Ministry for Primary Industries
Manatū Ahu Matua

2015 Pest Risk Assessment: '*Candidatus* Liberibacter solanacearum' associated with imported carrot seeds for sowing

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Growing and Protecting New Zealand

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Cover photo

Carrots with and without symptoms of '*Candidatus* Liberibacter solanacearum' (Lso): Lso symptomatic carrots with leaf discoloration (left); Lso symptomatic carrots with leaf curling (middle); healthy carrots (right). Note the size reduction in carrot roots. Photo credit: Joe Munyaneza, USDA.

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New Zealand is a member of the World Trade Organisation and a signatory to the Agreement on the Application of Sanitary and Phytosanitary Measures ("The Agreement"). Under the Agreement, countries must base their measures on an International Standard or an assessment of the biological risks to plant, animal or human health.

This document provides a scientific analysis of the risks associated with '*Candidatus* Liberibacter solanacearum' associated with the imported carrot seeds for sowing pathway. It assesses the likelihood of entry, exposure, establishment and spread of the bacterium in relation to imported seeds for sowing and assesses the potential impacts of the organisms should it enter and establish on carrot in New Zealand. The document has been internally and externally peer reviewed and is now released publically. Any significant new science information received that may alter the level of assessed risk will be included in a review, and an updated version released.

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EXECUTIVE SUMMARY

'*Candidatus* Liberibacter solanacearum' (Lso) was identified by rapid risk assessment through the Ministry for Primary Industries (MPI) emerging risk system as an organism that may require risk management on the imported carrot seed pathway (PP 14-130). This formal risk assessment has been prepared to support risk management decisions for the pathway.

The risk assessment is carried out in relation to the imported carrot seed pathway, from all countries. It addresses haplotypes C, D and E of '*Ca*. Liberibacter solanacearum' on carrot seed and other members of the Umbelliferae (Apiaceae) family. Known insect vectors overseas and potential insect vectors in New Zealand are considered because they may affect the level and type of impacts including the likelihood of transmission to novel hosts.

The overall risk estimation is negligible for imported carrot seed for sowing if Lso is not transmitted by seed of carrot (Table 1). The overall risk estimation is non-negligible if Lso is seed transmitted (Table 1); however, there is insufficient evidence to date that this pathway occurs. Uncertainty (unquantified) remains because the evidence for seed transmission has not yet been independently verified, with the issue still under discussion and investigation by international researchers. This uncertainty needs to be considered by risk managers, along with the likely low consequences of establishment and the likely lack of vectors in New Zealand, to make a decision as to whether the risk warrants risk management (Figure 1). New scientific information on seed transmission of Lso in carrots or celery, however, may warrant reassessment of the risk.

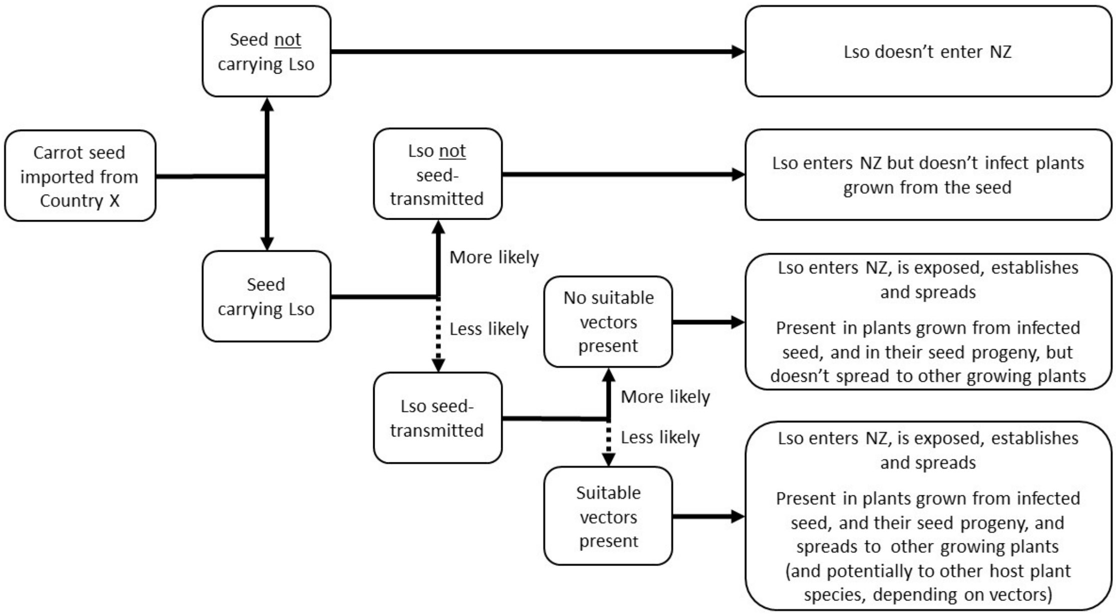

Figure 1. Scenario tree for establishment of '*Candidatus* Liberibacter solanacearum' in New Zealand as a result of importation of carrot seed for sowing.

Table 1. Summary of risk assessment for '*Candidatus* Liberibacter solanacearum' on carrot seed for sowing from all countries.

Species	Likelihood of:				Consequences of establishment:				Risk estimation on seed of carrot
	Entry	Exposure	Establishment	Spread	Economic	Environmental	Socio-cultural	Human health	
'*Candidatus* Liberibacter solanacearum' IF NOT seed-transmitted	High	Negligible	–	–	–	–	–	–	Negligible
'*Candidatus* Liberibacter solanacearum' IF seed-transmitted	High	High	High	High	No vectors: Low Vectors: Low (but more impact than without vectors) Uncertainty because consequences could be higher if other plant species affected.	No vectors: Negligible Vectors: Low (uncertain)	Negligible–low	Negligible	Non-negligible

1.1 '*CANDIDATUS* LIBERIBACTER SOLANACEARUM'

Scientific name: '*Candidatus* Liberibacter solanacearum'
(Alphaproteobacteria, Rhizobiales, Rhizobiaceae)

Synonym: '*Candidatus* Liberibacter psyllaurous'

Abbreviations: Lso, Clso

Common name: zebra chip (disease of potatoes)

1.2 PURPOSE

'*Candidatus* Liberibacter solanacearum' was identified by rapid risk assessment through the Ministry for Primary Industries (MPI) emerging risk system as an organism that may require risk management on the imported carrot seed pathway (PP 14-130). This formal risk assessment has been prepared to support risk management decisions for the pathway.

1.3 SCOPE

This risk assessment is carried out in relation to the imported carrot seed pathway, from all countries. It addresses haplotypes C, D and E of '*Ca*. L. solanacearum' on carrot seed and other members of the Umbelliferae (Apiaceae)[1] family.

Although celery has recently been reported as a host for '*Ca*. L. solanacearum', there is little information available to warrant a risk assessment on the imported celery seed pathway. Information relating to celery is provided where available in the risk assessment; however, the risk estimate conclusion in this risk assessment is for the imported carrot seed pathway. Risk managers may consider this conclusion when making risk management decisions for imported celery seed.

Known insect vectors overseas and potential insect vectors in New Zealand are considered because they may affect the level and type of impacts including the likelihood of transmission to novel hosts.

1.4 HAZARD IDENTIFICATION

1.4.1 Description

'*Candidatus* Liberibacter solanacearum' is an unculturable bacterium that lives in the phloem of its plant hosts causing disease on plants in the families Solanaceae and Umbelliferae. It is vectored by psylloids[2] which feed on the phloem contents.

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[1] Apiaceae is given as a synonym for Umbelliferae in the New Zealand Flora. Apiaceae is used at times in this risk assessment as it is widely used in the literature accessed.

[2] Psylloids are members of the superfamily Psylloidea. The superfamily contains several families including Psyllidae and Triozidae. Members of the Psyllidae (e.g., *Diaphorina citri*) are known as psyllids and members of the Triozidae (e.g., *Trioza erytreae*) are known as triozids.

1.4.2 Taxonomic issues

'*Candidatus* Liberibacter solanacearum' is thought to be the causal organism of diseases that affect plant species in the families Solanaceae and Umbelliferae. This species is a phloem-limited bacterium-like organism which has not been cultured on artificial media and can only survive within the phloem in the vascular system of a plant and inside its insect vector.

Candidatus is the name used for bacterial species that have not yet been successfully cultured. New names are assigned to the bacteria once they have been cultured and taxonomically described.

Liberibacters have been discovered relatively recently, with those associated with the devastating citrus disease huanglongbing (or citrus greening) the first to be recognised. There are six known species: '*Candidatus* Liberibacter americanus', '*Candidatus* Liberibacter africanus', '*Candidatus* Liberibacter asiaticus', *Candidatus* Liberibacter europaeus', '*Candidatus* Liberibacter solanacearum' and *Liberibacter crescens*.

The species names for liberibacter can be abbreviated to '*Ca*. L. sp.' (e.g., '*Ca*. L. solanacearum') and the species are frequently represented by the following abbreviations: Lam, Las, Laf, Leu, Lso (or Clam etc). This assessment will use Lso for '*Ca*. L. solanacearum'.

Several haplotypes (A, B, C, D, and E) have been recognised within Lso. These haplotypes are differentiated by single nucleotide polymorphisms (SNPs) in their 16S (5 SNPs), 16S/23S intergenic spacer region (11 SNPs) and 50S rRNA genes (25 SNPs). Haplotypes A and B have been found in association with Solanaceae in North and Central America and in New Zealand (haplotype A only) (Nelson et al. 2011; Nelson et al. 2013). Haplotypes C, D and E have been found more recently in Europe and Africa in relation to carrots and celery (Umbelliferae) (Nelson et al. 2013, Teresani et al. 2014).

1.4.3 Exporting country status

According to the import health standard IHS 155-02-05 Importing seeds for sowing, importation of carrot seed is permitted from all countries. Records from Quancargo (accessed 22/09/2014) show that since 1999 carrot seed (*Daucus carota*) has been imported from the following countries[3]:

> *Europe:* Denmark, France, Germany FDR, Italy, Netherlands, Russian Federation, United Kingdom;
> *Asia:* Bangladesh, China, Hong Kong, India, Japan, South Philippines, Singapore, South Korea, Thailand, UAE (United Arab Emirates);
> *Americas:* Brazil, USA, Venezuela;
> *Oceania:* Australia.

According to IHS 155-02-05 Importing seeds for sowing, importation of celery seed is permitted from all countries. Records from Quancargo show that since 1998 celery seed (*Apium graveolens*) has been imported from the following countries:

[3] The exporting country of origin for a consignment listed in Quancargo may not always be the country where the seed was produced.

Europe: Denmark, France, Germany FDR, Italy, Netherlands, Spain, United Kingdom;
Asia: China, Hong Kong, Japan, Taiwan, Thailand, Vietnam;
Americas: Chile, Mexico, USA;
Oceania: Australia.

Lso is reported from[4]:

Africa: Spain (Canary Islands) (Alfaro-Fernandez et al. 2012a), Morocco (Tahzima et al. 2014);
North America: <u>Mexico</u> (Munyaneza et al. 2009), **<u>USA</u>** [Arizona (Brown et al. 2010), California (Crosslin and Bester 2009), Colorado (Munyaneza 2012), Idaho (Crosslin et al. 2012b), Kansas (Munyaneza 2012), Nebraska (Munyaneza 2012), Nevada (Munyaneza 2012), New Mexico (Munyaneza 2012), Oregon (Murphy et al. 2014), Texas (French-Monar et al. 2010, Munyaneza 2012), Utah (Nischwitz 2015), Washington (Crosslin et al. 2012a), Wyoming (Munyaneza 2012)];
Central America and Caribbean: El Salvador (Bextine et al. 2013a), Guatemala (Nelson et al. 2011), Honduras (Munyaneza et al. 2013), Nicaragua (Bextine et al. 2013b);
Europe: Finland (Munyaneza et al. 2011), **<u>France</u>**[5] (Loiseau et al. 2014), **<u>Germany</u>** (Munyaneza et al. 2015), Norway (Munyaneza et al. 2012b), <u>Spain</u> (Alfaro-Fernandez et al. 2012b), Sweden (Munyaneza et al. 2012a);
Oceania: New Zealand (Liefting et al. 2009b).

<u>Note:</u> **<u>Netherlands</u>**: absent, confirmed by survey (CPC 2014: EPPO 2013, NPPO of the Netherlands, 2003)

<u>Vectors</u>

The known insect vectors of liberibacter are psylloids. For Lso the following vectors have been recorded:

Bactericera cockerelli (Šulc) (Psylloidea: Triozidae) – tomato/potato psyllid (TPP), on Solanaceae (references in OEPP/EPPO 2013):
North America: Canada, Mexico, USA;
Central America and Caribbean: El Salvador, Guatemala, Honduras, Nicaragua;
Oceania: New Zealand.

Trioza apicalis Foerster (Psylloidea: Triozidae) – carrot psyllid, on Umbelliferae (EPPO 2014b):
Asia: Mongolia;
Europe: Austria, Belarus, Czech Republic, **Denmark**, Finland, Former USSR (unconfirmed record), **France**, **Germany**, **Italy**, Latvia, Norway, Poland, **Russian Federation** (Eastern Siberia, Russian Far East, Southern Russia), Sweden, Switzerland, **United Kingdom**, Ukraine;

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[4] Countries in bold are those from which carrot seed has been exported to NZ (Quancargo, records since 1999)
Countries underlined are those from which celery seed has been exported to NZ (Quancargo, records since 1998)
[5] Recorded as present in France; found in two carrot fields in Central region in August 2012 and is currently being eradicated (CPC 2014).

Bactericera trigonica Hodkinson (Psylloidea: Triozidae) – on Umbelliferae:

Europe: Cyprus, Czech Republic, Greece, Hungary, Italy, Malta, Portugal, Slovakia, **Spain**, Switzerland;
Africa: Algeria, Spain (Canary Islands); [*B. trigonica* is likely to be present throughout the entire Mediterranean region (personal communication, J E Munyaneza, 25 January 2015];
Asia: Iran, Israel, Turkey.

1.4.4 New Zealand status

Lso is present in New Zealand (Liefting et al. 2009a), where it has been isolated from plants in the Solanaceae, including capsicum, tomato, potato, tamarillo, cape gooseberry and chilli (Liefting et al. 2009a). However, it is not known to occur in carrot (*Daucus carota*) or celery (*Apium graveolens*) in New Zealand. Therefore Lso is still considered a potential hazard in this risk assessment.

Only haplotype A has been recorded in New Zealand. Haplotype B (recorded from Solanaceae, and haplotypes C, D, and E (recorded from Umbelliferae) have not been recorded in New Zealand.

The known psylloid vector on Solanaceae, *Bactericera cockerelli*, is present in New Zealand (Gordon 2010).

The known vector on *Daucus carota* (Umbelliferae), *Trioza apicalis*, is not known to be present in New Zealand: not recorded in PPIN (2014) or Gordon (2010). The other recorded vector (*Bactericera trigonica*) is not known to be present in New Zealand: not recorded in PPIN (2014) or Gordon (2010).

1.4.5 General geographic distribution

Lso has been recorded in[6]:

Africa: Spain (Canary Islands) (Alfaro-Fernandez et al. 2012a), Morocco (Tahzima et al. 2014);
North America: Mexico (Munyaneza et al. 2009), **USA** [Arizona (Brown et al. 2010), California (Crosslin and Bester 2009), Colorado (Munyaneza 2012), Idaho (Crosslin et al. 2012b), Kansas (Munyaneza 2012), Nebraska (Munyaneza 2012), Nevada (Munyaneza 2012), New Mexico (Munyaneza 2012), Oregon (Murphy et al. 2014), Texas (French-Monar et al. 2010, Munyaneza 2012), Utah (Nischwitz 2015), Washington (Crosslin et al. 2012a), Wyoming (Munyaneza 2012)];
Central America and Caribbean: El Salvador (Bextine et al. 2013a), Guatemala (Nelson et al. 2011), Honduras (Munyaneza et al. 2013), Nicaragua (Bextine et al. 2013b);
Europe: Finland (Munyaneza et al. 2011), **France**[7] (Loiseau et al. 2014), **Germany** (Munyaneza et al. 2015), Norway (Munyaneza et al. 2012b), Spain (Alfaro-Fernandez et al. 2012b), Sweden (Munyaneza et al. 2012a);
Oceania: New Zealand (Liefting et al. 2009b).

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[6] Countries in **bold** are those from which carrot seed has been exported to NZ (Quancargo, records since 1999)
Countries underlined are those from which celery seed has been exported to NZ (Quancargo, records since 1998)
[7] Recorded as present in France; found in two carrot fields in Central region in August 2012 and is currently being eradicated (CPC 2014).

Lso has been recorded from carrot (*Daucus carota*) in the following countries: Canary Islands (Spain) (Nelson et al. 2013), Finland (Munyaneza et al. 2010), France (Loiseau et al. 2014), Morocco (Tahzima et al. 2014), Norway (Munyaneza et al. 2012b), Spain (Nelson et al. 2013), Sweden (Munyaneza et al. 2012a). There are currently surveys in other European countries for the presence of Lso on carrots (personal communication, J E Munyaneza, 28 January 2015).

Lso has been recorded from celery (*Apium graveolans*) in the following countries: Spain (Teresani et al. 2014).

1.4.6 Commodity association

The commodity for this risk assessment is carrot (*Daucus carota*) and celery (*Apium graveolans*) seed for sowing. Lso has been recorded from carrot and celery. The bacterium is found in the phloem sieve tubes which transport sap containing sugars and other nutrients around the plant. Therefore it is assumed that it can be found in any part of the plant that contains phloem tissue, including the seed coat.

1.4.7 Host plant and vector associations

Host plants:

Lso has been detected in solanaceous crops and weeds in the Americas and New Zealand (EPPO 2014a, Liefting et al. 2009a,b).

Hosts in the Solanaceae include: potato, *Solanum tuberosum* (EPPO 2014a); tomato, *S. lycopersicum* (EPPO 2014a); capsicum, *Capsicum annuum* (EPPO 2014a); tamarillo, *S. betaceum* (Liefting et al. 2009a,b); Cape gooseberry, *Physalis peruviana* (Liefting et al. 2009a,b); eggplant, *S. melongena* (Munyaneza et al. 2013); tobacco, *Nicotiana tabacum* (Aguilar et al. 2013); silverleaf nightshade, *Solanum elaeagnifolium* (Thinakaran et al. in press); bitter sweet nightshade, *Solanum dulcamara* (Murphy et al. 2014).

The presence of Lso was detected in symptomless Cape gooseberry (*Physalis peruviana*) in New Zealand (Liefting et al. 2009a,b). These plants were collected from a garden in South Auckland, located close to a commercial glasshouse where infected tomatoes had been found. For the moment, it is not known whether *P. peruviana* only acts as a symptomless reservoir of the pathogen or can also develop disease symptoms. Although the psyllid vector (*B. cockerelli)* can be found on many plants (numerous species in 20 plant families), it has been reported to complete its life cycle only on Solanaceae, Convolvulaceae and Lamiaceae. Its preferred hosts include aubergine, capsicum, tomato, and potato (EPPO 2014a).

Lso has been detected in carrots (*Daucus carota*) and celery (*Apium graveolens*) in Europe (Munyaneza et al. 2014, Teresani et al. 2014).

Vectors:

***Bactericera cockerelli* (Hemiptera: Triozidae)**

Although it can be found on many plants (numerous species in more than 20 plant families), the psyllid vector (*B. cockerelli)* has been reported to complete its life cycle only on Solanaceae, Convolvulaceae and Lamiaceae. Its preferred hosts include aubergine, capsicum, tomato, and potato.

Host plants include (from Ouvrard (2014), unless otherwise stated): all records from Solanales, Solanaceae:

Capsicum
Capsicum annuum L. (bell pepper, chilli pepper, capsicum)
Lycium
Physalis philadelphica Lam. (tomatillo)
Solanum
Solanum lycopersicum L. (tomato)
Solanum melongena L. (aubergine, eggplant)
Solanum tuberosum L. (potato)
Nicotiana tabacum L. (tobacco) (OEPP/EPPO 2013)

***Trioza apicalis* (Hemiptera: Triozidae)**

Host plants include (Ouvrard 2014): all records from Apiales, Umbelliferae:

Anthriscus sylvestris (L.) Hoffm. (cow parsley)
Carum carvi L. (caraway)
Daucus
Daucus carota L. (wild carrot)
Daucus carota subsp. *carota*
Daucus carota subsp. *sativus* Arcang.
Heracleum sphondylium L. (hogweed)
Laserpitium latifolium L. (broad-leaved sermountain)
Pastinaca sativa L. (parsnip)
Petroselinum crispum (Mill.) Fuss (parsley)
Peucedanum ostruthium (L.) W. Koch (masterwort)

***Bactericera trigonica* (Hemiptera: Triozidae)**

Host plants include (Ouvrard 2014):

Apiales, Umbelliferae:
Daucus carota L.
Asterales, Asteraceae:
Ambrosia artemisiifolia L. (common ragweed) [uncertain (Ouvrard 2014)]

1.4.8 Potential for establishment and impact

Lso is already present in New Zealand on solanaceous plants and in the insect vector *Bactericera cockerelli*. Haplotypes not known to be present in New Zealand occur in countries in Europe that have climatic similarities to parts of New Zealand, as do the vectors *Trioza apicalis* and *Bactericera trigonica*. Therefore there is potential for these haplotypes and vectors to establish in New Zealand.

Lso has been associated with damage to commercial carrot crops in Europe (Munyaneza 2013). New Zealand is a significant producer of carrot seed for export. There is potential for haplotypes of Lso associated with Umbelliferae to cause economic damage to New Zealand additional to that already caused by haplotypes associated with Solanaceae.

1.4.9 Hazard identification conclusion

Given that Lso:

- is associated with seed of carrot *Daucus carota* (and celery *Apium graveolens*);
- is present in countries from which carrot seed and celery seed can be exported to New Zealand;
- is not recorded from New Zealand on carrot or celery;
- haplotypes C, D, and E, associated with carrot and celery, have not been recorded in New Zealand;
- can potentially establish in New Zealand;
- can potentially cause unwanted impacts;

Lso is considered a hazard on seed of carrot and celery in this risk assessment.

1.5 BIOLOGY

This risk assessment addresses the Lso haplotypes on carrot and celery (C, D and E). Although Lso has been found on celery, it has been found more frequently and widely on carrot and there is more information in relation to this host. Therefore this section will largely discuss carrot. Although haplotype A is already present in NZ on Solanaceae, the haplotypes on Solanaceae will also be mentioned as there is much more information available.

Lso is one of several known species of liberibacter which occur in both the phloem tissue of host plants and in psylloid vectors. Lso was first discovered in association with solanaceous plants in North America and New Zealand and is regarded as the causal agent of zebra chip disease of potatoes. In North America, Central America and New Zealand, two haplotypes, A and B, have been recorded (Nelson et al. 2011; Nelson et al. 2013). These are vectored by *Bactericera cockerelli*, and have been recorded from a number of plant species in the Solanaceae. Only haplotype A has been recorded in New Zealand (Nelson et al. 2013). More recently Lso has been found in Europe and Africa in carrots and celery, with three haplotypes, C, D and E, identified (Nelson et al. 2013, Teresani et al. 2014). In northern Europe, Lso has been found in the carrot psyllid *Trioza apicalis* and in more southern countries it has been detected in *Bactericera trigonica* (Munyaneza 2013). However, in France and Morocco the vector has not been identified (Loiseau et al. 2014, Tahzima et al. 2014), and it is possible that other psylloid species are involved. It is not yet known if the different haplotypes elicit biological differences in the plant or insect hosts (Munyaneza 2013).

Symptoms

Carrots

Carrots affected by Lso and the carrot psyllid *T. apicalis* show symptoms of leaf curling with yellow, bronze and purple discoloration, twisting of petioles, stunting of shoots and tap roots, and proliferation of secondary roots (Munyaneza et al. 2010). Carrots associated with Lso and the vector *B. trigonica* show similar symptoms (Alfaro-Fernandez et al. 2012a, b). As the carrot psyllid *T. apicalis* itself is considered a pest of carrots, it had long been thought (before the existence of Lso was known) that the psyllids injected toxins that affect the plants. In a study to determine which symptoms to attribute to psyllids and which to Lso (Nissinen et al. 2014), high Lso titre in plants significantly affected root weight but not the number of curled leaves. This suggests leaf-curling symptoms are caused by the psyllid feeding alone (probably a gall-forming reaction). Subsequent leaf discoloration is correlated with multiplication of the bacteria. Electron microscopy revealed blockage of phloem cells by bacteria and collapse of heavily infected cells which would result in restriction of the phloem transport. As a result sucrose is likely to accumulate in the source leaves which might cause the observed leaf discoloration (Nissinen et al. 2014).

Symptoms in psyllid-affected carrots associated with Lso are similar to the symptoms of infection by phytoplasmas and *Spiroplasma citri*. However, symptoms are produced when the latter organisms are absent. In addition, mixed infections have been detected. Lso has been detected in asymptomatic plants (Loiseau et al. 2014).

Celery

Lso has also been associated with vegetative disorders in celery; symptoms include an abnormal amount of shoots, curling of stems and yellowing (and severe stunting in one cultivar). It has been detected in celery grown next to carrot in Spain suggesting that carrot was the most probable source of inoculum (Teresani et al. 2014). The emergence of the disease in celery crops may be linked to the proximity of infected carrots with Lso, to the presence of *B. trigonica* populations and probably to the existence of other psyllid vector species (Teresani et al. 2014).

Detection

Symptoms associated with infections of Lso cannot always be distinguished from those from other organisms such as phytoplasmas and *Spiroplasma citri* in carrot and mixed infections are frequently detected (Terasani et al. 2014). In addition, plants hosting the bacterium may be asymptomatic (Loiseau et al. 2014, Munyaneza et al. 2014). Several PCR assays have been developed for the detection of Lso using both conventional PCR and real-time PCR (Munyaneza et al. 2014). Electron microscopy can be used to show the presence of BLOs (bacteria-like organisms) in phloem sieve tubes in host plant tissue but is not diagnostic for genus or species.

Effects of environmental conditions on Lso are not well understood, but it does appear to be heat sensitive as occurs with two of the liberibacter species associated with huanglongbing, '*Ca*. L. americanus' and '*Ca*. L. africanus'. Temperatures above 32ºC appear to inhibit Lso and the development of zebra chip symptoms in potato (Munyaneza et al. 2012). Temperatures at or below 17°C significantly slowed, but did not prevent, liberibacter development and the optimum development of liberibacter and zebra chip symptoms in the potato plants was observed at a daily temperature regime of 27 to 32°C (Munyaneza et al. 2012). Terasani et al. (2014) note that the fact that Lso was detected in greenhouse plants grown at 15–25ºC but not in the same plants after one month at about 30ºC, suggests that high temperature may affect prevalence of the pathogen.

Transmission

As with other liberibacter species, Lso is spread from infected to healthy plants by psylloid vectors. Two species are associated with Lso in carrot and celery: *Trioza apicalis* in northern Europe and *Bactericera trigonica* in southern Europe and Lso has been detected in both psyllid species (Munyaneza 2010, Alfaro-Fernandez et al. 2012). There may be other vector species and the vectors have not been identified in France or Morocco (Loiseau et al. 2014, Tahzima et al. 2014). Transmission of Lso to carrot seedlings by the carrot psyllid has been demonstrated, with transmission taking place within 3 days (Nissinen et al. 2014). In this study, Lso titre in carrots exposed to psyllids was correlated with the Lso titre in the psyllids. However, the authors observed individual carrot plants in which transmission of Lso seemed to be unsuccessful even though the Lso titre was high in the psyllids (Nissinen et al. 2014).

Vertical transmission (transovarially) of Lso has been shown in *B. cockerelli* but there is no information yet for *T. apicalis* or *B. trigonica* (Munyaneza 2013). Likewise, horizontal transmission (from feeding on infected plant hosts) has been shown in *B. cockerelli* but no information yet for *T. apicalis* or *B. trigonica* (Munyaneza 2013).

Although Lso is naturally transmitted in nature to other growing plants by psylloids, it may also be spread experimentally by grafting and dodder.

A recent study by Bertolini et al. (2014) suggests that Lso is transmitted by seed in carrot. However, this remains to be confirmed by an independent laboratory or further studies. The real-time PCR assay used in this study can potentially amplify a wide range of other bacteria that may be present as environmental contamination. Positive samples were sequenced by the authors and determined to be Lso haplotype E based on the 16S and 50S rRNA genes. However, the sequences were not deposited in GenBank (or a similar sequence database) which is a standard requirement of publishing, and as a result are not readily available for analysis. Although electron microscopy showed the presence of BLOs (bacteria-like organisms) in the phloem sieve tubes of the seed coat and in the phloem of the carrot mid-rib seedlings grown from positive seed, this result is inconclusive as liberibacters cannot be diagnosed from morphology only. Seed transmission has not yet been clearly demonstrated for other liberibacter species (personal communication, Lia Liefting, October 2014; Hilf et al. 2013, Hilf 2011, van Vuuren et al. 2011).

Control

Currently, the only means to manage diseases associated with Lso is to focus on effective control of its psylloid vectors (Munyaneza 2012).

1.6 RISK ASSESSMENT

Several scenarios will be considered in this risk assessments as a result of uncertainty around two important factors. Current evidence suggests a lack of suitable vectors in New Zealand for Lso in carrots and celery. However, there is some uncertainty around this and information is included for outcomes if suitable vectors are present. There is also uncertainty around seed transmission and outcomes are included for both with and without seed transmission. The scenario tree (Figure 2) indicates the possible pathways addressed in the risk assessment.

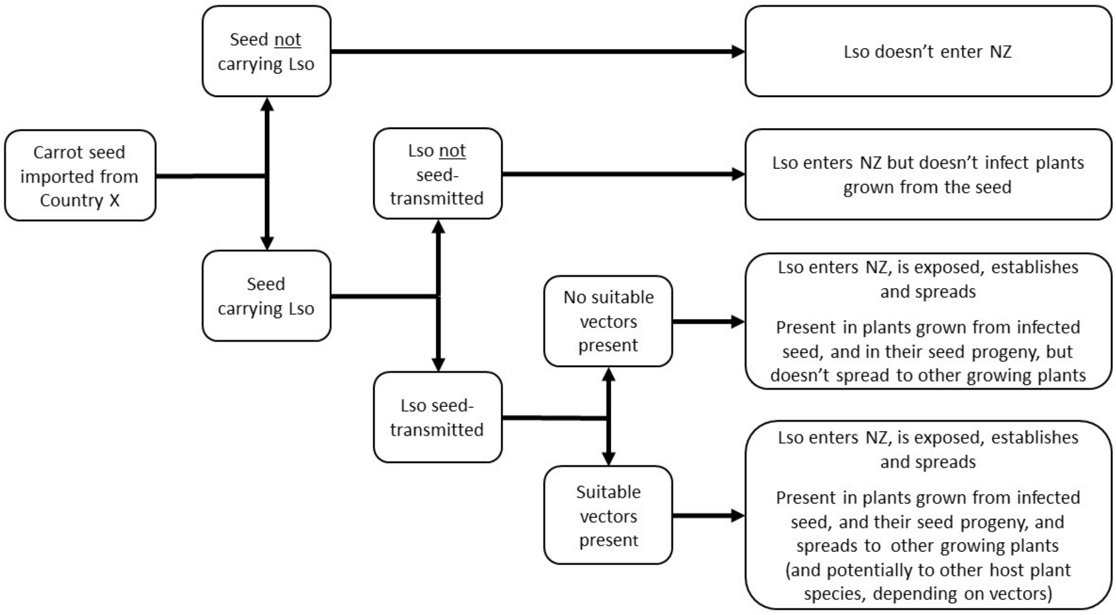

Figure 2. Scenario tree for establishment of '*Candidatus* Liberibacter solanacearum' in New Zealand as a result of importation of carrot seed for sowing.

1.6.1 Entry assessment

Although Lso has been recorded from carrot and celery in several countries in Europe and Africa (Canary Islands, Finland, France, Morocco, Spain and Sweden), it is not known how widespread it is through Europe or Africa nor if it occurs elsewhere. It has been suggested that the carrot haplotype D arose in Europe (Nelson et al. 2013), but others speculate that it may have been introduced into Europe in carrot seeds as it has not yet been recorded in any naturally occurring plant species in Europe (Bertolini et al. 2014) and because it appears to be an emerging disease in several countries (e.g., Loiseau et al. 2014). The association of Lso with vegetative disorders is recently discovered perhaps in part due to similarities to other vegetative disorders and advances in detection technologies.

New Zealand can import carrot seed from all countries: in 2014 seeds have arrived from USA, Australia, France, Netherlands, UK, Italy, India, Japan, Afghanistan, Malaysia, Denmark, Czech Republic, Sri Lanka, and Germany (Quancargo, October 2014). Much of the seed imported from Europe in 2014 was from the Netherlands where Lso has been determined to be absent by survey (CPC 2014). Lso has not been reported from Italy, Denmark, Germany and Czech Republic, but has been recorded in France. It should be noted, however, that seed can be traded from country to country which means that the country from which seed has been imported to New Zealand is not necessarily that in which it was produced. For example, seed imported from the Netherlands may have been originally sourced from other countries.

Carrots affected by Lso and the insect vector show symptoms of leaf-curling, discoloration of leaves, stunting of shoots and tap roots, and proliferation of secondary roots (Alfaro-Fernandez et al. 2012, Munyaneza 2013). Symptoms of Lso can be confused with those associated with phytoplasmas and *Spiroplasma cit*ri in carrots (Munyaneza 2013). Plants in the field can be a mixture of symptomatic and asymptomatic and the rate of infection in the field can be variable (up to 100%). It is likely that seed will be harvested from infected plants along with uninfected plants.

Several PCR assays have been developed to detect Lso in plant material and Lso has been detected in carrot seed using PCR assays of whole seeds. This is not unexpected as liberibacters occur systemically in phloem tissue and therefore can be present in the phloem tissue in the seed coat which is maternal tissue. It is unclear if seed containing Lso can be distinguished visually from seed that does not contain Lso as no description of symptoms on carrot seed were found during the preparation of this risk assessment. However, given that host plants can be asymptomatic, that symptoms of Lso can be confused with those phytoplasmas and *Spiroplasma cit*ri in carrots, and that it is not clear if seeds show symptoms, it is assumed here that it is not possible to tell whether a seed lot contains Lso without diagnostic PCR tests.

It is not clear if the provenance of imported carrot seed is always known but there is the possibility that seed lots can be of mixed origins and not traceable (Bertolini et al. 2014).

No specific diagnostic tests or treatments for Lso are required by the IHS to import carrot seed into New Zealand, therefore if viable Lso is present it will be undetected.

Effects of environmental conditions on Lso are not well understood, but it does appear to be heat sensitive as occurs with two of the liberibacter species associated with huanglongbing, '*Ca*. L. americanus' and '*Ca*. L. africanus'. Temperatures above 32ºC appear to inhibit Lso and the development of zebra chip symptoms in potato (Munyaneza et al. 2012). Carrot seed is generally exported to New Zealand by air as commercial cargo or express parcel, but may also be sent by sea (Quancargo 2014). It is assumed that Lso is likely to survive the conditions under which it is stored and transported.

To summarise, carrot seed is imported from a wide range of countries including those from regions where Lso is known to occur. Although the bulk of imported seed has come from countries where it is not recorded from carrot, seed can come from anywhere. Although Lso is associated with seed, it cannot be detected by visual inspection and no diagnostic tests or treatments are carried out on carrot seed imported to New Zealand. The proportion of seed with Lso likely to enter New Zealand is uncertain and may be highly variable. However, even if the presence of viable Lso in carrot seed is a low frequency event, the large numbers of seed imported for sowing, combined with the number of shipments over a year, mean that it is likely to enter the country.

In the context of millions of seeds being imported into New Zealand over time, the likelihood of Lso entering New Zealand on seed is considered to be high; but the proportion of seeds with Lso is highly uncertain.

1.6.2 Exposure assessment

For the purposes of this risk assessment, it is assumed in this section that carrot seed that has been infected with Lso has entered New Zealand.

There is uncertainty as to whether Lso can be transmitted by seed from infected parent plants. A recent study by Bertolini et al. (2014) demonstrated that the bacterium can be transmitted from infected seeds to the resulting seedlings. However, this finding remains unconfirmed by an independent laboratory or further studies. Seed transmission has not yet been clearly demonstrated for other liberibacter species (personal communication, Lia Leifting, October 2014; van Vuuren et al. 2011.

If Lso is not seed transmitted, then even though the bacterium may be present in phloem tissue in the seed coat, then plants grown from infected seed will not be infected. In this case, exposure is considered to be negligible.

If, however, Lso is seed transmitted, then exposure of Lso to a host plant simply requires seed-to-seedling transmission to occur, i.e., that a carrot plant derived from a seed is infected. In the context of millions of seeds being planted in New Zealand over time, the likelihood of Lso being transmitted to a host plant in this scenario is considered to be high.

Given that:

- there are indications that Lso may be seed transmitted in carrot, but verification is needed;
- transmission by seed has not yet been clearly demonstrated for any other liberibacter species;
- if Lso is not transmitted by seed, no growing plants will be infected;
- if Lso is transmitted by seed, then over time there will be infected carrot plants growing;

The likelihood of exposure is considered to be negligible if Lso is not seed transmitted, and high if it is seed-transmitted, however there is uncertainty around whether Lso can be transmitted by seed.

1.6.3 Assessment of establishment and spread

If Lso is not transmitted by seed there will be no establishment as the bacterium will not be able to move from the imported seed to a growing plant (see previous section, 1.6.2).

For the purposes of this risk assessment, however, this section will also consider the scenario that Lso is seed transmitted and that infected plants have therefore been grown from imported seed. As a seed transmitted pathogen can be transmitted vertically from generation to generation of the host plant, Lso would therefore be considered to have established if it was present in growing carrot plants that were producing seed.

In the scenario that Lso is seed-transmitted, the likelihood of establishment is considered to be high.

In the absence of a suitable vector, the progeny of infected plants would be affected and it is likely that seed would be spread to new locations by human movement. However, without a vector, other growing carrot plants would not be affected. The seed would be used either to produce carrots for consumption or to produce seed which may be re-exported.

The known carrot Lso vectors, *T. apicalis* and *B. trigonica,* are not present in New Zealand although there is the possibility they could be introduced as has occurred with *Bactericera cockerelli*. If a suitable vector was present Lso would be transferred to other growing plants within the crop resulting in a likely increase in both the number of plants hosting the bacterium and the number showing disease symptoms. In a survey of Lso in carrot crops in Norway, where *T. apicalis* is present, the estimated liberibacter infection rate ranged from 33.3 up to 100% in carrot plants (Munyaneza et al. 2014). The likelihood of spread for Lso in a wider area would be high as a result of psyllid dispersal flights. Long distance spread would be achieved through wind-assisted movement of psyllids, and through accidental human-mediated movement of infected adult psyllids alone or as life stages ranging from egg to adult on plant material such as carrot leaves.

It seems unlikely that other potential psylloid vectors are already present on carrots in New Zealand: there appears to be no records of psylloids on carrots in New Zealand (Gordon 2010, PlantSynz, accessed September 2014; personal communications: N. Martin, G. Walker), or from Umbelliferae in New Zealand (Gordon 2010). However, it should be noted that: there are undescribed species in New Zealand (e.g., Gordon 2010); although psylloids tend to be narrowly host specific, they can sometimes feed out of their host range; and some species are known to have a relatively wide host range (e.g., *Bactericera cockerelli*). Nevertheless, as psylloids are not recognised as pests of carrots in New Zealand, if there were species present capable of feeding on carrot it is unlikely that there would be anything beyond occasional feeding. Therefore any such species would be unlikely to play a significant role in spread of Lso if it was capable of vectoring the bacterium.

To summarise, in the scenario that Lso is seed transmitted, spread of Lso to new locations would be high through human movement of seed; spread would be enhanced and presence at a location further intensified in the presence of suitable vectors.

In the scenario that Lso is seed-transmitted, the likelihood of Lso spreading within New Zealand is considered to be high.

1.6.4 Consequence assessment

The degree of impact from Lso depends on the presence of a suitable vector. The known psylloid vector on solanaceous species, *B. cockerelli,* is present in New Zealand (Gordon 2010). However, the known psylloid vectors on carrots and celery

(Umbelliferae), *T. apicalis* and *B. trigonica*, are not recorded from New Zealand. So far, no psylloid species are known to be associated with carrots or celery in New Zealand. In the following sections, consequences are considered in both the presence and absence of a suitable vector on these two host species.

1.6.4.1 Economic consequences

Carrot production in New Zealand: The total area for New Zealand planted in carrots was 2,047 ha in 2013, the main regions being Canterbury (823 ha), Manawatu-Wanganui (429 ha), Southland (300 ha), Auckland (194 ha) and Waikato (166 ha) (Fresh Facts 2013).

Seed for production of New Zealand carrots is imported; however, New Zealand also exports seed (NZIER 2014) with over half of the world's carrot seed grown in mid-Canterbury each year (MPI 2014). Specialist seed producers in New Zealand are contracted to agricultural multinational seed companies who grow seed on contract. This seed is exported, mainly to the Netherlands (Fresh Facts 2013). Carrot seed is then imported, including seed that has originated in New Zealand, for the new season's crop (NZIER 2014).

In 2013 and 2014 (up to September) seed for sowing was imported from the following countries: Australia, China, Denmark, France, India, Italy, Japan, Netherlands, United Kingdom, USA (Quancargo, accessed September 2014[8]). In 2013 carrot seed exports totalling $27.0m went to 16 countries including Netherlands ($24.6m) and France ($1.4m) (Fresh Facts 2013). Domestic sales of carrots (fresh and processed) were valued at $30 million in 2013, and exports were valued at $7.5 million (fresh), $2.2 million (processed) and $27.0m (seed) (Fresh Facts 2013). The total GDP contribution of carrots in 2012 was $56.5m (NZIER 2014).

Celery production in NZ: It is assumed in this assessment that celery production is considerably less than for carrots in New Zealand, as it was included in the category of 'other vegetables' estimated in sector profiles for fresh and processed vegetables in Fresh Facts (2013) rather than treated separately.

Currently, it has not been independently verified that Lso can be transmitted by seed to progeny. If Lso is not seed transmitted it will have no impact on carrot production in New Zealand, because there will be no disease in new plants grown from seed even if Lso is present in the coat of the seed used for sowing.

However, given the uncertainty around seed transmission, this risk assessment will also consider the scenario where Lso is seed transmitted, both in the absence and presence of suitable vectors.

Lso is seed transmitted but no suitable vectors are present:

If Lso is seed transmitted then progeny grown from seed containing Lso may be diseased, but Lso would not be able to be transmitted to growing plants that are free of the liberibacter. The study of Bertolini et al. (2014) determined that 12–42% of seedlings grown from Lso positive seed lots tested positive for Lso 150 days post-

[8] The exporting country of origin for a consignment listed in Quancargo may not always be the country where the seed was produced.

germination. For diseased plants there would be impacts on both yield and quality. However, the proportion of plants affected may be variable and some plants may not express symptoms of disease. Both domestic and export production may be affected in terms of yield and quality. In addition, for seed that is exported, countries that are currently free of Lso may require measures to manage risk. Australia, for example, has announced emergency measures that include options of PCR tests or heat treatment.

Lso is seed transmitted and suitable vectors are present:

If either of the current known vectors of Lso on carrot (*Trioza apicalis* and *Bactericera trigonica*) were present in New Zealand then there would be higher economic impact as they would be able to vector the liberibacter to other growing plants resulting in much higher levels of disease expressed. In a survey of Lso in carrot crops in Norway, where *T. apicalis* is present, the estimated liberibacter infection rate ranged from 33.3 up to 100% in carrot plants (Munyaneza et al. 2014). Currently the only means to manage diseases associated with Lso is to focus on effective control of its psyllid vectors (Munyaneza, 2012, Munyaneza et al 2014). Therefore the production costs for carrots may increase though the implementation of additional controls. Impacts could be moderate to severe for the New Zealand carrot seed industry; however within the context of the entire New Zealand economy they are likely to be low.

There is some uncertainty around whether there are potential insect vectors (other than *Trioza apicalis* and *Bactericera trigonica*) already present on carrots in New Zealand. As there appears to be no psyllids that feed on carrots in New Zealand, and there are no psyllids currently known in New Zealand that feed on plants in the same family, it seems very unlikely (see section 1.6.3) but cannot be ruled out.

The potential economic consequences within New Zealand are uncertain due to the uncertainty around whether Lso can be transmitted by carrot seed.

If Lso is not transmitted by seed, then the potential economic consequences within New Zealand are likely to be negligible as the liberibacter cannot establish and will not be present in progeny plants.

If Lso can be transmitted by seed, but there are no suitable vectors present, then the potential economic consequences within New Zealand are likely to be low due to requirements for some importing countries and some impact on local production.

If Lso can be transmitted by seed and there are suitable vectors present then the economic consequences are uncertain but likely to be low for the New Zealand economy as a whole due to requirements for some importing countries and increased impact on local production, although consequences could be higher if other crop species were affected.

1.6.4.2 Environmental consequences

Any environmental consequences that might arise from the establishment of Lso haplotypes on carrot would depend on the presence of suitable vectors to transmit the liberibacter to growing plants of native species. If there was no suitable vector, then there would be no impact on native plant species.

Plant species that could be affected by Lso in New Zealand depends on potential insect vectors and their host range(s). Lso has been recorded from carrot (*Daucus carota*) and celery (*Apium graveolens*) which are members of the Umbelliferae (Apiaceae). Currently it is unknown whether different Lso haplotypes have any significance in terms of host or vector specificity, disease symptoms or impact. However, it has been suggested that the host range of the liberibacter may be more dependent on the host plant range of the vector than on plant species itself.

There are both adventive and indigenous species of Umbelliferae in the natural environment in New Zealand in at least 34 genera; two of these genera are endemic and another 13 contain endemic taxa (NZ Flora 2014).

In the genus *Daucus* there is a single indigenous species, *Daucus glochidiatus* (native carrot, New Zealand carrot) which has a conservation status of threatened, nationally vulnerable (NZPCN 2014). This species occurs in the North, South and Chatham Islands in coastal, lowland to montane habitats on cliff faces, rock outcrops, talus slopes, in short tussockland or grassland and in open forest (NZPCN 2014).

In the genus *Apium* there is an indigenous species with two varieties – *A. prostratum* subsp. *prostratum* var. *filiforme* (New Zealand celery) is not threatened, whereas *A. prostratum* subsp. *denticulatum* (Chatham Island celery) is considered at risk, not common (NZPCN 2014). However, the latter is endemic to the Chatham and Antipodes Islands, where it is abundant and found in coastal habitat.

The known vectors of carrot haplotypes of Lso, *Trioza apicalis* and *B. trigonica*, have not been recorded in New Zealand. If they were present, then given their known host ranges (section 1.4.7), it is possible that they could feed on other species of *Daucus* and perhaps *Apium* and that Lso could be transmitted to these species

There is uncertainty as to whether there are other potential psyllid vectors already present on carrots in New Zealand, or capable of feeding on carrot: psylloids are not recognised as pests of carrots in New Zealand, and there appears to be no records of psylloids on carrots in New Zealand (Gordon, 2010; PlantSynz, accessed September 2014; personal communications: N. Martin, G. Walker), or from Umbelliferae in New Zealand (Gordon 2010). However, it should be noted that there are undescribed species in New Zealand (e.g., Gordon 2010). In addition, although psylloids tend to be narrowly host specific, they can sometimes feed out of their host range, and some species are known to have a relatively wide host range (e.g., *Bactericera cockerelli*).

Lso haplotype A is already present in New Zealand in Solanaceae along with its polyphagous psylloid vector *Bactericera cockerelli* which is known to feed outside the Solanacaeae. Therefore the possibility already exists for this vector to spread Lso haplotype A to native species although there is some uncertainty as to which species might be able to host the liberibacter and whether disease symptoms would be expressed. In addition, Lso has potentially been detected by a diagnostic endpoint PCR in other psylloid species in New Zealand (Scott et al. 2009): *Trioza* sp. (associated with *Pittosporum* and most likely *Trioza vitreoradiata*) and an unidentified *Acizzia* species that was collected from *Acacia*. However, this has not been confirmed by repetition of the same diagnostic, testing with an alternative diagnostic or sequencing amplicons (personal communication, J V Dohmen-Vereijssen October 2014). Of the known psylloid species in New Zealand (Gordon 2010), *T. vitreoradiata* and two other endemic triozids (*Trioza irregularis* and *Trioza panacis*) are recorded from plant hosts in the same order (Apiales) as carrot, but not in the same family. Therefore, although there is great uncertainty around which plant species could be affected by Lso in New Zealand, the potential already exists for Lso to spread to other non-solanaceous plants and psylloid species in New Zealand.

In the scenario where Lso is seed-transmitted, the potential environmental consequences within New Zealand are considered to be negligible if there is no suitable vector. There is uncertainty around whether there are potential vectors and consequent host plant range but if present then the environmental consequences within New Zealand are considered to be low.

1.6.4.3 Sociocultural consequences

Lso has been recorded from carrot (*Daucus carota*) and celery (*Apium graveolens*) which are members of the Umbelliferae. Both species are grown domestically in New Zealand. Reported symptoms of disease include leaf discoloration, stunting of shoots and tap roots, and proliferation of secondary roots. (Some reported symptoms, such as leaf curling, may be caused by psyllid feeding alone (Nissinen et al. (2014)).

If Lso is not transmitted by seed, there would be no disease in new plants grown from seed even if Lso is present in the coat of the seed used for sowing. Therefore there would be no impact on home gardeners.

If Lso is transmitted by seed and there is no suitable vector, the purchase of infected carrot seeds or seedlings would result in a reduction in both yield and quality for home gardeners. If infected seed was harvested from infected plants for sowing or if the plants were left to produce self-sown seedlings, the liberibacter could be found in descendants but would not spread to other plants.

The known vectors (*Trioza apicalis* and *Bactericera trigonica*) have not been reported in New Zealand. However, if an effective vector was present, any carrot (or celery) plant could potentially be affected. As a result there would be an increased impact on home gardeners in terms of yield and quality of produce. Potentially other garden plant species could be affected depending on the host range of the vector.

The potential socio-cultural consequences within New Zealand are considered to range from negligible to low.

1.6.4.4 Human health consequences

There are no known human health consequences.

The potential human health consequences within New Zealand are considered to be negligible.

1.6.5 Risk estimation

The likelihood of entry of Lso is considered to be high. The likelihood of exposure is considered to be negligible if Lso is not seed transmitted, but high if it is seed transmitted. The likelihood of establishment and spread is considered to be negligible if Lso is not seed transmitted, and high if it is seed transmitted. The potential consequences within the context of the entire New Zealand economy are considered to be negligible if Lso is not transmitted by seed, and likely to be low if it is transmitted by seed, although there will be more impact if vectors are present along with greater uncertainty, depending on host range of the vector(s) and Lso. The potential environmental consequences of establishment within New Zealand are considered to be negligible if there are no vectors present and uncertain but probably low if vectors are present, depending on host range of the vector(s) and Lso. The potential socio-cultural consequences within New Zealand are considered to range from negligible to low. The potential health consequences within New Zealand are considered to be negligible.

The overall risk estimation is negligible for imported carrot seed for sowing if Lso is not transmitted by seed of carrot (Table 2). The overall risk estimation is non-negligible if Lso is seed transmitted (Table 2); however, there is insufficient evidence to date that this pathway occurs. Uncertainty (unquantified) remains because the evidence for seed transmission has not yet been independently verified, with the issue still under discussion and investigation by international researchers. This uncertainty needs to be considered by risk managers, along with the likely low consequences of establishment and the likely lack of vectors in New Zealand, to make a decision as to whether the risk warrants risk management (Figure 3). New scientific information on seed transmission of Lso in carrots or celery, however, may warrant reassessment of the risk.

Note: active monitoring for new information on changes in distribution and impact for Lso on carrots has been set up in MPI's emerging risk system.

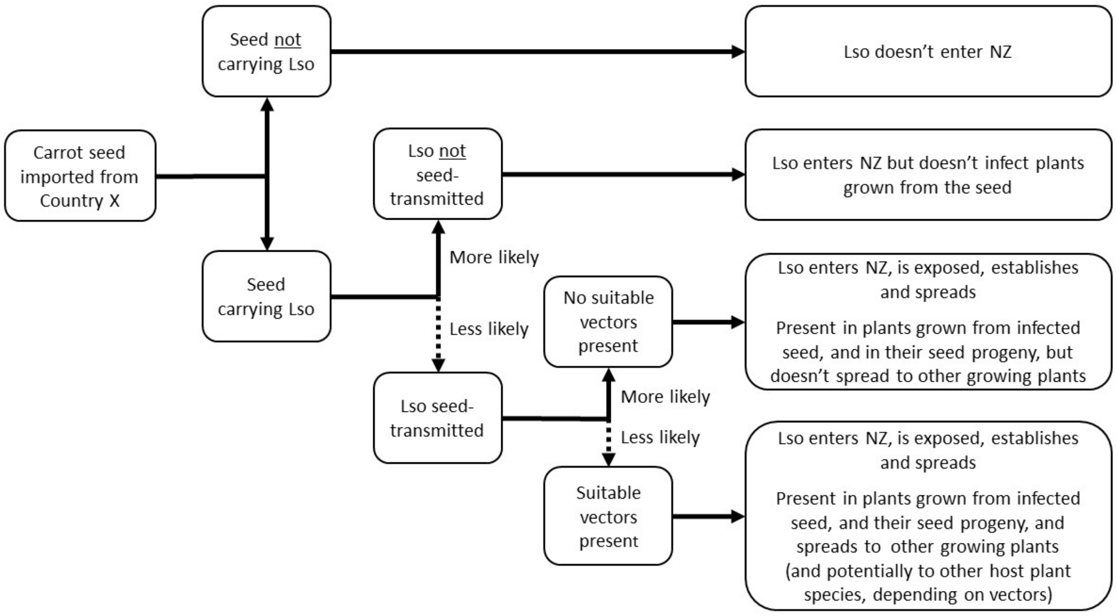

Figure 3. Scenario tree for establishment of '*Candidatus* Liberibacter solanacearum' in New Zealand as a result of importation of carrot seed for sowing.

Table 2. Summary of risk assessment for ‘*Candidatus* Liberibacter solanacearum’ on carrot seed for sowing from all countries.

Species	Likelihood of:				Consequences of establishment:				Risk estimation on seed of carrot
	Entry	Exposure	Establishment	Spread	Economic	Environmental	Socio-cultural	Human health	
‘*Candidatus* Liberibacter solanacearum’ IF NOT seed-transmitted	High	Negligible	–	–	–	–	–	–	Negligible
‘*Candidatus* Liberibacter solanacearum’ IF seed-transmitted	High	High	High	High	No vectors: Low Vectors: Low (but more impact than without vectors) Uncertainty because consequences could be higher if other plant species affected.	No vectors: Negligible Vectors: Low (uncertain)	Negligible–low	Negligible	Non-negligible

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APPENDIX: PSYLLOIDEA IN NEW ZEALAND

The following information is extracted from Gordon et al. (2010) (p. 267–8):

Superfamily Psylloidea: Jumping plant-lice

These small plant-suckers attack plants as nymphs, feeding on the phloem via stomatal pores in leaves. Nymphs tend to be confined to one host species or to a group of closely related species. They are flattened and non-jumping. Adults, which are winged, are less discriminating and sometimes feed and oviposit on plants that do not support their nymphs. Leaf pit-galls and closed woody galls are a common feature of species of Triozidae and some Psyllidae also form galls.

The New Zealand psylloid fauna has 19 described genera, of which 12 are represented only by adventive species, mostly from Australia. Others are shared with Australia, with endemic species on both sides of the Tasman (e.g. *Acizzia*, *Anomalopsylla*, *Ctenarytaina*). Notable in the present classification is the absence of endemic genera, although a small number of endemic species are likely to fill some of this gap in the future. In all, there are more than 90 described and undescribed species. Of the six families of Psylloidea worldwide, only the Phacopteronidae and Carsidaridae are not found in New Zealand, but two other families – Calophyidae and Homotomidae – are each represented by only a single adventive species. The Psyllidae has 40 species and one subspecies, of which 23 (60%) are adventive. In contrast, the Triozidae has 54 species, only three of which are adventive (though not all yet determined to species); all the rest are endemic, including 19 undescribed species. The number of adventives species has grown over recent decades in parallel with the increase in aircraft traffic and the availability of exotic host plants such as plantation eucalypts. About a third of the New Zealand psyllid species are adventive.

Psyllids are usually fairly narrowly host-specific, with related species feeding on related plant groups. In New Zealand, the genus *Trioza* has radiated on host plants in five genera of Asteraceae, particularly *Olearia* – 10 of 15 described species of *Trioza* are on that genus. This loyalty to particular plant groups does not prevent psyllids from using more unusual host groups when circumstances allow or demand, e.g. the endemic spondyliaspidine *Ctenarytaina fuchsiae* on *Fuchsia* . Although most psyllids worldwide use host plants among dicotyledonous angiosperms, in New Zealand two endemic triozine species complete their development on gymnosperm species (*Halocarpus*, Podocarpaceae).

Psylloids affect many native plant genera, including *Alseuosmia*, *Carmichaelia*, *Dacrydium*, *Discaria*, *Dodonaea*, *Fuchsia*, *Pseudopanax*, and *Schefflera*. Some psylloids severely modify their host, like the psyllid on *Pittosporum*, pitting and causing yellow streaks to appear on distorted leaves.

Psylloidea recorded in New Zealand (Gordon et al. 2010)

Information taken from Order Hemiptera Suborder Sternorrhyncha (p. 400-401.) [compiled by R. Henderson, D. A. J. Teulon, P. J. Dale, V. F. Eastop & M. A. W. Stufkens.], with the addition of host plant family and order.

† belongs to a new genus; genus name to be changed.

E = endemic, A = adventive (naturalised alien).

Psylloidea			Adventive / Endemic	Host Plant:		
	Family	Species		Genus	Family	Order
	Psyllidae					
		Acizzia acaciae (Maskell, 1894)	A	*Acacia*	Leguminosae	Fabales
		Acizzia acaciaebaileyanae (Froggatt, 1901)	A	*Acacia*	Leguminosae	Fabales
		Acizzia albizziae (Ferris & Klyver, 1932)	A	*Acacia*	Leguminosae	Fabales
		Acizzia conspicua (Tuthill, 1952)	A	*Acacia*	Leguminosae	Fabales
		Acizzia dodonaeae (Tuthill, 1952)	E	*Dodonaea*	Sapindaceae	Sapindales
		Acizzia exquisita (Tuthill, 1952)	A	*Acacia*	Leguminosae	Fabales
		Acizzia hakeae (Tuthill, 1952)	A	*Hakea*, *Grevillea*	Proteaceae	Proteales
		Acizzia jucunda (Tuthill, 1952)	A	*Acacia*	Leguminosae	Fabales
		Acizzia uncatoides (Ferris & Klyver, 1932)	A	*Acacia*, *Albizia*, *Paraserianthes*	Leguminosae	Fabales
		Acizzia n. sp.	A	*Acacia*	Leguminosae	Fabales
		Anoecoconeossa communis Taylor, 1987	A	*Eucalyptus*	Myrtaceae	Myrtales
		Anomalopsylla insignita Tuthill, 1952	E	*Olearia*	Compositae	Asterales
		Anomalopsylla n. spp. (2)	2E	*Olearia*	Compositae	Asterales
		Arytainilla spartiophila (Foerster, 1848)	A	*Cytisus*	Leguminosae	Fabales
		Atmetocranium myersi (Ferris & Klyver, 1932)	E	*Weinmannia*	Cunoniaceae	Oxalidales
		Baeopelma foersteri (Flor, 1861)	A	*Alnus*	Betulaceae	Fagales
		Blastopsylla occidentalis Taylor, 1985	A	*Eucalyptus*	Myrtaceae	Myrtales
		Cardiaspina fiscella Taylor, 1962	A	*Eucalyptus*	Myrtaceae	Myrtales
		Creiis liturata Froggatt, 1990	A	*Eucalyptus*	Myrtaceae	Myrtales
		Cryptoneossa triangula Taylor, 1990	A	*Eucalyptus*	Myrtaceae	Myrtales
		Ctenarytaina clavata Ferris & Klyver, 1932	E	*Kunzea*, *Leptospermum*	Myrtaceae	Myrtales
		Ctenarytaina eucalypti (Maskell, 1890)	A	*Eucalyptus*	Myrtaceae	Myrtales
		Ctenarytaina fuchsiae (Maskell, 1890)	E	*Fuchsia*	Onagraceae	Myrtales
		Ctenarytaina longicauda Taylor, 1987	A	*Lophostemon*	Myrtaceae	Myrtales
		Ctenarytaina pollicaris Ferris & Klyver, 1932	E	*Kunzea*	Myrtaceae	Myrtales
		Ctenarytaina spatulata Taylor, 1997	A	*Eucalyptus*	Myrtaceae	Myrtales
		Ctenarytaina thysanura Ferris &	A	*Boronia*	Rutaceae	Sapindales

Psylloidea			Adventive / Endemic	Host Plant:		
	Family	Species		Genus	Family	Order
		Klyver, 1932				
		Ctenarytaina n. sp.	A	*Acmena*	Myrtaceae	Myrtales
		Ctenarytaina n. spp. (x2)	2x E	*Leptospermum*	Myrtaceae	Myrtales
		Eucalyptolyma maideni Froggatt, 1901	A	*Eucalyptus*	Myrtaceae	Myrtales
		Glycaspis granulata (Froggatt, 1901)	A	*Eucalyptus*	Myrtaceae	Myrtales
		†*Gyropsylla zealandica* (Ferris & Klyver, 1932)	E	host unknown		
		†*Psylla apicalis* Ferris & Klyver, 1932	E	*Sophora*	Leguminosae	Fabales
		†*Psylla carmichaeliae carmichaeliae* Tuthill, 1952	E	*Carmichaelia*	Leguminosae	Fabales
		†*Psylla c. indistincta* Tuthill, 1952	E	*Carmichaelia*	Leguminosae	Fabales
		Psyllopsis fraxini (Linnaeus, 1758)	A	*Fraxinus*	Oleaceae	Lamiales
		Psyllopsis fraxinicola (Foerster, 1848)	A	*Fraxinus*	Oleaceae	Lamiales
	Calophyidae		A			
		Calophya schini Tuthill, 1959	A	*Schinus*	Anacardiaceae	Sapindales
	Homotomidae		A			
		Mycopsylla fici (Tryon, 1895)	A	*Ficus*	Moraceae	Rosales
	Triozidae					
		Bactericera cockerelli (Sulc, 1909)	A	*Capsicum*, *Solanum* (incl. *Lycopersicon*)	Solanaceae	Solanales
		Trioza acuta (Ferris & Klyver, 1932)	E	*Ozothamnus*	Compositae	Asterales
		Trioza adventicia Tuthill, 1952	A	*Syzygium*	Myrtaceae	Myrtales
		Trioza alseuosmiae Tuthill, 1952	E	*Alseuosmia*	Alseuosmiaceae	Asterales
		Trioza australis Tuthill, 1952	E	*Brachyglottis*	Compositae	Asterales
		Trioza bifida (Ferris & Klyver, 1932)	E	*Olearia*	Compositae	Asterales
		Trioza colorata (Ferris & Klyver, 1932)	E	*Halocarpus*		
		Trioza compressa Tuthill, 1952	E	*Olearia*	Compositae	Asterales
		Trioza crinita Tuthill, 1952	E	*Olearia*	Compositae	Asterales
		Trioza curta (Ferris & Klyver, 1932)	E	*Metrosideros*	Myrtaceae	Myrtales
		Trioza dacrydii Tuthill, 1952	E	*Halocarpus*	Podocarpaceae	Pinales
		Trioza decurvata Tuthill, 1952	E	*Dracophyllum*	Ericaceae	Ericales
		Trioza dentiforceps Dumbleton, 1967	E	*Olearia*	Compositae	Asterales
		Trioza discariae Tuthill, 1952	E	*Discaria*	Rhamnaceae	Rosales
		Trioza doryphora (Maskell, 1880)	E	*Olearia*	Compositae	Asterales
		Trioza emarginata (Ferris & Klyver, 1932)	E	*Coprosma*	Rubiaceae	Gentianales
		Trioza equalis (Ferris & Klyver, 1932)	E	*Aristotelia*	Elaeocarpaceae	Oxalidales
		Trioza falcata (Ferris & Klyver, 1932)	E	*Aristotelia*	Elaeocarpaceae	Oxalidales
		Trioza fasciata (Ferris & Klyver, 1932)	E	*Muehlenbeckia*	Polygonaceae	Caryophyllales
		Trioza flavida Tuthill, 1952	E	*Olearia*	Compositae	Asterales
		Trioza gourlayi Tuthill, 1952	E	*Olearia*	Compositae	Asterales

Psylloidea			Adventive / Endemic	Host Plant:		
	Family	Species		Genus	Family	Order
		Trioza hebicola Tuthill, 1952	E	*Hebe*	Plantaginaceae	Lamiales
		Trioza irregularis (Ferris & Klyver, 1932)	E	*Pseudopanax*	Araliaceae	Apiales
		Trioza latiforceps Tuthill, 1952	E	*Olearia*	Compositae	Asterales
		Trioza obfusca (Ferris & Klyver, 1932)	E	*Hebe*	Plantaginaceae	Lamiales
		Trioza obscura Tuthill, 1952	E	*Hebe*	Plantaginaceae	Lamiales
		Trioza panacis Maskell, 1890	E	*Pseudopanax*	Araliaceae	Apiales
		Trioza parvipennis Tuthill, 1952	E	*Brachyglottis*	Compositae	Asterales
		Trioza schefflericola Tuthill, 1952	E	*Schefflera*		
		Trioza scobina Tuthill, 1952	E	*Olearia*	Compositae	Asterales
		Trioza styligera (Ferris & Klyver, 1932)	E	*Brachyglottis*	Compositae	Asterales
		Trioza subacuta (Ferris & Klyver, 1932)	E	*Brachglottis*	Compositae	Asterales
		Trioza subvexa Tuthill, 1952	E	*Olearia*	Compositae	Asterales
		Trioza vitreoradiata (Maskell, 1879)	E	*Pittosporum*	Pittosporaceae	Apiales
		Trioza n. spp. (x18)	18x E	?	?	?
		Gen. et spp. indet. (x2)	2x A	*Casuarina*	Casuarinaceae	Fagales