO Working Party on Phytosanitary Regulations decided in June 2010 that a PRA should be performed. In 2010, a different haplotype of the bacterium was found on carrots in Finland, transmitted by the carrot psyllid *Trioza apicalis* (Hemiptera, Triozidae).

2a - Name of the pest

Candidatus Liberibacter solanacearum (Liefting *et al*. 2008a, 2008b, 2009a, 2009c)

Synonym: *Candidatus* Liberibacter psyllaurous (Hansen *et al*., 2008).

See details under 8.

The present PRA uses the name "*Candidatus* Liberibacter solanacearum ", because

- the economically most important host of two haplotypes of the bacterium belongs to the Solanaceae family.
- it is validly published and there is reference material (Liefting *et al*., 2009c; Civerolo, 2010);
- it corresponds to the first detection of the organism;
- it seems to be more consistently used in literature, including recent US literature;

2b - Indicate the type of the pest

Bacterium

2d - Indicate the taxonomic position

Bacteria
Proteobacteria
Alphaproteobacteria
Rhizobiales
Rhizobiaceae
Candidatus Liberibacter

3 - Clearly define the PRA area

EPPO member countries

4 - Does a relevant earlier PRA exist?

yes

Justification:

A PRA was prepared by the NPPO of Germany in 2010 (Stefani, 2010). It has been used for the present PRA. Where sections were used, this is indicated by "(Stefani, 2010)".

In addition,

- Canada conducted a PRA in September 2008 (Kristjansson & Damus, 2008).
- Australia conducted a PRA in September 2009 on *Ca.* L. psyllaurous in reaction to the recent detections in New Zealand (Biosecurity Australia, 2009).

These PRAs were also consulted.

5 - Is the earlier PRA still entirely valid, or only partly valid (out of date, applied in different circumstances, for a similar but distinct pest, for another area with similar conditions)?

not entirely valid

5b - Explain

Justification:

The German PRA applies mostly to that country, and for some elements to other EU countries. In particular, several pathways are closed for Germany (and EU countries), but are opened for some countries in the PRA area. The German PRA needed to be adjusted and completed for the whole PRA area.

6 - Specify all host plant species (for pests directly affecting plants). Indicate the ones which are present in the PRA area.

Justification:

Among the known host plants of *Ca.* L. solanacearum are some cultivated and wild species of Solanaceae, as well as carrot (*Daucus carota*, Apiaceae). The bacterium has also been reported on *Bidens* sp. (Asteraceae) and Celeriac (*Apium graveolens rapaceum*, Apiaceae). There are several indications that the host range is much broader including plant species of several plant families. Details and references are given below:

1. Cultivated host plants on which *Ca.* L. solanacearum was found

- Solanaceous plants:
  - potato (*Solanum tuberosum*) (Hansen *et al*., 2008; Liefting *et al*., 2008a),
  - tomato (*Solanum esculentum*) (Liefting 2008, Liefting *et al.*, 2009a, c; Munyaneza *et al*., 2009c),
  - *Capsicum* spp. (including bell pepper/sweet pepper *Capsicum annuum* - Liefting 2008, Liefting *et al.*, 2009a, c, Munyaneza *et al.*, 2009a, and chilli *C. frutescens* - Liefting *et al.* 2009c),
  - tamarillo (*Solanum betaceum)* (Liefting *et al*., 2008b)
  - Cape gooseberry (*Physalis peruviana*) (Liefting *et al*., 2008b, 2009c) (see note 1 below),
  - Eggplant (syn. aubergine) (*Solanum melongena*) (Munyaneza, 2010b, pers. comm. 2010-10) (see note 2 below).

- Carrots (*Daucus carota*) (a separate haplotype of the bacterium has been detected on carrots in Finland) (Munyaneza *et al*., 2010a, b, Nelson *et al.* 2011). For details regarding carrot see, Annex 1

- Celeriac (*Apium graveolens rapaceum*). (Cobos-Suarez, Spanish NPPO, pers. comm. June 2011)

Note 1- Cape gooseberry (Physalis peruviana)

Of the host plants above, Cape gooseberry is the only one for which symptomless occurrence has been reported (Liefting, 2008b). This initial 2008-report related to both Cape gooseberry and tamarillo. While symptoms and damage on tamarillo were later reported (e.g. Watson, 2009), no information was found in the literature regarding Cape gooseberry. It is not clear whether symptoms might develop on this plant and if it can act as a reservoir plant for commercial crops.

Note 2 - Eggplant (*Solanum melongena*)

There is no published work on eggplant as a host or of damage on eggplant crops, but it is thought that the bacterium has infected eggplants in the field (Munyaneza, pers. comm., 2010-10). Eggplant was not found as a host to date in New Zealand (Liefting, pers. comm. 2010-10). It has been shown as an experimental host (see below) and, together with pepino (*Solanum muricatum*) and tomatillo (*Physalis ixocarpa*), is considered as having an unknown host status by Biosecurity Australia (2009).

2. Wild host plants

Ca. L. solanacearum has been detected in a number of wild species:

- Solanaceae: silverleaf nightshade (*Solanum elaeagnifolium*), wolfberry/common box thorn (*Lycium barbarum*), black nightshade/"Eastern black nightshade" (*Solanum ptychantum*) (USA, Wen *et al*., 2009).
- Asteraceae: *Bidens* sp. (weed, New Zealand, species unidentified, Liefting pers. comm. in Nelson (ed), 2009)

3. Uncertainties on host plants

Ca. L. solanacearum was originally found only on Solanaceae, but a haplotype of the bacterium has recently been found on *Daucus carota* (carrot) which is not a member of the Solanaceae (Munyaneza *et al*., 2010a, Nelson *et al*., 2011). This recent finding in a non-Solanaceae plant species suggest that *Ca*. L. solanacearum is likely to have more host plants than currently known, both among Solanaceae and in other families. For example:

- Scott *et al*. (2009) reported positive results for *Ca*. L. solanacearum after testing some psyllids (*Acizzia* sp., *Trioza* sp.) collected from *Acacia* and *Pittosporum* species, as well as foliage samples from *Acacia* and *Pittosporum* on which these psyllids were collected. Species are not specified and no further data has been published so far.

-Berry *et al*. (2010) conducted a study on *Ca*. L. solanacearum on different plants sampled in crop or nearby fields and found 34 species positive, including the following at multiple sites: *Malva parviflora* (Malvaceae), *Polygonum aviculare* (Polygonaceae), *Pisum sativum* (Fabaceae), *Solanum nigrum* (Solanaceae), *Cypressus* sp. (Cupressaceae), volunteer potatoes (Solanaceae).

4. Presence of host plants in the PRA area

All cultivated host plants listed in 1. above are present in the PRA.

Among the wild host plants mentioned above (question 2), *Lycium barbarum* is widespread in the PRA area. *Solanum elaeagnifolium* is present in Mediterranean countries of the PRA area and is on EPPO A2 List as an invasive alien plant in the EPPO region (EPPO, 2007). The host *Bidens* sp. in New Zealand was not identified at the species level but several *Bidens* spp. occur in the PRA area (*B. cernua*, *B. connata*, *B. frondosa*, *B. radiata*, *B. tripartita*, according to Flora europaea, 2011).
Solanum ptychantum is not present according to Flora europaea, 2011. Several other species of Solanaceae are present in the PRA area according to the same source, including *Lycium chinense, Nicandra physalodes* (used as ornamental), *Physalis alkekengi, Solanum carolinense, S. dulcamara, S. luteum, S. nigrum, S. nitidibaccatum, S. physalifolium, S. sarachoides, S. triflorum*.

5. Experimental host plants
Datura stramonium (Brown, 2009), *Datura* spp. (Crosslin *et al.*, 2010).

6. Note on hosts of *B. cockerelli* (as it is important for the pathways)
Bactericera cockerelli (Sulc) (Hemiptera, Psyllidae; Burckhardt & Lauterer 1997; tomato/potato psyllid) was shown as a vector for *Ca.* L. solanacearum on Solanaceae in North and Central America and New Zealand. The literature generally reports this species to be found on many plants (numerous species in 20 plant families), and to complete its life cycle on some Solanaceae, Convolvulaceae and Lamiaceae (e.g. Al-Jabr, 1999, based on earlier publications). Wallis (1955) mentions 46 species on which the insect can reproduce, of which 42 are Solanaceae. The following species are generally cited amongst its preferred hosts: *Solanum melongena* (aubergine), *Capsicum* sp. (peppers), *Lycopersicon esculentum* (tomato) and *Solanum tuberosum* (potato) (Biosecurity Australia, 2009; Yang & Liu, 2009). Studies conducted in New Zealand following the introduction of *B. cockerelli* (Martin, 2008) indicated a little number of plants as good hosts; they showed a clear host association with pepper, tomato, potato, eggplant and poor host status of *Ipomoea batatas* (sweet potato, Convolvulaceae), *Nicandra physalodes* (weed in New Zealand, used as ornamental in PRA area) and a few other weeds. Nevertheless, this species seems to feed on more species then those it can reproduce on, and in its area of origin it overwinters on wild plant species. *Bactericera cockerelli* does not occur in the PRA area.

All other information regarding vectors is under 15a & b.

7 - Specify the pest distribution

Justification:
Section 1 below indicates records based on the identification of the bacterium and additional records based on disease symptoms. These records have been divided based on original references, recent information received by the EPPO Secretariat and input by the expert working group. The existing PRAs have not been used for this answer, as they do not discriminate between records of the bacterium and diseases which may be associated with the bacterium (the Australian PRA gives records of "psyllid yellows and zebra chips", while the German PRA does not seem to discriminate between the pathogen and the different diseases, but contains additional records that are now among records to be clarified). Irrespective of published information, there is a major uncertainty on the distribution of *Ca.* L. solanacearum worldwide and in the EPPO region. Its known distribution has evolved rapidly since the first identification in 2008. It is likely to evolve further as testing is done in more locations, and as test methods evolve to reliable validated protocols allowing to avoid both false negatives and false positives.

Section 2 gives records found in the literature that are not considered valid, and section 3 gives uncertain records still to be clarified.
Note: distribution records of the vectors *Bactericera cockerelli* and *Trioza apicalis* are summarized, respectively in section 15b and in Annex 1.

1. Distribution of *Ca.* L. solanacearum (syn. *Ca.* L. psyllaurous) based on identification records of the bacterium since its first identification in 2008 and additional records based on reports of disease symptoms

Records of *Ca*. L. solanacearum below indicate the host plants in which the bacterium has been shown to be present.

Additional records are marked with ♦. These relate to earlier reports of zebra chip symptoms on potato, prior to the identification of the bacterium in 2008. There is no publication on the detection of the bacterium for these records, but they might be associated with *Ca.* L. solanacearum: although the symptoms of zebra chip on their own are not characteristic of the disease (see notes on diseases in section 8), the presence of the bacterium has been demonstrated for many prior records of zebra chip disease in the USA (Munyaneza *et al.* 2007a,b; 2008)

On Solanaceae hosts

North America: Mexico[2] (Coahuila, Sinaloa, Munanyeza *et al.* 2009a,b,c - tomato, potato, *Capsicum*; ♦Nuevo Leon; Gudmestad & Secor, 2007)

USA[3]

Arizona	Brown *et al.*, 2010 (tomato) ♦Munyaneza *et al.*, 2007a (potato)	Nevada	♦Munyaneza *et al.*, 2007a (potato)
California	Crosslin & Bester, 2009 (potato); Crosslin *et al.*, 2010 (tomato)	New Mexico	♦Munyaneza *et al.*, 2007a (potato)
Colorado	McKenzie & Shatters, 2009 (tomato), Wen *et al.*, 2009 (potato)	Texas	Abad *et al.*, 2009 (potato) French-Monar *et al*, 2010 (tomato)
Kansas	Crosslin & Bester, 2009 (potato)	Wyoming	Wen *et al.*, 2009 (potato)
Nebraska	Wen *et al.*, 2009 (potato)		

Note: some records above are based on testing done on samples collected in previous years, i.e. the bacterium was already present (e.g. for Colorado, the samples on tomato had been collected in 2002).

Central America: Honduras (departments of Intibucá, Ocotepeque and Francisco Morazán) (Espinoza, 2010; Rehman *et al.*, 2010 - potato), Guatemala (Secor *et al.*, 2009 - potato).

Oceania: New Zealand (Liefting *et al.* 2008a, b, 2009a, b, c - tamarillo, Cape gooseberry, potato, tomato)

On carrot

EPPO region: A haplotype of *Ca.* L. solanacearum has been identified on carrots in Finland (Munyaneza *et al.*, 2010a, b, Nelson, 2011)

Presence of *Ca*. L. solanacearum has also been recently confirmed (in 2011-06) in Spain on carrot and celeriac in the following regions of Spain: Islas Canarias, Castilla-La Mancha, Comunidad Valenciana. All carrot plots belong to the same company in Spain (Cobos-Suarez, Spanish NPPO, pers. comm. June 2011). Since this PRA was conducted, additional research has been conducted and *Ca*. L. solanacearum was found in carrot in Norway and Sweden (Munyaneza *et al.*, 2011, 2012).

2. Records found in the literature but not considered valid

- Canada (Alberta). This record (probably based on Carter 1939 in Cranshaw 1993, reported by EPPO, Australian and German PRAs) was denied by the NPPO of Canada (in September 2010) in answer to the publication of EPPO (2009). The NPPO of Canada informed the EPPO Secretariat that following further investigations nothing indicates to date that *Ca.* L. solanacearum occurs in Alberta on tomato or potato, and that the original record is thought to relate to psyllid yellows only. Although the vector *B. cockerelli* occurs occasionally in several Canadian provinces under glasshouse, it is not thought to be able to overwinter in Canada in the field.
- USA (Florida). This was reported in Wen *et al*. 2009, but is generally not mentioned in publications listing states where zebra chip occurs. Detection is thought to have been made on material imported from another state and the bacterium is not thought to be present in Florida (Munyaneza, pers. comm., 2010)
- USA (Washington)[3]. Detection of *Ca.* L. solanacearum in *B. cockerelli* was reported in Munyaneza (2009d) (referring to Liefting *et al.*, 2009c, Lin *et al.*, 2009), However, *Ca*. L. solanacearum has never been found naturally in *B. cockerelli* in Washington but only in psyllids used in experiments (Munyaneza, pers. comm. 2010). *B. cockerelli* migrates northwards in North America every year and reaches Washington State in late summer, but the bacterium has never been detected in potato plants (or other crops). The reasons for this are not known (cool temperatures impacting symptom expression? Mature plants showing some resistance or tolerance to the disease? Munyaneza *et al.*, 2009d).
- USA (Idaho, Montana, North Dakota, Utah, Minnesota) [4]. Biosecurity Australia (2009) lists records of "psyllid

[2] In January 2011, it was also found in the State of Mexico (Ling *et al*., 2011). This PRA was not updated thoughout to take this information into account.

[3] At the end of 2011, the presence of *Ca.* L. solanacearum was reported from fields in the Columbia basin (both in Oregon and Washington, US) at low incidence (Hamm *et al.*, 2011, presentation at the Zebra Chip Annual Reporting Session, 2011-11-06/09). This PRA was not updated thoughout to take this information into account.

yellows and zebra chip", and includes Idaho, Montana, North Dakota, Utah. Stefani (2010) mentions Minnesota. These states do not appear in recent publications from USA researchers listing states where zebra chip or *Ca.* L. solanacearum occur in the USA. According to information available to date, these records are considered to relate to psyllid yellows only, and are not associated with *Ca.* L. solanacearum (Munyaneza, pers. comm., 2010). It is now suspected that psyllid yellows on potato might be due to *B. cockerelli* on its own (or with other unknown pathogens), in the absence of the bacterium (see notes on diseases in Annex 2).

- EPPO region (Romania, Russia). Zebra chip-like symptoms have been observed on potato in recent years in South-West Russia and Romania and are mentioned in some publications (e.g. "Eastern Europe and Southern Russia" in Gudmestad & Secor, 2007). Studies conducted on pathogens have shown the presence of the stolbur phytoplasma, which is known to cause similar symptoms on tubers, but *Ca.* L. solanacearum has not been detected (Kolber *et al.*, 2010). In initial studies in Russia (Kolber, pers. comm., 2010; Acs *et al.* 2009), one individual of the psyllid *Trioza chenopodi* was suspected to carry *Ca.* L. solanacearum, based on preliminary testing. However further testing has not confirmed this result.

3- Reports to be clarified

The reports below are mentioned in the literature, but no original literature reference to the bacterium was found and their status could not be clarified as valid or not.

- Canada (Ontario). Stefani (2010) lists Ontario in the distribution list of *Ca.* L. solanacearum. The only reference found in the literature is Ferguson & Shipp (2002), which reports new pests in Ontario greenhouse vegetables including *B. cockerelli*. Ontario was not mentioned in the Canadian NPPO clarification above regarding Alberta
- Mexico (El Bajío) (Garzón Tiznado *et al.*, 2009). The article shows the association between a bacteria-like organism, "permanent yellowing disease"/"enfermedad permanente del tomate" and *B. cockerelli*. It refers to *Ca.* L. solanacearum, noting similarities (transmission, time for symptom expression) but mentioning that symptoms might differ from those observed on tomato due to *Ca.* L. solanacearum. The pathogen isolated in this study and *Ca.* L. solanacearum have not been compared.
- Mexico (in general). Many publications refer to a wide complex of diseases of tomato and potato identified in various regions, including purple top, purple top-brown tuber, zebra chip, permanent yellow of tomato, etc. The detailed distribution of *Ca.* L. solanacearum is difficult to extract from this as no formal detection of the bacteria was made. Two diseases "tomato permanent" and "potato purple top-brown tuber" with symptoms elsewhere shown to be associated with *Ca.* L. solanacearum have been reported (Guttierez *et al.* 2009, Diaz *et al.*, 2008; Secor & Rivera-Varas, 2004; Garzon-Tiznado, 2009), but some other pathogens may also be associated with the different diseases/symptoms (see note on diseases in Annex 2).
- Caribbean: Civerolo (2010) mentions that zebra chip affects potatoes in North and Central America, the Caribbean and in New Zealand. No further reference was found.

Stage 2: Pest Risk Assessment - Section A: Pest categorization

8 - Does the name you have given for the organism correspond to a single taxonomic entity which can be adequately distinguished from other entities of the same rank?

yes

Justification:

The pest belongs to a kind of phloematic, mostly tropical and subtropical bacteria of the genera *Candidatus* Liberibacter. The name *Candidatus* is normally used by taxonomists and plant pathologists when an organism is well characterized but is unculturable (Jagoueix *et al*., 1994). A molecular and phylogenetic characterisation lists all species of Liberibacter in one classification (Lin *et al*., 2009). (from Stefani, 2010).

The species psyllaurous, on potato and tomato was suggested by Hansen *et al*. (2008) as a new species of *Candidatus* Liberibacter. In the same year New Zealand notified a disease of tomato and pepper caused by a phloematic bacterium of the genus *Candidatus* Liberibacter. As the pest was found in close relation to its hosts of the family Solanaceae the

[4] At the end of 2011, the presence of *Ca.* L. solanacearum was reported from Idaho at low incidence (Nolte *et al*., 2011). This PRA was not updated thoughout to take this information into account.

name for the newly identified species suggested in New Zealand was *L. solanacearum* (Liefting *et al*., 2008a; 2009b). This pathogen was later found associated with zebra chip disease in the USA (Abad *et al*. 2009).

A polymorphism of eight single nucleotides in the 16S-ISR-23S rDNA Region differentiates *Ca.* L. psyllaurous from *Ca.* L. solanacearum: hence both strains could be regarded as two different genetic populations or geographic variants of one species (Wen *et al*., 2009). Nelson *et al*. (2011) identified three haplotypes of the bacterium. Two haplotypes are associated with zebra chip/psyllid yellows of potato and other solanaceous plants in North and Central America and New Zealand. The third haplotype is associated with carrots in Finland. Its vector *Trioza apicalis* overwinters on *Picea abies* (Norway spruce) and to some extent on pine and junipers (Kristoffersen & Anderbrant, 2007).

Since 2009, publications refer to *Ca.* L. solanacearum and *Ca.* L. psyllaurous as synonyms (e.g. Wen *et al*., 2009; Lin *et al*., 2009; Nelson *et al*. 2011) and use *Ca.* L. solanacearum.

The bacterium was shown to be transmissible (Crosslin & Munyaneza, 2009; Secor *et al.*, 2009). It does produce consistent symptoms, but some of these are similar to other pathogens. In both tomato and potato, there are indications of distinct psyllid-associated diseases, depending on whether *Ca.* L. solanacearum is associated with the vector *Bactericera cockerelli* or not. Notes on the diseases caused by the bacterium are given in Annex 2.

10 - Is the organism in its area of current distribution a known pest (or vector of a pest) of plants or plant products?

yes (the organism is considered to be a pest)

Justification:

Ca. L. solanacearum was identified in 2008, and shown to be associated with zebra chip disease of potato, which has been observed since the 1990s with increasing importance (Munyaneza *et al.*, 2007b). The bacterium/vector complex has caused serious damage in the Americas and New Zealand (Rehman, 2010; Liefting *et al.*, 2009a, Munyaneza *et al.* 2009c; Liefting, 2008 & pers. comm.), especially on potato and tomato (field and glasshouse). On potato, plant growth is affected, chips[5] made from infected tubers show dark stripes that become markedly more visible upon frying, and hence are unacceptable to manufacturers. Whole crops might be rejected above a certain level of presence of the disease. Infected tubers may not produce plants when planted. The bacterium is also associated with damaging diseases of tomato, *Capsicum* and tamarillo (see details under answer to 2.1). The vector *B. cockerelli* on its own, in the absence of the bacterium is also reported as damaging (it is not known if this is caused by the vector - e.g. toxic saliva - or if another agent is associated); however, damages are reported to be higher, commonly leading to plant death, when the bacterium occurs together with the vector (Sengoda *et al*., 2010).

12 - Does the pest occur in the PRA area?

Yes, on carrot

Justification: A haplotype of *Ca.* L. solanacearum was detected in Finland, following observation of symptoms on carrot plants (Munyaneza *et al.*, 2010a, b, Nelson *et al.*, 2011). To date, the bacterium is not known to be present in other countries but this may change since the bacterium was only recently detected in carrots although it was probably associated with carrots for many years already. Since this PRA was conducted, the bacteria was also found in Spain (Cobos-Suarez, Spanish NPPO, pers. comm. June 2011), Norway and Sweden (Munyaneza *et al.*, 2011, 2012)

13 - Is the pest widely distributed in the PRA area?

not widely distributed

Justification: Data so far indicate a limited distribution, only on carrot, only in a limited part of Finland, Norway, Sweden and Spain, (see Annex 1).

14 - Does at least one host-plant species (for pests directly affecting plants) occur in the PRA area (outdoors, in protected cultivation or both)?

yes

Justification:

[5] Note that the the American word "chips" is equivalent to the British word "crisps" (and the American word "French fries" is equivalent to the British word "chips"). Throughout this PRA we have used the American terms as damage on these food products is mainly described with those terms.

All cultivated Solanaceae hosts are present in the PRA area: the most important is potato, followed by tomato. Potato is cultivated in the open field whilst tomato is cultivated in the field or under protected conditions. Potato and tomato are also widely cultivated in private gardens throughout the PRA area.

Capsicum spp. (e.g. sweet pepper and chilli) are cultivated in the PRA area (outdoors or protected cultivation), commercially and in gardens. Eggplant (see uncertainty on host status under question 6) is also cultivated in the PRA area, mostly in the southern and eastern part of the region.

Tamarillo is cultivated in Madeira, Portugal (throughout the island, commercial crops of approx. of 2 ha, mainly in the municipalities of Santana and Santa Cruz, for the local market, grown from sowing of local plants) (A. Silva, Centro de Desenvolvimento de Fruticultura Subtropical, Madeira, pers. comm., 2010). It is also cultivated in gardens in Portugal (incl. continental). No data have been found on cultivation in other Mediterranean countries in the PRA area, but it is sold as a garden plant.

No data were found on commercial cultivation of Cape gooseberry (*Physalis peruviana*) in the PRA area (although some internet sites mention an interest in commercial cultivation of this plant in Europe – no further data found). However, it is a garden plant sold and grown from seed (many websites, e.g. http://www.rustica.fr/articles-jardin/fruits-et-verger/repiquer-coqueret-perou,1822.html; http://www.ifioridelbene.com/product.php?id_product=18).

Some wild species shown to be hosts are also present.

Annex 3 gives FAOSTAT data from 2008 on area and production of commercial cultivated hosts.
Annex 7 gives maps of production of potato and tomato in the PRA area.

15a - Is transmission by a vector the only means by which the pest can spread naturally?

yes

Justification:

Ca. L. solanacearum is transmitted by psyllids. It was originally shown to be transmitted by *Bactericera cockerelli* (tomato/potato psyllid) on its solanaceous hosts in the Americas and New Zealand. A haplotype of the bacterium was recently found to also be transmitted by *Trioza apicalis* (carrot psyllid) on carrot (Munyaneza *et al*., 2010b, Nelson et al 2011). For details on *T. apicalis*, see Annex 1. Transmission studies have shown the vector to be very effective in transmitting the bacterium (acquisition and transmission within 2 hours of colonizing the plant) (Munyaneza, 2010).

Ca. L. solanacearum has not been shown to be transmitted by seeds (Liefting, pers. comm., 2010, based on unpublished experiments on seedlings from 1,030 tomatoes, 225 *Capsicum*, and 225 tamarillo collected from fruits produced by infected plants).

Regarding seed potatoes, there is uncertainty on to what extend potato plants grown from infected tubers would be infected and in turn would produce infected daughter tubers. Henne *et al.* (2010a) showed plants grown from infected seed potatoes to grow poorly and produce fewer, smaller or no tubers, reducing the possibility that natural spread (e.g. through volunteer potatoes) would be significant. Munyaneza (unpublished data, 2010) obtained similar results. However, recent information by Pitman *et al.* (2011) and Berry *et al.* (2010) indicate transmission of *Ca.* L. solanacearum to plants grown from infected potatoes (symptomatic or asymptomatic) and detection of the bacterium in volunteer potato. Galaviz *et al.* (2010) consider infected seed potato tubers an important source of inoculum in Mexico. In any case, further spread would require a vector.

Uncertainties regarding vectors

Ca. L. solanacearum has already been shown to have two psyllid vectors, so there are suspicions to date that more psyllid species are vectors of this bacterium. In New Zealand, the bacterium has been found on *Acizzia* and *Trioza* psyllids (species not mentioned) collected from *Acacia* and *Pittosporum* species (Scott *et al*., 2009). *Acizzia jamatonica* (Asian species) is present in the PRA area (Northern Italy and Southern Switzerland) (on *Albizia julibrissin* - Constantinopol acacia).
It is not yet clear if some additional European species of the genera *Bactericera* or *Trioza* are possible vectors of the bacterium. Approximately 170 species of psyllids occur in the Central European regions, including from the genera *Bactericera* and *Trioza* (Burckhard *et al*., 1999).
Note: After this PRA was conducted, *B. trigonica* was reported as associated with *Ca.* L. solanacearum in carrots in Canary Islands, and with *Bactericera* sp. in mainland Spain (Alfaro-Fernández et al., 2012a & 2012b).

For the purpose of this PRA, it is currently assumed that there is no pathway for spread of the bacterium from carrots to Solanaceae and vice versa because *T. apicalis* does not feed on Solanaceae and *B. cockerelli* does not feed on carrot. Two other psyllids in the PRA area are reported having carrot as host: *Bactericera trigonica*[6] and *B. nigricornis* (Lundblad, 1929; Bey, 1931; Krumrey & Wendland, 1973; Hodkinson, 1981; Burckhardt & Freuler, 2000). In the literature, *B. trigonica* is not mentioned on solanaceous plants, but *B. nigricornis* has been recorded on potato (Hodkinson, 1981; Ozbek *et al*., 1987; Ossiannilsson, 1992; Fathi, 2011). The distribution of *B. nigricornis* covers Europe and North Africa (Ossiannilsson, 1992). This might be a potential vector to transmit the bacteria between carrot and Solanaceae. In Finland, *B. nigricornis* has been recorded twice near Turku (southwestern Finland) prior 1975 (Mattila & Södderman, 2010) and has not been observed in fields where *Ca.* L. Solanacearum was observed (Nissinen, pers. comm., 2010). To date, the bacterium is not known to occur where these psyllids occur in the PRA area.
One individual of the psyllid *Trioza chenopodii* (whose hosts are mostly *Chenopodium* spp.) (from Southern Russia) was originally suspected to carry *Ca.* Liberibacter solanacearum after preliminary tests on this individual (Acs *et al.* 2009); however, further testing did not allow confirmation that it was *Ca.* L. solanacearum (M. Kolber, FITOLAB, HU, pers. comm., 2010).

15b - Is the vector present in the PRA area?

Yes for *Trioza apicalis*² (see the annex 1)
No for *Bactericera cockerelli*

Justification:

Distribution data of *B. cockerelli*
EPPO region: Absent.
North America:

- Canada (Alberta, British Columbia, Ontario, Quebec, Saskatchewan) (Ferguson *et al.*, 2003). It may survive all year round in protected conditions but outdoor populations only occur late in the growing season after migration from USA.
- Mexico: Chihuahua, Coahuila-Nuevo León, Guanajuato, Sonora and Sinaloa, Tlaxcala (Cadena-Hinijosa *et al.*, 2003; Rubio Covarrubias *et al.*, 2006; Munyaneza *et al*., 2007a)
- USA: Arizona, California, Colorado, Idaho*, Kansas, Minnesota, Montana, Nebraska, Nevada, New Mexico, North Dakota*$, Oklahoma, Oregon*, South Dakota, Texas, Utah, Washington*, Wyoming (CISR undated; Abdullah, 2008, Crosslin *et al*., 2010; Munyaneza *et al.* 2009 and personal communication – Oregon).

*Late season presence only, migrate late into the growing season
$ reported as first detection on potato in August 2010 (PotatoPro, 2010; NDSU, 2010).
Central America: Guatemala, Honduras (departments of Intibucá, Ocotepeque and Francisco Morazán) (Espinoza, 2010; Rehman *et al.*, 2010).
Oceania: New Zealand (recently introduced, first detected in May 2006 in Auckland – see map in Crop and Food Research, 2009).

16 - Does the known area of current distribution of the pest include ecoclimatic conditions comparable with those of the PRA area or sufficiently similar for the pest to survive and thrive?

yes

Justification:

The climate classification of Köppen-Geiger indicates that the pest and its vector *B. cockerelli* are present in very different types of climates, some of which are present in the EPPO region (see Annex 4).
Ca. L. solanacearum is also found in carrots outdoors in southern Finland, Norway, Sweden, and in Spain in the PRA area.

B. cockerelli is present in a wider range of climates than *Ca.* L. solanacearum, and these climates occur in the PRA area. It is also present under protected conditions, in similar conditions as in the PRA area. *B. cockerelli* is a migratory species in the Americas: it overwinters in the warmer areas of its distribution range (Mexico and Southern USA) and it migrates north in Western USA and up to southern Canada in spring and summer. In some northern places, it has been

[6] After this PRA was conducted, *B. trigonica* was reported as associated with *Ca.* L. solanacearum in carrots in Canary Islands, and with *Bactericera* sp. in mainland Spain (Alfaro-Fernández et al., 2012a & 2012b)

recorded as breeding in the field (at least 1 generation per year) (e.g. Washington, Oregon). Data is lacking on climatic factors that influence psyllid migration and survival in winter. In particular it is not yet clear why psyllids that reach Washington in late summer do not seem to carry *Ca.* L. solanacearum, and why populations seem to die out in winter (too cold or lack of host plant(s) in the environment). However Pletch (1947) reported that nymphs may survive exposure to repeated frosts and temperature as low as -14°C. Recent experiments showed that *B. cockerelli* can survive cold (up to -15°C for 24h) although adults were less resistant than nymphs (Henne *et al.*, 2010b). From its distribution in the Americas, *B. cockerelli* would not have been expected to establish in New Zealand in the field as climates are rather different.

17 - With specific reference to the plant(s) which occur(s) in the PRA area, and the damage or loss caused by the pest in its area of current distribution, could the pest by itself, or acting as a vector, cause significant damage or loss to plants or other negative economic impacts (on the environment, on society, on export markets) through the effect on plant health in the PRA area?

yes

Justification:

The pest could cause significant damage provided that a vector is present or introduced in the PRA area. Potato and tomato, on which serious economic damage is reported where the pest and its vector occur, are widely grown in the PRA area. The pest may cause severe damage and crop losses in open field crops as well as on glasshouse crops, especially tomato. Possible damage would be similar to those caused where the pest occurs, i.e.

- damage and death of plants in cultivation and in gardens (potato, tomato, pepper, tamarillos, Cape gooseberry)
- reduction of yield and loss of cultivated hosts (potato, tomato, pepper, tamarillos) (e.g. Liefting *et al.*, 2009a;)
- unmarketable potato tubers, rejection of potato crops for fresh markets or for processing industry (chips, French fries) due to the presence of zebra chip (Munyaneza *et al.*, 2007; Goolsby *et al.*, 2007)
- environmental damage due to increased use of pesticides and threats to IPM programmes by the necessary control of the vector (Teulon *et al.*, 2009)
- loss of export markets (as occurred in New Zealand) (Liefting, pers. comm. 2010)
- social impact as shown in USA and New Zealand (CNAS, 2009; Liefting, pers. comm. 2010).

As far as known the warmer potato cultivation regions in the PRA area could have favourable conditions for severe epidemics in warmer and more humid years. In tunnels or glasshouses with vegetable cultivation (tomato, pepper) all ecoclimatic conditions are present for severe epidemics up to total destruction of the vegetable production.

For Solanaceae, damage would depend on the occurrence of a vector of the bacterium, i.e. the already known *B. cockerelli* or another psyllid able to vector the bacterium already present in the PRA area.

18 - Summarize the main elements leading to this conclusion.

- Known serious pest of especially potato and tomato, with economic, environmental and social damage. Also damaging *Capsicum*, tamarillo, and new evidence of possible damage on carrots. Probably eggplant.
- Wide commercial cultivation of host plants (especially potato, tomato, *Capsicum*, eggplant).
- All cultivated host plants are also used in gardens
- Weed hosts are also present in the PRA area
- Suitable eco-climatic conditions are present in the PRA area.

Although the vector identified for solanaceous hosts, *B. cockerelli*, is not present in the PRA area, it could be introduced (probability of introduction on various commodities studied in a separate EPPO PRA). The vectors on carrot (*Trioza apicalis and Bactericera trigonica*) are present, but do not attack solanaceous plants, limiting their impact for the further spread of *Ca.* L. solanacearum within the region. There is uncertainty on whether other psyllids present in the PRA area could also be vector for the bacterium.

Stage 2: Pest Risk Assessment - Section B: Probability of entry of a pest

1.1 - Consider all relevant pathways and list them

On Solanaceae, *Ca*. L. solanacearum is transmitted by *B. cockerelli*. *Ca.* L. solanacearum is found in most parts of its host plants. The bacterium is able to infest and multiply in the vector, and the vector may be transported over long distances via plants or fruits. The present PRA considers the bacterium alone and the complex bacterium/*B. cockerelli* on several pathways. Regarding possible association of the bacterium with the vector, the bacterium is intrinsic to the insect, i.e. transmitted to the progeny (Hansen *et al*., 2008) and all life stages may carry the bacterium.
Thomas *et al.* (2011) investigated the entry pathway for *B. cockerelli* into New Zealand. They could not conclude on a definitive pathway of entry but considered that it might plausibly have been introduced by the smuggling of primary host material (infested host plants or host fruits, or voluntary introduction of the insect whose identity was mistaken for a potential biocontrol agent).

Together, the pathways considered cover three situations, which often present different probabilities for entry (and later establishment and spread):
- the vector *B. cockerelli* is introduced at the same time as *Ca.* L. solanacearum;
- there is no vector on Solanaceae hosts in the PRA area at the time of entry of *Ca.* L. solanacearum (situation currently assumed due to the absence of *B. cockerelli*);
- a vector is present in the PRA area at the time of entry of *Ca.* L. solanacearum (covering the uncertainty on vectors in 15a and the possibility that *B. cockerelli* might be introduced in the PRA area before the bacterium enters).

A. Association with *B. cockerelli* on a solanaceous commodity (studied in detail in this PRA)
Of the pathways studied in this PRA, those relating to the vector being transported on commodities are considered to have the highest risk, as they would introduce both the bacterium and the vector. The same pathways (without the elements relating to the bacterium) are considered in the PRA for *B. cockerelli*. It should be noted that *B. cockerelli* has a wider host range in the family Solanaceae than *Ca*. L. Solanacearum. For the purpose of this PRA, all Solanaceae were considered together in this pathway because *B. cockerelli* may acquire the bacterium, and then be transported on one of its host plants (which might or might not be a host of *Ca*. L. solanacearum).

Pathway A1. *B. cockerelli* on plants for planting of Solanaceae (except fruits and seeds) from countries where *Ca.* L. solanacearum occurs
This pathway considers the possibility that the bacterium might be carried inside the vector itself carried in its host plants. In addition, the bacterium might also be in the plants. *Note: this pathway covers all countries where both the bacterium and the vector are known to occur, i.e. to the exception of Canada where the vector is known to occur but not the bacterium.* Import of solanaceous plants for planting is prohibited or heavily regulated in most countries of the PRA area.

Pathway A2. *B. cockerelli* on fruit of solanaceous plants (e.g. tomato, *Capsicum* spp., eggplant, tamarillo, Cape gooseberry) from countries where *Ca.* L. solanacearum occurs
B. cockerelli feeds and lays eggs on green parts, and fruits could be a pathway if accompanied with green parts. Fruit consignments could also be contaminated by psyllids after harvest. The bacterium might be present in the vector and in the fruits.

B. Association with a solanaceous commodity, without *B. cockerelli* (studied in detail in this PRA)
These pathways relate to the bacterium being transported on a host commodity, in the absence of the vector in the commodity. Because of many common elements with the pathways A1 and A2 above, they are presented in parallel in this section. A difference is made in the PRA as to whether a vector would be present in the PRA area or not. This is relevant as there are uncertainties on the possible vectors for Solanaceae hosts in the PRA area.

Pathway B1: Plants for planting of Solanaceae (in particular tomato, *Capsicum* spp.) from countries where *Ca.* L. solanacearum occurs (excluding seeds)
Seedlings or young plants of tomato and *Capsicum* spp. from areas where *Ca.* L. solanacearum occurs might be infected latently. Given uncertainty on the host range of the bacterium, this pathway is extended to all Solanaceae. Details are given in this pathway for the known hosts of *Ca*. L. solanacearum that might be traded as plants for

planting (i.e. tomato and *Capsicum* sp., including ornamental plants for planting of chilli).
It also covers other possible trade of plants for planting of Solanaceae, including:

- *Solanum betaceum* (tamarillo) and *Physalis peruviana* (Cape gooseberry). These are known hosts of the bacterium, but minor crops in the EPPO region.
- *Solanum muricatum* (pepino) and *Physalis ixocarpa* (tomatillo*).* These were regulated by the Australian NPPO when *Ca.* L. solanacearum was first found in New Zealand (Biosecurity Australia, 2009). They are currently not considered to be hosts. They probably represent small pathways into the PRA area.
- *Nicotiana tabacum* (tobacco). No further information was sought on this.

Pathway B2: Fruit of Solanaceae (in particular tomato, *Capsicum* spp., eggplant, tamarillo, Cape gooseberry) from countries where *Ca.* L. solanacearum occurs
Given uncertainty on the host range of the bacterium, this pathway is extended to all Solanaceae. Details are given in this pathway for the known hosts of *Ca*. L. solanacearum that might be traded as fruits (i.e. tomato, *Capsicum* spp., eggplant, tamarillo, Cape gooseberry). The bacterium might be present in the fruit, but also in green parts attached to the fruit. Eggplant, tamarillo and Cape gooseberry have also been included in this pathway as it is assumed that their fruits could also carry the bacterium, although no reference has been found on this. It also covers other possible trade of fruits of Solanaceae, including pepino (*Solanum muricatum*) and tomatillo (*Physalis ixocarpa*) (with the same reservations as above).

Pathway 3: Seed potatoes (including microplants and minitubers) and ware potatoes from countries where *Ca.* L. solanacearum occurs
Potato tubers may be infected by the bacterium (Hansen *et al*., 2008, Liefting *et al.*, 2008a). Infected tubers could be a source of inoculum of the bacterium in potato fields. Both seed potatoes and ware potatoes are considered in this pathway. The psyllid vectors will not be associated with potato tubers as they can only be associated with green parts.

C. Pathways with outlined consideration

Pathway 4: *B. cockerelli* on plants for planting of *Micromeria chamissonis, Mentha* spp., *Nepeta* spp. and *Ipomoea batatas*
These species can sustain the development of *B. cockerelli*, and plants for planting could carry any stage of the vector, carrying the bacterium or not. There is insufficient data on imports of these plants from areas where the complex bacterium/vector occurs, but they might be imported as ornamental or herb. The expert working group considered that this is a relevant pathway but it is not considered in detail due to lack of information on trade. Other aspects are similar to the consideration of plants for planting of Solanaceae (Pathway A1). However in contrast to Solanaceae plants for planting, there are no restrictions on the movement of this material in some countries of the PRA area (e.g. EU, Norway and Switzerland)
Data on imports of plants for planting from some countries (France, Germany, Italy, the Netherlands) over the period 2006-2010 indicate that there is very limited import of *Nepeta*,*Mentha* and *Ipomoea* species into these countries (see Table 1). Among the exporting countries, *B. cockerelli* is present only in USA (no import of *Mentha* or *Micromeria* was reported).

Table 1: Imports on Mentha, Nepeta and *Ipomoea* plants for planting from non-EPPO countries to France, Germany, Italy, the Netherlands in 2006-2010 (in number of plants). Source: NPPOs

	Mentha	**Nepeta**	***Ipomoea batatas***	***Ipomea* sp.**
Barbados	9500	0	0	0
Colombia	0	7100	0	0
Costa Rica	19300	13250	45552	50896
Ecuador	234700	105200	0	0
Ethiopia	28100	111102	0	0
Kenya	756595	21200	0	467208
Tanzania	0	104454	0	0
USA	0	122	0	7229

Although these species are reported as hosts there is no further data on the association of *B. cockerelli* with these plants. USDA-Aphis (2001) did not list *B. cockerelli* as a pest of Mentha in Honduras.

Pathway 5: *B. cockerelli* on living parts of Solanaceae (except fruits, seeds and plants for planting)
This covers especially cut flowers and cut branches. The expert working group considered that this is a relevant pathway but it is not considered in detail due to lack of information on trade. In contrast to Solanaceae plants for planting, there are no restrictions on the movement of this material in some countries of the PRA area (e.g. EU, Norway and Switzerland).

D. Pathways not considered

Seeds of cultivated host plants
Ca. L. solanacearum has not been shown to be transmitted by seed (unpublished work on tomato, pepper and tamarillo; Liefting, pers. comm., 2010-10).

Weed hosts of the bacterium
Ca. L. solanacearum has been found so far on a few weed species (*Bidens* sp., *Solanum elaeagnifolium*, *Lycium barbarum, S. ptychantum*). These weeds are more likely to be moved as seeds (in consignments of for example. plant products or soil), but *Ca.* L. solanacearum has not been shown to be transmitted by seed. However for *Solanum elaeagnifolium*, soil associated with plants for planting has been found as a possible pathway for this species, as it may carry plant parts which could then develop (EPPO PRA – EPPO, 2006). There could then be a possibility that plants growing from such plant parts would carry the bacterium. However, transfer would need a vector to pick it up in the plant and transfer it further. There is too little data on the prevalence of the bacterium on plants, on transmission, etc.

***B. cockerelli* on weeds**
B. cockerelli feeds on a number of weeds, but this pathway would require living/green weeds carrying eggs or nymphs (adults are likely to leave if disturbed). Weeds may be present in containers of pot plants.

***B. cockerelli* on other plants indicated on host lists**
A number of plants are identified in the literature as minor hosts, or as plants on which *B. cockerelli* feeds but does not reproduce, or as plants on which it overwinters. The analysis focused on its main solanaceous crop hosts (pathways 1, 2 and 3), on the three hosts of pathway 4. More comprehensive lists are given in Wallis (1955) and Trumble (2010) and include lettuce, sunflower, pea, radish, vetches/Beans, corn, and sugar beet as “less known-hosts”. It is thought that such commodities would not be imported from North America or New Zealand as plants that would be able to carry the pest. *Ipomoea batatas* (sweet potato) was also recorded as one of the hosts of *B. cockerelli* able to carry all life stages (Biosecurity Australia, 2009; considered as a poor host by Martin, 2008), but *B. cockerelli* is not likely to be associated with roots. Nevertheless, it appears that this species is nowadays not only traded as a tuber but also as an ornamental plant for planting. As such it may be a pathway for *B. cockerelli*.
Spruce is indicated on the list of Trumble (2010) as a non-crop host. Other conifers such as pine and cedar are also mentioned in the literature as possible overwintering plants. It is interesting to note that the recently found vector of *Ca.* L. solanacearum on carrot, *Trioza apicalis*, feeds on spruce during the period preceding the diapause (Valterová *et al.*, 1997). However, only adults overwinter on these plants.

Other psyllid vectors
See uncertainties under 15a.

Hitch-hiking of infective *B. cockerelli*
Adults are not likely to stay on commodities at export, conveyances, etc. as they would fly away. They would also not survive in transport without suitable plants to feed on (for longer than e.g. 2-3 days), except at cold temperatures.
B. cockerelli can be transported on other goods (e.g. clothing cited by Teulon *et al.*, 2009).) but this would likely result in local spread.

Natural spread of *B. cockerelli*
Ca. L. solanacearum is unlikely to reach the PRA area through the natural spread of *B. cockerelli*. Even if *B. cockerelli* is reported to be transported long distances by wind current, it is not considered possible that it will be transported from the Americas or New Zealand to the PRA area. Entry on *B. cockerelli* carried by commodities is covered under pathways 1 and 2.

Pathways A1 and B1

A1 - *B. cockerelli* on plants for planting of Solanaceae (except seeds) from countries where *Ca.* L. solanacearum occurs	B1 - Plants for planting of Solanaceae (in particular tomato, *Capsicum* spp.) (except seeds) from countries where *Ca.* L. solanacearum occurs
1.3a - Is this pathway a commodity pathway?	
Yes This pathway is closed for some countries in the PRA area, but not for all. See 3.1 for details on requirements.	
1.3b - How likely is the pest to be associated with the pathway at origin taking into account factors such as the occurrence of suitable life stages of the pest, the period of the year?	
moderately likely ***Level of uncertainty:***: medium ***Justification:*** For this association: the bacterium needs to be associated with the vector and the vector with the commodity. Association of the bacterium with the vector: Where *B. cockerelli* occurs, the vector may acquire the bacterium by feeding on the phloem of infected plants. In particular, it feeds and reproduces on the known cultivated solanaceous hosts of the bacterium (potato, tomato, pepper, tamarillo, Cape gooseberry). Infective psyllids may easily transmit the pest when feeding on other plants. *B. cockerelli* is a very mobile insect and searches appropriate plants to colonize them massively (Abdullah, 2008). Secor *et al.* (2009) found that 25% of the psyllids in a potato crop infected by the bacterium were infested and infectious. All stages of the vector may be infested especially the nymphs and the adult forms (Hansen *et al.*, 2008). The bacterium is transmitted to the progeny. *B. cockerelli* also feeds on other solanaceous plant species, and the role of these species as a reservoir for the bacterium or in the acquisition process is not known. Association of the complex bacterium/vector with the plants for planting. Greenhouse production is mentioned in the literature as a factor favouring infestations of *B. cockerelli*. Tomato and pepper crops can be infested, and carry eggs, nymphs and/or adults. Plants in the field may also be infested. Adults are less likely to be associated with the pathway than eggs or nymphs as they do not stay on the plants when moved. In New Zealand, at least one grower reported seedling tomatoes arriving at their property infested with *B. cockerelli* (Teulon *et al.*, 2009).	moderately likely ***Level of uncertainty:*** medium ***Justification:*** Seedlings and young plants may be infected with the bacterium by vector transmission or grafting with infected plant material (Crosslin & Munyaneza, 2009). Tomato and pepper may be cultivated in the field or under protected condition, and psyllids might transmit the bacterium to plants for planting, and between infected plants in both situations. Mitigating factors are associated with this pathway: - in the USA, not all populations of the psyllid are infective (Munyaneza *et al.*, 2008) - In New Zealand, the bacterium has not been detected in all regions known to have the psyllid (Teulon *et al.*, 2009). In addition, losses associated with the bacterium have been observed in greenhouse tomato only, and not yet field tomato were damage is due only to the *B. cockerelli* (10%) (Liefting, pers. comm., 2010). - Where the pest occurs, association with pepper is not clear (or eggplant: see section 6 for uncertainty on host status), and it seems that levels of infection are lower than for tomato.

A1 - *B. cockerelli* on plants for planting of Solanaceae (except seeds) from countries where *Ca*. L. solanacearum occurs	**B1 - Plants for planting of Solanaceae (in particular tomato, *Capsicum* spp.) (except seeds) from countries where *Ca.* L. solanacearum occurs**
Infective psyllids may also be associated with plants for planting of Solanaceae which are not a host of the bacterium because the psyllid can first acquire the bacterium from a host plant and subsequently move to a non-host plant. Once acquired, the bacterium persists in the vector and is transmitted to the progeny.	
1.4 - How likely is the concentration of the pest on the pathway at origin to be high, taking into account factors like cultivation practices, treatment of consignments?	
Unlikely ***Level of uncertainty:*** medium ***Justification:*** Concentration of the bacterium in the vector may be high: the bacterium can be present in eggs, nymphs, adults. Adult forms may bear a higher amount of bacteria than the other stages (Hansen *et al*., 2008). Nevertheless, not all psyllids in the area where *Ca*. L. solanacearum occurs are infested by the bacterium. Treatments applied to crops would reduce the populations of psyllids, but some insects might still carry the bacterium. However, concentration of the vector-bacterium complex on the plants for planting would presumably be quite low: treatments are routinely applied to crops where *B. cockerelli* is present to keep damage below the acceptable level. Plants for planting for export are also likely to be submitted to strict treatments to reduce presence of insect pests.	Moderately likely ***Level of uncertainty:*** high ***Justification:*** Where the tomato psyllid is present in tomato crops, it is likely that treatments are applied to keep the disease levels down, but this would not prevent presence of the pest. There is no treatment against the bacterium. Concentration of the bacterium in the plants may be high. Scientific data on the role of seedlings and young plants in the spread of the disease are not sufficient for a more detailed evaluation. (from Stefani, 2010). Diseases caused by *Ca*. L. solanacearum on solanaceous hosts of *Ca*. L. solanacearum have not been detected so far by border inspections. However, this may be explained by the fact that the import of Solanaceae is forbidden in many EPPO countries.

1.5 - How large is the volume of the movement along the pathway?

Minimal (import forbidden in many countries in the PRA area)

Level of uncertainty: high, No data on volume or trade for non-EU countries

Justification:

EU and countries having similar regulations (e.g. Norway, Switzerland)

According to Council Directive 2000/29/EC (EU, 2000), the importation in the EU from third countries of plants for planting of *Solanaceae* is prohibited (except from European countries and countries in the Mediterranean region). In Germany, young plants are produced within the country or mostly imported from neighbouring countries like the Netherlands, Belgium or Italy. No young plants or seedlings are imported from infested areas. (from Stefani, 2010).

Other EPPO-countries

Not all countries in the PRA area have specific requirements on imports of plants for planting of Solanaceae (see 3.1 for this pathway). Trade to these countries is not known, but it is supposed that if seedlings are imported, they would mostly come from within the PRA area. Available trade data does not allow differentiation between planting material for tomato or pepper and other non-woody plants for planting. Other Solanaceae species have not been considered in detail here.

A1 - *B. cockerelli* on plants for planting of Solanaceae (except seeds) from countries where *Ca*. L. solanacearum occurs	**B1 - Plants for planting of Solanaceae (in particular tomato, *Capsicum* spp.) (except seeds) from countries where *Ca.* L. solanacearum occurs**
Note: *Solanum betaceum* (tamarillo) is only cultivated in Madeira (Portugal). In Madeira, the source material of commercial crops is sowing of local plants (Silva, Centro de Desenvolvimento de Fruticultura Subtropical, PT, pers. comm., 2010). Tamarillo is also used as a garden plant and seems to be sold as seed for this purpose (from internet nursery/garden centre sites). The main areas of production are in South America, and even if some plants for planting were imported, it is supposed that it would come from these areas, i.e. where *Ca*. L. solanacearum is also not known to occur.	
1.6 - How frequent is the movement along the pathway? rarely ***Level of uncertainty:*** medium, no data on frequency of imports, but likely to be infrequent ***Justification:*** Available trade data do not allow differentiation between planting material for tomato or pepper and other non-woody plants for planting. If seedlings were imported from areas where the bacterium and/or vector occur, they would arrive at the time appropriate for planting, e.g. only in few months of the year.	
1.7 - How likely is the pest to survive during transport /storage?	
likely ***Level of uncertainty:*** low ***Justification:*** *Ca*. L. solanacearum is able to survive in all stages of *B. cockerelli*, eggs, nymphs or adults. The survival of the bacterium will depend on the survival of its vector on plants for planting. This is considered to be likely: eggs or nymphs of the vector colonizing the plants could remain viable and still carry the bacterium. Adults could continue to feed on the plants.	very likely ***Level of uncertainty:*** low ***Justification:*** In general bacteria may easily survive in infected young plants. Transport and storage of young plants have no effect on the survival of the bacterium. As symptoms of *Ca*. L. solanacearum primarily show after 3-4 weeks (Hansen *et al*., 2008) a possible infection on young plants remains latent. Scientific data on the survival of *Ca*. L. solanacearum in seedlings and young plants in respect to the spread of the disease are not yet available. (from Stefani, 2010)
1.8 - How likely is the pest to multiply/increase in prevalence during transport /storage?	
unlikely ***Level of uncertainty:*** high (at present it is unknown if the bacterium can multiply in the vector) ***Justification:*** Answer to this question depends on multiplication of the bacterium in the vector and of the vector on the commodity. There are currently no specific data on multiplication of the bacterium within *B. cockerelli*. Multiplication of the vector is unlikely as transportation of such plants is likely to take a short time (few days). Abdullah (2008) records the following time periods for development in controlled environment:	moderately likely ***Level of uncertainty:*** medium (do storage and transport temperature play a role in survival of such bacteria?) ***Justification:*** The bacterium can multiply in infected young plants (Hansen *et al*., 2008).

A1 - *B. cockerelli* on plants for planting of Solanaceae (except seeds) from countries where *Ca*. L. solanacearum occurs	**B1 - Plants for planting of Solanaceae (in particular tomato, *Capsicum* spp.) (except seeds) from countries where *Ca.* L. solanacearum occurs**
- pre-mating period: 3.8-5 days - pre-oviposition period: 5.9-8 days - egg incubation period: 5.7-8.2 days - nymphal period: 19.1-23.8 days Even if transport occurred under very favourable conditions, it is unlikely that adults emerge and lay eggs as they require specific conditions to reproduce.	
1.9 - How likely is the pest to survive or remain undetected during existing management procedures (including phytosanitary measures)?	
likely ***Level of uncertainty:*** low ***Justification:*** Survival or detection depends both on the bacterium and the vector. Neither the bacterium nor its vector are subject to specific phytosanitary import requirements by countries of the PRA area. Where imports of solanaceous plants are not prohibited in the PRA area, a PC might be required, leading to some general inspection or targeted inspections against other pests, at origin and at import. It is not certain that the vector would be detected and very unlikely that *Ca.* L. solanacearum would be detected. For the bacterium to be detected, first *B. cockerelli* needs to be detected and tested for presence of the bacterium. Such tests are currently not carried out and the bacterium is therefore likely to remain undetected. Visual inspection might allow detecting *B. cockerelli*. Eggs are difficult to detect: they are laid on the foliage, attached by short stalks (less than 0.2 mm), but detection requires use of a dissecting microscope. Nymphal stages and adults might be observed. Faeces resulting from feeding on the phloem, as white granular substance are visible (Teulon *et al.*, 2009). If consignments are treated with insecticides, the adults or nymphs (including the bacterium) might be destroyed but eggs are difficult to kill. The vector will be more difficult to detect on a plant for planting than on fruit because the area of green plant parts is much higher than the green parts attached to fruits.	very likely ***Level of uncertainty:*** medium ***Justification:*** Phytosanitary inspections will not necessarily detect the bacterium as symptoms are not very characteristics and infection on young plants may remain latent for a long period. Symptoms on tomato plants develop a minimum of 3-4 weeks after infection (Hansen *et al.*, 2008). In the case of young plants, symptoms might show earlier than on riper plants. There are no data available on this. Specific testing exists but is currently not applied in the absence of phytosanitary requirements.
1.10 - How widely is the commodity to be distributed throughout the PRA area? limited ***Level of uncertainty:*** low ***Justification:***	

<table>
<tr><th>A1 - B. cockerelli on plants for planting of Solanaceae (except seeds) from countries where Ca. L. solanacearum occurs</th><th>B1 - Plants for planting of Solanaceae (in particular tomato, Capsicum spp.) (except seeds) from countries where Ca. L. solanacearum occurs</th></tr>
<tr><td colspan="2">There are no data on imports from countries where the pest occurs, or on their destinations within the PRA area. As the PRA area produces a lot of these host plants (especially for tomato and Capsicum spp.), it seems likely that if plants are imported, they will not be moved further within the PRA area.</td></tr>
<tr><td colspan="2">1.11 - Do consignments arrive at a suitable time of year for pest establishment?
yes
Level of uncertainty: low
Justification:
Young plants will be imported and planted at the most suitable time for their development. In greenhouses, conditions will always be suitable for establishment of the Ca. L. solanacearum - B. cockerelli – complex.</td></tr>
<tr><td colspan="2">1.12 - How likely is the pest to be able to transfer from the pathway to a suitable host or habitat?</td></tr>
<tr><td>very likely
Level of uncertainty: low
Justification:
B. cockerelli has many host plants. If adults emerge, they are likely to find a suitable host to feed upon while searching for a suitable host for egg laying. Infective psyllids may easily and effectively transmit Ca. L. solanacearum (e.g. to potato and tomato) (Hansen et al, 2008; Liefting et al., 2009b; Munyaneza et al., 2008).</td><td>Very unlikely if there is no vector in the PRA area
Moderately likely/likely if a vector is present in the PRA area, depending on whether plants are established in the field/under protected conditions.
Level of uncertainty: medium (possible role of other vectors in the PRA area)
Justification:
Transfer to a suitable host would require the presence of a vector. No other vector than B. cockerelli is currently known for solanaceous plants and this species does not occur in the PRA area. There is an uncertainty on whether other psyllids in the PRA area could act as vector on solanaceous crops (see question 15a).

Transfer from infected rootstock to a crop could also occur through grafting (Crosslin & Munyaneza, 2009). Grafting of tomato (and pepper) is used to increase the yield and prolong the harvest season (Stefani, 2010). Grafted tomato plants are mostly cultivated in glasshouses. However, for the pest to spread further, a vector should be present.</td></tr>
<tr><td colspan="2">1.13 - How likely is the intended use of the commodity (e.g. processing, consumption, planting, disposal of waste, by-products) to aid transfer to a suitable host or habitat?</td></tr>
<tr><td>very likely
Level of uncertainty: low
Justification:
Transfer of the bacterium will be aided by transfer of the vector to a suitable host. Plants for planting will allow the stages of B. cockerelli present (eggs or nymphs) to continue their development until adult emergence, if conditions are suitable to development.</td><td>Very unlikely if there is no vector in the PRA area
Likely if a vector is present in the PRA area
Level of uncertainty: low
Justification:
Young plants are intended for planting, which would favour transfer if a vector is present in the area.</td></tr>
</table>

Pathways A2 and B2

<table>
<tr><th>A2. B. cockerelli on fruits of Solanaceae (e.g. tomato, Capsicum spp., eggplant, tamarillo, Cape gooseberry)</th><th>B2. Fruit of Solanaceae (in particular tomato, Capsicum spp., eggplant, tamarillo, Cape gooseberry) from countries where Ca. L. solanacearum occurs</th></tr>
<tr><td colspan="2">1.3a - Is this pathway a commodity pathway?
Yes
See 3.1 for details on requirements by various countries in the PRA area.</td></tr>
<tr><td colspan="2">1.3b - How likely is the pest to be associated with the pathway at origin taking into account factors such as the occurrence of suitable life stages of the pest, the period of the year?</td></tr>
<tr><td>moderately likely
Level of uncertainty: low
Justification:
The bacterium needs to be associated with the vector and the vector to the commodity.

Association of the bacterium with the vector: See pathway A1.
Association of the complex bacterium/vector with the fruits: B. cockerelli is a common pest of tomato, pepper and eggplant in areas where it is present. Eggs are laid and nymphs feed on the green parts of the plant; they are reported to be found mostly on foliage (see datasheet). As there are no, or minimal amounts of leaves, attached to the fruit, the psyllid can possibly be associated with fruit only if there are green parts attached to it: stems or calyx or other. This might be the case for all fruits considered. Vine tomatoes present a higher risk as they are harvested and marketed with parts of branches. Adults might be associated with consignments if they contaminate consignments at or after harvest. However, this is less likely because adults will fly away when disturbed.

Infective psyllids may also be associated with fruits of Solanaceae which are not a host of the bacterium because the psyllid can first acquire the bacterium from a host plant and subsequently move to a non-host plant. Once acquired, Ca. L. solanacearum persists in the vector and is transmitted to the progeny

Even if the bacterium and psyllid seem widespread where the bacterium occurs, they may not be associated with the pathway:
- in the USA, not all populations of the psyllid are infective (Munyaneza et al., 2008)</td><td>moderately likely
Level of uncertainty: low
Justification:
The bacterium has been detected in fruits of tomato, chilli, sweet pepper. Fruits may show symptoms or may latently be infected. For all the plant species considered, the bacterium may also be present in the green parts associated with the fruit. Vine tomatoes present a higher risk as they are harvested and marketed with branches.

The bacterium would infect fruits if transmitted to the plant by the vector during the growing season.

Where the pest occurs, association with pepper is not clear, and it seems that levels of infection are at least lower than for tomato.

Details on uncertainty: There is uncertainty whether eggplant, tamarillo, Cape gooseberry fruit carry the bacterium as no publication refer to its detection in the fruit but only in plants.</td></tr>
</table>

A2. *B. cockerelli* on fruits of Solanaceae (e.g. tomato, *Capsicum* spp., eggplant, tamarillo, Cape gooseberry)	B2. Fruit of Solanaceae (in particular tomato, *Capsicum* spp., eggplant, tamarillo, Cape gooseberry) from countries where *Ca.* L. solanacearum occurs
- In New Zealand, the bacterium has not been detected in all regions known to have the psyllid (Teulon *et al.*, 2009). In addition losses associated to the bacterium have been observed in greenhouse tomato only, and not yet field tomato where damage is due only to *B. cockerelli* (10%) (Liefting, pers. comm., 2010).	
1.4 - How likely is the concentration of the pest on the pathway at origin to be high, taking into account factors like cultivation practices, treatment of consignments?	
unlikely ***Level of uncertainty:*** low ***Justification:*** Concentration of the bacterium in the vector: see Pathway A1. Concentration of the vector on the commodity. In case of psyllid infestation, crops are submitted to treatment, and this would reduce the concentration on the pathway. In addition, the vector is not likely to be present in big quantities on green parts attached to the fruit (see 1.3b). Fruits produced by plants affected by the pest are reported to be smaller or of lower quality, and might be sorted before dispatch. In the presence of intensive measures in New Zealand (Robertson, 2008), only one psyllid was found on tomato and capsicum fruit for export over 3 years. Concentration of the bacterium in the fruit: see Pathway B2	unlikely ***Level of uncertainty:*** low ***Justification:*** In the case of an epidemic, large concentrations of the bacterium may be found within the twigs and stems of the fruits as well as within the fruits. There is no chemical treatment after the harvest by which the amount of pathogens could be reduced. Because of the step-by-step drying of the twigs and the fruit stalks the plant tissue would not remain suitable for the bacterium. Infected tomatoes have a strawberry like form when they develop symptoms and are normally removed during the sorting process. (from Stefani, 2010). In addition, in case of infestation of *B. cockerelli*, tomato crops would be treated, reducing the concentration of the bacterium on the fruit.
1.5 - How large is the volume of the movement along the pathway? Minimal ***Level of uncertainty:*** (1.): medium; (2.): low – almost certainly low although there is uncertainty about exact import volumes ***Justification:*** **1. Tomato, pepper, eggplant** Import volumes of tomato, pepper and eggplant fruits to the PRA area from countries where the pest occurs seem low. These are major vegetables in the PRA area, but imports originate mostly from the PRA area (see CIRAD, 2009 a, b). The largest quantities of peppers from countries where the pest occurs are imported as dry peppers, for which there is no risk of further spread. In the UK, there has been no import of tomato and pepper fruit from New Zealand since 2000 (CSL, 2009). Some export/import data for tomato, pepper and eggplants were found in FAOSTAT and are provided in Table 2, 3, 4 respectively. It should be noted that data may be inconsistent between exports and imports reports. Nevertheless, volume are minimal.	

A2. *B. cockerelli* on fruits of Solanaceae (e.g. tomato, *Capsicum* spp., eggplant, tamarillo, Cape gooseberry)	**B2. Fruit of Solanaceae (in particular tomato, *Capsicum* spp., eggplant, tamarillo, Cape gooseberry) from countries where *Ca.* L. solanacearum occurs**

Table 2. Tomato (Faostat, 2007, number gives quantities in tonnes as declared by exporting (importing) countries)

Destination / From	**USA**	**New Zealand**	**Canada**
France	0 (7)		
Netherlands	3 (0)		
Norway			(2)
Russian Federation	2 (0)		
Switzerland	20 (3)	0 (19)	

Table 3. Sweet pepper and chilli (green) (Faostat, 2007, number gives quantities in tonnes as declared by exporting (importing) countries)

Destination / From	**USA**	**Mexico**	**Honduras**	**Guatemala**
Belgium	2 (0)			
Denmark	2 (0)			
Finland	8 (0)			
France		0 (1)		
Germany	8 (2)		83 (0)	
Ireland	87 (0)			
Italy		19 (13)		
Netherlands	155 (44)	38 (15)	83 (1)	
Norway	168 (0)			
Russian Federation	0 (20)			
Spain	0 (77)	0 (93)		
Turkey	16 (0)			
UK	137 (52)	0 (3)	350 (0)	0 (1)

Table 4. Eggplant (Faostat, 2007, numbers give quantities in tonnes as declared by exporting (importing) countries)

A2. *B. cockerelli* on fruits of Solanaceae (e.g. tomato, *Capsicum* spp., eggplant, tamarillo, Cape gooseberry)	**B2. Fruit of Solanaceae (in particular tomato, *Capsicum* spp., eggplant, tamarillo, Cape gooseberry) from countries where *Ca.* L. solanacearum occurs**

Destination / From	USA
France	5 (0)
Spain	15 (0)

2. Tamarillo and Cape gooseberry
Columbia is the only important supplier of tamarillo for the PRA area. There are notifications from Switzerland (Zurich) where tamarillos are imported from Peru, Ecuador, Columbia, Brazil, Kenya during the whole year, from South Africa from October to January and from New Zealand from April to October (Berri, 2010). (from Stefani, 2010).
Data are missing on import of tamarillos and Cape gooseberry to the PRA area from New Zealand, but it is presumed to be low: these are not main fruits in the PRA area. Imports of tamarillo are mostly coming from Colombia (Anon., 2008).

1.6 - How frequent is the movement along the pathway?
very rarely
Level of uncertainty: high (Frequency of import for all fruits)
Justification:
Frequency of imports of all fruits are not known, but they relate to low quantities of import, i.e. not likely to be very frequent. In Switzerland, tamarillos are imported from New Zealand only between April and October (Berri, 2010).

1.7 - How likely is the pest to survive during transport /storage?

A2:
Likely
Level of uncertainty: low
Justification:
Fruits have to be harvested, sorted, packed, delivered and marketed within a short time period (a few days).
Survival in fruit and green parts associated, see B2.
Survival in the vector: *Ca.* L. solanacearum is able to survive in all stages of *B. cockerelli*, eggs, nymphs or adults and its survival will be influenced by the survival of its vector. *B. cockerelli* is likely to survive during transport/storage as green parts on which the pest feeds are likely to be fresh and allow feeding during that duration. If the temperature is low, the psyllid will have no activity and can survive a few days without feeding.

B2:
Moderately likely
Level of uncertainty: low
Justification:
Fruits have to be harvested, sorted, packed, delivered and marketed within a short time period (a few days).
In fruit and green parts, the bacterium may survive this period and remain infectious. The concentration of pathogens and viability decreases progressively when twigs and stems dry. No data is available on the period during which living pathogen cells can be found in dried plant tissue. (from Stefani, 2010).

A2. *B. cockerelli* on fruits of Solanaceae (e.g. tomato, *Capsicum* spp., eggplant, tamarillo, Cape gooseberry)	**B2. Fruit of Solanaceae (in particular tomato, *Capsicum* spp., eggplant, tamarillo, Cape gooseberry) from countries where *Ca.* L. solanacearum occurs**
Recent experiments showed that psyllids can feed on tomato fruit without calices (without choice of food) but a high mortality of the psyllid was recorded (unpublished data, Liefting, pers. comm., 2010)	
1.8 - How likely is the pest to multiply/increase in prevalence during transport /storage?	
unlikely ***Level of uncertainty:*** high (at present it is unknown if the bacterium can multiply in the vector) ***Justification:*** Answer to this question depends on multiplication of the bacterium in the vector and of the vector on the commodity. There is no specific data on multiplication of the bacterium within *B. cockerelli*. Regarding multiplication of the vector, transport of fruit would not be long enough to allow emergence of adults, reproduction and egg laying. Even if adults emerge, they would find a limited amount of material suitable for feeding and egg laying. Adults have been shown to feed on fruit and might transmit the bacterium further in experiments with only fruits (see 1.12), but these experiments have also shown a high mortality of the vector.	unlikely ***Level of uncertainty:*** medium ***Justification:*** The physiological conditions after the harvest within the twigs and stems are not suitable for the propagation of the pathogen. The bacteria survive and remain infectious as long as the green plant tissue stays fresh. In general ripe fruits are not suitable for the bacteria. More detailed scientific information is not available. (from Stefani, 2010)
1.9 - How likely is the pest to survive or remain undetected during existing management procedures (including phytosanitary measures)?	
likely ***Level of uncertainty:*** low ***Justification:*** Survival or detection depends both on the bacterium and the vector. Treatments applied to reduce the population levels of the psyllid where it occurs might reduce the incidence of the bacterium, but not eliminate it. For the bacterium to be detected, it would need *B. cockerelli* to be both detected and tested against the bacterium. In the country of origin, such investigations would depend on whether the psyllid is found on species known to be attacked by the bacterium, or on other hosts. However such specific tests are not likely to be carried out in the absence of specific requirements. Neither the bacterium nor its vector are subject to specific phytosanitary import requirements by countries of the PRA area. Although the bacterium is likely to remain undetected, fruits might be inspected at	likely ***Level of uncertainty:*** low ***Justification:*** Before harvest, crops would generally be treated when the psyllid is present, to keep disease levels down. However, this would not suppress the bacterium. Tomato fruits might be misshapen with a strawberry-like appearance and uneven development of fruit locules (Liefting *et al.* 2009a), so they may be noticed at inspection for other pests. Specific testing exists but is not currently applied in the absence of phytosanitary requirements.

A2. *B. cockerelli* on fruits of Solanaceae (e.g. tomato, *Capsicum* spp., eggplant, tamarillo, Cape gooseberry)	B2. Fruit of Solanaceae (in particular tomato, *Capsicum* spp., eggplant, tamarillo, Cape gooseberry) from countries where *Ca.* L. solanacearum occurs
origin for the presence of pests. Visual inspection might allow detecting eggs or nymphs of *B. cockerelli*. However, the inspection would not likely focus on green parts but rather on the fruits. Fruits will not be submitted to treatment in the absence of the phytosanitary requirements, and the vector could remain on consignments.	
1.10 - How widely is the commodity to be distributed throughout the PRA area? limited ***Level of uncertainty:*** low ***Justification:*** Import from countries where the pest is present seems to be to only few countries. Fruits may be theoretically moved to other countries within the EU after their import, but this seems unlikely.	
1.11 - Do consignments arrive at a suitable time of year for pest establishment?	
yes ***Level of uncertainty:*** low ***Justification***: The fruits concerned might be imported at any time of the year. They might also arrive at times when the conditions are suitable for the emergence of adults. See also pathway B2.	yes ***Level of uncertainty:*** low ***Justification:*** Tomatoes and peppers are imported and marketed during the whole year in various quantities. It is assumed that they might arrive in the PRA area during the sowing, propagating and planting season for tomatoes and peppers in the open field, tunnels or glasshouses (no specific data). There are notifications from Switzerland (Zurich) where tamarillos are imported from New Zealand only between April and October (Berri, 2010), which is a favourable period for pest establishment. (from Stefani, 2010)
1.12 - How likely is the pest to be able to transfer from the pathway to a suitable host?	
likely ***Level of uncertainty:*** low ***Justification:*** *B. cockerelli* has many host plants. If adults emerge, they are likely to find a host to feed, while searching for a suitable host for egg laying. Preferred hosts of *B. cockerelli* are also hosts of the bacterium. Infective psyllids may easily and effectively transmit *Ca*. L. solanacearum to certain endemic crops (e.g. potatoes and tomatoes) (Hansen *et al*, 2008; Liefting *et al.*, 2009b; Munyaneza *et al.*, 2008). There are known situations where fruit packaging is in close proximity of	Very unlikely if no vector in the PRA area Unlikely if vector present in the PRA area ***Level of uncertainty:*** low ***Justification:*** Transfer to a suitable host would require the presence of a vector. No other vector than *Bactericera cockerelli* is currently known for solanaceous plants and *B. cockerelli* does not occur in the PRA area. There is an uncertainty on whether other psyllids in the PRA area could act as vector for these crops. If a vector occurs in the PRA area, it would have to feed on fruit to acquire the bacterium and transfer it further. One question to be clarified is how likely is such

A2. *B. cockerelli* on fruits of Solanaceae (e.g. tomato, *Capsicum* spp., eggplant, tamarillo, Cape gooseberry)	**B2. Fruit of Solanaceae (in particular tomato, *Capsicum* spp., eggplant, tamarillo, Cape gooseberry) from countries where *Ca.* L. solanacearum occurs**
greenhouses where solanaceous hosts are grown (see Dutch PRA for *Tuta absoluta,* Potting *et al*., 2010) and transfer from tomato fruits infested by Tuta *absoluta* to greenhouse tomato plants was reported.	vector is to feed on the fruit or remaining green parts on the fruit. Some controlled experiments in New Zealand have shown that *B. cockerelli* can transmit the bacterium from infected tomato fruit without calyces to healthy sweet pepper plants, although with high mortality (unpublished information, Liefting, pers. comm. 2010). In the present pathway, transfer would require a vector already present at destination to feed on the fruit or on small remaining green parts. Even if the vector is present, this seems unlikely if there are living plants around that the vector could feed on instead of fruit. In the experiments above (Liefting, pers. comm. 2010), the psyllid only had fruits at disposition to eat.
1.13 - How likely is the intended use of the commodity (e.g. processing, consumption, planting, disposal of waste, by-products) to aid transfer to a suitable host?	
unlikely ***Level of uncertainty:*** low ***Justification:*** All fruits concerned are intended for consumption or processing. Processes such as washing might eliminate the pest. However, green plant parts are thrown away. If *B. cockerelli* is close to emergence, it might be able to complete its development on the discarded plant part long enough to emerge and transmit the bacterium to a suitable host.	very unlikely ***Level of uncertainty:*** low ***Justification:*** Fruits of tomato, pepper, eggplant (also tamarillo and Cape gooseberry) are intended for consumption or processing, for fresh market or for food industry. Twigs, stems, leaves or other green plant parts are discarded. This bacterium may not survive in domestic or industrial waste or in compost as it is an obligate parasite. Furthermore no psyllid vector has been described that feeds on plant debris and thereby acquires the pest. (from Stefani, 2010)

3. Seed potatoes (including microplants and minitubers) and ware potatoes from countries where *Ca.* L. solanacearum occurs

1.3a - Is this pathway a commodity pathway?

yes

Justification:

This pathway is closed for some countries in the PRA area (import prohibited), but not for all. See 3.1 for details on requirements.

1.3b - How likely is the pest to be associated with the pathway at origin taking into account factors such as the occurrence of suitable life stages of the pest, the period of the year?

- Likely for both ware potatoes and seed potatoes

Level of uncertainty: medium

Justification:

Ca. L. solanacearum has been detected in potato tubers (Li *et al.*, 2009; Secor *et al.*, 2009).

1.4 - How likely is the concentration of the pest on the pathway at origin to be high, taking into account factors like cultivation practices, treatment of consignments?

Moderately likely for ware potatoes

Unlikely for seed potatoes (including microplants and minitubers)

Level of uncertainty: high (Question is difficult to answer because we have no information about areas from which the trade of potatoes occurs)

Justification:

The infection rate of potatoes will depend on the prevalence of infected psyllids. In general, where psyllids are present, heavy spraying programmes are applied to control the pest (Teulon *et al.*, 2009; Abdullah, 2008; Liu & Trumble, 2006). These control programmes will reduce the concentration of the bacterium on this pathway. In addition, there is a higher disease incidence with early exposure to the psyllid and at a younger growth stage (Munyaneza *et al.* 2007b). Transmission by psyllids to potato during the growing season seems to be higher at the beginning of the season. Finally, production of seed potatoes is often subject to stringent production conditions, certification systems, pest control, and inspections in the field and of tubers, which are likely to reduce the concentration.

It should be noted that the level of infection of the tubers is not necessarily related to the risk: when the concentration of the bacteria in the crop is high, symptoms will appear and measures be taken, whereas when the concentration is low, plants may remain asymptomatic and infected tubers will not be detected.

The likelihood of association is lower for seed potatoes than for ware potatoes because seed potatoes are usually grown under more stringent crop protection conditions including more intensive control strategies against insects.

The bacterium has not been found in potato crops in major potato producing areas in Northwestern USA[7] (see distribution of the disease under question 7 and distribution of the psyllid under question 15b). In these areas, infested psyllids have only been found at the end of the growing season during their migration (Munyaneza, 2010a). Goolsby *et al.* (2007, citing older references) showed that migratory psyllids are associated with zebra chips disease in Texas. Gudmestad (2010) showed that migratory psyllids found in North Dakota and Nebraska transport the bacterium (over 20% adults are positive).

Detailed data on infection:

- Munyaneza *et al.*, 2007a: psyllids from a severely zebra chip-infested field were put on healthy potato plants in glasshouse or in cages in the field. Symptoms were observed on 67.5% of the plants in glasshouse and 42.5% in the field (with variation depending on cultivar). Zebra chip symptoms on fried chips were observed on 59.2% in glasshouse and 57% in the field (with variation depending on cultivar).

[7] At the end of 2011, the presence of *Ca.* L. solanacearum was reported from fields in the Columbia basin (both in Oregon and Washington, US) and in Idaho at low incidence (Hamm *et al.*, 2011; Nolte *et al.*, 2011). This PRA was not updated thoughout to take this information into account

- Munyaneza *et al.*, 2007b: percentages in fried chips 63.9 to 87.5% with experiments with different colonies of psyllid, in cage or uncaged.
- Secor *et al.*, 2009: 25% of infested psyllids in zebra chip-infested fields.

1.5 - How large is the volume of the movement along the pathway?

minimal

Level of uncertainty: low: although data is inconsistent and no data are available for other countries in the PRA area for which the pathway is open, seed and ware potatoes mostly originate from within the PRA area. No data for microplants and minitubers but trade is supposed to be minimal.

Justification:

Seed potatoes

The current trade of seed potatoes (tubers) from countries where *Ca.* L. solanacearum is present is very low compared to the total trade of seed potato. Import of seed potatoes from countries outside the EPPO region is prohibited by many EPPO countries (e.g. EU countries, Norway, Switzerland) (see details in 3.1). The movement of microplants and minitubers from North America to the PRA area is not known, but is likely to represent a very small volume.

Ware potatoes

The current trade of ware potatoes from countries where *Ca.* L. solanacearum occurs is very low compared to the total trade. Import from countries where the bacterium occurs is not possible at the moment for EU countries. Requirements of other countries of the PRA area vary from nothing, to general requirements for all fruits and vegetables, to specific requirements targeting specific pests (checked from EPPO collection of phytosanitary regulations) (see details in 3.1).

Limited data are available on trade volumes (see below) from countries where the pest is present but both for seed potatoes and ware potatoes we do not know if potatoes are actually traded from areas where the pest is present.

Data on imports from/export from countries where the bacterium occurs

- Eurostat and Faostat show no import from Mexico, Guatemala and Honduras in 2007.

For USA and New Zealand, data are not consistent, but indicate minor quantities:

- USA export data (http://www.fas.usda.gov/gats/default.aspx) does not always differentiate between seed and ware potatoes. Some EPPO countries import potato from USA (Russia, Israel) but in limited quantities. (EPPO PRA for Epitrix, 2010).

- Import data from Eurostat show small quantities imported in some years from the USA:

Table 5. Import of seed potatoes in EU countries from USA in 1995-2008 (in 100 kg). Eurostat, extracted in 2010-01 (taken from EPPO PRA for Epitrix, 2010)

		United states			
Year	Month	UK	Ireland	Italy	Netherlands
1995		**:**	**:**	1000	**:**
2001		:	400	:	:
2005		180	:	:	:

- Export/import data from FAOSTAT for 2007 show some exports of potato (ware or seed - no separate categories) from USA, Canada and New Zealand to some countries within the PRA area http://faostat.fao.org/DesktopModules/Faostat/WATFDetailed2/watf.aspx?PageID=536. Apart for Russia there is inconsistency between the export data and the import data but volumes are nevertheless minimal.

Table 6. Export data (import data) of potatoes in 2007 (quantity in tonnes)

Destination / From	**USA**	**New Zealand**
Finland		23 (0)
France	31 (0)	
Norway	(3)	

Russian Federation	1896 (1929)	
UK	3571 (0)	38 (0)
Ukraine	48 (0)	

Note: export data for all commodities in both PRAs is given in Annex 5.

- Information requested from Mediterranean countries for the EPPO PRA for Epitrix:
Morocco and Tunisia do not import seed potatoes from North America (NPPO 2009-12-31 and NPPO 2010-01-02, respectively).

1.6 - How frequent is the movement along the pathway?

rarely

Level of uncertainty: medium (lacking data on frequency of import)

Justification:

The frequency of import to other countries seems irregular. Imports to a country one year may be absent another year.

1.7 - How likely is the pest to survive during transport /storage?

very likely

Level of uncertainty: low

Justification:

Ca. L. solanacearum may easily survive in potato tubers (in the phloem) for several weeks after harvest. It is not yet known how long the organism remains active and infectious. The normal storage conditions (4-6 to 7-10°C, at 95% air humidity) (Holley, 2003) does not eliminate the organism. (From Stefani, 2010). It was shown that infected seed potato tubers may produce plants infected with the bacterium in the next growing season (Pitman *et al.*, 2011).

1.8 - How likely is the pest to multiply/increase in prevalence during transport /storage?

unlikely

Level of uncertainty: medium

Justification:

After harvest of the potatoes, bacteria may reproduce in potato tubers and cause symptoms as long as storage temperatures are suitable (Ciampi *et al.*, 1980, cited in Stefani 2010). Normally, potatoes are stored at low temperature (5°C) which will probably not allow for multiplication of the bacterium. Therefore, we assess this question as "unlikely" but with a medium uncertainty since data are lacking on population dynamics of the bacterium during transport/storage.

1.9 - How likely is the pest to survive or remain undetected during existing management procedures (including phytosanitary measures)?

Likely for seed potatoes

very likely for ware potatoes

Level of uncertainty: low

Justification:

Plant protection measures in the exporting countries are mostly taken against the psyllids. Measures against psyllids seem to be taken everywhere where the psyllid and the combination psyllid/bacterium are present, in order to keep damage under a threshold. Treatments against the insect vector reduce the incidence of damage but would not suppress the bacterium (Goolsby *et al.*, 2007).

The bacterium can be present and symptomless and therefore it is likely to survive and remain undetected. There are no specific measures on this pathway that would eliminate the bacterium from the tubers. Where import is possible (not prohibited) in the PRA area, seed and ware potatoes are subject to specific phytosanitary requirements against

other pests. These would imply certain phytosanitary measures against these other pests, including inspection which might help detecting the disease.
Production of seed potatoes is likely to be subject to stringent requirements, such as production condition, certification systems, pest control, inspection in the field and of tubers, and the bacterium might be detected during the production process.

1.10 - How widely is the commodity to be distributed throughout the PRA area?

limited
Level of uncertainty: low

Justification:
The trade seems limited to few countries in the region. The quantities are small and most countries have strict requirements for potatoes, so it is not so likely that potatoes imported from New Zealand or USA are moved to other countries within the PRA area.

1.11 - Do consignments arrive at a suitable time of year for pest establishment?

yes
Level of uncertainty: low

Justification:
Seed potatoes are imported at appropriate periods for planting: usually January-April. Every tuber that was infected in the previous season may contain living pathogens at the normal planting date.

Consignments of ware potatoes may arrive throughout the year.

1.12 - How likely is the pest to be able to transfer from the pathway to a suitable host or habitat?

Very unlikely for ware potatoes and seed potatoes (incl. microplants and minitubers) if no vector is present in the PRA area
Unlikely, for ware potatoes if there is a vector in the PRA area (but only if ware potatoes are planted)
Moderately likely for seed potatoes once planted if there is a vector in the PRA area (high uncertainty, see below).
Level of uncertainty: Medium

Justification:
The pest is systemic in the potato plant and tubers. It can only propagate and move in the phloem. For the bacterium to transfer to a host plant, a vector would have to be present, acquire the bacterium on infested plants produced by infected tubers (the vector feeds on green parts only) and transmit it to a host plant. No other vector than *B. cockerelli* is currently known on potato, and this species does not occur in the PRA area. There is an uncertainty on whether other psyllids in the PRA area could act as vector for potato (see also 15b).

Even if infected potatoes are planted, it has been reported that seed potatoes infected by *Ca.* L. solanacearum germinate poorly or not at all. Henne *et al.* (2010a) found 20% of zebra chip affected tubers sprouting, depending on cultivar and severity of zebra chip in the tubers. Secor *et al.* (2009) obtained similar results. In some cases, tubers with symptoms produce healthy appearing plants that produce progeny tubers with or without zebra chip. Emergence is delayed, plants grow for a week or two and then stop growing for weeks before dying. All tubers collected from the plants failed to sprout. This study did not show seed-tuber borne infections as epidemiologically important in Texas (which is one area where the vector is readily present, as well as the bacterium). Plants produced by infected seed tubers did not seem to impact surrounding plants, i.e. they do not serve as focal points for further transmission (hypothesis that they are dead by the time adult vectors arrive, or are hidden by the canopy of healthy potato plants) (Henne *et al.*, 2010a). This would reduce the likelihood of transfer to a suitable host.

In addition ware potatoes are normally not planted (although they might be by private persons/consumers).

Details on uncertainty: Medium. What the concentration of bacteria would be in the canopy of plants grown from seed potatoes, and how potato tubers would act as source for vector to acquire bacterium; whether some other psyllids occurring in the PRA area could transmit the bacterium to potato.

1.13 - How likely is the intended use of the commodity (e.g. processing, consumption, planting, disposal of waste, by-products) to aid transfer to a suitable host or habitat?

Very unlikely for seed potatoes if there is no vector in the PRA area
Likely for seed potatoes if a vector is present in the PRA area
Very unlikely for ware potatoes with or without vector in the PRA area.
Level of uncertainty: low

Justification:
Seed potatoes are intended for planting and a possibility of transfer would exist (provided a vector occurs and with limiting factors as detailed in 1.12).

Ware potatoes are consumed or industrially processed to different products, e.g. chips, French fries, starch, animal fodder. The pest is not able to survive in industrial waste or waste water because *Ca.* L. solanacearum is an obligate parasite which cannot survive outside its host plants (or its vectors).

1.14c - The overall probability of entry should be described and risks presented by different pathways should be identified

The risk of entry of *Ca.* L. solanacearum varies depending on whether it enters on *B. cockerelli*, or if a vector is present or not in the PRA area for Solanaceae. Some of the pathways considered from areas where the bacterium occurs, such as potatoes and plants for planting of Solanaceae, are closed for many countries in the PRA area (in particular EU countries). The risks of entry obtained below are therefore not relevant for these countries as the pathways do not exist. The EWG summarized the risk as follows:
There is a medium to high uncertainty throughout this assessment (all sources of uncertainty are detailed under section 2.17).

Commodity	**Risk of entry of the bacterium (entry includes arrival of the pest and transfer to a host plant)**		
	If a vector would be present in the PRA area	**If no vector in the PRA area**	
		Risk of entry of the bacterium with the vector	**Risk of entry of the bacterium without the vector**
Plants for planting of Solanaceae (pathways A1 and B1) [Not relevant for countries where the pathway is closed (e.g. EU)]	Moderate (with a high likelihood of survival and transfer to a host, but seemingly a low volume pathway)	Moderate	Very low
Fruits of Solanaceae (pathways A1 and B1)	Low/Very low depending on the species (larger pathway for tomato and *Capsicum*, small for others, but transfer to a host is unlikely)	Moderate/Low	Very low
Seed potatoes (pathway 3) [Not relevant for countries where the pathway is closed (e.g. EU)]	Low (usually produced under stringent conditions; small pathway; unlikely to be associated with this pathway in the first place, although transfer to a host would be more likely)	N/A	Very low
Ware potatoes (pathway 3) [Not relevant for countries where the pathway is closed (e.g. EU)]	Moderate/Low (small pathway, but not produced under stringent conditions and could be planted)	N/A	Very low
Plants for planting of *Micromeria chamissonis*, *Mentha* spp., *Nepeta* spp., and *Ipomoea batatas* (pathway 4)	Low	Low	Very low
Living parts of Solanaceae (pathway 5)	Very low	Low	N/A

Stage 2: Pest Risk Assessment - Section B: Probability of establishment

The answers consider the establishment of the bacterium and of *B. cockerelli* as the establishment of the bacterium depends on either the presence of a suitable psyllid vector in the PRA area or on establishment of *B. cockerelli*.

1.15 - Estimate the number of host plant species or suitable habitats in the PRA area.

moderate number

Level of uncertainty: medium (Host range of the bacterium)

Justification:

Host plants for the bacterium: potato, tomato, *Capsicum* spp. (such as sweet pepper and chilli), eggplant, tamarillo, Cape gooseberry, carrot and some weeds (see section 6). Given that the bacterium has been found outside its original solanaceous host range, there is an uncertainty on whether other species could be hosts.

B. cockerelli has more host plants, but still in moderate numbers (Wallis, 1955, mentions 46 species on which the insect can reproduce, of which 42 are Solanaceae). Among these, its main solanaceous hosts plants (tomato, potato, sweet pepper, eggplant, tamarillo, Cape gooseberry, etc.) are grown in the PRA area, as well as other crops and weed hosts.

1.16 - How widespread are the host plants or suitable habitats in the PRA area?

very widely

Level of uncertainty: low

Justification:

For Solanaceae that are known hosts of *Ca.* L. solanacearum:

- Potato and tomato are widely cultivated throughout the PRA area (see maps in Annex 6).
- Peppers are cultivated mostly in the southern and south-eastern part of the region.
- Tomato and pepper are grown either in the field or in glasshouses, tunnels or under plastic.
- Tamarillo is grown outdoors for fruit production in Madeira and cultivated throughout Portugal (commercial crops about 2 ha for the local market) (A. Silva, Centro de Desenvolvimento de Fruticultura Subtropical, Madeira, pers. comm., 2010).
- All cultivated hosts (including tamarillo and Cape gooseberry) can also be present in private gardens.

Some other cultivated or managed hosts of *B. cockerelli* (see *B. cockerelli* categorization section in the PRA for *B. cockerelli*) are also grown in the PRA area.

Data from Faostat 2008 on area and production are given in Annex 3.

Crop	**Area harvested in the PRA area (ha)**
Potato	6 955 446
Tomato	1 029 148
Chillies and peppers, dry	62 230
Chillies and peppers, green	261 657

Weed hosts:

Lycium barbarum: throughout the region; *Solanum elaeagnifolium*: western and southern part of the EPPO-region (DAISIE, 2008)

1.17 - If an alternate host or another species is needed to complete the life cycle or for a critical stage of the life cycle such as transmission (e.g. vectors), growth (e.g. root symbionts), reproduction (e.g. pollinators) or spread (e.g. seed dispersers), how likely is the pest to come in contact with such species?

unlikely

Level of uncertainty: medium (uncertainty on whether other psyllid species could act as a vector)

Justification:

The known vector on Solanaceae, *B. cockerelli,* is currently not present in the PRA area. *T. apicalis*, the vector present in the PRA area on carrot, does not feed on the bacterium's solanaceous hosts (see Annex 1). There is an uncertainty on whether other psyllid species in the PRA area could act as vectors (see 15a).

B. cockerelli may overwinter on wild plants (e.g. *Lycium*, solanaceous weeds) and some of these are widely recorded in the PRA area.

1.18a - Specify the area where host plants (for pests directly affecting plants) or suitable habitats (for non parasitic plants) are present (cf. QQ 1.15-1.17).

The whole PRA area (for the bacterium and for *B. cockerelli*)

1.18b - How similar are the climatic conditions that would affect pest establishment, in the PRA area and in the current area of distribution?

largely similar

Level of uncertainty: low

Justification:

The bacterium can survive over a wide range of temperatures, as shown from its current distribution. It occurs in carrot and celeriac in Finland, Norway, Sweden, and in Spain (see answer to question 7). The bacterium can only spread and infect other plants through a vector or by human activities (e.g. vegetative reproduction). Establishment of the bacterium in Solanaceae is therefore largely dependent on establishment of *B. cockerelli*. Climatic conditions might not be suitable throughout the PRA area in the field for establishment of the vector, but would be so in heated greenhouses.

In a PRA for *Ca*. L. solanacearum in Canada, Kristjansson & Damus (2008) estimated that establishment of *Ca*. L. solanacearum has a low probability because the psyllid vector may not overwinter anywhere outdoors in Canada. They considered that establishment in greenhouses may occur but only locally and could be mitigated with control measures against the vector.

Details for the bacterium

Climatic conditions in the open field (potato cultivation) in the PRA area are similar to those where the disease presently occurs, in particular in New Zealand. The cultivation under protected conditions depends on the crop plant and the variety but is designed to have the optimal temperature and humidity for the crop. There are currently not much data on the temperature requirements of the bacterium for infection and reproduction. Workneh *et al*. (2010) showed that infection can occur over a wide range of temperatures (15-32°C). The bacterium can probably survive as long as its host plant is present. In case of annual crops, it will depend on a vector to survive the cropless period.

The rate of symptom development in the tubers is affected by temperature. According to Munyaneza (2010), *Ca*. L. solanacearum seems to be heat sensitive based on laboratory experiments on potato. At temperatures of 16°C or lower, tuber symptoms develop at a much slower rate than at higher temperatures. This is confirmed by Workneh *et al*. (2010). Temperatures of 35°C or higher seem to limit development of zebra chip symptoms. The optimum temperature for Liberibacter development in potato plants was estimated at approx. 28°C (Munyaneza, 2010). Field observations indicate that symptoms on potato seem to be less severe at low than at high temperatures. It should be noted that the bacterium is not present in Washington State naturally although climatic conditions are favourable to its development as shown in controlled field experiments conducted in that state (Munyaneza, pers. comm. 2010)[8]. In New Zealand, where the climate is much cooler than in southern USA, potato plants infected with *Ca*. L. solanacearum do not always develop zebra chip symptoms (Ogden, 2011).

[8] Since this PRA was conducted, , the presence of *Ca*. L. solanacearum was reported from fields in the Columbia basin (both in Oregon and Washington, US) at the end of 2011 at low incidence (Hamm *et al*., 2011)

Details for *Bactericera cockerelli*

Climatic conditions are more important for the establishment potential and development of the vector than for the bacterium. In its current area of distribution in North America, *B. cockerelli* is migratory: it overwinters in the southern part of its range, and then migrates northward annually during spring and summer, carried by wind and currents as temperatures increase. However, this pattern is not observed in New Zealand, where the vector maintains populations in potato growing areas from year to year. In New Zealand, the pest has established outside and inside glasshouses. In the field, areas with warmer summers are more suitable than areas with cooler summer conditions. It is not known why *B. cockerelli* does not survive during winter in the northern part of its range in the USA (e.g. Washington). It may be due to the climatic conditions (e.g. too low temperatures) or to other factors (e.g. absence of a suitable host to overwinter). In a PRA for Canada, Kristjansson & Damus (2008) assessed that it is unlikely that this psyllid could overwinter anywhere outdoors in Canada. However, recent experiments indicate that *B. cockerelli* can survive cold temperatures (with nymphs surviving up to -15°C for 24h) (Henne *et al*., 2010b).

There is circumstantial evidence that in New Zealand *B. cockerelli* may have first established on tomato in glasshouse and then have spread to field crops (Teulon *at al*., 2009). This may also happen in northern areas within the EPPO region.

It should be noted that, analysing the original distribution of the vector in the Americas using CLIMEX, presence of the vector would not have been expected in New Zealand, certainly not on the southern island which has a much cooler climate than the original area of distribution.

Climate maps, temperature and precipitation graphs comparing the climate of some locations where the vector is present with the climate in the PRA area are given in Annex 7. Given its current distribution in the Americas and New Zealand, it is thought that *B. cockerelli* would be able to establish and overwinter outdoors in the Southern and Central European part of the PRA area, as well as in areas with mild winters in the Northern part of the PRA area, comparable to those of Christchurch, New Zealand. It is unlikely to establish in the Eastern part of the region (east of Poland). However transient populations could occur there after migration, similar to the situation in Canada late in the season after migration from southern USA.

1.19 - How similar are other abiotic factors that would affect pest establishment, in the PRA area and in the current area of distribution?

no judgement

Level of uncertainty: medium

Details of uncertainty: medium. No data on the effect of abiotic factors on the development of the bacterium and its vector. Generally, abiotic vectors are not considered to have a large effect on the potential area of establishment. The presence of host plants and the climate are considered critical for establishment.

Justification:

Not known. There are no references in literature on the influence of abiotic factors for the colonisation of hosts and the development of the disease. In general, bacterial diseases develop better on well fertilized hosts and on very nitrogenous soil. Well fertilized stronger plants may be more attractive to psyllids (from Stefani, 2010).

1.20 - If protected cultivation is important in the PRA area, how often has the pest been recorded on crops in protected cultivation elsewhere?

often

Level of uncertainty: low

Justification:

Tomato, pepper, eggplant are widely cultivated under protected conditions (tunnels, plastic or glasshouses) in the PRA area. *Ca.* L. solanacearum (and *B. cockerelli*) have been recorded on tomato and pepper crops in protected conditions in both North America and in New Zealand (Hansen *et al.*, 2008; Liefting *et al.*, 2009a, b; Brown *et al.*, 2010, Ferguson & Shipp, 2002). In New Zealand, they were first recorded in glasshouses, and are causing serious outbreaks on glasshouse tomatoes.

1.21 - How likely is it that establishment will occur despite competition from existing species in the PRA area, and/or despite natural enemies already present in the PRA area?
very likely
Level of uncertainty: low

Justification:
Natural enemies: At the moment the control of *Ca.* L. solanacearum is not possible and no natural antagonists against phloematic bacteria are known. Beneficial organisms against *B. cockerelli* are known but are very unlikely to prevent establishment. Some beneficial organisms are applied in integrated control measures in tomato glasshouse production but are not very effective (Al-Jabar, 1999). In experiments, Lacey (2009) also showed some efficacy of three fungi, *Isaria fumosorosea*, *Metarhizium anisopliae* and *Beauveria bassiana*, some of which are present in the PRA area.

Competition: No competition with other phloematic bacteria is known. If another vector is present in the PRA area on Solanaceae (see 15a), *B. cockerelli* might compete with this species and this might influence its establishment, but there are no data on this.

1.22 - To what extent is the managed environment in the PRA area favourable for establishment?
highly favourable
Level of uncertainty: low

Justification:
All cultivated hosts in the open field:
Pest control strategies are in place for crops in the open field (potatoes, tomato) in the PRA area, for example against aphids serving as vectors of viruses. However, insecticide treatments are not systematically used in potatoes within the PRA area (see EPPO PRA on Epitrix, and see 1.23) or may not be timed appropriately to control vector population.

In some part of the PRA area, solanaceous crops are grown all year round (e.g. in the Mediterranean area), which will favour establishment. Host weeds or volunteers may be found in potato or tomato crops. Their presence will favour survival or reproduction of the bacterium and therefore establishment (provided that a vector is present).

Crop rotation is used in the PRA area, but it is unlikely to have an effect on establishment of the bacterium.

There is no information on the managed environment for tamarillo crops on Madeira, Portugal.

Cultivation in glasshouses/under protected conditions (e.g. tomato, *Capsicum* spp. and eggplant)
Glasshouse conditions seem appropriate for establishment, as shown in New Zealand where the pest was first found on tomato and pepper under glasshouse. Psyllids may also develop more rapidly in glasshouses and acquire and transmit the bacterium more efficiently than outdoors because of the optimal temperatures for both the bacterium and the psyllid.

Grafting of tomato and pepper is a technique commonly used in at least some part of the EPPO region (e.g. EU) to increase yield, prolong the harvest season and control other pests (e.g. nematodes in the soil, or the fungal pathogen *Pyrenochaeta lycopersici*). In the course of grafting contaminated rootstocks might infect the shoot tip so that the whole plant would be infected. Mechanical transmission is not reported for this bacterium.

Sanitation/hygienic measures are usually applied in glasshouses. They may contribute to controlling the vector and avoiding establishment of the bacterium. Such measures include treatment of glasshouses (spraying, fogging) before new plantings; limiting access of third persons to glasshouses; removal of plant debris at the end of the growing season; and removal of emerging weeds.

All cultivated hosts in gardens
Potato, tomato, pepper, eggplant, tamarillo and Cape gooseberry cultivated in gardens are normally not treated very often with insecticides. Weed hosts may be present in gardens and acts as a reservoir.

1.23 - How likely is it that existing pest management practice will fail to prevent establishment of the pest?
very likely

Level of uncertainty: low (lack of data on practices in other countries in the PRA area)

Justification:
There is no effective management practice against *Ca.* L. solanacearum itself. Insecticides that are already applied may affect population development of the vector but they are unlikely to be able to prevent establishment also because insecticides are not frequently used in the production of ware potatoes (at least in part of the PRA area) and no psyllids are currently recorded as pests of cultivated Solanaceae in the PRA area, so no specific control measures exist.

Existing pest management practices for field crops: potato, tomato
Insecticide applications might help to control the vector, but would not be targeted enough to prevent establishment. In addition, alternative hosts are likely to be present.

Pest control in potato crops. Current plant protection practices for potato are quite different within the EPPO region (from EPPO PRA on Epitrix, 2010) but will not be able to prevent establishment of the psyllid:
- Italy: Potatoes are frequently sprayed with fungicides (to target late blight) but also with insecticides, primarily pyrethroids, against Colorado potato beetle and aphids, and neonicotinoids against noctuids and the new target *Phthorimaea operculella*. The numbers of insecticides applied are roughly 5 per growing season and it is considered that such strategy also controls *Epitrix hirtipennis*. (Bugiani, Italian NPPO, pers. comm., 2010)
- Poland (Sahadjak, Polish NPPO, pers. comm., 2010): Farmers typically apply 1 to 2 treatments per season against Colorado beetle, as needed. In exceptional cases 3 treatments are used (an insecticide is applied in combination with a fungicide), and very small plantations often are not protected at all. The most common products are neonicotinoids and pyrethroids. In farms specializing in large-scale potato production and seed production, a seed dressing (containing imidacloprid) is used against the Colorado beetle. Additionally, the following products are also used against aphids in seed production: mineral oil, lambda-cyhalothrin, pirimicarb. Typically potatoes are grown in a 4-year rotation (in about. 80% of case), less frequently in a 2-3-year rotation (10-15%). About 2-3% of potato plantations are grown in monoculture but with vegetables intercrops (in regions specialized in growing very early potatoes). Waste/downgraded potatoes are typically used as animal feed and not let as culls in the fields. Farm-saved seeds are largely used, in particular in small farms.
- Russia (Popovich, Russia NPPO, pers. comm., 2010): potato is often grown in monoculture. Insecticides target primarily Colorado beetle, one treatment is applied against each generation. A larger range of chemicals is available in Russia compared to the EU, as more organophosphates and carbamate are still registered (e.g. dimethoate, malathion, carbosulfan). Waste/downgraded potatoes are typically used as animal feed and not left as culls in the fields.
- UK (Giltrap, Fera, pers. comm., 2010): as Colorado beetle is not present in the UK, ware potatoes received an average of 1 insecticide spray per year.
- Germany (Stefani, 2010), e.g. against aphids vector of viruses, Colorado beetle. Approved active ingredients in Germany are: thiamethoxam, thiachloprid, clothianidin, deltamethrin, lambda-cyalothrin, cypermethrin and azadirachtin. As an example: an application dose of 0.5 l/ha cypermethrin which is used against the Colorado beetle may also be effective against psyllids.
- In some part of the EPPO region (e.g. where Colorado beetle is not present), no insecticide treatments are applied on potatoes.

Monitoring. Field crops are subject to monitoring, but this might not allow the bacterium or the vector to be detected before it is established.

Existing pest management practices under protected conditions:
Ogden (2011) noted that control of *B. cockerelli* in greenhouses was easier that for field crops as most tomatoes and capsicums grown for the fresh market are produced in modern hydroponic greenhouses. The plants are grown on strings and are intensively worked. The frequent removal of lower leaves and the upright growth habit of the plants greatly assists in crop monitoring, spray coverage and psyllid control. Tomatoes and capsicums grown indoors in the PRA area are also mostly grown with similar practices. It should be noted that, since the establishment of *Tuta absoluta* in many countries of the PRA area, the use of screenhouses has largely increased.
Pest management practices in tomato (from Stefani, 2010)
- *Pest control*. Technical advice for protected crops is highly developed in most parts of the PRA area. Efficient control strategies may hinder the establishment of the bacterium in glasshouses. However, cropping under protected conditions often relies on targeted IPM strategies, including targeted biological control agents, which

might make establishment of the bacterium and its vector more likely. In New Zealand, protected cultivation uses similar IPM management and high-level production techniques, but this did not prevent establishment of the pest.

- Important pests of tomato are whiteflies (*Bemisia tabaci*, *Trialeurodes vaporariorum*), aphids (*Aphididae*), mites (*Tetranychidae*), thrips (*Thysanoptera*) and *Tuta absoluta*. Approved substances in the EU include: thiamethoxam, imidacloprid, buprofezin, fenbutatin-oxid, cypermethrin, abamectin, lambda-cyalothrin, deltamethrin, azadirachtin, indoxacarb, spinosad, esfenvalerate. All these active substances except indoxacarb, esfenvalerate and fenbutatin-oxid are reported as giving control of *B. cockerelli* in the New-Zealand Code of practice for the Management of *B. cockerelli* (reproduced in Appendix B of Biosecurity Australia, 2009). The recently introduced pest *T. absoluta* is an emerging pest of tomato in a number of EPPO countries and has resulted in modification of practices. Where *T. absoluta* is present some practices may mitigate the risk of establishment of *B. cockerelli* (e.g. increase number of insecticide applications, cultivation in screenhouses).
- *Monitoring*: Tomatoes are grown over several months (9 to 10 months per year). A regular monitoring of pests is usually performed and might allow detection of disease symptoms and psyllids. Yellow traps are normally used and will help detecting the presence of psyllids. However, the bacterium might be established before it is detected.
- *Crop rotation*. Crop rotation might be used in glasshouse tomatoes against some pathogens or pests, such as spider mites (*Tetranychus urticae*), several species of aphids, leaf mining flies (*Liriomyza bryoniae*), thrips (*Frankliniella occidentalis*). However, such crop rotation is not commonly used as because of producers are generally highly specialised. Where it is used, it might have an effect on establishment by hindering colonisation by *B. cockerelli*.

<u>All cultivated hosts in organic production or in gardens</u>
Whether in the field or in glasshouse, pest management options currently available in organic farms (or in private gardens) will fail to prevent establishment.

The measures applied to carrots in Finland seem to have failed to prevent arrival of the pest in at least 14 fields (although data is lacking on the origin of this infection).

1.24 - Based on its biological characteristics, how likely is it that the pest could survive eradication programmes in the PRA area?

<u>Different likelihood depending on the vector</u>
Very likely if a vector is already present
Likely if *B. cockerelli* is introduced at the same time
Unlikely if no vector is present
Level of uncertainty: low

Justification:
For Solanaceae, an eradication programme would rely on early detection of the bacterium, which might be difficult since the pest might be present in asymptomatic plants, and the symptoms are not very characteristic.
Ca. L. solanacearum has a wide range of host plants, including weeds (in particular *Lycium* spp.). While crops could be destroyed, garden plants and wild hosts might serve as a reservoir. In New Zealand, eradication of *B. cockerelli* was concluded to be not feasible because the pest was already well established, as shown by a wide distribution, lack of linkages between infested sites and unknown pathway into New Zealand.

<u>In the absence of the vector</u>, it will be possible to eradicate the bacterium by eradicating the infested crop. However, verification measures should be applied to make sure that the pest was limited to that crop, and the vector was not present. If the bacterium is in seed potatoes breeding material, the bacterium might remain undetected for several generations of potato material during multiplication of the material, during which time a vector could be introduced. If seed potatoes are no longer produced from infected material, the bacterium will finally be eliminated since it cannot maintain itself on an annual crop.

<u>If *B. cockerelli* is introduced at the same time or a vector is present</u>, eradication would generally be very difficult. Eradication may be possible if *B. cockerelli* is discovered in a glasshouse in an area where it cannot establish outdoors (e.g. areas where it is unlikely to overwinter) but would still be difficult. For successful eradication early detection will be essential (the pest might be present for some time before it is detected as in New Zealand).

1.25 - How likely is the reproductive strategy of the pest and the duration of its life cycle to aid

establishment?
Moderately likely in the absence of the vector
Very likely if a vector is present or *B. cockerelli* enters at the same time
Level of uncertainty: low (but there is a lack of details on multiplication of the bacterium in the plant and in the vector)

Justification:
The bacterium colonizes and multiplies in the phloem of the plant (Secor *et al*., 2009; Liefting *et al*., 2009a). It has not been proven that the bacterium multiplies in the vector; but it is spread in a persistent manner. Research is currently being conducted. The bacterium is also transmitted to the progeny of the vector (Hansen *et al*., 2008) and might be carried by eggs, nymphs or adults.

Establishment would be facilitated by the reproductive strategy of the vector, if a vector was present or introduced at the same time. *B. cockerelli* has a short life cycle and may have 1 to 5 life cycles within one season. One life cycle may be completed within 4 weeks under favourable conditions (Liu *et al*., 2006a; Abdullah, 2008). Given the climatic conditions in the PRA area and the cultivation period of the crops or hosts, the vector might have 2 to 3 life cycles in some areas.
Females lay many eggs
- 500 eggs per female (Wallis, 1955)
- 184-258 eggs per female specifically in greenhouse tomatoes (Abdullah, 2008)
- 36 to 720 on potato, tomato or chilli pepper (Yang & Liu, 2009, citing older publications)
- 29 on eggplant and 39 on bell pepper (Yang & Liu, 2009)

Short development times and high rates of oviposition allow populations to increase explosively in optimal conditions (Liu & Trumble, 2004).

1.26 - How likely are relatively small populations to become established?

Very likely if a vector is present or *B. cockerelli* enters at the same time
Moderately likely for perennial crops if no vector is present (but the population will remain limited to the plant it was imported on unless the plant is used for vegetative reproduction).
Unlikely for seed potatoes if no vector is present (potatoes that are grown from seed potatoes is an annual crop. The bacterium may maintain over a longer time if the seed potatoes are used to produce other seed potatoes).
Very unlikely for other species if no vector is present
Level of uncertainty: low

Justification:
If *Ca*. L. solanacearum is introduced, a small population could establish. For annual crops, in the absence of a vector, the bacterium will probably disappear with its crop. For seed potatoes or perennial crops (e.g. tamarillo), a small population may establish.

Successful establishment would depend on the presence of a vector colonizing hosts of *Ca*. L. solanacearum, either already present or introduced at the same time.

1.27 - How adaptable is the pest? Adaptability is:

High for *Ca*. L. solanacearum
Moderate for *Bactericera cockerelli*
Level of uncertainty: medium

Justification:
Ca. L. solanacearum was identified in 2008, but had presumably been associated with some diseases of potato and tomato at least since they were first observed in the 1990s. The pest has since been detected on other solanaceous crops (*Capsicum*, tamarillo, Cape gooseberry) in New Zealand, and on weeds. It has then been found in Finland on a non-solanaceous crop, carrot, associated with a different vector than the one in its area of origin. There is now suspicion that it might be present on more species (see question 7). In consequence *Ca*. L. solanacearum seems to already have adapted to a wider range of hosts and vectors than originally thought. Nelson *et al*. (2011) identified three haplotypes of the bacterium. The first two are distributed in North/Central America and New Zealand, while the third has only been detected on carrots in Finland.

For *B. cockerelli*, adaptability is moderate. It has a moderate host range, is present in a large number of crop conditions. It may migrate over long distances (hundreds of kilometres) to escape unfavourable weather conditions. Resistance to pesticides has developed. There also seem to be several populations of the pest, native Texas populations and invasive populations (Liu *et al.*, 2006a) with some populations showing a level of pesticide resistance (Liu & Trumble, 2007).

1.28 - How often has the pest been introduced into new areas outside its original area of distribution?

Not relevant for the bacterium[9]
Rarely for *B. cockerelli*
Level of uncertainty: low
Details on uncertainty: How *Ca.* L. solanacearum was introduced into New Zealand and Finland. It is also unknown how the vector *B. cockerelli* was introduced into New Zealand.

Justification:

***Ca.* L. solanacearum**

The origin of *Ca.* L. solanacearum is not known. It is not known whether all detections on other continents (than Americas) or host plants are due to new introductions. Recent records on other continents, on other hosts and with other vectors trigger questions on the real distribution and pathways for spread of the bacterium.

The origin of *Ca.* L. solanacearum in New Zealand is uncertain, but the disease emerged in 2008, 2 years after the vector *B. cockerelli* was discovered. The vector was recorded for the first time in May 2006 in Auckland in a glasshouse for tomato and *Capsicum* in the North Island. Several facilities were found infected and *B. cockerelli* was considered to be already well established there (Gill, 2006) and had established throughout the North Island and the top-West part of the South Island (Liefting *et al.*, 2009a). The bacterium has spread to many places in the North and South Island. It is, however, not present everywhere the vector is present (Teulon *et al.*, 2009)

B. cockerelli

Outside its range in the Americas, *B. cockerelli* is known to have been introduced only into New Zealand (first recorded in May 2006 in a glasshouse in Auckland, see above). Thomas *et al.* (2011) investigated the entry pathway for *B. cockerelli* into New Zealand. They could not conclude on a definitive pathway of entry but considered that it might plausibly have been introduced by the smuggling of primary host material (infested host plants or host fruits, or voluntary introduction of the insect whose identity was mistaken for a potential biocontrol agent).

There are no interceptions records of *B. cockerelli* in Europhyt (accessed 18th August 2011). There are also no records of interceptions for the UK (CSL, 2009). In New Zealand, the psyllid has been found, thus far, at one occasion only during pre-export inspections (carried out on every lot of tomato or *Capsicum* fruit for export), after measures were implemented against this pest (Robertson, 2008).

1.29a - Do you consider that the establishment of the pest is very unlikely?

Yes for Solanaceae hosts in the absence of a vector
No for Solanaceae hosts in the presence of a vector or if *B. cockerelli* enters at the same time
No for carrot

Level of uncertainty: low
Justification:
If *Ca.* L. solanacearum enters the PRA area, it can probably survive on the plants on which it was introduced as long as the plants do not die. On seed potatoes, the infection may be maintained as long as new seed potatoes are being produced from the line originating from the infected ones which had been imported. It is thought that these cases will not lead to long term establishment, but they could lead to transient populations.

In general, establishment for longer periods is only likely if the vector, *B. cockerelli* is also introduced, as in New

[9] After this PRA was conducted, the bacterium, Ling *et al.*, 2011 discovered the bacterium on greenhouse tomatoes in Eastern Mexico whereas it was priviouslyu only reported on field tomatoes in Western Mexico.

Zealand, or if another psyllid species in the PRA area could serve as vector.

Ca. L. solanacearum appears to have established on carrot at least in Finland.

1.29c - The overall probability of establishment should be described.

Justification:

Regarding establishment of *Ca.* L. solanacearum on potato and other solanaceous species, establishment depends on the presence of a suitable vector. Probability of establishment is:

- Very low in the absence of a vector, low when the pest is introduced with seed potatoes or plants for planting of perennial crops.
- Very high if *B. cockerelli* has already established or another vector is present in the PRA area at the time when the bacterium enters.
- High if the bacterium is introduced at the same time as *B. cockerelli*, as for the probability of establishment of *B. cockerelli*.

The probability of establishment of *B. cockerelli* in the PRA area is high with a low uncertainty, in areas with suitable climatic conditions (i.e. in the Southern and Central European part of the PRA area, as well as in areas with mild winters in the Northern part of the PRA area) and in glasshouses. The host plants are widely distributed, the reproductive strategy and migratory habit of *B. cockerelli* would help establishment, and it has already established outside of its original range.

Note: The bacterium is present on carrot in the PRA area, associated with *T. apicalis* in Finland. The vector associated with the bacterium on carrot and on celeriac in Spain is *B. trigonica* in Canary Island and a *Bactericera* sp. in mainland Spain. There is no known way of transmissions from carrot and celeriac to Solanaceae.

Major uncertainties influencing the assessment

- Whether other psyllids present in the PRA area or outside the PRA area could act as vector of the bacterium for Solanaceae.

Stage 2: Pest Risk Assessment - Section B: Probability of spread

1.30 - How likely is the pest to spread rapidly in the PRA area by natural means?
Very unlikely if no vector is present
Likely if a vector is present or *B. cockerelli* enters at the same time.
Level of uncertainty: medium

Justification:
Ca. L. *solanacearum* is expected to spread rapidly if a vector is present or introduced at the same time. The experience with *B. cockerelli* in New Zealand has shown that the bacterium may be spread over distances of more than 1000 km within a period of 4 years after the vector's introduction, but this is a combination of both natural and human-mediated dispersal (Teulon *et al.*, 2009). *B. cockerelli* is known to migrate long-distance to exploit its solanaceous hosts. Goolsby *et al.* (2007, citing older references) and Gudmestad (2010) have shown that migratory psyllids found in North Dakota and Nebraska transport the bacterium (over 20% adults are positive). The nearest place of origin for these migratory psyllids is Texas, i.e. over 600 km away. *B. cockerelli* also transmits the bacterium to the progeny, increasing the risk of further spread.

Rapid localized spread in the USA suggests that *B. cockerelli* is a good flyer although there are not definitive figures on the flight capacity in the literature. *B. cockerelli* is also known to be transported by wind over long-distances during its migrations in North America (Abdullah, 2008). Natural spread is also considered important in New Zealand (Teulon *et al.*, 2009). It is expected that existing winds in the PRA area will also play a role in spread of *B. cockerelli.*

1.31 - How likely is the pest to spread rapidly in the PRA area by human assistance?
Unlikely if no vector is present
Likely if a vector is present or *B. cockerelli* enters at the same time
Level of uncertainty: low

Justification:
The bacterium could be spread with movement and trade of infected plant material. Plants for planting (especially with tomato plants and seed potatoes) present a higher probability of spread than fruit. Infected plants for planting and fruit may be asymptomatic. Within a place of production, the bacterium can be spread during grafting of young tomato or pepper plants (Crosslin *et al.*, 2010; Crosslin & Munyaneza, 2009).

However, spread of the bacterium by movement of infected plant material will only result in establishment of new foci if a vector is present in the areas where the material is moved. If the vector would be introduced, it could also easily be spread by human assistance. It could be spread by trade of plants for planting, fruits of Solanaceae with green parts (e.g. vine tomatoes). Transport on clothing or other items is more likely to lead to local spread than to long distance spread because adults can only survive few days in an active state without feeding but this may play a role once the psyllid has entered the PRA area. In New Zealand, it is thought to have dispersed also through human mediated means, such as infested host material and inanimate goods (e.g. clothing) (Teulon *et al.*, 2009).

1.32 - Based on biological characteristics, how likely is it that the pest will not be contained within the PRA area?
Very likely for field crops in the presence of the vector or if the vector is introduced at the same time
Moderately likely for protected crops in the presence of the vector or if the vector is introduced at the same time
Very unlikely if the vector is not present
Level of uncertainty: medium (can it be detected early enough? Role of host weeds?).

Justification:
Containment would depend on early detection of the bacterium, which may be difficult (infected plants may be asymptomatic; symptoms might not be characteristic). The species is new to science and therefore not easily recognized. Intensive monitoring for the bacterium would be necessary, relying on efficient detection methods that are available.

In the presence of the vector, such as in New Zealand, it is unlikely that *Ca.* L. solanacearum will be contained because natural spread cannot be prevented in areas where the pest can established outdoors. Containment of the vector might be possible under protected conditions.

There is still little literature on the importance of weeds or volunteer potatoes as reservoirs for *Ca.* L. solanacearum and how these plants are sought by *B. cockerelli*. Wen *et al*. (2010) studied *Solanum elaeagnifolium*, *S. rostratum* and *Physalis virginiana* in Texas and showed that *Ca.* L. solanacearum was present at very low frequencies in these weeds.

1.32c - The overall probability of spread should be described.

The probability of spread depends on whether a vector is present or introduced at the same time. It is:
- very low if no vector is present
- high if a vector is present or introduced at the same time. The pest and its vector are then likely to spread rapidly (e.g. several hundreds kilometres a year), and are likely to be contained only in very specific situations (e.g. indoor outbreaks detected early).

Stage 2: Pest Risk Assessment - Section B: Conclusion of introduction and spread and identification of areas of potential establishment

1.33a - Conclusion on the probability of introduction and spread.

The bacterium *Ca.* L. solanacearum is known to be present in the PRA area in carrot (associated with *Trioza apicalis*) and celeriac but is not known to be present in Solanaceae. The psyllid *B. cockerelli* is known to transmit the bacterium in Solanaceae. This psyllid species is not present in the PRA area and the present PRA focuses on the *Ca.* L. solanacearum **-** *B. cockerelli* **-**complex and their risk for Solanaceae and not for other crops.

The probability of entry is rated as moderate due to the possible introduction of the bacterium, *Ca.* L. solanacearum and the psyllid, *B. cockerelli*, at the same time. In absence of the vector the probability of entry is very low.
At least part of the PRA area is suitable for establishment of both the bacterium and the vector and the probability of establishment is rated as “high”.

The probability of introduction (entry and establishment) is rated as “moderate”.
The probability of spread is high in the case *B. cockerelli* would also be present.

Note that the conclusions (rating levels) would be different if a psyllid species already present in the PRA area would be able to transmit the bacterium in Solanaceae. To date, such a psyllid species is not known (see also page 2 “General comments on the scope of this PRA”).

1.33b - Based on the answers to questions 1.15 to 1.32 identify the part of the PRA area where presence of host plants or suitable habitats and ecological factors favour the establishment and spread of the pest to define the endangered area.

For glasshouse crops, the whole PRA area.

For field crops, it is not possible to exclude any part of the PRA area. The endangered area covers areas where the vector could overwinter outdoors i.e. southern and central European part of the PRA area, as well as areas of mild winters in the northern part of the PRA area, comparable to those of Christchurch, New Zealand (Annex 7), but also the areas that could be reached by annual migration i.e. most of the PRA area. For example, it is not expected that *B. cockerelli* could survive cold winters e.g. in Scandinavian regions and the eastern PRA area, but it might reach these regions through annual migration (similarly to the situation in Canada), although it is uncertain that it could transmit the bacterium or that the diseases would develop.

Stage 2: Pest Risk Assessment - Section B: Assessment of potential economic consequences

2.1 - How great a negative effect does the pest have on crop yield and/or quality to cultivated plants or on control costs within its current area of distribution?

massive

Level of uncertainty: low

Justification:

Ca. L. solanacearum causes severe damage in potato and tomato in its current area of distribution. It causes losses in yield and quality. Pest control requires effective control strategies against the vector, leading to increased spraying and higher costs in the open field as well as in glasshouse. (from Stefani, 2010). Historically, zebra chip was reported from Mexico and Central America in mid-1990s and its impact has increased. Symptoms are observed in USA potato fields since 2000, and damage reported since 2004-2005 (Crosslin *et al.*, 2010). The bacterium had been detected years before symptoms were found and the disease became a problem, e.g. McKenzie & Shatters (2009) detected the bacterium in 2008 in tomato samples from 2002. Below details are given about the impact of the bacterium.

Where it occurs, control of *Ca.* L. solanacearum relies on effective monitoring and management strategies against its vector (Munyaneza *et al.*, 2008). The psyllid needs to be controlled from emergence of the crop throughout the season until foliage desiccation. On potato, control aims at keeping zebra chip incidence under manageable levels by applying insecticides against the psyllid (Goolsby *et al.*, 2007). From the available literature, this strategie does not allow to completely eliminate damage and the vector is difficult to control (spraying should ensure thorough coverage of whole plants).

Effects on potato

The main impact of *Ca.* L. solanacearum on potato is:

- Yield reduction: death of plants, reduced production of tubers, smaller tubers. Undersized tubers are unmarketable, increasing the economic loss (Munyaneza *et al.*, 2007)
- Internal discoloration of the tubers affects the marketability of the tubers for processing and fresh market
- The discoloration is accentuated when the potatoes are fried (e.g. for French fries or chips) leading to rejection of consignments for chips and French fries (Goolsby *et al.*, 2007; Munyaneza *et al.*, 2008). Gharalari *et al.* (2009) reports that harvest from a potato field is rejected for chip processing over 20% zebra chip infection, causing additional losses to producers and processors.
- The content of potato tubers is modified: sugar content and specific gravity is affected which can also result in a rejection of consignments even in the absence of zebra chip symptoms (Ogden, 2011); dry matter is reduced (Liefting *et al.*, 2008a); mineral content (Miles *et al.*, 2009); phenolic compounds (Navarre *et al.*, 2009).
- Potato tubers affected by zebra chip usually do not sprout and cannot be used as seed (Munyaneza *et al.*, 2007, Henne *et al*. 2010)

Data on losses on ware potato

USA

In the USA, zebra chip disease was sporadically important economically until the 2004 and 2005 growing seasons when it caused millions of dollars in losses to producers and processors (Gudmestad & Secor, 2007) in Southwestern USA. Production in Texas and neighbouring states is important to supply fresh potatoes for the production of crisps by the industry at a period when no such fresh tubers are available from other producing areas (e.g. in winter and early spring). It is increasing in importance in other potato growing regions (Crosslin & Bester, 2009) but its was not found to date in major production areas such as the Pacific North-West[10].

Wen *et al.* (2009) report potato growers accounts of millions of dollars in losses and reduction in the total hectarage of the winter and spring potato crop by more than 20%. In Texas, losses on some individual farms have exceeded USD 2 million (approx. EUR 1.4 million) annually during recent seasons (CNAS, 2009). During studies conducted in 2006 and 2009 (CNAS, 2006, 2009) industry experts estimated that infestations of zebra chip could readily affect 35-40 % of Texas potato acreage (for both years), and potential losses in the value of Texas annual potato production was estimated, respectively for 2006 and 2009, at USD 25.86 million and USD 33.4 million annually (resp. EUR 18.5

[10] At the end of 2011, the presence of *Ca.* L. solanacearum was reported from fields in the Columbia basin (both in Oregon and Washington, US) and in Idaho at low incidence (Hamm *et al.*, 2011; Nolte *et al.*, 2011). This PRA was not updated thoughout to take this information into account

million and EUR 23.9 million). Nevertheless, Goolsby *et al.* (2007) note that incidence of zebra chip may be kept below economic levels in the fields where the potato psyllid was kept at low density for the entire season. This requires careful monitoring of the crop and frequent insecticide applications. There is no detailed data available on increase of control costs in the USA. In 2010, psyllid pressure in Texas was similar to previous years; however the percentage of adults with the bacterium was much lower, which resulted in a low incidence of zebra chip (Goolsby *at al.*, 2010). Studies in Texas and Washington suggest that earlier infection in potato result in more severe symptoms compared to infections that occur later in the season.

New Zealand

In New Zealand, zebra chip resulting from Liberibacter transmission by the tomato / potato psyllid has affected potato and tomato production since early 2007 and became epidemic in the North Island during the 2008 season. In the first report of zebra chip on potato, the mean yield from potato crops was approximately 60% less than expected, and harvested tubers had less dry matter (13%) than normal (19%) (Liefting *et al.* 2008a). Teulon *et al.* (2009) report that some potato growers had minor losses, probably due to other pesticide applications against other pests (in particular against tuber moth), having kept psyllid populations down. Export markets for potato were temporarily closed in New Zealand when the bacterium was found.

Losses in potato for the 2008-2009 growing season was estimated to be up to NZD 47 million (approx. EUR 25 million) (caused by the psyllid and the bacterium). Yield reduction in potato production was estimated to be 25-40%. Losses on some individual farms have exceeded NZD 2-5 million (EUR 1.1-2.6 million) in 2009. Field solutions in 2008/2009 often required up to 14-18 applications of insecticides, where prior to *B. cockerelli* introduction, insecticide spray programmes were typically 4-6 applications across the crop (Liefting, pers. comm., 2010).

It is hoped that losses will reduce over time as growers learn to manage the psyllid. The reason that losses were so great in 2008-2009 was that many growers were caught unaware of the threat posed by the psyllid and *Ca.* L. solanacearum (despite an extensive awareness programme by the industry). Pest control in 2009-2010 was much better, but came at a cost of increased frequency of agrichemical applications. Losses were less obvious in 2010 than in previous years when whole crops were burned off with *Ca.* L. solanacearum: in 2009-10 there were still many problems with crop rejections, but the situation is probably improving. (S. Ogden, NZ, pers. comm., 2011). In addition, Berry (2010) reports estimated economic losses to the New Zealand potato industry in 2008-2010 of NZD 100 million (approx. EUR 57 million) and increased and ongoing management cost, with NZD 700-1200/ha for a total of approx. NZD 7million /year (i.e. approx. EUR 400-680/ha, total EUR 4 million/year).

It should be noted that despite the fact that *Ca.* L. solanacearum is detected in *B. cockerelli* from all areas of New Zealand at most times of the year (Berry *et al.,* 2010), there is a low incidence of zebra chips disease in tubers. This may be explained by the cooler climate in New Zealand compared to those parts of the USA where higher impacts are recorded.

Ogden (2011) notes that impact varies across the country. Details of the increase of control cost per hectare in each region of New Zealand are given by Kale (2011). The impact is lowest in Canterbury (region on the South Island, its main city is Christchurch), where foliar symptoms are rarely seen and to date there is no zebra chip in tubers (but all growers are using intensive agrichemical programmes to control *B. cockerelli).* Canterbury grows both seed crops (short, 90 day crops) and processing crops (up to 150 day crops), but there are still no problems in the long growing period crops. Ogden (comm. pers. 2011) noted that it is hard to say which areas are most affected, but one thing that is remarkable is that in Hawkes Bay (North Island), despite very high numbers of psyllids (and the presence of foci of *Ca.* L. solanacearum), growers can still produce crops that process well.

Mexico and Central America

In Mexico and Guatemala, zebra chip is economically important (Munyaneza *et al.*, 2007a). In Mexico, since 2003 zebra chip incidence in the states of Cohauila and Nuevo Leon has been as high as 100% in some fields. Significant economic damage, often leading to abandonment of entire potato fields has been reported (Munyaneza *et al.*, 2007a). In Nuevo Leon, in 2004 incidence reached 80% in some fields (Gudmestad & Secor, 2007). It has been estimated that 70% of the area planted with potato is affected by *B. cockerelli* (Diaz-Valasis *et al.*, 2008, citing others) and that incidence of zebra chip vary between 20-60% of potato planted surface in Nuevo Leon and Coahuila states, while in other growing areas such as those from Chihuahua, Sonora and Sinaloa it is around 10% (Galaviz *et al*., 2010). In Guatemala, zebra chip is a serious problem of market potatoes, subsistence gardens, processed potatoes (Secor & Rivera-Varas, 2004).

In Honduras, disease incidence ranged from 50-95% in commercial potato fields where heavy infestations by the psyllid (associated with browning in some tubers) were observed in 2006-2009. *Ca.* L. solanacearum was detected in 2009. Zebra chip disease poses a serious threat to potato production (Rehman *et al.*, 2010) and no potatoes have been planted in Ocotepeque department in 2009-2010 because of heavy losses observed in previous years (Espinoza, 2010).

Effect on seed potatoes

In the USA, outbreaks to date have not occurred in major seed potato production areas (Pacific North-West), and there has not been impact to date[11]. In New Zealand, certain growers have stopped producing seed potatoes because of zebra chip disease. There is uncertainty on to what extend potato plants grown from infected tubers would be infected and in turn would produce infected daughter tubers. Henne *et al.* (2010a) showed plants grown from infected seed potatoes to grow poorly and produce fewer, smaller or no tubers, reducing the possibility that natural spread (e.g. through volunteer potatoes) would be significant. Munyaneza (unpublished data, 2010) obtained similar results. However, recent information by Pitman *et al*. (2011) indicates transmission of *Ca.* L. solanacearum to plants grown from infected potatoes (symptomatic or asymptomatic). Galaviz *et al*. (2010) consider infected seed as an important source of inoculum in Mexico.

Experimental studies on potato

In a field experiment in the USA, Munyaneza *et al.* (2008) observed a reduction of the number of acceptable tubers per plant and up to 93% potato yield losses when potato plants were exposed to psyllids. Commercial yield loss ranged from 55.2 to 93%. In a greenhouse experiment in Mexico, Diaz-Valasis *et al.* (2008) observed reduction of average yield in two consecutive years (by 49.4 and 70%) and tuber numbers (by 19.2 and 70%).

Effects on tomato

The main impacts on tomato are:
- yield reduction: death of plants, reduced fruit set, smaller fruits
- fruits might be deformed (strawberry-like form) (and degraded or destroyed at sorting).

Data on losses on tomato

In USA, yield losses have been reported up to 85% and 50% in commercial crops in western North America in 2001 and 2004, respectively (Hansen *et al.*, 2008). Brown *et al.* (2010) observed 60% of tomato plants in commercial greenhouses exhibiting leaf curling, shortened internodes and chlorosis, and 'vein-greening". The incidence of the first three symptoms was higher when the bacterium was associated with the vector (60% against 20%). French-Monar *et al.* (2010) report 30% of plants showing symptoms on field tomatoes.

In New Zealand, the disease was reported in January 2008 from three commercial glasshouse tomato growers in Auckland, and losses up to NZD 1 million (approx. EUR 0.6 million) were reported (Liefting *et al.*, 2009a). Losses associated with the bacterium had been observed only in greenhouse tomato, and not field tomato where damage was due only to the *B. cockerelli*. In recent estimates, yield reduction is estimated at 10% (Liefting, pers. comm., 2010).
Ogden (2011) reported that a survey conducted in 2011 showed that yield loss for greenhouse production was 4-6%, mainly due to the very aggressive approach taken by growers in removing infected plants and the associated production loss while replacement plants come into production. The frequent removal of lower leaves and the upright growth habit of the plants greatly assists in crop monitoring, spray coverage and *B. cockerelli* control.
Field tomatoes can be badly affected with fruit being soft and lower sugars if pest control does not work. The growth habit of crops grown for processing makes spray coverage and psyllid control difficult (Ogden, 2011)

In Mexico, disease incidences of 18 to 40% were observed in tomato fields in Sinaloa in March 2009 (Munyaneza *et al.*, 2009b).

Effects on other crops

Pepper. No detailed data have been found on impact on pepper in the countries where the bacterium is present. Liefting *et al.* (2009a) reported damage similar to those on tomatoes in glasshouse pepper in New Zealand. Ogden (2011) reported that, for capsicum grown in modern hydroponic greenhouses, effect on fruit yield was negligible, and cosmetic effects were very minor. In Mexico, the first detection of the bacterium was associated with an infection rate of 1.5% in a field (Munyaneza *et al.*, 2009a). Impact on peppers is limited in New Zealand compared to the situation in California (US) due to insecticide treatments (S. Ogden, NZ, pers. comm., 2011).

Tamarillo. *Ca.* L. solanacearum was first detected in asymptomatic plants (Liefting *et al.*, 2008b), but serious damage

[11] At the end of 2011, the presence of *Ca.* L. solanacearum was reported from fields in the Columbia basin (both in Oregon and Washington, US) and in Idaho at low incidence (Hamm *et al.*, 2011; Nolte *et al*., 2011). This PRA was not updated thoughout to take this information into account.

was later detected in New Zealand (Watson, 2009). Symptoms include downward cupping and slight pink colouring of new growth followed by yellowing on mature leaves and significant die-back on young branches Symptoms may be limited to some parts of the tree. If shoots are produced, no fruit set is observed. Symptoms on trees are debilitating and progress to tree death, within 1-4 months (Watson, 2009; Ogden, 2011). In New Zealand many growers were forced to leave the industry: only 40 growers remain, compared to 120 prior to the arrival of the pest.

Cape gooseberry. *Ca.* L. solanacearum was first detected in asymptomatic plants (Liefting *et al.*, 2008b). No later mention of damage was found.

Eggplant. No data.

Note: this PRA focuses on the *Ca.* L. solanacearum-*B. cockerelli* complex affecting Solanaceae and hence impact on carrot and celeriac is not included. For information on *Ca.* L. solanacearum and its vector *Trioza apicalis* in carrot see Annex I.

2.2 - How great a negative effect is the pest likely to have on crop yield and/or quality in the PRA area without any control measures?

massive

Level of uncertainty: low

Justification:

On Solanaceae hosts, *Ca.* L. solanacearum is likely to have a similar impact as observed in New Zealand. The disease is expected to destroy the crops if no control measures were applied and in the case of potatoes may even lead to render whole regions unsuitable for potato crops. It would also have an impact on tomato yield and quality.

The quality requirements for the fresh market for potato and tomato are very stringent in most of the PRA area. For potatoes in particular, zebra chip could lead to a greater level of rejection than in the USA.

The direct impact on potato and other Solanaceae host crops grown outdoors is expected to be higher in the southern part of the PRA area than in the northern part and eastern part because of more favourable conditions for development and possibly also survival of the vector. There is uncertainty about the ability of the vector to survive and transmit the bacteria in more northern and eastern areas of the PRA area and, thereby about the impact of the pest in more northern areas (see also Annex 7). In the Northwestern USA impact of the bacterium is limited as it seems that it is not transmitted by the vector (which arrives late in the year by migration) and/or does not result in symptoms in potato[12]. Based on the present distribution of the vector in New Zealand it is expected that the vector can survive in areas in Northwestern Europe in or nearby major seed potato producing countries like the Netherlands and the UK (Scotland) (see also Annex 7).
The impact on seed potatoes in the PRA area is unclear as it is debated in countries where the bacterium is present (see 2.1).
As indicated under 2.1 control programmes against the vector are important to reduce damage levels. Thus, without any control measures the negative effect of *Ca.* L. solanacearum on potato and tomato and possibly also pepper and tamarillo in the PRA will be massive at least in the southern part of the PRA area. The uncertainty of this assessment is low for potato and tomato and medium for pepper and tamarillo. There is a high uncertainty about the effect on other solanaceous crops.

2.3 - How easily can the pest be controlled in the PRA area without phytosanitary measures?

with much difficulty

Level of uncertainty: low

Justification:

Control of *Ca.* L. solanacearum requires control of the vector. See also answer to question 1.23 where current practice in potato production in the PRA area is described. Control of the vector is very difficult and requires monitoring (with

[12] At the end of 2011, the presence of *Ca.* L. solanacearum was reported from fields in the Columbia basin (both in Oregon and Washington, US) and in Idaho at low incidence (Hamm *et al.*, 2011; Nolte *et al.*, 2011). Not enough data is currently available to revise this PRA.

yellow sticky traps) and intensive spraying programmes with insecticides. Details on control options and references are given below.

Potato production

On potato in New Zealand, experience from the 2008 season showed that despite intensive insecticide applications with currently available products, significant yield losses and tuber quality issues (e.g. specific gravity) can occur.

In Mexico up to 12 applications were made during the growing season (tomato and potato) in 2008 (Vega-Gutiérrez *et al.*, 2008). Abamectin*[13], cyfluthrin*, dimethoate*, esfenvalerate*, pyriproxyfen* were commonly applied insecticides. Lack of control was attributed to inadequate use of pesticides and lack of IPM programmes.

In the USA, a typical spray programme on potato would be a spray at planting (typically imidacloprid) then after one month, one application every 7-10 days (see reference below). Monitoring is carried out using yellow sticky cards (changed weekly) and weekly sampling of leaves. The strategy aims at bringing the level of infestation below the damage of rejection of potatoes.

The following pesticides are mentioned in the USA against *B. cockerelli*: imidacloprid*, spiromesifen*, dinotefuran† used in a rotation, pyriproxyfen*, pymetrozine*, abamectin* (Goolsby *et al.*, 2007; Secor, 2009; Liu & Trumble, 2005, 2006). In New Zealand, the list of active substances includes acephate†, metamidophos†, imidacloprid*, thiacloprid*, buprofezin, abamectin*, cypermethrin*, deltamethrin*, lambda-cyhalothrin*, esfenvalerate*, spinosad* (adults), spirotetramat (larvae) (Appendix B of Biosecurity Australia, 2009). Oberon (spiromesifen) is the only available product in the USA effective against eggs. Registration of spiromesifen is sought in New Zealand, as a better alternative to current treatments.

In laboratory studies in New Zealand (Berry *et al.*, 2009) dichlorvos†, lambda-cyhalothrin*, methomyl*, taufluvalinate† and methamidophos† were shown to have an effect on the psyllid (but also kill natural enemies). Increased use of organophosphates, carbamates and pyrethroids in potato may increase resistance selection pressure against the potato tuber moth and aphid pests. Azadirachtin†, spiromesifen, abamectin*, spirotetramat, thiacloprid* had some efficacy, with azadirachtin, spiromesifen and spirotetramat being selective.

The insecticide armoury is much larger in North America than in the EU. The active substances that are indicated above and marked with an "*" are listed as authorized in at least some EU countries[14], but not always for use on potato or tomato; active substances marked with "†" are not authorized. The status of spirotetramat and spiromesifen is still pending evaluation. It should be stressed that dinotefuran is not authorized in the EU, so that the rotation of active substances as recommended in the insecticide programme in the USA will not be applicable in at least the EU-countries within the EPPO-region. This will increase the risk of development of resistance against active substances which are available. Imidacloprid is also not authorized in potato production in some EU countries (e.g. France, UK). In New-Zealand, it has taken up to 2 years to get newer products registered to control *B. cockerelli*.

Control of *B. cockerelli* in organic production will not be possible. Organic potato production is increasing in the EU although still very limited (about 15 000 ha out of 2 million, i.e. less than 1% of the area – Eurostat 2010).

Protected crops

For greenhouse crops, there are presently no biological control agents or IPM-compatible insecticides registered for control of the psyllid (Berry *et al.*, 2009). Entomopathogenic fungi have been investigated against *B. cockerelli* (Lacey *et al.*, 2009) with positive preliminary results in laboratory experiments. The "code of practice for the management of the tomato/potato psyllid in greenhouse tomato and *Capsicum* crops" developed in New Zealand gives details on measures that may be implemented on these crops (reproduced in Appendix B of Biosecurity Australia, 2009). This includes in particular:

- training of personnel on monitoring techniques and identification of *B. cockerelli* and *Ca* L. solanacearum symptoms
- planting of pest-free seedlings

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[13] The active substances that are marked with an "*" are listed as authorized in at least some EU countries.

[14] EU (2010) http://ec.europa.eu/sanco_pesticides/public/index.cfm

- management of host plants (including weeds) in the surrounding of the greenhouse
- hygienic measures (e.g. removal of plant debris at the end of the growing season, cleaning and disinfection of the greenhouse before a new crop is planted)
- crop monitoring (crop scouting, traps) at least every week
- treatment of the crop with appropriate insecticides
- records of treatments

All measures should be accompanied by appropriate monitoring of vector populations in the area.

Stefani (2010) has stated that in glasshouse cultivation, crop rotation or periods without a crop may decrease population levels of *B. cockerelli* or even prevent establishment. Crop rotation is recommended for glasshouse tomatoes in case of the occurrence of some pests, such as spider mites (*Tetranychus urticae*), several species of aphids, leaf mining flies (*Liriomyza bryoniae*), thrips (*Frankliniella occidentalis*). In many cases, crop rotation will not be easy to implement as glasshouse production systems are often highly specialised growing one crop only. Crop rotation in glasshouse may also depend on contracts between production companies and commercial enterprises or syndicates for the delivery, processing and marketing of the vegetable products.

Other crops

Repeated sprays have been applied in tamarillo (contact insecticides such as dichlorvos[†], deltamethrin* and abamectin* have shown greater control than thiacloprid, pymetrozine, spiromesifen, spinosad, chlorantraniliprole). However, such spraying is unacceptable to growers (because of the cost) or the marketplace (because of the ecologicical impact) for this crop (Watson, 2009).

Crop species mentioned above are also grown in private gardens. Private owners are unlikely to be able to implement the level of measures needed to control the psyllid, favouring maintenance of high populations of the vector. Plants in private gardens can, therefore, act as an inoculum source for commercial crops.

2.4 - How great an increase in production costs (including control costs) is likely to be caused by the pest in the PRA area?

major

Level of uncertainty: high (difficult to estimate which additional costs would be incurred).

Justification:

Control would rely on implementation of intensive control measures against the psyllid vector. Pest control strategies are applied against other pests in tomato and potato in the PRA area (see 1.23), but additional monitoring activities and control measures are likely to be necessary as it occurred in New Zealand. Especially in zones where the Colorado beetle is not present, insecticides are not generally used and sprays will greatly increase production cost. In New Zealand, increases of costs have been reported due to the need for an intensive monitoring and pesticide control strategy against the pest. For potato, Berry *et al*. (2010) reports increased and ongoing management cost, with NZD 700-1200/ha for a total of approx. NZD 7million /year (i.e. approx. EUR 400-680/ha, total EUR 4 million/year). In 2009-2010 growers of process crops with 150 days growing period have applied up to 20 insecticides applications (7 days intervals). This is uneconomic and is of concern to all growers for environmental reasons and the risk of resistance developing (S. Ogden, NZ, pers. comm., 2011). Details of the increase control cost per hectare in each ragion of New Zealand is given by Kale (2011). In addition current IPM programmes against other pests might have to be abandoned or would be threatened.

Specific surveillance (to identify the best treatment period) and additional sprays will be needed. Time and money will be needed before IPM programmes are adapted to European and Mediterranean conditions, and will imply an additional cost for surveillance/monitoring (scouting) and advice.

2.5 - How great a reduction in consumer demand is the pest likely to cause in the PRA area?

moderate

Level of uncertainty: medium

Justification:

Local prices and local supplies will probably be affected to a high extend but in a more limited way at a regional scale.

Potato might be more affected than tomato.

The establishment of *Tuta absoluta* in Morocco and Algeria for example resulted in a dramatic increase of tomato price so that the local population faced difficulties to buy it. Prices were four times higher in Algeria (40 DA vs. 10 DA in 2008) (Ounas, 2009) and twice higher in Morocco (Fa, 2009), while price of tomato did not change in the EU.

Potatoes as well as tomatoes are consumed in large quantities and the consumer has certain high level demands in the fresh market. For tomato, infected tomato fruits are deformed and would have to be sorted and discarded. Potatoes with zebra chip symptoms are neither suited for consumption nor for industrial purposes and therefore are not marketable. The demand might shift to non-infested production areas.

Regarding industrial purposes, the pest might affect the demand from chip producers. It would increase rejection of potato lots or crops for the production of chips, and could lead to withdrawal of chip processors from certain countries. In New Zealand, possible withdrawal of potato chip processors would reduce the value of the industry by 65%.

Concerning seed potatoes impact is unclear (see 2.1) but it is however likely that, at least until the disease is better known, demand for seed potatoes coming from countries where *Ca.* L. solanacearum is present will decrease or seed exporters will be asked to justify and give the proof of *Ca.* L. solanacearum-free seeds. Eventually, it is possible that seed potato production is relocated to countries where this bacterium is not present.

2.6 - How important is environmental damage caused by the pest within its current area of distribution?

minimal

Level of uncertainty: low

Justification:

There are no reports on environmental damage linked to the bacterium and its vector. The main environmental impact is due to the increased use of insecticides to control the vector.

2.7 - How important is the environmental damage likely to be in the PRA area?

minor

Level of uncertainty: medium

Justification:

It is assessed that the environmental damage in the PRA region would be like in the current areas of distribution also be low unless there are rare plant species, which could be damaged or significantly affected by *Ca.* L. solanacearum. However, no evidence was found. (From Stefani, 2010). Note that the bacterium and the vector have been introduced into New Zealand without causing direct environmental damage (or at least such damage has not been reported).

However, the presence of the pest and its vector will probably lead to an increased use of pesticides and will probably disrupt existing IPM strategies. The impact is expected to be similar to where the pest presently occurs.

2.8 - How important is social damage caused by the pest within its current area of distribution?

moderate

Level of uncertainty: high. It is not known how the situation will evolve in New Zealand.

Justification:

Studies conducted on the impact of zebra chip disease in Texas estimated loss of employment due to the presence of the disease to about 960 out of 2800 jobs associated with potato industry (CNAS, 2009). In New Zealand, losses in business activity associated with potato production was estimated to NZD 47 million for 2008-2009 (approx. EUR 25 million) covering for losses at farm level and in economic activity supporting potato production, as well as in business activity would be lost in associated non-farm activities (due to reduced income associated with lost employment) (study by Potatoes New Zealand, unpublished, 2009). Industry was concerned that introduction of zebra chips will lead to withdrawal of major processors from New Zealand. No further study has been found while preparing this PRA but it seems that potato processors are still present in the country. It should be noted that the industry puts a major effort in intensive research programmes associated with training of farmers and monitoring of the psyllid.

2.9 - How important is the social damage likely to be in the PRA area?

moderate

Level of uncertainty: high. Would employment be lost due to withdrawal of processors?

Justification:

Overall the likelihood of social impact is moderate, but social damage might be high locally in areas where widespread damage occurs. The complex *Ca*. L. solanacearum/*B. cockerelli* may make it uneconomic to continue the production of potatoes or tomatoes. In situations where the presence of the bacterium would have an effect on the profitability/viability of individual farms or sourcing of potatoes and tomatoes for processors, there might be losses of employment or internal migration of people. Specialized producers might have to switch to other crops. Organic producers and production would be threatened by the need to use pesticides or by yield losses in case it remains organic.

Similar social damage as reported from New Zealand and USA could occur.

2.10 - How likely is the presence of the pest in the PRA area to cause losses in export markets?

very likely/certain

Level of uncertainty: low

Justification:

Many countries in the PRA area, especially EU countries, export tomatoes, peppers and potatoes (CIRAD, 2009) and the presence of the bacterium in one country is likely to have immediate effects on export markets. The pest will affect exports to countries where it is not present. In New Zealand, discovery of the bacterium resulted in the immediate cessation of trade for seed potatoes (Biosecurity Australia, 2009), tomato, *Capsicum* and other solanaceous fruits to key export countries, including eggplant and two other Solanum species of unknown host status. Some markets reopened under specific requirements 2-6 months after, but some were still closed nearly one year after (Teulon *et al.*, 2009). Potatoes were slightly less affected but cessation of trade of seed potatoes occurred (Biosecurity Australia, 2009). Reduced export receipts were estimated at NZD 5.22 million (EUR 2.8 million) for *Capsicum* in 2008 (2008 FOB value: $28.38 million versus 2007 FOB value: NZD 33.6 million, attributed to close of export markets and time needed to regain access), NZD 3 million (approx. EUR 1.6 million) for the greenhouse tomato industry (Teulon *et al.*, 2009).

The role of zebra chip in seed potato as a source of *Ca.* L. solanacearum is not clear (Henne *et al*. 2010), but it is likely to affect the marketability and might even affect the national and international trade of seed potatoes. For seed potatoes, even low levels of infection will result in rejection. It is possible that production will be severely affected in some regions where this disease occurs at least in the short term. Many markets will then be closed for seed potatoes like the Australian market for potatoes from New Zealand (Biosecurity Australia, 2009) or seed exporters will be asked to justify and give the proof of *Ca.* L. solanacearum-free seeds. Export of ware potatoes may also be affected.

2.11 - How likely is it that natural enemies, already present in the PRA area, will not reduce populations of the pest below the economic threshold?

likely

Level of uncertainty: medium (lack of data on natural enemies in Europe).

Justification:

In a similar situation in New Zealand, no natural enemies have been found in New Zealand for greenhouse crops (Berry *et al.*, 2009). Several psyllid species are present in the PRA area, each with its natural enemies. However it is not known whether these natural enemies would have an impact on populations of *B. cockerelli*.

Beneficial organisms against the vector are known, such as *Chrysoperla carnea* and *C. rufilabris*. They are not very efficient but are applied in integrated control measures in tomato glasshouse production (Al-Jabar, 1999). *C. carnea* is endemic to Europe. *C. carnea* is used for biocontrol in Europe e.g. against aphids (EPPO 2010, Standard PM 6/3 *List of biological control agents widely used in the EPPO region*, 2010). In experiments, Lacey (2009) also showed some efficacy of three fungi, *Isaria fumosorosea*, *Metarhizium anisopliae* and *Beauveria bassiana*, some of which are present in the PRA area.

2.12 - How likely are control measures to disrupt existing biological or integrated systems for control of other pests or to have negative effects on the environment?

very likely/certain

Level of uncertainty: low

Justification:

The pest has been reported to disrupt and compromise IPM systems in place for the control of other pests (e.g. Ogden, 2011) and to increase the use of pesticides in several countries (Mexico, USA, New Zealand). Resistance management strategies for other key pests of tomato and potato are threatened by the lack of registered insecticides (Berry *et al.*, 2009). In New Zealand, further development of IPM in potatoes has been threatened. In tomatoes, the established IPM programmes have been disrupted due to an increased number of applications of insecticides and thereby increasing the risk of resistance development against the insecticides (Teulon *et al.*, 2009). In tamarillo, the viability of low input/organic systems is threatened (Watson, 2009).

For organic systems, there are no effective control methods allowing economic production. In most of the PRA area (e.g. EU), most tomatoes are produced in IPM systems.

2.13 - How important would other costs resulting from introduction be?

major

Level of uncertainty: low

Justification:

Costs could be anticipated for research: host plants, management of the vectors, biological control agents, and plant protection products. Monitoring programmes would have to be conducted to delimitate the pest distribution, on various known or possible host plants.

In New Zealand, extensive research programmes have been started on control, biological control, detection of Liberibacter, tamarillo. The potato growers association maintains a website (www.potatoesnz.co.nz) to share information and has taken an implementation role. It has invested over NZD 0.5 million (approx EUR 0.3 million) in research so far, and estimates that NZD 5 million (approx. EUR 3 million) of research might be needed over the coming five years to fund further research into psyllid and develop diagnostic and management tools for growers. Calls for voluntary contributions for psyllid research have been made in 2010.

2.14 - How likely is it that genetic traits can be carried to other species, modifying their genetic nature and making them more serious plant pests?

unlikely

Level of uncertainty: high

Justification:

There is no such indication from the literature, neither for *Ca.* L. solanacearum, nor for the three related Liberibacter species.

2.15 - How likely is the pest to cause a significant increase in the economic impact of other pests by acting as a vector or host for these pests?

Impossible/very unlikely

Level of uncertainty: low

Justification:

Ca. L. solanacearum cannot act as a vector or host for other pests.

2.16 - Referring back to the conclusion on endangered area (1.33), identify the parts of the PRA area where the pest can establish and which are economically most at risk.

All areas where host plants are grown, i.e. the entire PRA area. The pest is likely to cause damage in all parts of the PRA area, on its host plants especially potato and tomato (for other Solanaceae this is less certain), both in the field and in greenhouses. A quantitative economic impact assessment for potato is included as Annex 8.

For field grown potatoes and tomatoes, the risk will be higher for areas where the vector can survive all year round. The Mediterranean Basin seems to be most suitable because of the climate and the cropping pattern (availability of hosts all year round). It is difficult to estimate how far north and east in the PRA area the complex *B. cockerelli*/ *Ca.* L. solanacearum will be able to establish and/or migrate to and cause damage (uncertainties concerning reservoir plants, migration, and survival of the vector at low temperatures and in the absence of a suitable host). The infection by the bacterium does not necessarily result in disease symptoms in the fields in areas where the temperatures are colder (e.g. Washington, South Island of New Zealand). The reasons why *B. cockerelli* does not survive in winter in the northwestern part of its range (e.g. Washington) are not clear, i.e. whether this is due to climatic conditions (too cold?) or to other factors (absence of overwintering plant).

Stage 2: Pest Risk Assessment - Section B: Degree of uncertainty and Conclusion of the pest risk assessment

2.17 - Degree of uncertainty: list sources of uncertainty

Major uncertainties:

- Host range of the bacterium. *Ca.* L. solanacearum has now also been found infecting non-solanaceous plants (i.e. carrot).
- The possibility that wild Solanaceae and other host plants could act as reservoir plants. In particular there are uncertainties whether alternative hosts that are common to *T. apicalis* and *B. cockerelli* (e.g. spruce) could act as a source of the bacterium in case *B. cockerelli* was introduced (i.e. providing a possible pathway from carrot to Solanaceae in the PRA area).
- Vectors
  - the bacterium may have more vectors than originally thought (i.e. there might be other vectors in the PRA area)
  - Whether a psyllid present in the PRA area could be on both carrot and Solanaceae, thereby increasing the risk of introduction and spread if the bacterium entered where this psyllid occurs (i.e. providing a possible pathway from carrot to Solanaceae in the PRA area)
  - the reasons why *B. cockerelli* does not survive in winter in the northwestern part of its range (e.g. Washington), and whether this is due to climatic conditions (too cold?) or to other factors (absence of overwintering plant). This uncertainty in turn generates a major uncertainty to define the possible zone of establishment of the vector in the field in the PRA area.
  - vertical transmission in *B. cockerelli*
  - persistence of the bacterium in *B. cockerelli* populations and factors affecting this (environmental conditions? other?)
  - difference between populations of *B. cockerelli* in North America (differences in the ability to transmit *Ca.* L. solanacearum?)
- endangered area
- if seed potatoes can act as a pathway especially at low levels of infection

2.18 - Conclusion of the pest risk assessment

Introduction

The probability of entry is considered very low in the absence of a vector and moderate to low if a vector is already present or if the known vector *B. cockerelli* would be introduced with the bacterium, or around the same time as the bacterium.

The probability of establishment is very low in cases where the bacterium is introduced without a vector. The bacterium may survive for several years in the host plant on which it was introduced but cannot spread naturally. It could only be spread by vegetative reproduction or movement of the infected plants through human activities. Note, that at present, there is no vector known in the PRA area which can transmit the bacterium to Solanaceae. However, because relatively little is known about the bacterium and its vectors, the presence of a psyllid species that could transmit the bacterium in Solanaceae cannot be fully excluded.

The probability of establishment is high in cases where a vector is present or introduced at the same time.

Overall, we assess a low probability of introduction of the bacterium with its vector on Solanaceae, *B. cockerelli*

Impact

In the case of introduction of *Ca*. L. solanacearum together with *B. cockerelli*, a massive impact is expected comparable to that in its current area of distribution. The vector can migrate over large distances with prevailing winds (hundreds of km) and the infested area can rapidly expand. Losses of crops, export markets and additional costs are expected be massive in the PRA area.

It is, therefore, recommended to consider pest risk management options both to prevent introduction of the bacterium on Solanaceae as to prevent introduction of the vector *B. cockerelli*.

It is difficult to assess the endangered area in the EPPO-region. However based on the massive losses known from North America and New Zealand, massive losses are expected in the production of potatoes and tomatoes with a low uncertainty in at least in the warmer parts of the PRA-area (Mediterranean Basin) and during the first 5 years after the introduction of *Ca.* L. solanacearum and *B. cockerelli*. A "worst-case scenario" would be:

- Yield losses of more than 50% and the loss of potato crop regions in parts of the PRA-area that are most favourable for establishment of the vector (e.g. Mediterranean Basin);
- Infestation of the major seed potato producing areas in NW-Europe
- The processing industry would not use potatoes with “zebra chips” risk;
- Crash of the export market of seed potatoes as well as of ware potatoes

Effects on commercial tomato production and loss of export markets for plants for planting and for fruit

For carrot, the situation is not clear. *Ca*. L. solanacearum is present in carrots in Finland and Spain but may also be present in other countries. The vector in mainland Spain is not yet known but is assumed to be a *Bactericera* sp. It is not clear how much of the damage on carrot can be attributed to the vector *Trioza apicalis* and how much to *Ca*. L. solanacearum. Given the potential economic importance of this pest, it is important to clarify the situation of the bacterium and its vector(s) in Finland and Spain on carrot, and to raise awareness of other countries of the PRA area to encourage them to check the situation, especially in occurrence of severe diseases of carrot attributed to attacks by *Trioza apicalis*[15]. It should also be studied whether psyllids feeds both on carrots and solanaceous plants[16].

Risk management (reduction) options are discussed in Stage 3 Pest risk management.

[15] Since this PRA was conducted, additional research has been conducted and *Ca*. L. solanacearum was found in carrot in Norway and Sweden (Munyaneza *et al.*, 2011, 2012).

[16] A EUPHRESCO research programme on Epidemiology and diagnosis of potato phytoplasmas and *Candidatus Liberibacter solanacearum* was initiated in 2011.

Stage 3: Pest Risk Management

As for the entry section, pathways A1 and B1 for plants for planting, and A2 and B2 are presented in parallel.
Measures considered for *B. cockerelli* infective for *Ca.* L. solanacearum may usefully be considered for *B. cockerelli* alone.

Pathways A1 and B1 Plants for planting of Solanaceae

<table>
<tr><th>B. cockerelli on plants for planting of Solanaceae (except fruits and seeds) from countries where Ca. L. solanacearum occurs</th><th>Plants for planting of Solanaceae (in particular tomato, Capsicum spp.) from countries where Ca. L. solanacearum occurs (excluding seeds)</th></tr>
<tr><td colspan="2">3.2 - Is the pathway that is being considered a commodity of plants and plant products?
yes</td></tr>
<tr><td colspan="2">3.12 - Are there any existing phytosanitary measures applied on the pathway that could prevent the introduction of the pest?
Yes for the EU, Norway and Switzerland.
No for some other countries.

Justification:
Plants of Solanaceae are generally submitted to measures in the PRA area, but these measures are not targeting the Ca. L. solanacearum, nor B. cockerelli. The measures would ensure general inspections for a PC, but detection of the pest would be difficult as symptoms might not show on young plants.

Measures in place
For the EU, import of plants for planting of Solanaceae is prohibited (except from European countries and countries in the Mediterranean region) (EU Directive 2000/29/EC). This pathway is also closed for Norway and Switzerland.
The pathways seem to be open for some countries in the PRA area from some origins (checked from EPPO collection of phytosanitary regulations summaries, for non-EU countries, 1999 to 2003 depending on countries), with phytosanitary requirements against other pests.
- Albania, Jordan, Moldova, Morocco, Tunisia (general requirements for all plants)
- Algeria (general requirements for all plants, free from Xanthomonas vesicatoria for tomato, free from stolbur phytoplasma for all Solanaceae plants.
- Israel (general requirements for all plants, prohibition for all plants for planting (except seeds, bulbs and tubers) originating in tropical or subtropical countries)
- Kyrgyzstan (general requirements for all plants and freedom from A1 A2 pests, specific requirements for Solanaceae plants in relation to several pests)
- Russia (general requirements and specific requirements for all plants in relation to specific pests)
- Turkey (general requirements for all plants, and specific requirements for Solanaceae, tomato and Capsicum annuum)
- Ukraine (general requirements for all plants and freedom from A1 A2 pests)</td></tr>
<tr><td colspan="2">3.13 - Can the pest be reliably detected by a visual inspection of a consignment at the time of export, during transport/storage or at import?</td></tr>
<tr><td>no
Justification: Visual inspection might allow detection of B. cockerelli but is likely to be reliable only for highly infested consignments. Eggs are laid on the foliage,</td><td>no
Justification: Plants may be asymptomatic.</td></tr>
</table>

attached by short stalks (less than 0.2 mm, requires dissecting microscope). Five nymphal stages, feeding on leaves, might be seen with careful inspection but might be confused with whiteflies. Faeces resulting from feeding on the phloem can be observed, as white granular substance (Teulon *et al*., 2009). Detection would require careful inspection of a large proportion of plants in a consignment. On plants, symptoms of the bacterium are not likely to show.	
3.14 - Can the pest be reliably detected by testing (e.g. for pest plant, seeds in a consignment)?	
No (Not relevant)	No currently, but to be reconsidered in the future ***Justification:*** Testing can be useful in terms of checking compliance by the exporting country, but it cannot be relied upon in terms of guaranteeing freedom. There is not much experience with testing for *Ca*. L. solanacearum. Development of methods is still under way. There is not a validated standard protocol. In addition, the pest is reported to have an irregular distribution in the whole plant, and there is a limit to the number of plants that can be tested. Testing could however be used in combination with other measures prior to export.
3.15 - Can the pest be reliably detected during post-entry quarantine?	
No ***Justification:*** *B. cockerelli* may be observed during post-entry quarantine. But such measure is not relevant for seedlings and not realistic for commercial consignments considering the mobility of *B. cockerelli* and difficulties of containment. It might be possible only for small quantities of high value material.	No ***Justification:*** Plants would have to be maintained in post-entry quarantine until they show symptoms caused by the bacterium. The post-entry quarantine period would be too long for the intended use of seedlings and young plants. It is also not sure that each infected plant will finally exhibit symptoms. A post-entry quarantine period might be feasible for small quantities of high value material.
3.16 - Can the pest be effectively destroyed in the consignment by treatment (chemical, thermal, irradiation, physical)?	
yes if considering only *B. cockerelli* no for the complex as the bacterium is also likely to be in the plants Possible measure if considering only *B. cockerelli*: specified treatment. ***Justification:*** possible measure: specified treatment. Treatment with insecticide prior to export to eliminate all stages of *B. cockerelli* would not ensure freedom from *B. cockerelli*. Several active substances should be used to kill all life stages (only spiromesifen is known to kill eggs). Methyl bromide treatment at export is possible but its long term use is uncertain as methyl-bromide is being phased out and its use is not favoured in many EPPO countries, see IPPC Recommendation *Replacement or reduction of the use of methyl bromide as a phytosanitary measure* (FAO, 2008).	no ***Justification:*** The bacterium cannot be destroyed in the plants.

Treatment with methyl-bromide would ensure freedom from the vector, but would not ensure that the plants are free from the bacterium, which could have been transmitted before the vector is destroyed. Such measure may be recommended in combination with measures ensuring freedom from the bacterium.	

3.17 - Does the pest occur only on certain parts of the plant or plant products (e.g. bark, flowers), which can be removed without reducing the value of the consignment?
no **(**Not relevant)

3.18 - Can infestation of the consignment be reliably prevented by handling and packing methods?

no
Justification: Handling and packing methods could prevent re-infestation of the consignment by *B. cockerelli*, but will not destroy individuals that are already present in the consignment. Such methods will have no effect on the bacterium present in plants.

3.19 - Could consignments that may be infested be accepted without risk for certain end uses, limited distribution in the PRA area, or limited periods of entry, and can such limitations be applied in practice?
No
Justification: Intended use is planting, which would create a risk that the bacterium is transmitted to other plants by a vector, if present.

3.20 - Can infestation of the commodity be reliably prevented by treatment of the crop?
no
Justification: Although treatment of the crop could reduce the populations of the vector, it cannot be ensured that it is completely controlled nor that the bacterium has not been transmitted to the plants. Publications mention that control of *B. cockerelli* requires thorough spraying to reach the insect on the underside of leaves.

3.21 - Can infestation of the commodity be reliably prevented by growing resistant cultivars?
no
Justification: No resistant cultivars have been found, although difference of susceptibility of tomato cultivars has been found (Liu & Trumble, 2004, 2005, 2006, Liu *et al*., 2006b, Casteel *et al*., 2006)

3.22 - Can infestation of the commodity be reliably prevented by growing the crop in specified conditions (e.g. protected conditions such as screened greenhouses, physical isolation, sterilized growing medium, exclusion of running water, etc.)?

no
Justification: For tomato, pepper and eggplant, it may theoretically be possible to cultivate the plants under protected conditions excluding *B. cockerelli* as the presence of the vector can be better monitored and control measures better applied. Screened glasshouses can be used for propagative material or high value crops on a small scale. The maintenance of screened greenhouses is very expensive and cost would be prohibitive on a large scale (even if it seems that use of screened greenhouses has recently expanded for tomato production in areas infested by *T. absoluta).* Stringent sanitation measures should be applied, including removal of plant debris from earlier crops and management of host plants around the greenhouse (see also under question 2.3). In addition, seedlings will need to be free from *Ca*. L. solanacearum, but there is currently to rountine testing methods.

The Panel on Phytosanitary Measures considered that this option was difficult to implement in practice in commercial production (to guarantee complete pest freedom for both the bacterium and the vector) and did not recommend this option.

3.23 - Can infestation of the commodity be reliably prevented by harvesting only at certain times of the year, at specific crop ages or growth stages?
No (Not relevant)

3.24 - Can infestation of the commodity be reliably prevented by production in a certification scheme (i.e. official scheme for the production of healthy plants for planting)?

no ***Justification:*** Not relevant for an insect	no ***Justification:*** Plants could be produced in a certification scheme (with measures ensuring a high level of protection against *Ca.* L. solanacearum, e.g. stringent testing regime, initial material found free, etc.). However, one difficulty might be to ensure the absence or control of psyllid populations at critical times. Certification also needs to rely on appropriate testing, and there is currently no validated standard protocol. For these reasons, certification is not considered as a possible measure for imports from countries where both the bacterium and vector is present. It could be reliable for areas where the vector is absent once a reliable testing system is available.

3.25 - Has the pest a very low capacity for natural spread?
no
Justification: The bacterium on its own has a very low (or no) capacity for natural spread. However, where it occurs on the Solanaceae, it is associated with its vector *B. cockerelli*, and therefore is considered to have the very high capacity of spread of its vector.

3.26 - Has the pest a low to medium capacity for natural spread?
no

3.27 - The pest has a medium to high capacity for natural spread
yes
Possible measure: pest-free area.
Justification: The complex *B. cockerelli*/*Ca.* L. solanacearum has a very high capacity of spread. The vector is very mobile and may fly over distances of several kilometres. The vector is very effective in transmission of *Ca*. L. solanacearum. Long-distance annual migrations on wind currents have also been shown.

3.28 - Can pest freedom of the crop, place of production or an area be reliably guaranteed?
yes
Justification: Considering the long-distance annual migrations of the complex *B. cockerelli*/*Ca.* L. solanacearum, the size of the pest-free area should be sufficient to guarantee that *B. cockerelli* will not arrive in the area through natural spread. For the countries where *B. cockerelli* is currently known to be present, this option was not considered possible by the EWG.

Pest freedom should be based on surveillance data:
- detailed monitoring, inspections and surveying to demonstrate freedom from *Ca*. L. solanacearum in Solanaceae production
- detailed monitoring, inspections and surveying to demonstrate freedom from *B. cockerelli*
- limitation on material used in the area to prevent introduction of *Ca*. L. solanacearum in the PFA.

Pest-free sites of production may be established under complete physical protection (screened greenhouses, see 3.22) but this may not be practical for commercial production. *When reviewing the PRA, the Panel on Phytosanitary Measures considered that it was difficult to implement in practice in commercial production and that this option was too risky for plants for planting*

3.29 - Are there effective measures that could be taken in the importing country (surveillance, eradication) to prevent establishment and/or economic or other impacts?

no

Justification: Surveillance could be put in place to detect the vector *B. cockerelli*, with traps (e.g. yellow traps) at points of entry, in cultivation areas and in glasshouses, inspected regularly (once a week). Potential vectors could also be tested to determine if they are infested by *Ca.* L. solanacearum. However, experience in New Zealand shows that surveillance and eradication has not been feasible. It is likely that the pest would be established in solanaceous crops long before it is detected and that it could not be eradicated

Yes

Justification:

If no vector is present in the importing country, *Ca.* L. solanacearum can be eradicated. Eradication would be possible only in the presence of a limited outbreak without the vector being also present (see also section 1.24).

However this option seems unpractical and it is not possible to guarantee plant freedom from *B. cockerelli.*

3.30 - Have any measures been identified during the present analysis that will reduce the risk of introduction of the pest?

Yes

Option	**against *B. cockerelli***	**against *Ca.* L. solanacearum**	**Justification**
Visual inspection	No	No	Eggs and nymphs are difficult to see. High chance not detecting low infestation levels Asymptomatic plants can be present.
Testing	Not relevant	In the future	No validated testing methods are presently available for routine testing
Post-entry quarantine	No	No	Not adapted to seedlings or young plants. Not all host plants will develop symptoms over time.
Treatment of the consignment	Yes	No	Methyl bromide treatment can destroy the psyllid but not the bacterium in the plant. Treatment with insecticides cannot guarantee pest freedom.
Remove part of the plant	No	No	the pathway is the whole plant
Prevention of infestation by packing/handling method	No	No	plants already infected at the production place
Limited distribution in time and/or space or limited use	No	No	Intended use is for planting
Treatment of the crop	No	No	Not reliable to guarantee pest freedom
Resistant cultivar	No	No	Not available
Growing the crop in specified conditions	No	Yes/no (in the future)	Complete physical protection against *B. cockerelli* is difficult to implement in commercial production. Plants should be tested and found free of the bacterium but no reliable testing method is presently available for routine tests..
Harvest at certain time	No	No	
Produced in a certification scheme	No	In the future	No validated testing methods are presently available for routine testing
Pest free site of production	No	Yes in absence of	may not be practical for commercial production

		the vector	
Pest free area	No	Yes in absence of the vector	Due to the mobility of *B. cockerelli* and its ability to migrate over large distance, large buffer zones will be needed between areas where the vector is known to be present and the PFA.
Surveillance and eradication	No	No	If no vector is present in the importing country, *Ca.* L. solanacearum can be eradicated. Eradication is only likely to succeed in the absence of the vector. Once the vector has been introduced eradication is very unlikely to succeed.

The following option is considered effective against the complex vector/bacterium: PFA for *Ca.* L. solanacearum in Solanaceae and *B. cockerelli.* A reliable testing method for *Ca.* L. solanacearum will be needed to confirm absence of the bacterium.

3.31 - Does each of the individual measures identified reduce the risk to an acceptable level?

Yes

3.34 - Estimate to what extent the measures (or combination of measures) being considered interfere with international trade.

The trade is thought to be very limited, so disturbance would be minimal. The pathway is also heavily regulated in most countries of the PRA area.

3.35 - Estimate to what extent the measures (or combination of measures) being considered are cost-effective, or have undesirable social or environmental consequences.

Justification:

Measures will have an impact on export from areas where both the bacterium and the psyllid occur. Export from these areas will only be possible for production in pest free places. Exporting countries will have costs linked to monitoring, testing, establishment and maintenance of free places of production/pest free areas. However similar measures are applied against other pests.

Production under protected conditions with conditions ensuring exclusion of the pest might not be feasible in most situations (high cost). Post-entry quarantine would also have a high cost.

Nevertheless the bacterium would be difficult to eradicate if introduced and could spread to other crops in the presence of a vector. The possible measures have lower cost than attempting eradication of bearing the costs of impact by *Ca.* L. solanacearum if it established.

3.36 - Have measures (or combination of measures) been identified that reduce the risk for this pathway, and do not unduly interfere with international trade, are cost-effective and have no undesirable social or environmental consequences?

yes

Because *B. cockerelli* can transmit *Ca.* L. solanacearum and the probability of introduction (entry and establishment) is very low in absence of the vector, methods to reduce the risk of introduction of *Ca.* L. solanacearum should be effective against both the vector and the bacterium. The selected measure is pest-free area for *Ca.* L. solanacearum in Solanaceae and *B. cockerelli.*

Pathways A2 and B2: Solanaceous fruit

Considering that the risk of tranfert from an infested fruit to a crop in the PRA area is very unlikely if *B. cockerelli* is not introduced at the same time as the infected fruit, it is considered that measures should prevent the entry of the vector. Therefore only measures for pathway A2 are recommended in this section. Nevertheless, instead of considering only commodities coming from 'countries where *Ca.* L. solanacearum occurs', measures are recommended for 'countries where *B. cockerelli* occurs'

***A2 B. cockerelli* on fruit of solanaceous plants (e.g. tomato, *Capsicum* spp., eggplant, tamarillo, Cape gooseberry) from countries where *B. cockerelli* occurs**

3.2 - Is the pathway that is being considered a commodity of plants and plant products?
Yes

3.12 - Are there any existing phytosanitary measures applied on the pathway that could prevent the introduction of the pest?
No
Justification:
Tamarillo and Cape gooseberry are not submitted to any measures. There are measures for tomatoes and *Capsicum* for some countries in the PRA area (see below). The measures would ensure general inspections for a PC, but detection of the pest would be difficult. Infested tomatoes might be deformed, but this would be difficult to detect during routine inspections.

For tomato and pepper fruits, this pathway seems open to some countries from some origins, with phytosanitary requirements against other pests or general requirements for all fruits and vegetables (or solanaceous fruits and vegetables) (e.g. PC, packing, free from soil, etc.), sometimes specific requirements for tomato fruit, generally no specific requirement for pepper fruits (checked from EPPO collection of phytosanitary regulations - for non-EU countries, 1999 to 2003 depending on countries - and EU Directive):

- EU countries, Switzerland (no requirements)
- Albania, Jordan, Moldova, Russia, Ukraine (PC and/or general requirements for all fruits and vegetables)
- Algeria (general requirements for fruits of Solanaceae)
- Israel (fruit from tropical or subtropical countries prohibited)
- Kyrgyzstan (all fruits and vegetables: place of production requirements for A1/A2 pests)
- Morocco (specific requirements for tomato fruits)

3.13 - Can the pest be reliably detected by a visual inspection of a consignment at the time of export, during transport/storage or at import?
no
Justification: Visual inspection might allow for detection of *B. cockerelli* but is likely to be liable to detect only highly infested consignments. Eggs might be seen on green parts attached to the fruits (less than 0.2 mm, requires dissecting microscope). Five nymphal stages, might be seen with careful inspection of green parts but might be confused with whiteflies. Faeces resulting from feeding on the phloem can be observed, as white granular substance (Teulon *et al.*, 2009). Detection would require careful inspection of a large proportion of fruits in a consignment. On fruits, symptoms of the bacterium are not likely to show.

3.14 - Can the pest be reliably detected by testing (e.g. for pest plant, seeds in a consignment)?
no
Justification: not relevant

3.15 - Can the pest be reliably detected during post-entry quarantine?
No. Not relevant for fruit

3.16 - Can the pest be effectively destroyed in the consignment by treatment (chemical, thermal, irradiation, physical)?
Yes in a Systems Approach; possible measure: specified treatment.
Justification:
Fumigation
Methyl bromide treatment is considered effective against all life stage of the psyllid and is a possible measure in Australia for tomato fruits from New Zealand in the following conditions:

- 48 g/m3 for 2 hours at 10-15°C
- 40 g/m3 for 2 hours at 16-20°C
- 32 g/m3 for 2 hours at 21°C + (Biosecurity Australia, 2009).

Nevertheless it should be noted that methyl-bromide is no longer registered in the EU and many other EPPO countries and will be phased out in 2015. Other types of fumigation may be effective but no specific data is currently available.

Brushing or washing fruit

Brushing of fruit is used specifically to remove dirt, debris and other extraneous material and to ensure that the fruit is of a high quality and in a saleable condition. Biosecurity Australia (2009) considers that brushing of fruit would be effective in removing all life stages of the psyllid on the surface of fruit, providing the brushing can reach all parts of the fruit.

Biosecurity Australia (2009) considers that brushing of fruit would be suitable for loose tomato and tamarillo fruit. These brushing processes are considered to be unsuitable for other fruit such as truss tomatoes and capsicum fruit, where spaces between the fruit and the calyx around the stem end provide a cryptic habitat where psyllids may reside. For these commodities, this measure should be used in a systems approach with the code of practice for the management of the tomato/potato psyllid in greenhouse tomato and *Capsicum* crops" developed in New Zealand (reproduced in Appendix B of Biosecurity Australia, 2009)

Ca. L. solanacearum, if present in fruits, would not be destroyed, but it is unlikely that a vector at destination feeds on green parts attached the fruit and acquires the bacterium (see question 1.12).

The Panel on Phytosanitary Measures considered that both treatments (washing and fumigation) should be applied to tomato fruits (in addition to removal of green parts) to guarantee pest freedom of the consignment.

3.17 - Does the pest occur only on certain parts of the plant or plant products (e.g. bark, flowers), which can be removed without reducing the value of the consignment?

Yes in a Systems Approach

possible measure: removal of parts of plants from the consignment

Justification: Removal of green parts for loose tomatoes followed by washing or brushing would likely ensure removal of *B. cockerelli*.

The concentration of the bacterium in the green parts of the fruits like twigs, stems and calyxes is higher but the bacterium can possibly also be found in the fruit flesh. *Ca*. L. solanacearum, if present in fruits, would not be destroyed, but it is unlikely that a vector at destination feeds on the fruit flesh and acquires the bacterium (see question 1.12). (Following the Australian PRA for fruits from New Zealand, requirements were made for fruits to be brushed and treated with methyl bromide, Biosecurity Australia, 2009.)

3.18 - Can infestation of the consignment be reliably prevented by handling and packing methods?

No but may be part of a Systems Approach

Justification: Handling and packing methods could prevent re-infestation by the psyllid, but will not destroy individuals that are already present in the consignment. Handling and packing has no effect on the bacterium.

3.19 - Could consignments that may be infested be accepted without risk for certain end uses, limited distribution in the PRA area, or limited periods of entry, and can such limitations be applied in practice?

no

Justification:

Immediate processing of the fruit and destruction of the waste (e.g. burning, deep burial) is possible, but it is not practical and difficult to control in practice. If green parts are discarded, some individuals of *B. cockerelli* might be able to complete development.

Import and immediate processing during winter might be effective but at present little information is available about temperature requirements of the vector and under which conditions it can survive host plant free periods. Therefore, it is not possible to assess the level of risk reduction and to set exact requirements under which conditions import would be possible with a very low risk of introduction.

3.20 - Can infestation of the commodity be reliably prevented by treatment of the crop?

no

Justification: Although treatment of the crop can reduce the populations of the vector, it cannot be ensured that it is completely controlled nor that the bacterium has not been transmitted to the plants (and fruits). Publications mention that control of *B. cockerelli* requires thorough spraying to reach the insect on the underside of leaves. Treatment of the crop is part of the Systems Approach developed in New-Zealand for export to Australia (Biosecurity Australia, 2009).

3.21 - Can infestation of the commodity be reliably prevented by growing resistant cultivars?
no
Justification: No resistant cultivars have been found, although difference of susceptibility of tomato cultivars has been found (Liu & Trumble, 2004, 2005, 2006; Munyaneza, unpublished data)

3.22 - Can infestation of the commodity be reliably prevented by growing the crop in specified conditions (e.g. protected conditions such as screened greenhouses, physical isolation, sterilized growing medium, exclusion of running water, etc.)?
Yes in a Systems approach
Possible measure: specified growing conditions
Justification:
For tomato, pepper and eggplant, it might be possible to cultivate the plant under protected conditions excluding *B. cockerelli*. In protected conditions the presence of the vector can be better monitored and control measures better applied. Screened glasshouses could be used for high value crops but are not normally used for fruit production. The maintenance of screened glasshouses is very expensive and cost would be prohibitive on a large scale.

Sanitation should be on the highest level. All plant debris of earlier crops should be removed and possible hosts of the vector in the surroundings should be destroyed. These measures are only partly efficient because they cannot always stop migrating psyllids as they are capable to fly several kilometres or be transported by the wind over several kilometres.
The Phytosanitary Compliance Programme for Export Loose Tomato Fruit to Australia of New Zealand (MAFBNZ, 2009) provides an example of Systems Approach against *Ca*. L. solanacearum and *B. cockerelli* for tomato (e.g. control strategies, monitoring, methyl bromide treatment). A similar approach may be applied to other Solanaceae fruits.
The Panel on Phytosanitary Measures considered that this option should only be implemented on the basis on bilateral agreement.

3.23 - Can infestation of the commodity be reliably prevented by harvesting only at certain times of the year, at specific crop ages or growth stages?
no
Justification: This is not relevant in the field.
Glasshouse crops like tomato are cultivated from March to the beginning of November. Psyllids (amongst them also the vector *B. cockerelli*) have their mobile development stages in summer. The cultivation of glasshouse crops in spring/beginning of summer and in autumn should serve for the prevention of the colonisation of possible covered crops by mobile and infested psyllids. However crops last for months and the bacterium may be transmitted.

3.24 - Can infestation of the commodity be reliably prevented by production in a certification scheme (i.e. official scheme for the production of healthy plants for planting)?
No. Not relevant for fruit production.

3.25 - Has the pest a very low capacity for natural spread?
no
Justification: The bacterium on its own has a very low (or no) capacity for natural spread. However, where it occurs on the species considered, it is associated with its vector *B. cockerelli*, and therefore is considered to have the high capacity of spread of its vector.

3.26 - Has the pest a low to medium capacity for natural spread?
no
3.27 - The pest has a medium to high capacity for natural spread
yes
Possible measure: pest-free area.

Justification: The complex *B. cockerelli*/*Ca.* L. solanacearum has a high capacity of spread. The vector is very mobile and may fly over distances of several kilometres. The vector is very effective in transmission of the pest. Long-distance annual migrations have also been shown.

3.28 - Can pest freedom of the crop, place of production or an area be reliably guaranteed?

yes

Due to the mobility of *B. cockerelli*, it is not considered possible to establish PFAs in regions of a country where the vector occurs or reaches by migration (e.g. western USA). The size of the pest-free area should be sufficient to guarantee that *B. cockerelli* will not arrive in the area through natural spread.

The following requirements should be applied:

- detailed monitoring, inspections and surveying to demonstrate freedom from *B. cockerelli*,
- limitation on material used in the area to prevent introduction of *B. cockerelli* in the PFA.

Pest-free site of production may be established under complete physical protection (screened greenhouses, see 3.22). It should also include packing on the site to prevent reinfestation. *However, the Panel on Phytosanitary Measures considered that it was difficult to implement in practice in commercial production and therefore expressed limitation on this option.*

3.29 - Are there effective measures that could be taken in the importing country (surveillance, eradication) to prevent establishment and/or economic or other impacts?

If no vector is present in the importing country, *Ca.* L. solanacearum can be eradicated. Eradication would be possible only in the presence of a limited outbreak without the vector being also present (see also section 1.24).

Justification: See pathways A1 and B1

3.30 - Have any measures been identified during the present analysis that will reduce the risk of introduction of the pest?

Yes

Option	**against *B. cockerelli***	**against *Ca.* L. solanacearum**	**Justification**
Visual inspection	No	No	Eggs and nymphs are difficult to see. High chance not detecting low infestation levels . Asymptomatic fruit can be present.
Testing	Not relevant	In the future	No validated testing methods are presently available for routine testing
Post-entry quarantine	No	No	Not relevant.
Treatment of the consignment	Yes	No	Treatment will destroy the psyllid and it is unlikely that a vector at destination will feed on the fruit to spread the bacterium further
Remove part of the commodity	In a SA	No	Removal of green parts for loose tomatoes followed by washing or brushing would ensure removal of *B. cockerelli*.
Prevention of infestation by packing/handling method	In a SA	No	Fruit are already infected at the production place
Limited distribution in time and/or space or limited use	No	Yes	Processing will destroy the bacteria but if green parts are discarded, the psyllid may escape.
Treatment of the crop	In a SA	No	Not reliable to guarantee pest freedom
Resistant cultivar	No	No	Not available
Growing the crop in specified conditions	In a SA	Yes	Complete physical protection against *B. cockerelli*
Harvest at certain time	No	No	
Produced in a certification scheme	No	No	Not relevant for fruit
Pest free site of production	Only in a screenhouse	Only in a screenhouse	But difficult to apply in commercial production
Pest free area	Yes	Yes in absence of the vector	Due to the mobility of *B. cockerelli* and its ability to migrate over large distance, large buffer zones will be needed between areas where the vector is known to be present and the PFA.
Surveillance and eradication	No	No	

The following measures are considered effective against the complex vector/bacteria:
- Pest-free area for *B. cockerelli*
- Pest-free site (under screen greenhouse) for *B. cockerelli*

3.31 - Does each of the individual measures identified reduce the risk to an acceptable level?

No.

Some measures may be combined in a Systems Approach: pest-free site under under complete physical protection with appropriate measures (monitoring, treatment of the crop), packing on the site to prevent reinfestation. Additionaly for loose tomato the following Systems approach is possible: grown under protected condition, monitoring, removal of green parts (loose tomatoes) followed by washing and fumigation, packing on the site to prevent reinfestation and inspection of the consignment prior to export.

Both options should only be implemented on the basis on bilateral agreement.

3.34 - Estimate to what extent the measures (or combination of measures) being considered interfere with international trade.

For tomato and *Capsicum*, the measures interfere to a certain extent with trade, but similar measures are already applied by some countries, and there is a limited trade from countries where the bacteria occurs. For tamarillo and Cape gooseberry, there are no measures at the moment, but trade from countries where the pest occurs is at most very limited.
In the absence of a vector in the PRA area, measures ensuring that *B. cockerelli* does not enter the area might be sufficient, because even if the bacterium enters the PRA area on its own (pathway B2), entry and establishment are very unlikely.

3.35 - Estimate to what extent the measures (or combination of measures) being considered are cost-effective, or have undesirable social or environmental consequences.

Measures would have costs linked to monitoring, testing, establishment and maintenance of pest free areas, intensive spraying against the psyllid. However similar measures are applied against other pests. Production under protected conditions with conditions ensuring exclusion of the pest might not be feasible (high cost). Treatment of the fruit with methyl bromide will have environmental consequences and its long term use is uncertain as methyl bromide is being phased out and its use is not favoured in many EPPO countries, see IPPC Recommendation *Replacement or reduction of the use of methyl bromide as a phytosanitary measure* (FAO, 2008).
Nevertheless, the bacterium would be difficult to eradicate if introduced, could spread to other crops in the presence of a vector. The possible measures have lower cost than attempting eradication of bearing the costs of impact by *Ca.* L. solanacearum if it established.

3.36 - Have measures (or combination of measures) been identified that reduce the risk for this pathway, and do not unduly interfere with international trade, are cost-effective and have no undesirable social or environmental consequences?

yes

1. PFA for *B. cockerelli* **OR**
2. Pest-free site under screenhouses with appropriate measures (monitoring, treatment of the crop, packing on the site to prevent reinfestation). This option should only be implemented on the basis on bilateral agreement. **OR**

3- Systems Approach only for tomato: grown under protected condition, removal of green parts (loose tomatoes) followed by washing and fumigation, packing on the site to prevent reinfestation and inspection of the consignment prior to export. This option should only be implemented on the basis on bilateral agreement

Pathway 3 - Seed potatoes (including microplants and minitubers) and ware potatoes from countries where *Ca*. L. solanacearum occurs

3.2 - Is the pathway that is being considered a commodity of plants and plant products?
yes

3.12 - Are there any existing phytosanitary measures applied on the pathway that could prevent the introduction of the pest?
yes
Justification:
Import of both seed and ware potatoes is regulated in many countries of the PRA area. Many countries prohibit import of seed and ware potatoes. However, some countries allow imports with either measures against other pests or general requirements for tubers. Prohibitions of imports from one origin because of another pest, might have as consequence to prohibit imports from a place where *Ca.* L. solanacearum occurs. Other requirements would not prevent the introduction of the pest. Inspection of tubers might allow some visual detection, but the pest might be present in asymptomatic tubers, and even if symptoms are present, testing would be needed.

Phytosanitary measures (checked from EPPO collection of phytosanitary regulations summaries - http://www.eppo.org/PUBLICATIONS/phytoreg/newtexts.htm, for non-EU countries, 1999 to 2003 depending on countries) are as follows:

Seed potatoes
Import of seed potatoes from countries outside the EPPO region is prohibited by many EPPO countries (EU countries, Norway, Switzerland). The pathway seems open for some other countries for certain origins, with phytosanitary requirements against specific pests or general requirements for all bulbs and tubers (e.g. PC, free from soil, disinfected etc.):

- Algeria (seed potatoes prohibited from Americas, except USA and Canada. Phytosanitary import requirements for other origins)
- Israel (prohibition of bulbs and tubers originating in tropical or subtropical countries; requirements in place for seed potatoes from UK, Ireland and NL).
- Jordan (seed potatoes not prohibited, phytosanitary import requirements in place)
- Morocco (seed potatoes not prohibited, phytosanitary import requirements in place)
- Moldova (general requirements for bulbs and tubers)
- Russia (seed potatoes prohibited from countries where *Phoma andigena, Thecaphora solani, potato Andean latent tymovirus, potato Andean mottle comovirus, potato black ringspot nepovirus, potato T trichovirus, potato vein-yellowing disease or wild potato mosaic virus, Globodera pallida* or *Globodera rostochiensis, Phthorimaea operculella, Synchytrium endobioticum* occur)
- Tunisia (seed potatoes prohibited from countries where PSTV occurs. Phytosanitary import requirements for various other origins).
- Kyrgyzstan (phytosanitary import requirements for Solanaceae tubers)
- Ukraine (general requirements for all bulbs and tubers)

Ware potatoes
In the EU countries, the importation of ware potatoes is only allowed from certain countries and generally only possible with specific requirements. Requirements from other countries in the EPPO-region vary from no requirements to general requirements for all fruits and vegetables, to specific requirements targeting specific pests

3.13 - Can the pest be reliably detected by a visual inspection of a consignment at the time of export, during transport/storage or at import?
no
Justification: Symptoms of zebra chip might be observed in tubers, but some tubers might not show symptoms, and symptoms are also not characteristic of *Ca.* L. solanacearum.

3.14 - Can the pest be reliably detected by testing (e.g. for pest plant, seeds in a consignment)?
no

Justification:
The detection tests published have been developed for research and monitoring of the disease in the crops but have not been evaluated extensively for phytosanitary purposes. A range of tests has been developed: real-time PCR (Li *et al.*, 2009; Wen *et al*, 2009) and; conventional PCR (Liefting *et al.*, 2009a; Crosslin & Munyaneza, 2009; Wen *et al.*, 2009). The prevalence of the pest might be low in the consignment (few infected tubers, low titer in infected tubers) and testing will not guarantee detection. Uneven distribution and variation in pathogen titre is suspected (Crosslin & Munyaneza, 2009).
In the near future, it is expected that methods will become available to screen nuclear stock material (microplants) for *Ca*. L. solanacearum. (i.e. limited amount of material). Symptoms have been shown to develop during micropropagation. For other seed potatoes and ware potatoes, there is no available reliable protocol for testing. There is no test available for routine testing. The current EPPO certification scheme also does not include testing for this pest.

3.15 - Can the pest be reliably detected during post-entry quarantine?
yes
Justification: There is currently no information on the period that would be required for symptom development.
Testing will be necessary during the post-entry quarantine with an approved test (e.g. RT PCR). Post-entry quarantine is only relevant for microplants and small quantities of minitubers. Testing by real time PCR is used by in the Scottish Seed Potato Classification Scheme by SASA (Scotland, GB) for imported potato material for propagation (C. Jeffries, SASA, pers. comm., 2011).

3.16 - Can the pest be effectively destroyed in the consignment by treatment (chemical, thermal, irradiation, physical)?
no
Justification: No treatments are available to destroy the bacterium in tubers.

3.17 - Does the pest occur only on certain parts of the plant or plant products (e.g. bark, flowers), which can be removed without reducing the value of the consignment?
No. Not relevant.

3.18 - Can infestation of the consignment be reliably prevented by handling and packing methods?
no
Justification: Not relevant. Contamination would occur before handling and packing

3.19 - Could consignments that may be infested be accepted without risk for certain end uses, limited distribution in the PRA area, or limited periods of entry, and can such limitations be applied in practice?
Yes for ware potatoes only
Possible measure: import under special licence/permit and specified restrictions
Justification:
Seed potatoes are to be planted and might produce infected plants (although seemingly unlikely to favour further infestation). Requiring seed potatoes to be processed would not be a possible measure.

Ware potatoes could be allowed for processing for industrial purposes in facilities with approved waste disposal facilities.
Consignments of ware potatoes could be accepted for consumption. However, there is some risk that consumers may use infected ware potatoes as seed potatoes in private gardens.

3.20 - Can infestation of the commodity be reliably prevented by treatment of the crop?
no
Possible measure in combination: specified treatment and/or period of treatment
Justification: Although treatment of the crop could reduce the populations of the vector, it cannot be ensured that the bacterium will be completely eliminated from potato crops, i.e. that the bacterium is not transmitted to some plants and therefore some tubers.

3.21 - Can infestation of the commodity be reliably prevented by growing resistant cultivars?
no
Justification: Potato cultivars have been shown to have different levels of susceptibility, but no resistant cultivar has been found (Civerolo, 2010). In a study on transmission of the disease (Crosslin & Munyaneza, 2009), zebra chip symptoms were induced on all cultivars tested (which included many of the major cultivars in North-West and South-West USA). Atlantic is reported as a very susceptible cultivar (Goolsby *et al*., 2007; Sengoda *et al.*, 2010).

3.22 - Can infestation of the commodity be reliably prevented by growing the crop in specified conditions (e.g. protected conditions such as screened greenhouses, physical isolation, sterilized growing medium, exclusion of running water, etc.)?
no
Justification: This would necessitate knowing that initial potatoes are free from *Ca*. L. solanacearum. This might be possible only in a certification scheme and for very high grade material in the near future when reliable testing methods are available for such material.

3.23 - Can infestation of the commodity be reliably prevented by harvesting only at certain times of the year, at specific crop ages or growth stages?
No. Not relevant for potato.

3.24 - Can infestation of the commodity be reliably prevented by production in a certification scheme (i.e. official scheme for the production of healthy plants for planting)?
No (possibly in the future but only in the absence of the vector)
Justification: Certification schemes for seed potatoes have been implemented in many countries (e.g. EPPO Standard PM 4/28) but are not yet designed to address *Ca.* L. solanacearum*.* Testing for *Ca*. L. solanacearum could be included in national certifications schemes as soon as a reliable testing method has been developed. In areas where the vector, *B. cockerelli*, is present pest freedom cannot be guaranteed by a certification scheme unless seed potatoes may only be produced under complete physical protection.

3.25 - Has the pest a very low capacity for natural spread?
no
Justification: The bacterium on its own has a very low (or no) capacity for natural spread. However, where it occurs on the species considered, it is associated with its vector *B. cockerelli*, and therefore is considered to have the high capacity of spread of its vector.

3.26 - Has the pest a low to medium capacity for natural spread?
no

3.27 - The pest has a medium to high capacity for natural spread
yes
Possible measure: pest-free area.
Justification: The complex *B. cockerelli*/*Ca.* L. solanacearum has a high capacity of spread. The vector is very mobile and may fly or be dispersed by wind over distances of many kilometres. The vector is very effective in transmission of the pest. Long-distance annual migrations have also been shown.

3.28 - Can pest freedom of the crop, place of production or an area be reliably guaranteed?
yes
Justification:
Due to the mobility of the complex *B. cockerelli*/*Ca.* L. solanacearum, it is not considered possible to establish PFAs in regions of a country where the vector occurs or reaches by migration (e.g. western USA). The size of the pest-free area should be sufficient to guarantee that *B. cockerelli* will not arrive in the area through natural spread. For the countries where *B. cockerelli* is currently known to be present, this option was not considered possible for ourdoor crops by the EWG.

Pest-free area is possible with the following requirements:
- detailed monitoring, inspections and surveying to demonstrate freedom from *Ca*. L. solanacearum in Solanaceae

production
- limitation on material used in the area to prevent introduction of *Ca*. L. solanacearum in Solanaceae production in the PFA.

3.29 - Are there effective measures that could be taken in the importing country (surveillance, eradication) to prevent establishment and/or economic or other impacts?

no

Justification: See pathways A1 and B1.

3.30 - Have any measures been identified during the present analysis that will reduce the risk of introduction of the pest?

yes

Justification:

- PFA for *Ca*. L. solanacearum in Solanaceae production
- post-entry quarantine (seed potatoes)
- processing (ware potatoes)

3.31 - Does each of the individual measures identified reduce the risk to an acceptable level?

yes

- ¨PFA for *Ca*. L. solanacearum in Solanaceae production
-post-entry quarantine (seed potatoes)
- processing (ware potatoes)

3.34 - Estimate to what extent the measures (or combination of measures) being considered interfere with international trade.

Justification:

There are already numerous measures imposed on this pathway. This pathway is closed for many countries in the PRA area (e.g. EU, Norway, and Switzerland). The measures would interfere with trade but not unduly. The pathway is considered as a minor one to the PRA area in any case.

3.35 - Estimate to what extent the measures (or combination of measures) being considered are cost-effective, or have undesirable social or environmental consequences.

Justification:

Measures would have costs linked to monitoring, testing, establishment and maintenance of pest free areas, intensive spraying against the psyllid. However similar measures are applied against other pests.

In addition, the bacterium would be difficult to eradicate if introduced, could spread to other crops in the presence of a vector. The possible measures have lower cost than attempting eradication of bearing the costs of impact by *Ca*. L. solanacearum if it established.

3.36 - Have measures (or combination of measures) been identified that reduce the risk for this pathway, and do not unduly interfere with international trade, are cost-effective and have no undesirable social or environmental consequences?

yes

Justification:

- Pest-free area for Ca. L. solanacearum in Solanaceae production
- post-entry quarantine (seed potatoes)
- processing (ware potatoes)

Conclusion of the pest risk management

For all pathways, a Phytosanitary certificate (and, if appropriate a Phytosanitary certificate of re-export) should be produced.

Plants for planting of Solanaceae	PFA for *B. cockerelli* **and** *Ca*. L. solanacearum in Solanaceae
Fruits of Solanaceae	1. PFA for *B. cockerelli* **OR** 2. Pest-free site under screenhouse for *B. cockerelli* (on the basis of a bilateral agreement) 3. For tomato only: grown under protected conditions, removal of green parts followed by washing and fumigation, and inspection of consignment) (on the basis of a bilateral agreement)
Seed potatoes (including microplants and minitubers)	1. PFA for *Ca*. L. solanacearum in Solanaceae production **OR** 2. Post-entry Quarantine for high grade material
Ware potatoes	1. PFA for *Ca*. L. solanacearum in Solanaceae production **OR** 2. Processing for industrial purposes
Plants for planting of *Micromeria chamissonis*, *Mentha* spp., *Nepeta* spp., and *Ipomoea batatas*	PFA for *B. cockerelli* **and** for *Ca*. L. solanacearum in Solanaceae
Living parts of Solanaceae (except fruits, seeds and plants for planting)	PFA for *B. cockerelli* **and** for *Ca*. L. solanacearum in Solanaceae

For Solanaceae, much data is available to indicate that the consequences of the introduction of *Ca.* L. solanacearum associated with the presence of vectors would be devastating for solanaceous hosts in the PRA area. A situation similar to that in countries where the bacterium occurs could be expected, resulting in major economic damage. The risk of entry, establishment, spread and impact of *Ca*. L. solanacearum all depend on the presence of a vector. In the current situation, for Solanaceae hosts, the known vector *B. cockerelli* does not occur in the PRA area, although there is uncertainty about whether other psyllids in the PRA area could transmit the bacterium.

None of the commodity pathways considered is large, but they present some risk of introduction. The presence of infective *B. cockerelli* on consignments increases the risk of introduction and spread of *Ca*. L. solanacearum. In addition, *B. cockerelli* is also liable to have an impact by itself (see EPPO PRA for *B. cockerelli*).

Ca. L. solanacearum poses a risk for the PRA area for its solanaceous hosts. In EU countries, where import of potatoes and plants for planting of solanaceous plants are prohibited, the risk is probably very low as long as the current regulations are in place. The risk for other countries in the PRA area is probably small as the pathways are small. However, the whole PRA area would be at risk of severe consequences in case of introduction of the bacterium and association with a vector. It therefore seems important to prevent introduction of both *Ca*. L. solanacearum and *B. cockerelli*, as per the present PRA and based on the EPPO PRA for *B. cockerelli*.

For those countries for which the pathways are not closed, the main pathways for the introduction of *Ca*. L. solanacearum are infective *B. cockerelli* on plants for planting of Solanaceae and fruits of Solanaceae.

Other pathways present low risks of introduction of the bacterium, in the absence of a vector, but there is still uncertainty concerning whether a vector already occurs in the PRA area, which would increase the risk. Consequently, measures are also proposed for seed potatoes and ware potatoes (against *Ca*. L. solanacearum as *B. cockerelli* cannot be introduced on these commodities), plants for planting of *Micromeria chamissonis*, *Mentha* spp., *Nepeta* spp., *Ipomoea batatas* and living parts of Solanaceae (except fruits, seeds and plants for planting). Plants for planting of *Micromeria chamissonis*, *Mentha* spp., *Nepeta* spp., and *Ipomoea batatas* is currently assumed to be a small pathway, but any increase in volume would increase the risk.

ANNEX 1 *Ca*. L. solanacearum on carrot and its vector *Trioza apicalis*

This annex gives information on *Ca*. L. solanacearum on carrot and its psyllid vector *Trioza apicalis*.
Note: After this PRA was conducted, *B. trigonica* was reported as associated with *Ca.* L. solanacearum in carrots in Canary Islands, and with *Bactericera* sp. in mainland Spain (Alfaro-Fernández et al., 2012a & 2012b).

1. Finding of *Ca.* L. solanacearum in the EPPO region

In 2010, *Ca.* L. solanacearum was detected on carrot in Finland and found to be associated with the psyllid species *Trioza apicalis* (Munyaneza *et al.*, 2010a, b). Plants were tested for *Ca.* L. solanacearum because of symptoms (as described below) in 14 commercial fields in Southern Finland; 5-35% of the plants showed symptoms (Munyaneza *et al.,* 2010a). It has been known for a long time prior to the detection of *Ca.* L. solanacearum that *T. apicalis* can cause up to 100% crop loss on carrot (Lundblad, 1929; Markkula *et al.,* 1976; Rygg, 1977; Nehlin *et al.,* 1994) and it should be noted that none of these authors mention leaf discolouration as a symptom of carrot psyllid feeding. Nissinen *et al.,* (2007) suggested that there may be a plant pathogen associated to the damage as the leaf discolouration developes approximately one month after psyllid removal. However, it is presently uncertain to which extent the observed yield loss might have been caused by *Ca.* L. solanacearum (see also below "symptoms"). *Ca.* L. solanacearum was also detected in 2011 on carrot plants in the following regions of Spain: Islas Canarias, Castilla-La Mancha, Comunidad Valenciana. All carrot plots belonged to the same company in Spain. Symptomatic plants have also been observed in celeriac but the causal agent was not confirmed (preliminary detection using molecular techniques). There is no data on the possible vector in Spain. Up to 2010, *Ca*. L. solanacearum has not been reported in carrots from other countries but the bacterium might be more widespread than presently known because until recently the bacterium was unknown from carrot[17].

The presence of *Ca.* L. solanacearum in carrot in Finland does not influence the risk analysis for solanaceous crops because there does not seem to be a means of transmission between carrot and solanaceous crops: *T. apicalis* does not naturally feed on solanaceous crops and *B. cockerelli* does not naturally feed on carrots; preliminary studies on transmission of *Ca.* L. solanacearum to potato by *T. apicalis* did not succeed since *T. apicalis* died within a few days when placed on potato in small clip cages, which suggests that feeding on potato was unsuccessful (Lemmetty & Nissinen, unpublished data, 2010-10). Similarly results of a preliminary study indicate that inoculation of *Ca*. L. solanacearum to carrot with *B. cockerelli* can occur at an extremely low rate if the psyllid is forced to feed on carrot (Munyaneza, unpublished data, 2010/2011). Further experiments suggested that the potato psyllid does not feed on the phloem of the carrot plant and this would explain the very low transmission rate observed during the transmission studies (Munyaneza, unpublished data). Carrots crops and Liberibacter-infected potato crops can be found in close proximity in USA, Mexico and New Zealand but no symptoms of *Ca.* L. solanacearum have been observed in carrots, (Munyaneza, personal observations). These observations suggest that the main pathway of introducing *Ca.* L. solanacearum into solanaceous species would be the introduction of infective *B. cockerelli* into the EPPO region.

The original detection of *Ca.* L. solanacearum in Finland was made following observation of symptoms in 14 commercial fields in Southern Finland in 2008. Similarly to several other economically important species of psyllids, it has long been suggested that *T. apicalis* affects carrots by injecting toxic saliva into the plants (e.g. Markkula *et al*., 1976) but before the discovery of *Ca.* L. solanacearum, no plant pathogens had been associated with *T. apicalis*. No details are available on the distribution of the pest in Finland. However, data so far indicate a limited distribution, only on carrot, only in a limited part of Finland. The findings were associated with damage to some carrot crops in the field, but information is lacking on the precise situation.

<u>Symptoms</u>. The bacterium was associated with plants showing symptoms of "leaf curling, yellow and purple discolouration of leaves, stunted growth of shoots and roots, proliferation of secondary roots" (Munyaneza *et al*., 2010a). *T. apicalis* has been considered until now to cause a severe disease of carrots. However, the importance of the bacterium in the disease caused on carrots still has to be established.

<u>Detection and transmission</u>. The bacterium was found in symptomatic (plant and root) and asymptomatic carrot plants (Munyaneza *et al*., 2010a). Results of a preliminary study indicate that inoculation of *Ca*. L. solanacearum to carrot

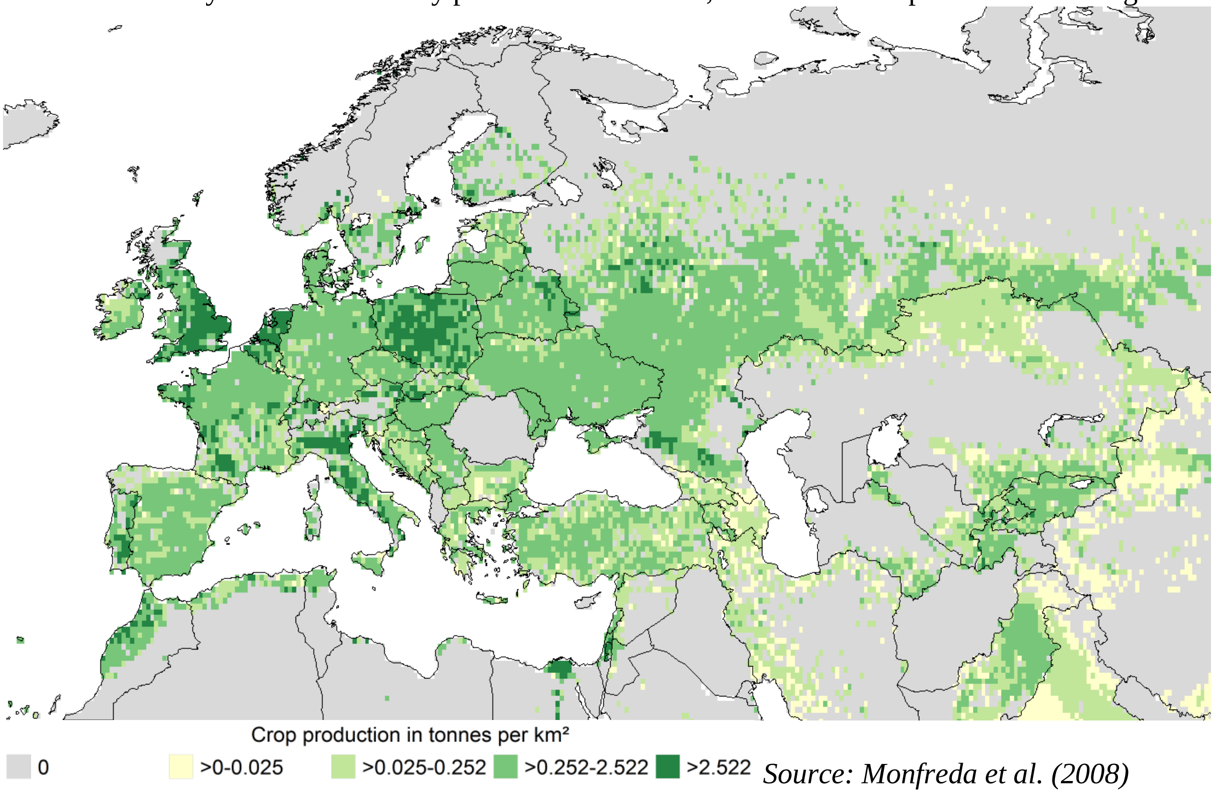
[17] Since this PRA was conducted, additional research has been conducted and *Ca*. L. solanacearum was found in carrot in Norway and Sweden (Munyaneza *et al*., 2011, 2012)

with *B. cockerelli* can occur at an extremely low rate if the psyllid is forced to feed on carrot (Munyaneza, unpublished data, 2010). Further experiments suggested that the potato psyllid does not feed on the phloem of the carrot plant and this would explain the very low transmission rate (Munyaneza, unpublished data, 2010). Carrots crops and Liberibacter-infected potato crops can be found in close proximity in USA, Mexico and New Zealand but no symptoms of *Ca.* L. solanacearum have been observed in carrots. (Munyaneza, pers. comm., 2010).
It should be noted that the haplotype of the bacterium found on carrot in Finland is different from the one found in the USA (Munyaneza *et al.*, 2010b, Nelson *et al.*, 2011). It was not been yet possible to evaluate the possible impact of the carrot haplotype on potato as in experiments *T. apicalis* did not feed on potato unsuccessful (Lemmetty & Nissinen, unpublished data, 2010-10). Some experiments are being conducted to see if *Ca.* L. solanacearum can be moved from infected potato plants to carrot plants by a parasitic plant (Cuscuta spp.) (Munyaneza, pers. comm., 2011-09).

Possibilities for establishment, containment and eradication. Details are lacking on the situation in Finland, but *Ca.* L. solanacearum was found in samples collected in 2008. It is supposed that at least in the limited area where it was found, it has been present for several years. Eradication of *Ca.* L. solanacearum is not likely to be possible due to the wide natural occurrence of carrot psyllid in Europe (Burckhardt, 1986; Ossiannilsson, 1992) and the wide host plant range of the vector (Valterová *et al*., 1997; see also below “3. *Trioza apicalis* in the PRA area – Host plants”). Thus, small populations of the vector species, *T. apicalis,* are likely to survive even if carrot cultivation would be abandoned and the bacterium can possibly persist in the vector and transmitted to the progeny as shown for *B. cockerelli* (Hansen *et al*., 2008)

2. Carrots in PRA area

Carrots are widely cultivated in many parts of the PRA area, for commercial production and in gardens.



Source: Monfreda et al. (2008)

Fig. 1. Carrot production in the EPPO region in year 2000

3. *Trioza* apicalis in the PRA area

Trioza apicalis is present in large parts of the PRA area (see below “distribution”). It does not seem to have the same migration patterns as *B. cockerelli* and no reports of long-distance transcontinental migrations have been found. *T. apicalis* overwinters in conifers and migrates to carrot crops at the beginning of the growing season. This might ensure a quite local spread of the bacterium from one year to the next but this is highly uncertain. In addition *T. apicalis* has been reported to have a periodic long-term fluctuation of populations, with outbreaks occurring only in some years (Laska & Rogl, 2008). Lazka (2011) note that *T. apicalis* is a major pest of carrot in Northern Europe but cause damage only occasionally in Central Europe.

Host plants: *Daucus carota*, *Petroselinum crispum* and *Carum carvi* (Burckhardt, 1986; Ossiannilsson, 1992). In addition to these, Valterová *et al*. (1997) found *T. apicalis* to lay eggs and develop to adults on *Coriandrum sativum, Pimpinella saxifraga, Pastinaca sativa, Foeniculum vulgare, Anthriscus cerefolium, Levisticum officinale, Pimpinella anisum, Antriscus sylvestris. T. apicalis* laid eggs, which did not develop to adults on *Aegopodium podagraria, Aethusa cynapium*, *Anethum cravelolens* and *Angelica archangelica* so these plants were not regarded as hosts by Valterová *et al*. (1997). Rygg (1977) observed that adults were able to live up to four weeks on *Anethum graveolens, Pastinaca sativa, Apium g. rapaceum* and *Carum carvi*. However, nymphs died at 1st or 2nd instar on *Apium g. rapaceum* and *Petroselium h. tuberosum*. Rygg (1977) did not observe egg-laying on *Aegopodium podagraria* and *Antriscus silvestris* of which the latter observation is contradictory to that of Valterová *et al*. (1997). In addition, *T. apicalis* adults were able to survive on non hosts (*Chrysanthemum vulgare*, *Marticaria inodora, Phleum pratense, Trifolium pratense*) for 4-6 days (Rygg, 1977). *T. apicalis* overwinters on conifers such as Norway spruce - *Picea abies*, Scots pine - *Pinus sylvestris*, juniper - *Juniperus communis* (Kristoffersen & Anderbrant, 2007).

Distribution. Many locations in the PRA area (Bey, 1931; Krumrey & Wendland, 1973). According to Ossiannilsson (1992), *Trioza apicalis* is common and widespread in Denmark, Sweden, Norway and in southern Finland. Ossiannilsson (1992) has provided a table with more detailed distribution within Scandinavia and Fennoscandia. In addition, the distribution area covers Austria, Czech Republic, Slovakia, France, Germany, United Kingdom, Italy, Poland, Switzerland, Russia (Buryatskaya district, Chitinsky district, Dagestan, Sakhalin, Far East), Ukraine (including Crimea), Mongolia (Ossiannilsson, 1992). Burckhardt (1986) has listed Leningrad region and Siberia from USSR in addition to those mentioned by Ossiannilsson (1992), but he considers records from Bulgaria and Georgia uncertain. In addition to these countries, Lundblad (1929) has mentioned Estonia, Latvia, Romania and even Japan as part of the distribution areas of *T. apicalis*.

Current control. The control of current populations of *T. apicalis* occurring in main carrot cultivation areas in Northern Europe demands several pesticide spays annually; the number of treatments has been increasing during last decades (Nehlin *et al*,. 1994; Tiilikkala *et al*., 1996; Nordhus *et al*., 2006; Kristoffersen & Anderbrant, 2007). In field experiments, good results were still obtained with 2-3 pyretroid treatments in 1995 in Finland (Tiilikkala *et al*., 1996). In Norway, more than 3-4 sprayings was seldom needed in 1987 (Rygg, 1987). Nehlin *et al*. (1994) mentioned that up to 8 insecticide sprays are needed against carrot psyllids in Sweden. Nordhus *et al.* (2006) report up to 11 pesticide sprays against carrot psyllid in Norway in certain areas with poor control over the pest. Therefore the insects were tested for insecticide resistance in Norway, but the genetic base of the resistance was not found (Nordhus *et al*., 2006).

4. Major uncertainties

- Precise situation and distribution of *Ca.* L. solanacearum in Finland and in Spain
- Situation in neighbouring and other EPPO countries
- Origin of *Ca.* L. solanacearum found in carrot
- Dispersal patterns and distances of *T. apicalis*
- Damage and possible impact of *Ca*. L. solanacearum on carrot: which symptoms are caused by the vector *T. apicalis* and which by *Ca*. L. solanacearum?

ANNEX 2. Notes on the diseases caused by *Ca.* L. solanacearum

Ca. L. solanacearum is new to science: it was discovered only in 2008. Nevertheless symptoms similar to those caused by *Ca*. L. solanacearum have been described before that date. It should be noted that there remains some uncertainty as to whether or how other pathogens, such as phytoplasmas, are involved in the diseases, and if the symptoms expressed are due to one pathogen only or if several pathogens are involved. As for huanlongbing of citrus caused by the three other known *Ca.* Liberibacter spp., association of other phytoplasmas to the symptoms is not clear.

In addition, it is not clear which diseases are due to *Ca.* L. solanacearum (or the complex *Ca.* L. solanacearum/*B. cockerelli*) and which might be produced by the vector on its own (or in association with other pathogens). In both tomato and potato, there are indications of distinct psyllid-associated diseases, depending on whether *Ca.* L. solanacearum is associated with the vector *Bactericera cockerelli* or not. On many crops (except maybe on tamarillo in New Zealand), the diseases seem to have occurred years before the bacterium was first detected.

Prior to the identification of *Ca.* L. solanacearum, the psyllid *Bactericera cockerelli* was known as a pest of potato and tomato, causing psyllid yellows. It causes plant yellowing which can be directly associated with a colonisation by the psyllids (Blood *et al.*, 1933; Richards & Blood, 1933; Pletsch, 1947; Wallis, 1955, all cited in Stefani, 2010). In 2007 DeBoer *et al.* (2007) proved that the disease is transmittable and distinguished it from simple physiological plant yellowing. Hansen *et al.* (2008) also associated *Ca.* L. solanacearum to psyllid yellows. However, Sengoda *et al.* (2010) later showed that zebra chip disease occurs in presence of the bacterium, while psyllid yellows can occur in the presence of *B. cockerelli* alone, and in this case does not have the same lethal outcome. A similar situation has been expressed by Brown *et al.* (2010) on tomato for vein greening disease (*B. cockerelli* / *Ca.* L. solanacearum) and psyllid yellows of tomato (*B. cockerelli* alone or with other undetermined pathogens).

<u>On potato</u>

Zebra chip disease of potato ("papa rayada" in Guatemala, "papa manchada" in Mexico) is generally associated with a symptomatic infestation of the potato tubers which is caused by *Ca.* L. solanacearum (Sengoda *et al.*, 2010; Munyaneza *et al.*, 2008). Tuber symptoms are dark stripes, brown discolouration of the vascular ring, necrotic flecking of tuber tissues, that become markedly more visible when tubers are fried (Abad, 2009; Crosslin *et al.*, 2010). Foliar symptoms are a chlorosis of the potato plant with leaf roll, leaf wilt and necrosis followed by the dying of entire plants, and other symptoms include purple top, shortened internodes, swollen axillary buds, aerial tubers. Disease symptoms appear after flowering if transmitted by the vector, and immediately after emergence in case of tuber-borne infections (Henne *et al.*, 2010). The etiology of zebra chip (as of other diseases associated with *Ca.* L. solanacearum) has not been established. While in some cases association with phytoplasma was not found (Munyaneza, 2007a), in other cases some phytoplasmas were associated with zebra chip: *Ca.* Phytoplasma americanum as the primary pathogen associated with zebra chip in Nebraska (Wen *et al.*, 2009); *Ca.* Phytoplasma australiense in New Zealand (in the 14 symptomatic plants tested, 7 plants tested positive for *Ca.* P. australiense only, 3 for *Ca.* L. solanacearum only, 4 for both - although *Ca.* L. solanacearum might have been there and not be detected by the tests) (Liefting *et al.*, 2009b). *Potato leafroll virus*, aster yellows, clover proliferation and stolbur phytoplasmas have been reported to cause zebra-chip like foliar symptoms (Wen, *et al.*, 2009; Secor *et al.*, 2006).

Haywire of potato (morphological characteristic of potato plants growing from tubers affected by a number of phytoplasmas) is usually associated with phytoplasmas, e.g. aster yellows (Henne *et al.*, 2010). However, plants with haywire symptoms grown from seed tubers with zebra chip symptoms were found positive for *Ca.* L. solanacearum but negative for phytosplasmas (Wen *et al.*, 2009).

Punta morada de la papa/purple top has been consistently mentioned in publications relating to zebra chip and to damage in Mexico. However Secor *et al.* (2009) notes that based on symptomatology, purple top of potato and zebra chip are two different diseases. Although it has been found in places where *Ca.* L. solanacearum was later found, punta morada, or some of its symptoms, has sometimes been found associated with other pathogens.

<u>On tomato and pepper</u>

Possible symptoms of the disease are chlorosis and yellowing of the leaves, leaf roll and plant decline and, ultimately plant death. On pepper plants, shortened internodes and overall stunting are also noted (Liefting *et al.*, 2009a)

On tomato, vein greening has been reported in cases of clear association with *Ca.* L. Solanacearum (Brown *et al.*, 2010). Psyllid yellows is reported to be associated with the presence of the bacterium (McKenzie & Shatters, 2009) but might also develop in the absence of the bacterium (Brown *et al.*, 2010). Zebra-chip-like foliar disease symptoms have also been associated with the presence of the bacterium (French Monar *et al.*, 2010). "Permanent yellowing disease" (or "enfermedad permanente del tomate") has previously been associated with phytoplasmas (Holguín-Pena *et al.*, 2007; Munyaneza, 2009b), but was associated with a bacteria-like organism by Garzon-Tiznado *et al.* (2009) with associated vein greening symptoms but without the presence of phytoplasmas.

<u>On tamarillo</u>
Symptoms may be limited to some parts of the tree. If shoots are produced, no fruit set is observed. Symptoms on trees are debilitating and progress to tree death, within 1-4 months (Watson, 2009). From the few references available, it seems that this is a new disease, previously unknown.

ANNEX 3 – Potato, tomato, sweet pepper and chilli, carrot, eggplant. Data on fruit production volumes and area in the PRA area (From FAOSTAT data 2008)

* = Unofficial figure | [ ] = Official data | F = FAO estimate | Fc = Calculated data

1- Potato

Country	Area Harvested (Ha)		Production (tonnes)		Seed (tonnes)	
Albania	9800		190000		27300	Fc
Algeria	91841		2171058		112479	Fc
Austria	22800		756945		53330	
Azerbaijan	68856		1077110		213627	
Belarus	396341		8748630		1560000	*
Belgium	63884		2943205		67000	
Bosnia and Herzegovina	40412		428635		47170	Fc
Bulgaria	21648		353060		21750	Fc
Croatia	15000		255554		21000	Fc
Cyprus	5110		115000		12279	F
Czech Republic	29788		769561		125000	
Denmark	40664		1705403		101660	
Estonia	8800		125200		30000	F
Finland	26200		684400		53100	
France	156200		6808210		319000	*
Germany	259800		11369000		559000	
Greece	33500		848000		93000	*
Hungary	25424		683935		55000	F
Ireland	12000		371900		37000	F
Israel	18010		557917		6000	F
Italy	70578		1603828		150000	F
Jordan	5843		139787		9500	Fc
Kazakhstan	163100		2354408		310200	
Kyrgyzstan	85000		1334900		270000	F
Latvia	37800		673400		119000	*
Lithuania	48400		716400		145000	
Luxembourg	604		21756		2741	
Malta	700		19000		910	Fc
Morocco	62800		1536560		106760	Fc
Netherlands	151900		6922700		310000	F
Norway	14388		398400		36300	
Poland	529500		10462100		1220000	
Portugal	38900		566600		65000	F
Republic of Moldova	31247		271039		55000	*
Romania	259744		3649020		1042331	
Russian Federation	2104000		28874230		6500000	*
Serbia	81172		843545		156338	Fc
Slovakia	14270		245277		43200	Fc
Slovenia	4427		100319		8350	Fc
Spain	81825		2365500		143000	F
Sweden	26900		853200		51000	F
Switzerland	11058		473000		24609	
Tunisia	24800		370000		25000	Fc
Turkey	147812		4196522		296000	*
Ukraine	1408900		19545400		4800000	F
United Kingdom	144000		5999000		350000	F
Uzbekistan	59700		1398700		62000	Fc

2- Tomato

Country	Area Harvested (Ha)		Production (tonnes)	
Albania	5050		162500	

Country	Area Harvested (Ha)		Production (tonnes)	
Algeria	19655		559249	
Austria	185		42109	
Azerbaijan	26609		438419	
Belarus	7602		274557	
Belgium	470		200000	F
Bosnia and Herzegovina	3840		40722	
Bulgaria	3474		134131	
Croatia	1226		32358	
Cyprus	328		23443	
Czech Republic	1202		27899	
Denmark	50	F	20000	F
Estonia	175		5392	
Finland	116		40467	
France	4122		714635	
Germany	308		65096	
Greece	25000		1338600	
Hungary	2275		205597	
Ireland	30	F	12000	F
Israel	5200	F	418990	
Italy	115477		5976912	
Jordan	11752		600336	
Kazakhstan	25100		549310	
Kyrgyzstan	9957		187221	
Latvia	13		41	
Lithuania	200		1300	
Luxembourg	1		83	
Malta	400	F	15746	
Morocco	18600		1312310	
Netherlands	1500		720000	
Norway	31		12017	
Poland	14640		702546	
Portugal	14297		1147600	
Republic of Moldova	7008		83802	
Romania	51460		814376	
Russian Federation	112210		1938710	
Serbia	20309		176501	
Slovakia	2939		56585	
Slovenia	187		4704	
Spain	54868		3922500	
Sweden	50	F	16200	
Switzerland	216		33459	
Tunisia	26000		1170000	
Turkey	300000	F	10985355	
Ukraine	80800		1492100	
United Kingdom	216		88690	
Uzbekistan	54000	*	1930000	*

3- Chillies and peppers, green

Country	Area Harvested (Ha)		Production (tonnes)	
Albania	2520		46600	
Algeria	20403		280397	
Austria	170		17693	
Belgium	101		20000	F
Bosnia and Herzegovina	3895		39890	
Bulgaria	3751		59524	
Croatia	3382		34760	
Cyprus	54		1728	
Czech Republic	300	F	7200	F
Finland	5		616	
France	600		18700	
Germany	41		1904	
Greece	3900		119900	
Hungary	3643		166579	

Country	Area Harvested (Ha)		Production (tonnes)	
Israel	3600	F	178423	
Italy	11721		325727	
Jordan	1924		51527	
Kazakhstan	4400	*	82000	*
Kyrgyzstan	100	*	1400	*
Morocco	7295		232220	
Netherlands	1200		330000	
Portugal	220	F	1250	F
Republic of Moldova	2413		15839	
Romania	20162		238682	
Serbia	18827		151317	
Slovakia	2067		24619	
Slovenia	183		4286	
Spain	18861		992200	
Switzerland	19		166	
Tunisia	22000	F	291000	
Turkey	88000	F	1796177	
Ukraine	15100		146000	
United Kingdom	100	F	14900	F
Uzbekistan	700	*	37000	*

4- Chillies and peppers, dry

Country	Area Harvested (Ha)		Production (tonnes)	
Algeria	3900	F	7800	F
Bosnia and Herzegovina	4000	F	30000	F
Bulgaria	200	F	700	F
Czech Republic	1615		1491	
Greece	85	F	350	F
Hungary	2243	F	13771	F
Kazakhstan	200	F	300	F
Kyrgyzstan	50	F	100	F
Morocco	1400	F	14000	F
Romania	31000	F	33000	F
Serbia	1500	F	3500	F
Slovenia	350	F	1300	F
Spain	1687	F	4939	F
Tunisia	3200	F	8000	F
Turkey	9000	F	20000	F
Uzbekistan	1800	F	3000	F

5- Carrots and turnips (note: FAOSTAT does not separate data for carrot and turnip)

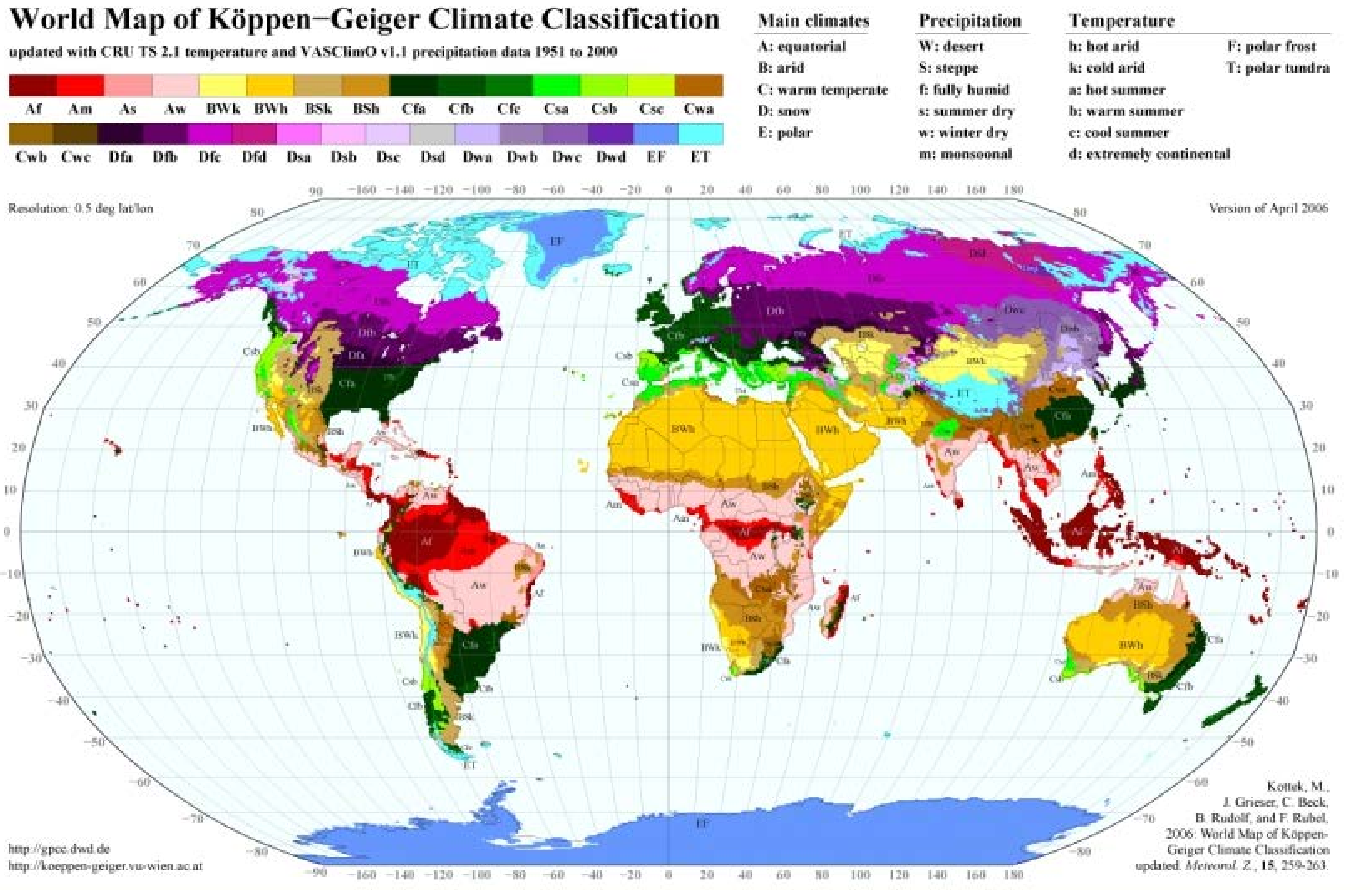
Country	Area Harvested (Ha)		Production (tonnes)	
Albania	290		6400	
Algeria	15025		254000	
Austria	1491		80849	
Azerbaijan	581		7369	
Belarus	13483		363561	
Belgium	3264		230000	F
Bosnia and Herzegovina	1878		27609	
Bulgaria	619		13437	
Channel Islands				
Croatia	412		7629	
Cyprus	67		1899	
Czech Republic	1088		34406	
Denmark	1600	F	70000	F
Estonia	538		15556	
Finland	1575		60751	
France	13324		298738	
Germany	10226		547073	
Greece	1400		47600	

Country	Area Harvested (Ha)		Production (tonnes)	
Hungary	2870		114400	
Ireland	700	F	24000	F
Isle of Man				
Israel	3100	F	211356	
Italy	12664		587319	
Jordan	157		7391	
Kazakhstan	13200		271100	
Kyrgyzstan	8208		173354	
Latvia	2183		36446	
Lithuania	2557		56973	
Luxembourg	7		310	
Malta	50	F	1129	
Morocco	9837		280995	
Netherlands	8600		531000	
Norway	1452		44508	
Poland	28213		817024	
Portugal	4500	F	180000	F
Republic of Moldova	2215		18583	
Romania	17955		234752	
Russian Federation	68950		1530170	
Serbia	7623		66202	
Slovakia	2562		37155	
Slovenia	171		3280	
Spain	7492		550000	F
Sweden	1700		91600	
Switzerland	1635		58702	
Tunisia	6800		53100	
Turkey	31000	F	591538	
Ukraine	42600		739600	
United Kingdom	11028		719270	
Uzbekistan	16800		910000	
TOTAL	**383690**		**11008134**	

6- Eggplant

Countries	Area Harvested (Ha)	Production (tonnes)
Albania	920	17400
Algeria	3773	53762
Austria	7	503
Belgium	11	4000
Bulgaria	260	7062
Cyprus	45	2566
France	417	12860
Greece	2900	85300
Hungary	100	840
Israel	530	37205
Italy	10862	321795
Jordan	3753	99902
Kazakhstan	2500	44280
Kyrgyzstan	100	100
Lithuania	200	500
Morocco	1745	34805
Netherlands	100	40000
Portugal	300	6500
Republic of Moldova	589	4697
Romania	10535	153677
Serbia	100	2000
Spain	3596	175000
Tunisia	16	230
Turkey	31000	813686
Ukraine	5800	61500
Uzbekistan	200	3700

ANNEX 4 Word Map of Köppen-Geiger Climate Classification



ANNEX 5. Trade data for potatoes tubers, peppers, tomatoes and eggplants fruit (quantities in tonnes)

This annex refers to quantities imported in the PRA area from countries where the pests are present. As export data given by countries where the pests are present may differ from the corresponding import data given by countries from the PRA area, import data are also indicated between brackets.

Note: this annex covers potato tubers, and fruit of tomato, sweet pepper and chilli, and eggplants. It is common to the PRAs for *Ca.* L. solanacearum and *B. cockerelli*, and therefore covers all host plants for all countries where one or the other occur.

Data for Canada is not relevant for the PRA on *Ca.* L. solanacearum (as the bacterium is not known to occur there); data for Canada for potato tubers might not be relevant as *B. cockerelli* is not known to occur in the field.

1- Potatoes

Mexico, Honduras, Guatemala: no export/import data to/by PRA area countries

Destination/Origin	**New Zealand**	**USA**	**Canada (see note above)**
Algeria			7374
Finland	23		
France		31	77
Montenegro			52
Netherlands			195
Norway		(3)	4055 (3979)
Portugal			287
Portugal			(287)
Russian Federation		1896 (1929)	(24)
Serbia			206 (61)
Turkey			2753 (2122)
UK	38	3571	
Ukraine		48	

2- Sweet peppers and chilli (fresh)

Destination/Origin	**USA**	**Mexico**	**Honduras**	**Guatemala**
Belgium	2			
Denmark	2			
Finland	8 (0)			
France		(1)		
Germany	8 (2)		83	
Ireland	87			
Italy		(13)		
Italy		19 (13)		
Netherlands	155 (44)	38 (15)	83 (1)	
Norway	168			
Russian Federation	(20)			
Spain	(77)	(93)		
Turkey	16			
UK	137 (52)	(3)	350	(1)

3- Tomatoes

New Zealand: no export of these commodities to PRA area.

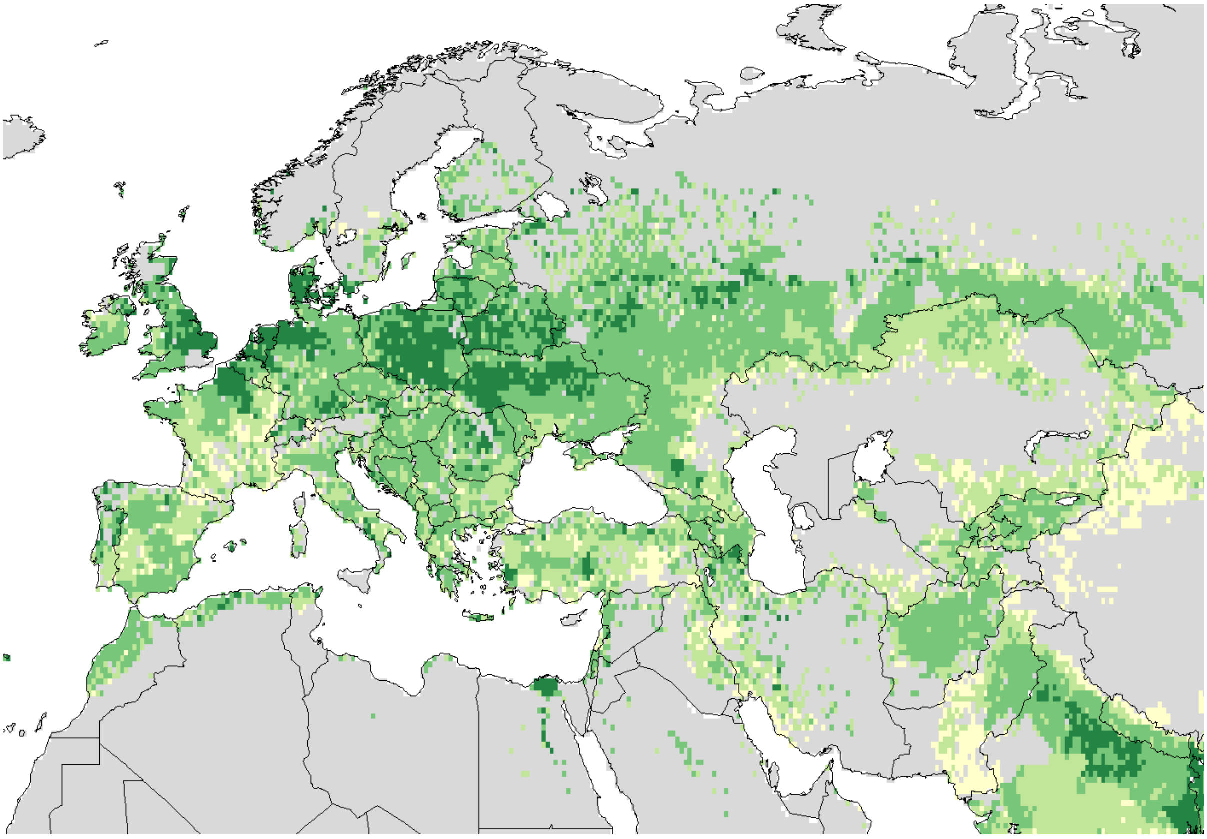
Destination/origin	USA	Canada	New Zealand
France	(7)		
Netherlands	3		
Norway		(2)	
Russian Federation	2		
Switzerland	20 (3)		(19)

4- Eggplant

Mexico, Honduras, Guatemala, Canada, New Zealand: no export to PRA area countries.

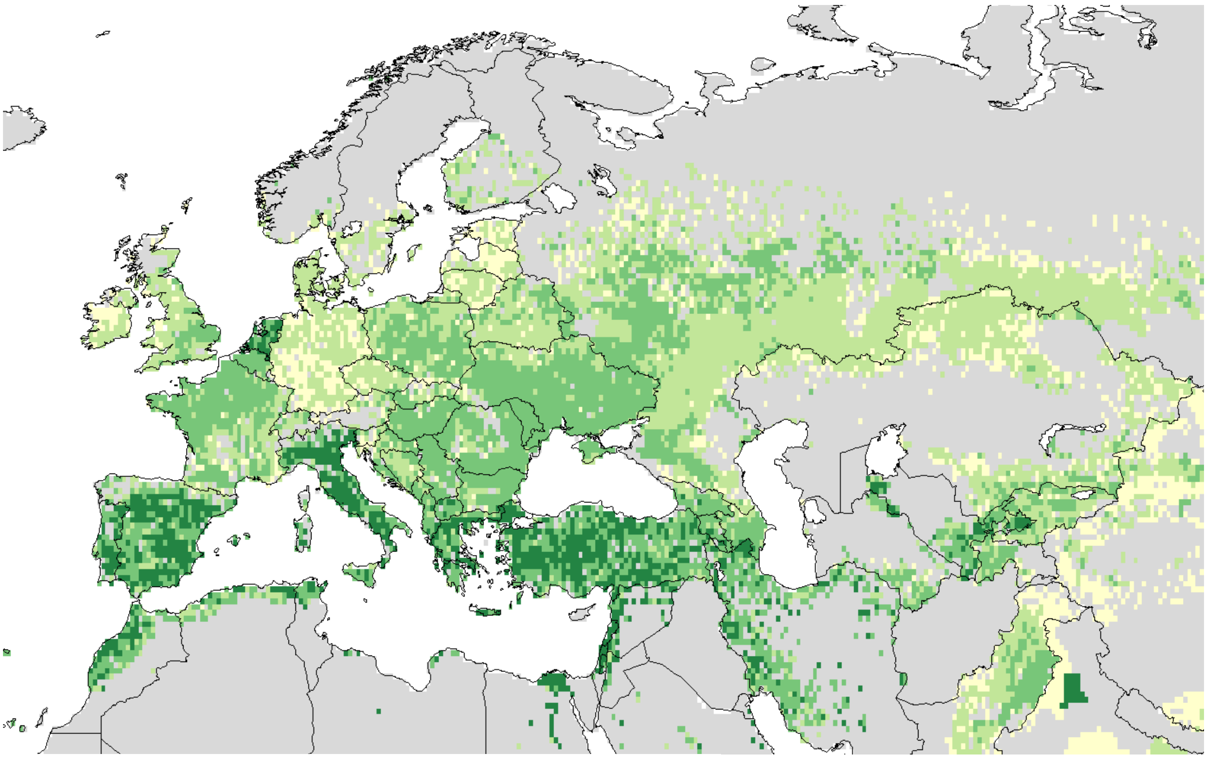
Destination/origin	USA
France	5
Spain	15

ANNEX 6. Maps of cultivation of potato and tomato



Source: Monfreda et al. (2008)

Fig. 1. Potato production in the EPPO region in year 2000



Source: Monfreda et al. (2008)

Fig. 2.Tomato production in the EPPO region in year 2000

Annex 7: Climatic suitability study for *Bactericera cockerelli*

A climatic study was performed using CLIMEX. A first set of parameters for the model (Table 1) was fixed considering available information about the pest's biology (temperature requirements, length of life cycle) and adjusted considering the known geographical distribution of *Bactericera cockerelli* in North America. The following elements of the biology were considered:

- The optimum temperature of development is 26-27°C. Oviposition, hatching, survival is reduced at 30-32°C and ceased at 35°C (List, 1939 cited in Wallis, 1955; Abdullah, 2007; Munyaneza, 2010)
- One generation is completed in 3-5 weeks at 21-27˚C (Pletsch, 1947).
- In laboratory experiments, a life cycle is completed in 20-27 days at 21-24°C, and in 25-37 days at 15.5-21 °C. No development in 55 days at 11°C (Pletsch, 1947).
- Wallis (1955) hypothesized that high humidity may be the factor preventing the pest from moving to East USA because *B. cockerelli* occurs in diminishing numbers eastwards from the 100th meridian, the approximate dividing line between the humid and dry areas of the USA).
- There also seems to be several populations of the pest: native Texas populations and invasive populations (Liu *et al.*, 2006a) which may have different thermal requirements, although this is difficult to determine because the distribution of these populations overlap in the USA.
- It is not known whether/how *B. cockerelli* overwinters in the northern part of its range in the Americas. In the Southern part (i.e. Southern USA, Mexico and Central America), it overwinters on wild hosts. Migrations of *B. cockerelli* occur: it is hypothesized that populations in South-Eastern US States migrate (with prevailing winds) in the spring to the north or northwest, where the summers are cooler (Wallis, 1955). Romney (1939 cited by Wallis, 1955) notes that it is not possible to find psyllids in Southern Arizona from the middle of June until late October or early November, when there is an influx from an unknown source. On the contrary, in Washington, *B. cockerelli* is generally first observed around mid-July and up to the first frost in late October (Munyaneza, unpublished data).
- **As a result of these migrations, transient populations of *B. cockerelli* are present in areas where they apparently cannot survive all year round. This characteristic cannot be taken into account by CLIMEX, so the resulting map should be considered with care as in Europe populations might also migrate to more northern areas to escape high temperatures during summer.**

The factors defined in Table 1 result in a map of potential distribution of *B. cockerelli* in North America (see Fig. 1) which is in line with the current distribution of the pest. This potential distribution does not include transient populations in the Northern part of its range as the psyllid where it is not established all year round. The model concludes that population of the psyllid may develop in Washington State, which is confirmed in experiments but not by observations in the field (Munyaneza, comm. pers., 2011). It is presently unknown why *B. cockerelli* does not overwinter in Washington State. The model was run for the EPPO region and the resulting map can be seen in Fig. 2. Based on the distribution in North America, the areas where climatic conditions are favourable for establishment are the Mediterranean Basin and Central Europe. Using the same parameters, establishment in New-Zealand would have been predicted as favourable only in one location (EI= 44 in Timaru, Fig. 3) but **several locations where *B. cockerelli* has established in New Zealand outdoors have a very different climate from the area in North America where the pest is present year round.** This is also demonstrated by the comparison of climate between some meteorological stations near sites where the psyllid was collected in New Zealand and the climate in North America (see Fig. 5 and 6). It should be noted that, analysing the original distribution of the vector in the Americas using CLIMEX, the presence of the vector would not be expected to establish in the major part of New Zealand (Fig. 3). On the contrary, the climate of some parts of New-Zealand where the psyllid has established is very similar to the climate in parts of North-western and Central Europe (see Figs 6, 7 and 8). Therefore, it can be considered that the pest could establish in at least parts of North-Western and Central Europe

As a consequence, and considering that

- Humidity does not appear to limit the psyllid populations in New Zealand (as the psyllid occurs in the humid region of Waikato and Pukekohe).
- In New Zealand, *B. cockerelli* has been shown to overwinter on host weeds both in the North Island (Hawkes Bay, Pukehoke) and in the South Island (Canterbury) (Berry *et al.*, 2010)
- In New Zealand, it does not seem that *B. cockerelli* migrates.
- A new population may have adapted to New Zealand conditions

Parameters have been modified slightly (i.e. by increasing the Moisture index and deleting the Wet stress), see Table 2. As a result, the predicted distribution fits much better with the actual distribution of the pest in New Zealand.

Table 1: Parameters used in CLIMEX to estimate the potential distribution of *B. cockerelli (*based on the thermal requirements and adjusted on the basis of the distribution in the USA)

Moisture Index					
SM0	**SM1**	**SM2**	**SM3**		
0	**0.1**	**0.4**	**0.7**		
Temperature Index					
DV0	**DV1**	**DV2**	**DV3**		
7	**16**	**30**	**32**		
Light Index (not used)					
Diapause Index (not used)					
Cold Stress					
TTCS	**THCS**	**DTCS**	**DHCS**	**TTCSA**	**THCSA**
0	**0**	**0**	**0**	**7**	**-0.001**
Heat Stress (not used)					
Dry Stress (not used)					
Wet Stress					
SMWS	**HWS**				
0.7	**0.03**				
Cold-Dry Stress (not used)					
Cold-Wet Stress (not used)					
Hot-Dry Stress (not used)					
Hot-Wet Stress (not used)					
Day-degree accumulation above DV0					
DV0	**DV3**	**MTS**			
7	**32**	**7**			
Day-degree accumulation above DVCS					
DVCS	***DV4**	**MTS**			
12	**100**	**7**			
Day-degree accumulation above DVHS					
DVHS	***DV4**	**MTS**			
35	**100**	**7**			

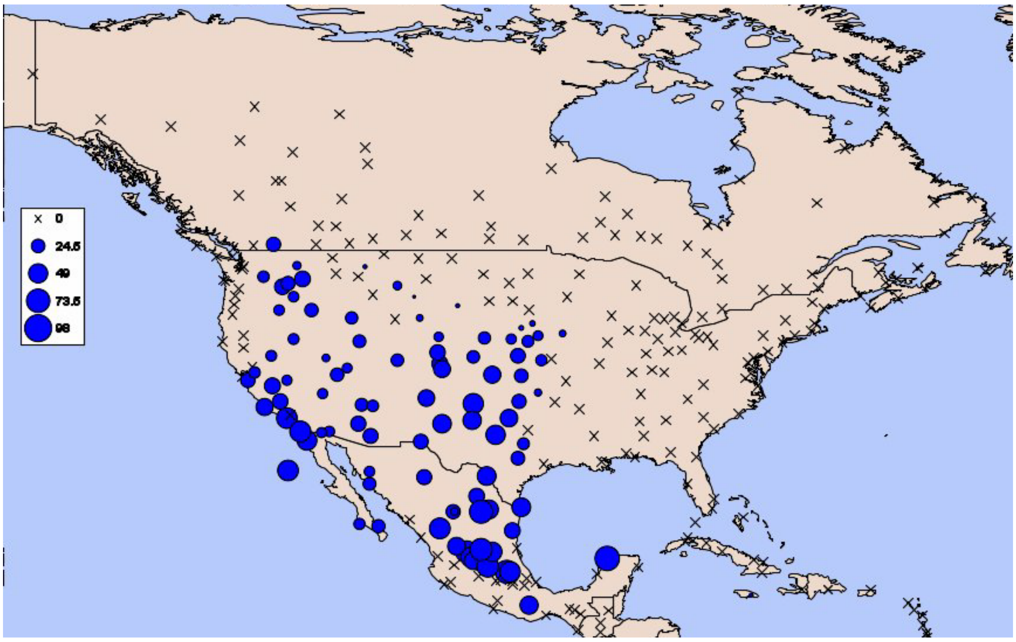


Fig. 1 Potential distribution of *Bactericera cockerelli* in Northern America based on the parameters set in Table 1. The dots represent the Ecoclimatic index (EI). An EI>35 is very favourable for establishment

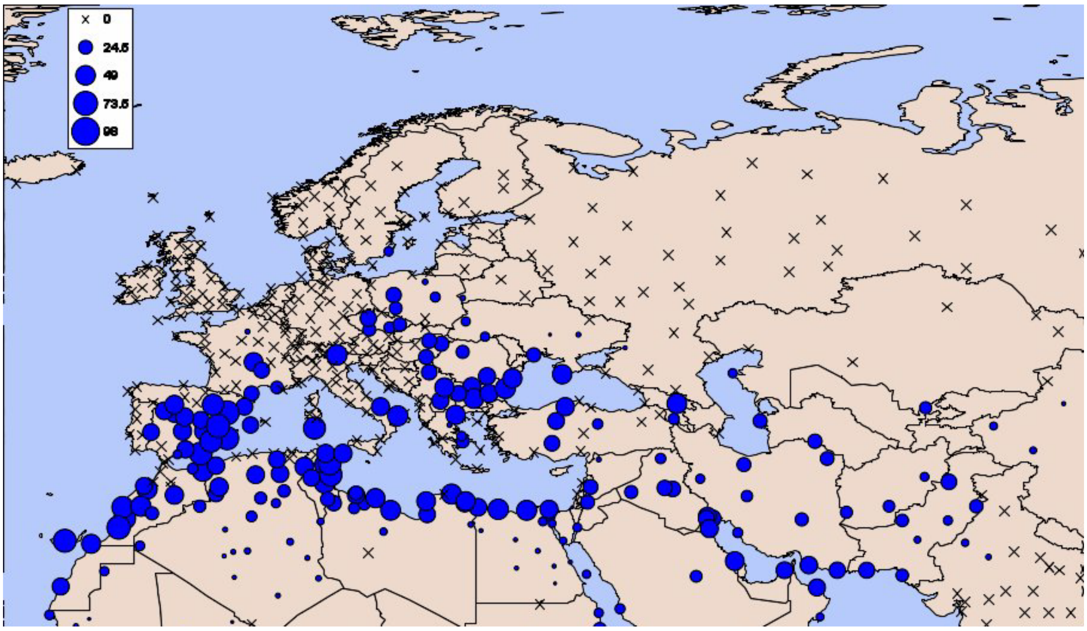


Fig. 2 Potential distribution of *Bactericera cockerelli* in the EPPO region with the parameters set in Table 1
The dots represent the Ecoclimatic index (EI). An EI>35 is very favourable for establishment

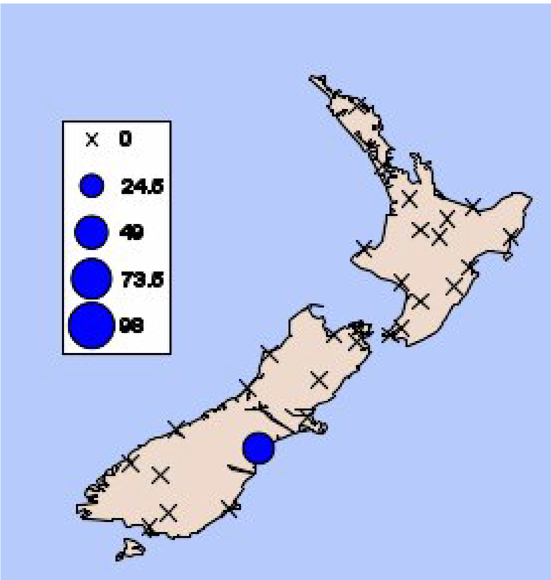


Fig. 3 Potential distribution in New-Zealand with the parameters set in Table 1.

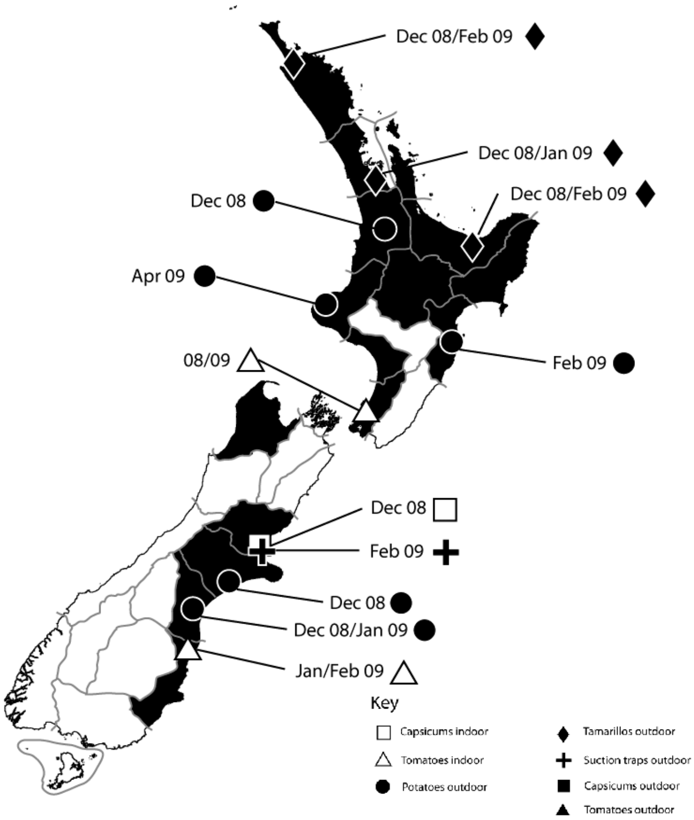


Fig. 4 *Bactericera cockerelli* distribution in New-Zealand according to Teulon *et al.*, 2009.

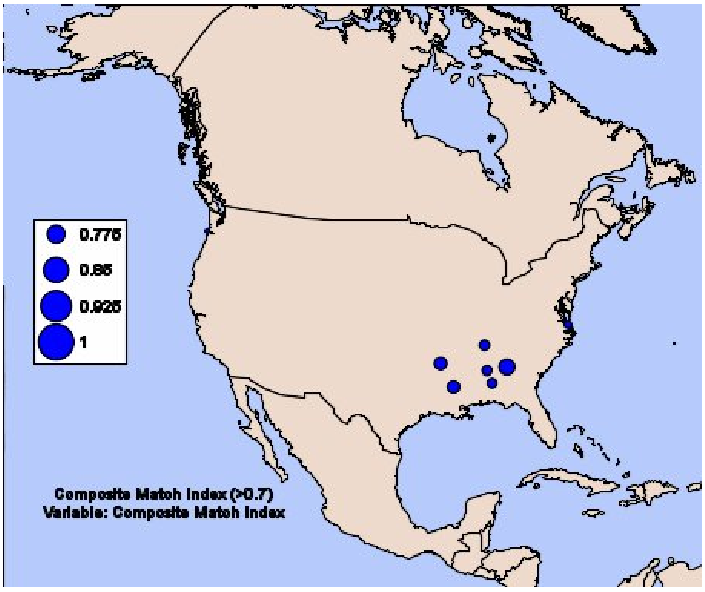


Fig 5. Comparison of climate between Auckland – NZ (where *B. cockerelli* is recorded) and North America

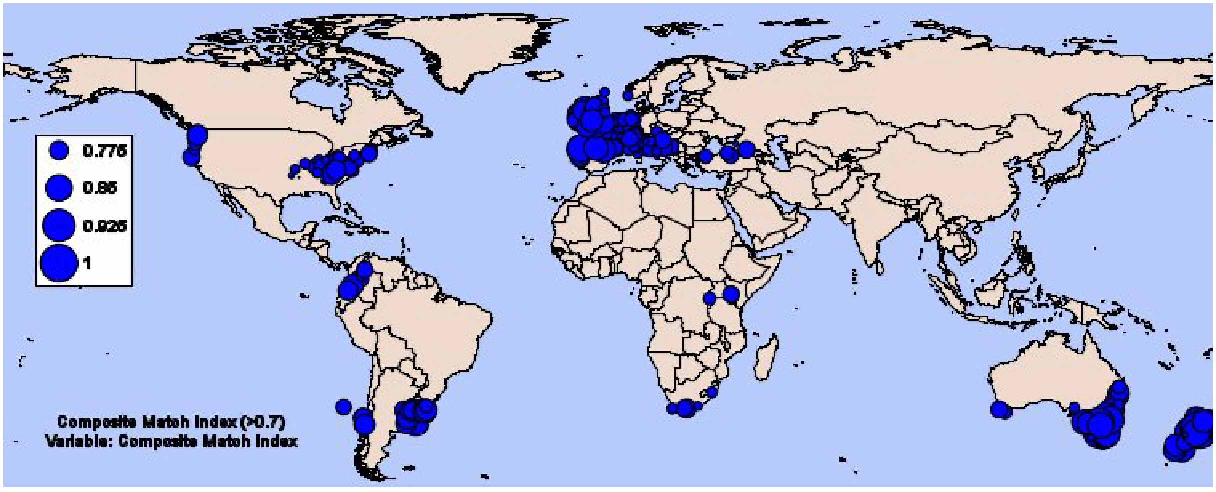


Fig 6. Comparison of climate between Palmerston North – NZ (where *B. cockerelli* is recorded) and the climate worldwide.

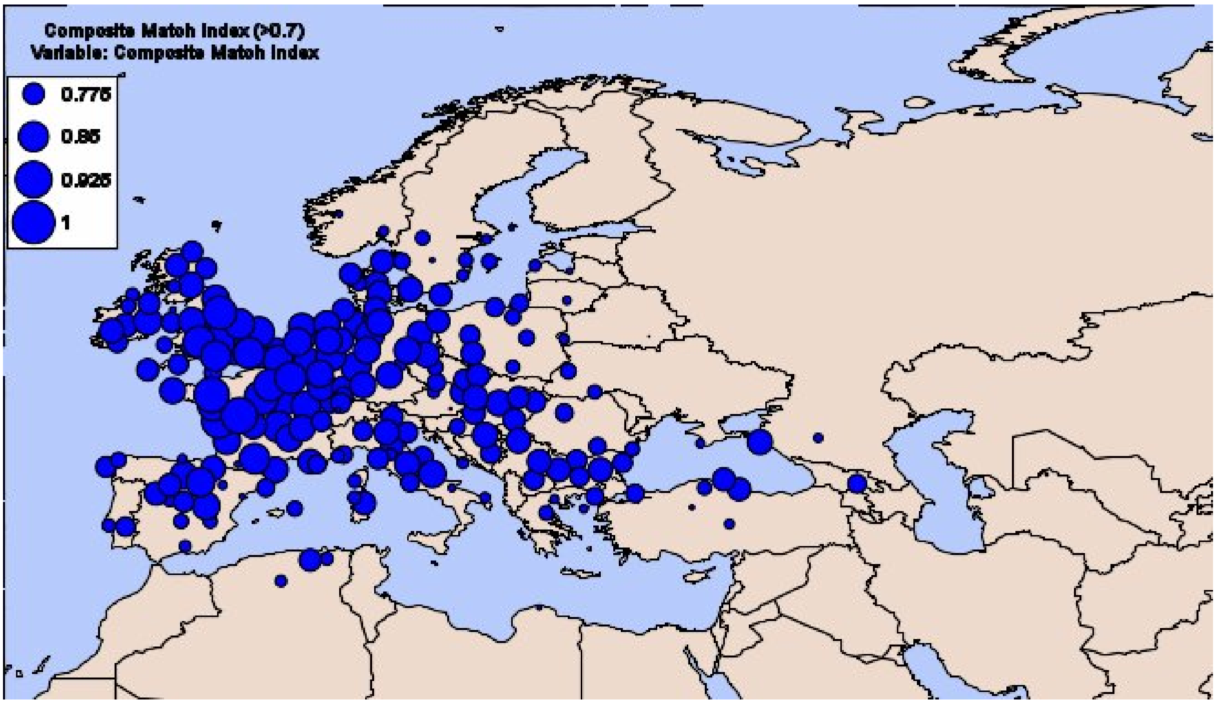


Fig 7. Comparison of climate between Christchurch – NZ (where *B. cockerelli* is recorded) and Europe

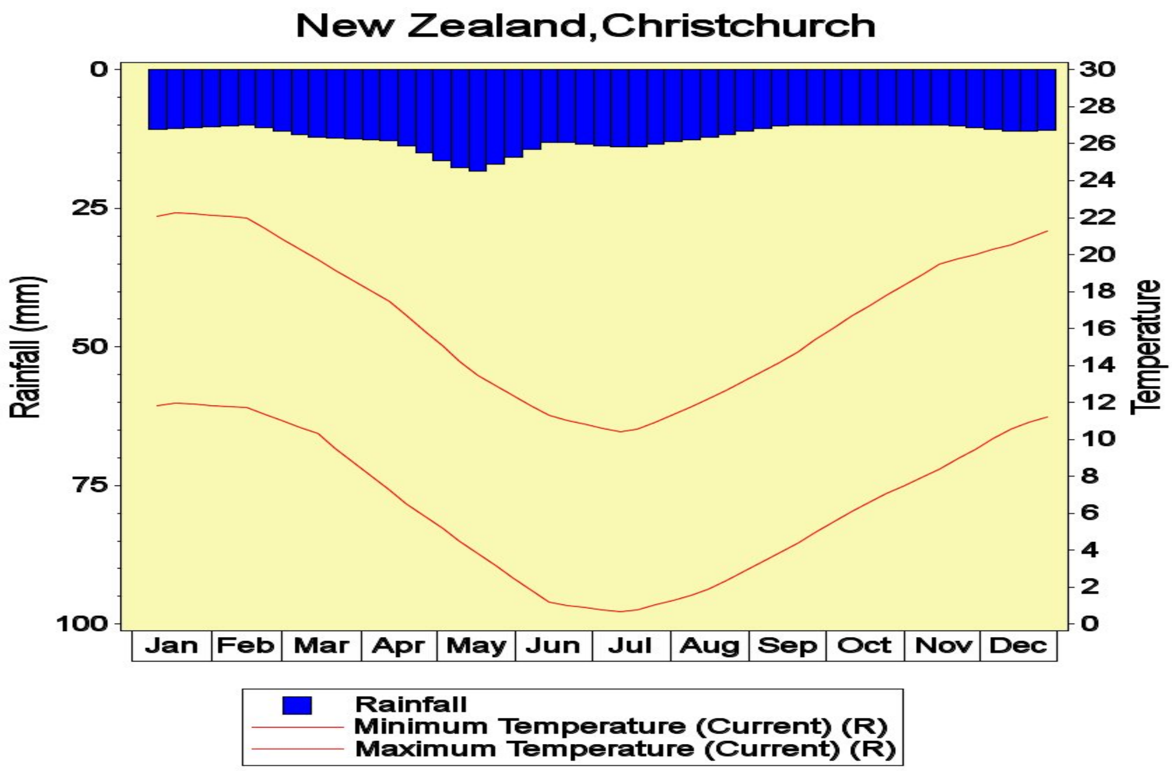


Fig 8. Climatic chart (rainfall and minimal and maximal temperature) for Christchurch, NZ.

Table 2: Parameters used in CLIMEX to estimate the potential distribution of *Bactericera cockerelli (adjusted from Table 1 on the basis of the distribution in New Zealand; modified parameters are highlighted in yellow.)*

Moisture Index					
SM0	**SM1**	**SM2**	**SM3**		
0	**0.1**	**0.7**	**1.2**		
Temperature Index					
DV0	**DV1**	**DV2**	**DV3**		
7	**16**	**30**	**32**		
Light Index (not used)					
Diapause Index (not used)					
Cold Stress					
TTCS	**THCS**	**DTCS**	**DHCS**	**TTCSA**	**THCSA**
0	**0**	**0**	**0**	**7**	**-0.001**
Heat Stress (not used)					
Dry Stress (not used)					
Wet Stress (not used)					
Cold-Dry Stress (not used)					
Cold-Wet Stress (not used)					
Hot-Dry Stress (not used)					
Hot-Wet Stress (not used)					
Day-degree accumulation above DV0					
DV0	**DV3**	**MTS**			
7	**32**	**7**			
Day-degree accumulation above DVCS					
DVCS	***DV4**	**MTS**			
12	**100**	**7**			
Day-degree accumulation above DVHS					
DVHS	***DV4**	**MTS**			
35	**100**	**7**			

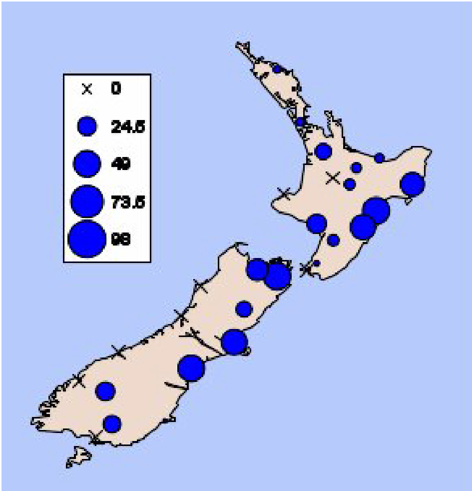


Fig. 9 Map of distribution of *Bactericera cockerelli* in New Zealand with the parameters set in Table 2.

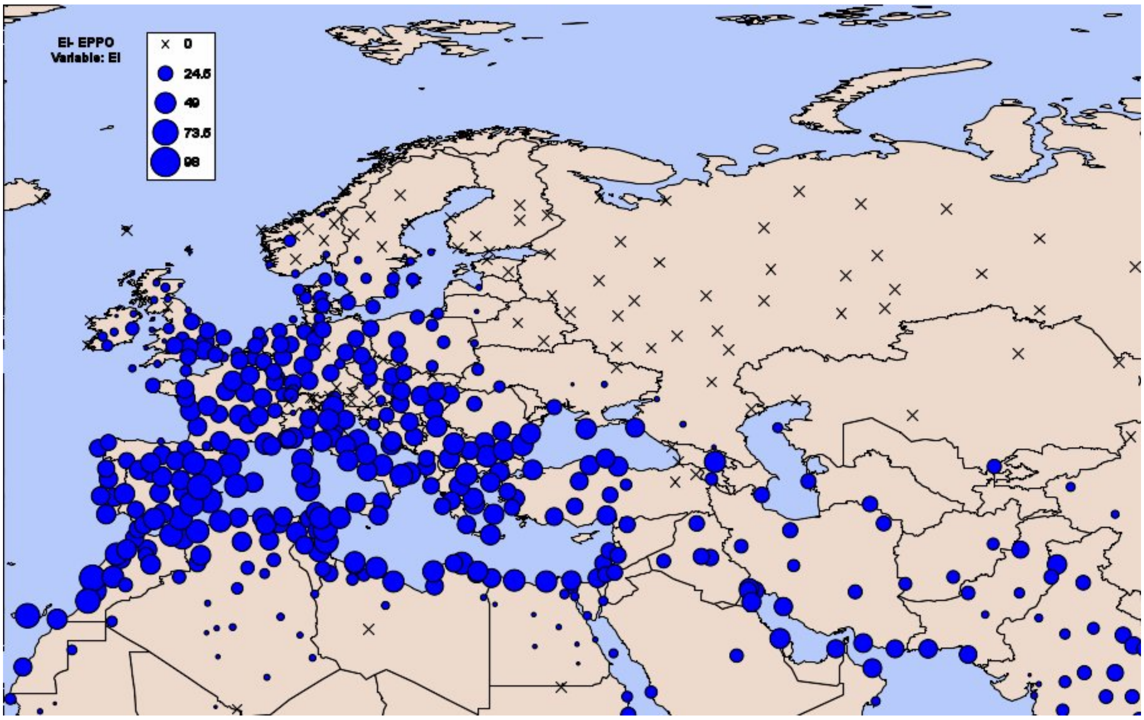


Fig. 10 Map of potential distribution of *Bactericera cockerelli* in the EPPO region with the parameters set in Table 2
The dots represent the Ecoclimatic index (EI). An EI>35 is very favourable for establishment

ANNEX 8. Economic impact assessment

A risk assessment model: Candidatus Liberibacter Solanacearum in the EU

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Abstract
Candidatus Liberibacter Solanacearum is a new bacterial species that has been found in association with serious diseases of tomatoes, potatoes and other solanaceous crops observed in the Americas, and recently discovered in New Zealand. Its potential for high yield and export loss and possibility of wide spread by a suitable vector underpin its high risk. In this risk assessment, we used economic models, GIS and expert opinion to determine the host distribution, potential pest spread, and economic consequences in the EU-25 in the case of an outbreak if governmental regulation is not applied. Data for the potato distribution and production in the EU-25 was obtained from a previous EU project called SEAMLESS. In this assessment we estimate the economic impact on potato based on a hypothetical scenario where the vector is introduced but doesn't show a migratory behavior to the South and accordingly the cold northern parts of Europe is not affected by the disease as the vector cannot overwinter there. Southern regions of Europe were highlighted as risk areas. The expected infested area (prevalence and incidence of the disease) estimated by the experts was 3.15% of the potato area in the EU. The total direct impact (i.e. yield loss and additional control costs) was estimated by 69 M €. Economic analysis, partial equilibrium modeling, showed that the majority of the impact will be borne by the consumers rather than the producers. Due to lack of accurate information about exact yield loss-population densities-climatic conditions relationships, pest spread, additional control costs and other biological information about the bacteria, uncertainty analysis were carried for direct and indirect impacts where we use Monte-carlo simulation. In the uncertainty analysis, two parameters, infested area and yield losses, in the economic model were considered stochastic. Uncertainty analysis showed that direct impact could range between 34 M € (best case scenario) and 188 M € (worst case scenario) with a mean of 98 M €

I. Introduction
This document presents a pest risk assessment for Candidatus Liberibacter Solanacearum. The risk assessment area considered in this document is the territory of the European Union (EU-25). Romania and Bulgaria were not included due to unavailability of data. The assessment includes identifying the value of assets at risk (i.e. potato), potential pest spread (i.e. prevalence and incidence) and potential economic consequences.

II. Data and methodology
The risk assessment model is a model for calculating EU level economic impacts of invasion of a novel pest into the EU, based on a spatially explicit information on the vulnerability of receptor environment (integrating climate suitability and host availability), qualitative information for pest spread (i.e. expert opinion on the expected infested area) and economic modeling (using partial budgeting and partial equilibrium techniques) that calculate the economic impacts (Soliman *at al.*, 2011).

a. Data
SEAMLESS[18] database (Janssen *at al.*,2009) was used to obtain the data required for establishment. SEAMLESS divide Europe into 12 environmental zones, where for each zone basic climatic parameters are provided (e.g. monthly temperature) and host information (e.g. area in ha., production in tonnes, and value of production in euros). Infested area (incidence and prevalence) was elicited from the experts of the EWG (Table 2)
Data of the partial equilibrium model was obtained from FAO statistics

b. Spatial resolution of the model
The model has three resolution (from coarse to fine):
(1) EU-25 (Romania and Bulgaria are not in the EU-25)
(2) Climatic regions (4 regions)
(3) Environmental zones (12 zones).

[18] SEAMLESS is an EU research project which aims to provide a computerized framework to assess the impact of policies on the sustainability of agricultural systems in the European Union at multiple scales. This aim is achieved by combining micro and macro level analysis, addressing economic, environmental and social issues, and facilitating the re-use of models and providing methods to conceptually and technically link different models (Van Ittersum, et al.,2008).

The indirect economic impact (partial equilibrium technique) and uncertainty analysis were done on the EU level, pest spread is estimated on the climatic region scale and direct economic impact (partial budgeting technique) and pest establishment were done on the environmental zone level.

c. Methodology

1. Establishment

The objective of the establishment part is to determine where the pest could get to if it is introduced to Europe. From the establishment section, we can calculate the total value of assets at risk. Experts mentioned that climatic conditions are more important for the vector. If we assume that the vector will not show a migratory behavior then the vector will be able only to establish in the southern and middle parts of Europe and not in the northern part of Europe. Accordingly we exclude the two northern zones of SEAMLESS (i.e. Boreal and Alpine north). These zones have summer temperature of 14.9^{o}C and 13.4^{o}C respectively.

Table 1 shows the 12 environment zones of Europe with the corresponding host information for each zone. For establishment and economic analysis, we consider 10 zones which have higher temperature than 16^{o}C.

Table 1 SEAMLESS zones and its corresponding economic data

ID	Environmental zones	Climatic region	Average temperature	Potato area (ha.)	Production (tons)	Output (€)	Crop protection potato – baseline (€)
1	Continental	North-east	20.1	314,136	9,492,998	949,592,250	44,010,900
2	Pannonian	Central	22.8	17,863	467,564	60,778,350	1,871,291
3	Boreal	North-east	14.9	NA	NA	NA	NA
4	Alpine South	Mediterranean	20.2	10,260	261,560	33,276,150	803,689
5	Mediterranean North	Mediterranean	24.8	70,213	1,739,099	340,809,750	23,053,275
6	Lusitanian	Maritime	21.5	31,373	504,187	94,081,050	15,649,110
7	Mediterranean Mountains	Mediterranean	23.6	18,540	524,585	96,065,325	4,140,788
8	Atlantic Central	Maritime	20.0	715,223	27,045,000	3,730,612,500	180,805,725
9	Nemoral	North-east	17.0	7,475	196,900	30,321,900	474,237
10	Alpine North	North-east	13.4	NA	NA	NA	NA
11	Mediterranean South	Mediterranean	25.9	104,264	2,138,479	552,305,250	44,168,850
12	Atlantic North	Maritime	18.1	436,480	14,964,075	1,729,372,500	77,747,400
	Total			1,725,827	57,334,446	7,617,215,025	392,725,265

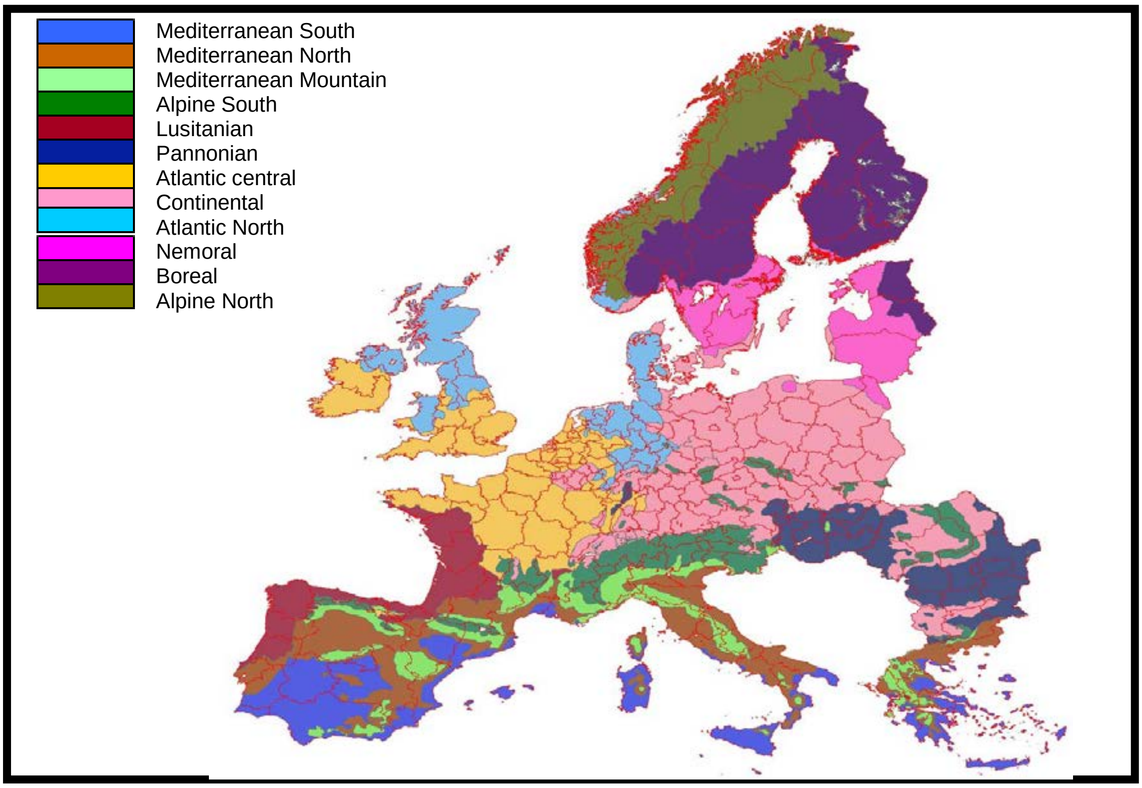

Figure 1 SEAMLESS 12 Environmental zones of Europe

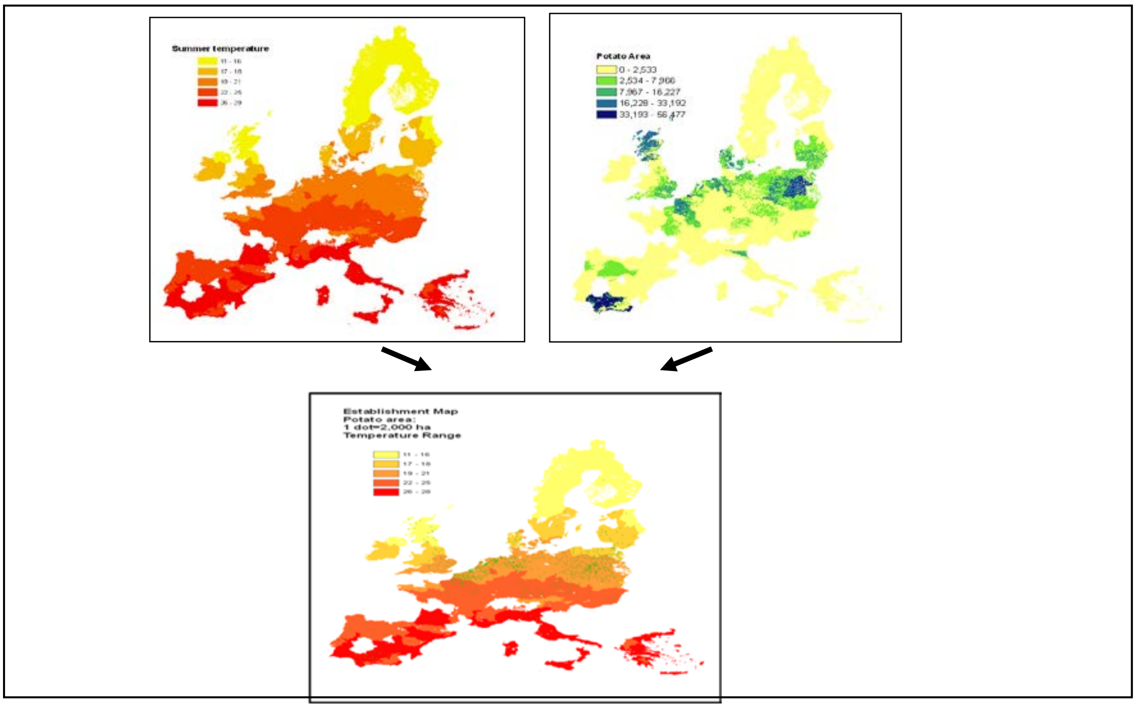

Figure 2: Establishment map, upper left (climate/°C), upper right (potato distribution/ha) and lower (integrated climate-host) – Fine resolution (3,156 zones)

Source: SEAMLESS (Janssen *at al.*,2009)

2. Pest spread

Using expert opinion, we tried to estimate of the expected infestation level of the disease in the EU in the case of an outbreak if regulation was removed. Infestation level is defined through two levels: (1) prevalence and (2) incidence. Prevalence is defined as percentage of potato fields in the EU which is infested by Candidatus Liberibacter solanacearum and incidence is defined as the proportion of potato plants within the field infected by Candidatus Liberibacter solanacearum. To define an outbreak, we consider the following scenario. One percent of the plants for planting of potato within the EU is infected with Candidatus Liberibacter solanacearum. Assume also that the vector, *Bactericera cockerelli*, was introduced to the EU but is not able to overwinter in the northern parts of Europe. Furthermore, we assume that no governmental regulation is imposed to control the pest or its vector. This does not mean that there is no control or containment applied by farmers and traders, but this is done at their own initiative, and not under the requirements of the law. From the infected potato material, the disease can be further transmitted through all available means (human, natural and vector). As a result of transmission, disease incidence could build up over time. We assume that after 5 years a steady state situation may be reached, i.e. the incidence of Candidatus Liberibacter solanacearum does not change any more in time.

The experts provide an estimation of the expected infestation (i.e. prevalence and incidence) level. Their uncertainty was quantified through a triangular distribution where the minimum and maximum values are those incidence values that according to their expertise bracket the range of possible outcomes of the scenario. The 12 environmental SEAMLESS zones were aggregated into 4 climatic regions. Infestation level was estimated by 3.15% of the EU. Figure 3 shows the 4 aggregated climatic zones used for infestation level.

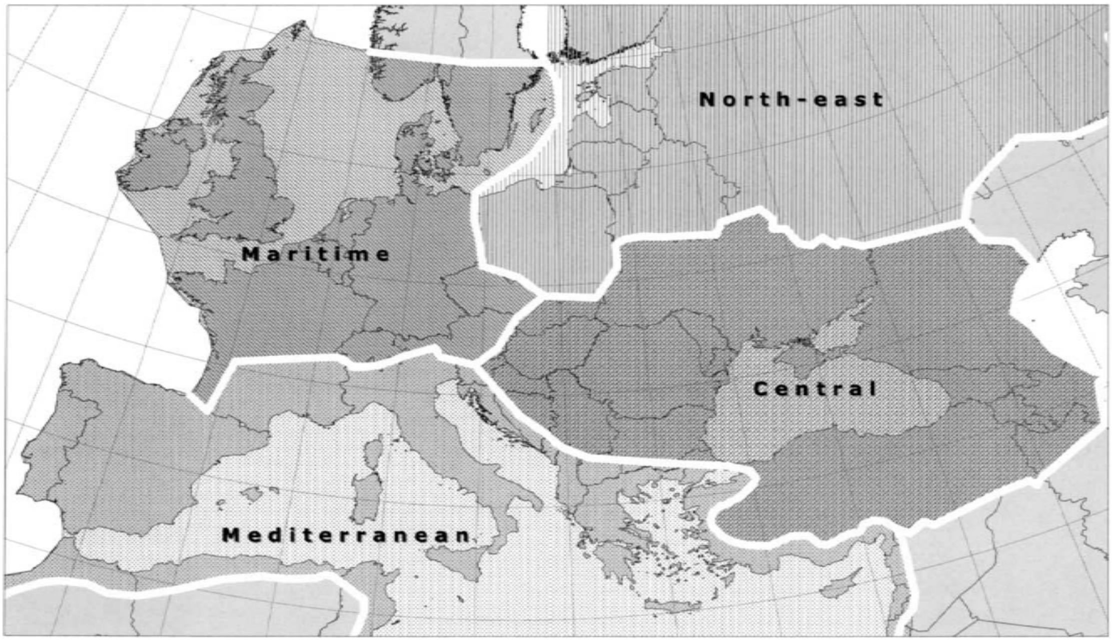

Figure 3 Map of the Climatic regions

Table 2 Estimated infestation level in the EU

Infestation/scenarios	**Best case scenario**	**Most likely scenario**	**Worst case scenario**
Prevalence level **1. Mediterranean** **2. Maritime** **3. Central** **4. North east**	1. 20% 2. 0% 3. 5% 4. 5%	1. 25% 2. 3% 3. 15% 4. 15%	1. 50% 2. 7% 3. 30% 4. 30%
Incidence level in each field **1. Mediterranean** **2. Maritime** **3. Central** **4. North east**	1. 5% 2. 0% 3. 3% 4. 3%	1. 40% 2. 5% 3. 25% 4. 25%	1. 80% 2. 10% 3. 50% 4. 50%

3. Economic impacts

Economic impact consists of direct (host related) and indirect (non-host related) impacts. The economic analysis consisted of two techniques to determine the economic impact (Soliman *at al.*,2010).

1. The partial budgeting technique (PB) to estimate the direct impact and to obtain insight in the distribution of losses within EU and

2. Partial equilibrium modeling (PE) to estimate the change in social welfare, resulted from direct and indirect impact, on EU level by considering the mitigation and adaption efforts done by the producers.

a. Partial budgeting (Direct impact)
Direct impact is the host related impact such as yield/quality losses and addition production cost (e.g. protection cost). Partial budgeting technique is used to estimate the direct impact. In the PB technique, the estimated direct impact is a probability-weighted sum of the change in margin, calculated as decrease in product value plus increase in costs:

$$T = \int \int g(\upsilon)\, f(x)\, (\Delta v(\upsilon,x) + \Delta c(\upsilon,x)\, d\upsilon\, dx \qquad (1)$$

where T is the total direct economic impact, $f(x)$ is the probability density function of area infested x, $g(\upsilon)$ is the probability density function of pest density υ , ΔV is the change in product value (quantity and quality effects) at an area of x and a pest density of υ and ΔC is the cost increase, relative to 'no pest invasion' scenario, at area infested x and pest density υ. Therefore, the changes in value and costs depend on the infested area and pest density, which is a function of x and υ.

Literature showed a variation in yield losses estimation. For potato, Liefting *at al.* (2008) estimate yield loss by 60% in 2007, while Tuelon *at al.* (2009) report that some potato growers had minor losses probably due to other pesticide applications against other pests having kept populations down. Yield loss was estimated in NZ in 2008-09 by 25-40%.

We assumed a linear relationship between temperature and yield loss, where at 16^{o}C yield loss is zero (pest survive but didn't show yield loss yet), then increasing by 10% with each 2 degrees, reaching 60% yield loss at 28^{o}C. We assumed also that protection cost will increase by 10%

b. Partial equilibrium (Direct and Indirect impact
Indirect impact is the non-host related impacts. Partial equilibrium technique is used to account for the direct and indirect impact. The partial equilibrium technique accounts for mitigation (e.g. producers set higher prices to pass part of the negative impact to the consumers) and adaptation (e.g. adjust the production practices to reduce the negative impact of the pest) effects taken by the producers. Therefore, the results of the partial equilibrium technique doesn't account only for impact on producers but it extend it to the consumers by taking into account mitigation and adaptation possibilities and therefore avoiding the overestimation of the impact estimated by the partial budgeting technique.

Setup of the partial equilibrium model
Two markets are distinguished, domestic market (EU) and foreign market (Rest of the World). Supply and demand are presented in the domestic market, where demand depends on domestic price and consumer behavior. The domestic supply is divided between affected producer and non-affected producers, where supply of affected producer depends on domestic price, producer behavior and is also determined by the proportion of farmers that is not affected by the pest, while affected producers depends furthermore on the proportional yield loss, caused by the disease, and by the reduced net price for the product that affected farmers experience as a result of increased costs of production. Furthermore, price in the domestic and world market are linearly related. Trade balance between domestic and foreign markets is expressed by the excess supply (demand) resulted from the difference between domestic supply and demand, which should be equal to excess demand (supply) in the foreign market. The excess demand (supply) of foreign market in return will depend on world price and foreign consumer (producer) behavior.

We assume that (1) crop products in the EU and in ROW are perfect substitutes and their respective prices differ only by the transportation costs and tariffs, (2) the domestic market for the potentially affected commodity is perfectly competitive, implying product homogeneity and, (3) the contribution of domestic producers of that affected commodity to the total world supply is insufficient to exert influence on the world price, the exchange rate and domestic markets for other commodities. The demand and supply in the EU are given by equations 3a-3g (Surkov *at al.*, 2009).

The first equation (3a) describes the demand (D_i) in the domestic market as a function of domestic price (P_i).

$$D_i = \chi_i P_i^{-\eta_i} \qquad (3a)$$

Where η_i is the price elasticity of demand and χ_i is scale parameter. The supply in the domestic market has two components (equation 3b): supply by affected farmers (SA_i) and supply by non-affected farmers (SN_i).

$$S_i = SA_i + SN_i \qquad (3b)$$

The supply by non-affected farmers (SN_i) depends on the price P_i, with supply elasticity ϑ_i and scale parameter β_i, and is also determined by the proportion of farmers that is not affected by the pest (1-z):

$$SN_i = \beta_i P_i^{\theta_i}(1 - z_i) \qquad (3c)$$

The supply by affected farmers (*SA_i*) depends furthermore on the proportional yield loss, h_i, caused by the disease, and by the reduced net price for the product that affected farmers experience as a result of increased costs of production v_i (e.g. for control or sanitation) (3d):

$$SA_i = (1 - h_i)\beta_i (v_i P_i)^{\theta_i} z_i \qquad (3d)$$

Price in the domestic and world market are linearly related where μ_i represents, e.g. transport costs or tariffs (3e):

$$P_i = WP_i + \mu_i \qquad (3e)$$

The equilibrium condition for international trade is expressed by two equation, 3f and 3g. The first of these (3f) calculates export or import (X_i) as a difference between domestic supply and demand

$$X_i = S_i - D_i \qquad (3f)$$

The second equation (3g) expresses the relationship between international trade and world price (WP_i), where υ_i is a scale parameter, α_i is the proportion of the banned export and ω_i is export/import elasticity.

$$X_i = \upsilon_i \alpha_i (WP_i)^{\omega_i} \qquad (3g)$$

Inputs for partial equilibrium model presented in table 3

Table 3 Parameters for the partial equilibrium model

Parameter	Seed	Ware	Total potato
Production	5,988,000	57,575,011	63,563,011
Imports	3,407	1,388,150	1,391,557
Total supply	**5,991,407**	**58,963,161**	**64,954,568**
Consumption	5,122,736	56,899,161	62,021,897
Exports	868,671	2,064,000	2,932,671
Total demand	**5,991,407**	**58,963,161**	**64,954,568**
Producer price (€/tonne)	346[a]	147	---
World price (€/tonne)	400[a]	181	---
Supply elasticity	0.15[a]	3.2[b]	---
Demand elasticity	-1[a]	-0.5[d]	---
Excess demand (Export) elasticity	-0.7[f]	-3.4 [f]	---
Excess supply (Import) elasticity	---	---	---

** source: FAO(2003)*
[a] Breukers et al. (2008)
[b] SEAMLESS
[c] Chern and Just (1978)
[d] Gorter (1992); Bunte et al.(0000)
[e] Yen et al. (2004); Balestrieri (1983)
[f] own calculation

III. Results

1. Establishment

Total value of assets at risk was estimated by 7,617 M €

2. Economic impacts

a. Partial budgeting model

Table 4 shows the deterministic results of the partial budgeting method. The results shows that the Mediterranean region has the highest risk. It was expected that central region also could have some high risks, however, due to the data coverage is only for the EU-25, so Romania and Bulgaria are not included. This leads to a lower risk for that region.

Table 4 Direct impact (yield loss and control cost) per climatic zone (€)

	min	most likely	max
1. Mediterranean	6,761,346	67,613,457	270,453,829
2. Maritime	0	1,455,000	6,790,002
3. Central	32,189	804,733	3,218,933
4. North east	2,345	58,632	234,528
Total	6,795,880	69,931,823	280,697,291

b. Partial equilibrium model

The model was based on the most likely scenario of the pest spread (i.e. aggregated incidence level of 3.15% on the EU level). The results showed that domestic Supply of ware and seed potatoes (affected and non-affected producers) will decrease by 0.23% and 0.93% respectively, which will increase the domestic market price by 0.44% and 0.99% respectively, and this domestic price increase will drive the domestic demand to decrease by 0.22% and 0.99% respectively. The shortage in domestic supply will be covered by a decrease in the exports which account for 1.23% and 0.59% respectively. At the same time, the increase in domestic price will trigger an increase in the world price by 0.36% and 0.85% respectively.
The majority of the negative impact will be borne by the consumers. Therefore the consumer surplus for ware and seed potato will decrease by 37 and 17 M € respectively, while the net impact on producers (affected and non-affected) is minor due to increase in price which compensate the yield reduction resulted from the pest. The ware producer surplus increased by 1.1 M € while seed producers surplus decreased by 2 M €.

IV. Uncertainty analysis

Partial budgeting

We repeat the same calculation but letting the infested area variable to be stochastic (i.e. triangular distribution with min, most likely and max values mentioned in table 2), then by using Monte-carlo simulation of 500 replicate (figure 4), the result shows a variation between 34 and 188 M € with a mean of 98 M €, standard deviatioin 27 M €, mode 88 M and median 96 M €.

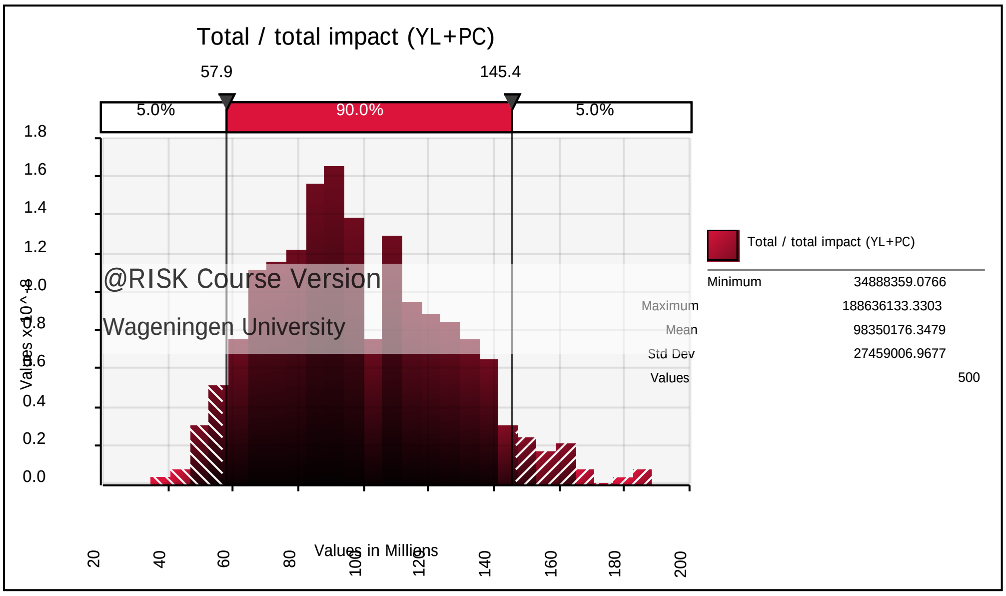

Figure 4 Monte-carlo simulation for direct impact

Partial equilibrium

A triangular distribution for the incidence level on the EU level was aggregated based on the min, most likely and max values estimated by the experts on the climate zone level. The values for the triangular distribution were min=0.3%, most likely=3.15% and max=12.69%. We assume that yield loss will follow a triangular distribution of min=25%, most likely=30% and max=60%. A 500 iterations was used to generate the results. The results of Monte-carlo simulation showed that the impacts could range from 13 to 215 M € in the EU.

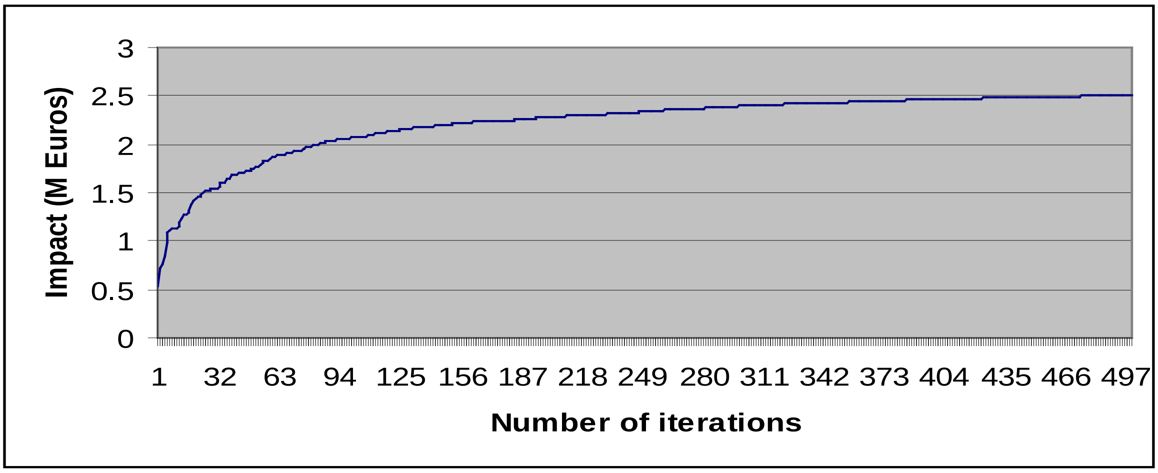

Figure 5 Positive impact on producer of ware potato

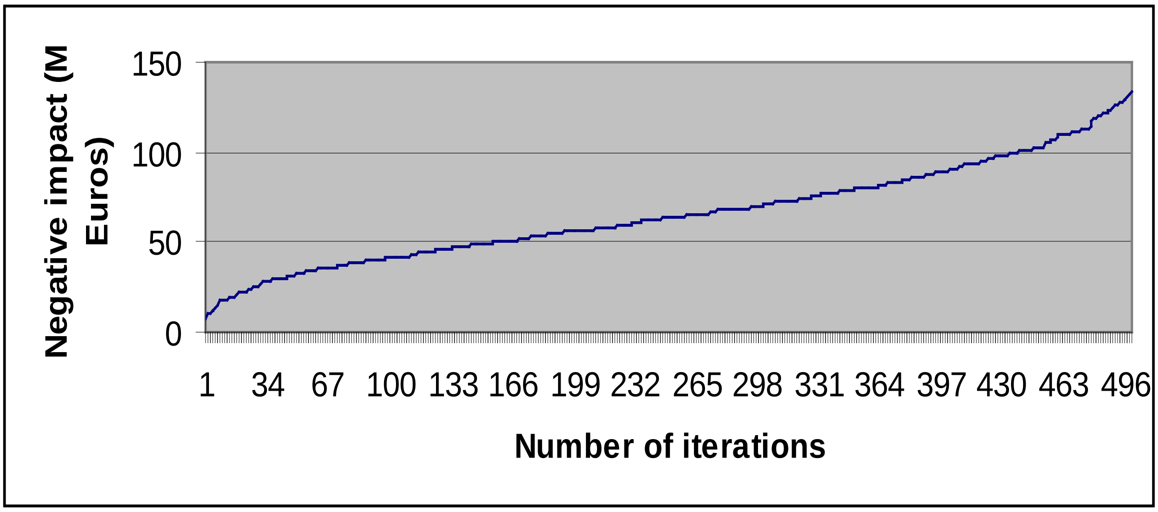

Figure 6 Negative impact on consumer of ware potato

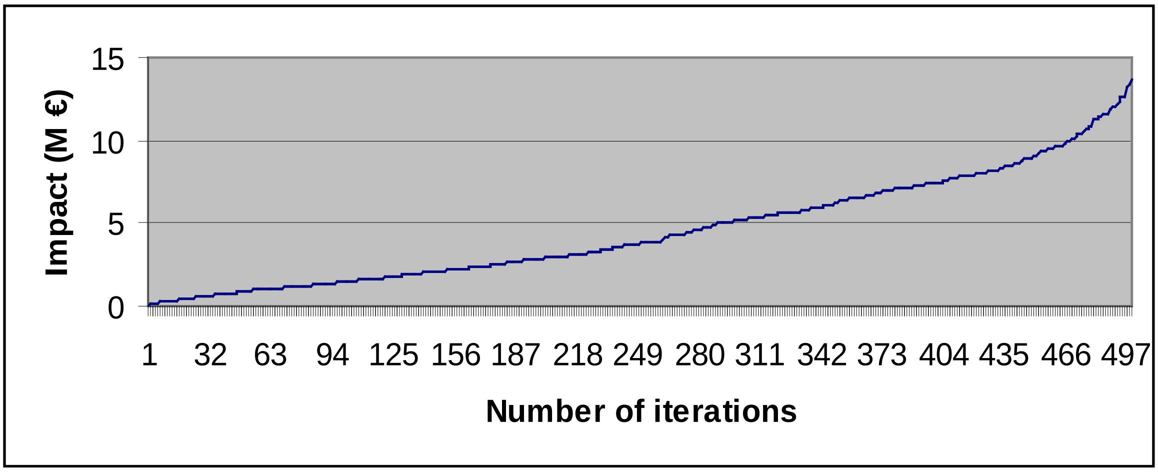

Figure 7 Negative impact on producer of seed potato

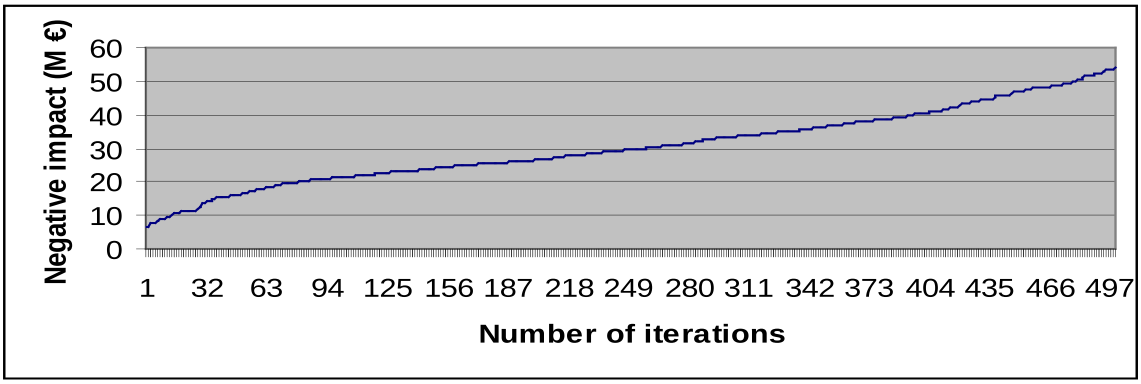

Figure 8 Negative impact on consumer of seed potato

V. Conclusion

The potential establishment for *Candidatus* Liberibacter Solanacearum seems to vary depending on the crops and vectors concerned. For our risk assessment, concedering only potato and assuming that potato psyllid (i.e. *B. cockerelli*) is introduced along with the bacterium, and the vector will not show a migratory behavior to the south, we expect that zebra chip disease will show in all Europe expect the northern parts with the very cold climate despite that the bacterium can establish everywhere in Europe. This is because the vector will not be able to overwinter in these northern regions. The highest wide spread of the disease is expected in the Mediterranean region of the EU. North east of Europe and central regions are expected to have a similar range of spread and then the lowest spread of the disease is expected in the Maritime region. The resulted economic direct impact is expected to be around 70 M €, however due to high uncertainty in the infestation level, yield losses and control costs, a wide boundary of impacts were estimated from 34 to 188 M € in the EU, with a mean of 98 M € and standard deviation of 27 M €, mode 88 M and median 96 M €. We expect that the majority of the negative impact will be borne by the consumers rather than the producers.

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