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European and Mediterranean Plant Protection Organization
Organisation Européenne et Méditerranéenne pour la Protection des Plantes PM 9/25 (1)

National Regulatory Control Systems
Systèmes de lutte nationaux réglementaires

PM 9/25 (1) *Bactericera cockerelli* and '*Candidatus* Liberibacter solanacearum'

Specific scope

This Standard describes a national regulatory control system for *Bactericera cockerelli* and the bacterial pathogen '*Candidatus* Liberibacter solanacearum' the cause of zebra chip disease in potato. The scope is as follows:

- Exclusion from the EPPO region of *B. cockerelli* an efficient vector of '*Ca*. L. solanacearum' within solanaceous crops (e.g. potato, tomato)
- Eradication of incursions of *B. cockerelli*
- Exclusion from the EPPO region of '*Ca.* L. solanacearum' haplotypes A and B. Although reference will only be made to haplotypes A and B, the Standard would also apply to new non-European haplotypes of '*Ca.* L. solanacearum' which may have different host ranges, or which may be vectored more efficiently by psyllids which are widespread in the region.

The reduction of the risk of spreading '*Ca.* L. solanacearum' haplotypes C, D and E to potato production systems and potatoes being moved within the EPPO region may be recommended in future when more information is available but is not covered in this Standard.

Specific approval

First approved in 2017-09.

1. Introduction

In 2012 EPPO recommended that its member countries should regulate '*Ca.* L. solanacearum', Solanaceae haplotypes and its vector *B. cockerelli* (Hemiptera: Triozidae), commonly known as the tomato/potato psyllid, as quarantine pests. Neither the vector nor haplotypes A and B are present in the EPPO region (A1 pests). Details of their biology, distribution and economic importance are available in EPPO data sheets (EPPO, 2013a,b) and the EPPO Global Database (https://gd.eppo.int/).

'*Candidatus* L. solanacearum' is a phloem-limited unculturable bacterium that is spread from infected to healthy plants by psyllid vectors in a persistent and trans-ovarial manner. So far five haplotypes of '*Ca.* L. solanacearum' (A, B, C, D and E) have been found. Haplotype A is found from Honduras and Guatemala through western Mexico to the western USA and in New Zealand. Haplotype B is found from eastern Mexico and northwards through Texas. Haplotypes A and B ('Solanaceous haplotypes') are associated with zebra chip disease in potatoes and diseases of other solanaceous plant species (e.g. *Solanum lycopersicum*, *Capsicum annuum*, *Nicotiana* spp.).

Haplotypes C, D and E have been found in several EPPO countries (see details in the EPPO Global Database) in plants from the family Apiaceae. They are associated with diseased carrots (*Daucus carota*) (C, D, E) as well as diseased celery (*Apium graveolens*), chervil (*Anthriscus cerefolium)*, fennel (*Foeniculum vulgare)*, parsley (*Petroselinum crispum)* and parsnip (*Pastinaca sativa*) (haplotypes D, E) (Alfaro-Fernández *et al.*, 2017; Hajri *et al.*, 2017). Zebra chip symptoms have been reported from a few commercial potato lots in Spain, and haplotype E was detected in the symptomatic tubers (Cambra, 2014).

The five haplotypes are not yet known to elicit biological differences, for example in the susceptibility of plants to infection or in the efficiency of transmission by psyllid vectors, although recently haplotype B was said to be more pathogenic than haplotype A (Wen *et al.* 2013). The recent discovery in Finland of potato volunteers infected with haplotype C and of ware potato tubers in Spain infected with haplotype E would suggest that all haplotypes can infect potato (Monger *et al.*, 2015) but transmission is limited between the different plant families because of the lack of a vector that is able to feed efficiently on plants in both families. Similarly, the solanaceous-infecting haplotype B can infect carrot (Munyaneza *et al.*, 2016).

Several experiments on seed transmission in carrot (and other Apiaceae) were conducted: the results of Bertolini *et al.* (2014) supporting seed transmission could not be

confirmed in more recent experiments (e.g. Loiseau *et al.*, 2017a,b). Reduction in the incidence of symptoms of '*Ca.* L. solanacearum' in carrot found in areas using only tested seed (M. Cambra, PHYLIB end of project meeting, 2014) would support seed transmission as being important in the epidemiology of the pathogen. However, this reduction could also be due to reduction of incidence of the vectors, which was not documented. Seed transmission in solanaceous hosts has not been demonstrated, although tests were conducted in the USA and New-Zealand on true potato seeds (J. Munyaneza, pers. comm.) and on tomato seeds (L. Liefting, pers. comm.).

The known vector of haplotypes A and B is *B. cockerelli* (tomato/potato psyllid), which also causes direct damage to solanaceous crops. The known vector of haplotype C is *Trioza apicalis* (carrot psyllid), which also causes direct damage to carrot crops. The spread of haplotypes D and E is mostly associated with *Bactericera trigonica*, although *Bactericera tremblayi* and *Bactericera nigricornis* have also been implicated. In Spain *B. trigonica* is the predominant psyllid in carrot and celery crops and is frequently found in potato fields growing near carrot and celery crops. *Trioza apicalis* occurs in Europe and spruce is a favourite overwintering host. *Bactericera trigonica* is mostly restricted to Mediterranean countries and the Middle East and *B. nigricornis* occurs across Asia and Western Europe. The full range of vector species and their distribution still needs to be determined.

Potato is not a good host for *T. apicalis*. So far it has not been possible to infect potato plants using infective *T. apicalis* or *B. tremblayi* (Monger *et al.*, 2015; Antolinez *et al.*, 2017a) but this was possible with *B. trigonica* (Teresani, 2014; Antolinez *et al.*, 2017a; Antolínez *et al.*, 2017b). It is considered that high numbers of vectors have the potential to lead to epidemics of '*Ca.* L. solanacearum' in carrots and celery but probably not in potato unless a more efficient vector is found for transmission of '*Ca.* L. solanacearum' from infected potato to healthy potato plants. Investigations are being conducted in Europe in the framework of the POnTE and PhyLib II projects.

Bactericera cockerelli is primarily found on plants in the family Solanaceae, including crop plants such as *Solanum tuberosum* (potato), *S. lycopersicum* (tomato), *Solanum melongena* (eggplant), *C. annuum* (pepper), *N. tabacum* (tobacco), *Lycium barbarum* and *Lycium chinense* (goji berry), and non-crop species such as nightshade (*Solanum* spp. including *Solanum elaeagnifolium*), *Physalis* spp. (groundcherry) and *Lycium* spp. (matrimony vine). It can also reproduce and develop on some species in the family Convolvulaceae, including *Ipomoea batatas* (sweet potato) and *Convolvulus arvensis* (field bindweed). Adults have been collected from plants in from more than 20 families. Munyaneza *et al.* (2016) demonstrated that *B. cockerelli* rarely probes the phloem of carrot.

Bactericera cockerelli is present in North America, Central America, New Zealand and Norfolk Island and was recently detected (February 2017) in Australia. It is a strong flier. In North America, *B. cockerelli* migrates annually, primarily with wind and hot temperatures in late spring, from its overwintering and breeding areas in the South-western USA and Northern Mexico to northerly regions of the USA and Southern Canada. It has recently been shown to overwinter also in the North-western USA. In countries and regions where there is no winter, the temperatures are relatively cool and suitable host plants are available (e.g. Mexico, Central America), *B. cockerelli* is able to reproduce and develop all year around.

Immature stages are essentially sedentary and do not actively disperse but long distance transport, particularly in plants moving in trade, is possible. *Bactericera cockerelli* was introduced into New Zealand, probably as eggs with plant material from the Western USA. Entry on fruit of host species (e.g. tomato, pepper) is possible, especially when they are associated with green parts (e.g. truss tomato and *Capsicum* fruit). In Florida, *B. cockerelli* has been intercepted on peppers and eggplants from Mexico (nymphs were found under the calyx; Halbert and Munyaneza, 2012). No life stages of *B. cockerelli* are associated with potato tubers or soil.

Given the impact of *B. cockerelli* in regions where it occurs, its introduction in the EPPO region would have serious economic consequences, especially if the insects were carrying '*Ca.* L. solanacearum'. In addition, it could also transmit efficiently within solanaceous plants the '*Ca.* L. solanacearum' haplotypes currently present in Europe at very low incidence (haplotypes C and E have been detected infecting potato several times).

2. Outline of the system

It is recommended that EPPO countries establish a national regulatory control system for *B. cockerelli* and '*Ca.* L. solanacearum' (haplotypes A and B) and, based on this Standard, include measures to prevent their introduction into the country, carry out surveillance on potato and other solanaceous hosts and, if present, contain and attempt to eradicate *B. cockerelli* and '*Ca.* L. solanacearum'.

Measures may also be considered against '*Ca.* L. solanacearum' (haplotypes C, D, E) to prevent the introduction of '*Ca.* L. solanacearum' into the potato production system, which may include reduction of levels of the pathogen in Apiaceae crops. They are not detailed in this version of the Standard but may be developed at a later stage.

The national regulatory control system should provide sufficient guarantees to allow export of potatoes within the EPPO region in conformity with EPPO Standard PM 8/1.

It is also recommended that EPPO member countries at risk prepare a pest specific contingency plan (based on EPPO Standard PM 9/10 *Generic elements for contingency plans*) to ensure that the necessary management and operational arrangements are in place to deal with an outbreak.

Pest-specific plans should be developed in consultation with industry sectors to make sure they are feasible and rehearsed to help ensure prompt and effective official action can be taken in the event of an outbreak occurring.

3. Control system

The objectives of the control system for *B. cockerelli* and '*Ca.* L. solanacearum' haplotypes A and B are:

- to raise awareness
- to prevent the introduction of the pests into the country
- to prevent the introduction of the pests into the potato production system and other solanaceous hosts
- to determine if the pests are present in the country through surveillance of potential hosts (e.g. solanaceous hosts) and, if present, to determine their distribution
- to prevent their spread
- to eradicate the pests where it is feasible
- to provide guidance on phytosanitary measures if eradication is unsuccessful.

3.1 Raising awareness

Early detection and reporting are critical to the success of the control system, particularly for *B. cockerelli* should it be introduced. All those handling potential hosts throughout the supply chain from growers, importers, packers, processors and retailers should be aware of what psyllids look like and the potential symptoms of '*Ca.* L. solanacearum' in the growing crop (potato, tomato, pepper) and the harvested produce (see EPPO data sheets for details; EPPO, 2013a,b).

Promotional activities can involve, for example, pest identification cards, the internet, posters and workshops involving growers, potato traders and processors. Psyllid species are small insects and are not well suited to public reporting, but may be recognized by amateur entomologists, for example.

3.2 Pathways of introduction

3.2.1 Bactericera cockerelli

The following potential pathways have been identified from countries where *B. cockerelli* occurs:

- Seed potato tubers (including minitubers) and ware potato tubers if the tubers have sprouts or a green stem or leaf parts present
- Plants for planting of Solanaceae other than potato (covered above)
- Fruit of Solanaceae (especially when they are associated with green parts such as truss tomato)
- Living parts of Solanaceae (except fruits, seeds and plants for planting), for example cut flowers and cut branches and foliage such as ornamental *Physalis* spp.
- Plants in the families Convolvulaceae (e.g. *Ipomoea batatas*) and Lamiaceae (e.g. *Micromeria chamissonis*; syn. *M. douglasii*), *Mentha* spp. (mint)

3.2.2 'Candidatus L. solanacearum' haplotypes A and B

The following potential pathways have been identified from countries where '*Ca.* L. solanacearum' haplotypes A and B (EPPO, 2012a) occur.

- entry of *B. cockerelli* infested with '*Ca*. L. solanacearum' (see 3.2.1)
- seed potatoes (including microplants and minitubers) and ware potatoes
- plants for planting of Solanaceae (other than potato) excluding seeds from countries where '*Ca.* L. solanacearum' occurs
- fruit of Solanaceae (in particular tomato, *Capsicum* spp., eggplant, tamarillo, Cape gooseberry).

3.3 Measures to prevent introduction

3.3.1 Bactericera cockerelli

The holding and handling of *B. cockerelli* should be prohibited and, since containment measures for live populations will be very difficult and expensive to achieve, import of this pest for research purposes even under special permit or licence is not recommended. Collaboration with countries in which the pest occurs is recommended as a lower-risk alternative.

To prevent the introduction of *B. cockerelli*, potato breeding material should be inspected according to post-entry quarantine requirements (EPPO Standard PM 3/21, under revision). All seed potatoes intended for planting in the EPPO region and all ware potatoes should come from a pest-free area for *B. cockerelli.* EPPO Standard PM 3/61 *Pest free areas and pest-free production systems for quarantine pests of potato* should be followed.

Plants for planting of Solanaceae, Convolvulaceae and Lamiaceae should come from a pest-free area for *B. cockerelli.* Fruits of Solanaceae should come from pest free areas for *B. cockerelli.* Equivalent measures may be considered as identified in the pest risk analysis (EPPO, 2012a,b).

Living parts of *Solanaceae* (except fruits) e.g. cut flowers and cut branches foliage should come from pest free areas for *B. cockerelli.* All material at risk of being infested with *B. cockerelli* indicated in 2.1 should be inspected for *B. cockerelli,* particularly for eggs.

3.3.2 'Ca. L. solanacearum' Haplotypes A and B

The holding and handling of '*Ca.* L. solanacearum' haplotypes A and B should be prohibited, except under special permit or licence, as recommended in EPPO Standard PM 3/64 *Intentional import of organisms that are plant pests or potential plant pests*.

To prevent the introduction of '*Ca.* L. solanacearum' haplotypes A and B, potato breeding material should be tested according to post-entry quarantine requirements described in EPPO Standard PM 3/21 (under revision).

Based on the perceived risk nuclear stock or initial material should be tested for freedom from '*Ca.* L. solanacearum' haplotypes A and B. All seed potatoes intended for

marketing in the EPPO region should come from a pest free area for '*Ca.* L. solanacearum' haplotypes A and B. The EPPO standard PM 3/61 *Pest free areas and pest-free production systems for quarantine pests of potato* should be followed.

Plants for planting of Solanaceae (except seeds) should come from a pest-free area and pest-free production and distribution system for '*Ca.* L. solanacearum' haplotypes A and B. Seed of other hosts, particularly solanaceous hosts (e.g. tomato) may also need to be considered for regulation if it is shown that transmission of '*Ca.* L. solanacearum' can occur.

3.4 Surveillance

3.4.1 General surveillance

Surveillance should be done in accordance with ISPM 6 *Guidelines for Surveillance*.

Bactericera cockerelli and '*Ca.* L. solanacearum' haplotypes A and B should be considered as notifiable pests. All persons suspecting or confirming the presence of *B. cockerelli* or '*Ca.* L. solanacearum' (haplotypes A and B) should notify the NPPO.

Potentially infested hosts may be officially inspected at import. ISPM No 31 *Methodologies for sampling of consignments* may be used as a basis for establishing sampling rates.

In certification schemes for seed potato, both the growing crop and tubers are inspected. In general, there is less official monitoring of ware potato crops and tubers, although tubers are inspected at grading and many EPPO countries undertake monitoring of ware potatoes for other pests that could potentially lead to the detection of *B. cockerelli* or '*Ca.* L. solanacearum' (haplotypes A and B). A good example is the official annual survey of potato crops for ring rot (*Clavibacter michiganensis* subsp. *sepedonicus*) and brown rot (*Ralstonia solanacearum*) that is undertaken by European Union countries.

Inspectors should be made aware of the potential signs of infestation by *B. cockerelli* and the characteristic symptoms of '*Ca.* L. solanacearum' infection. Symptoms are described in EPPO data sheets.

In carrot, '*Ca.* L. solanacearum' haplotype B induces disease symptoms including leaf reddening (Munyaneza *et al.*, 2016), which appears similar to that described for haplotype C (Nissinen *et al.*, 2014).

3.4.2 Specific surveys

Specific surveys are necessary following an outbreak, or when the pest-free status of a country or an area for *B. cockerelli* or '*Ca.* L. solanacearum' (haplotypes A and B) needs to be established. Specific surveys are recommended for potato and other solanaceous crops (e.g. tomato, pepper). Weeds (e.g. *Solanum dulcamara*, *Solanum nigrum*) should also be included in surveys. Adult *B. cockerelli* may be sampled using preferably yellow sticky traps or yellow water traps. Sweep nets, vacuum trapping and sampling leaves may also be used, but these methods are less efficient. The height at which the sticky trap is set in the field appears significant, with lower traps giving better results; a standard trap, set in the crop just below the canopy of the plants is used by both the USA and New Zealand researchers. Egg and nymphal sampling requires visual examination of foliage. Psyllid populations are initially highest at field edges. For crops grown under protection, traps may also be located near potential points of pest entry.

Where a country considers that *B. cockerelli* poses a significant threat to its potato industry and wants to protect itself by increasing the probability of detecting an outbreak at an early stage, the NPPO should target surveys in high-risk locations, e.g. where host fruits from countries where the pest is known to occur are imported or packed.

3.4.3 Identification

Host material suspected of being infected with *B. cockerelli* or '*Ca.* L. solanacearum' should be subject to confirmatory examination and testing according to agreed diagnostic protocols for *B. cockerelli* (EPPO not yet developed) and '*Ca.* L. solanacearum' (ISPM 27 DP 21, 2017; EPPO, in preparation). It is important to quickly identify the psyllid vectors and '*Ca.* L. solanacearum' haplotype since the severity of measures to be applied depends on the vector species and the '*Ca.* L. solanacearum' haplotype. Determining the population level of *B. cockerelli* present and the incidence of '*Ca.* L. solanacearum' may give an indication of the likely source. Infected psyllids should be tested for '*Ca.* L. solanacearum'.

3.5 Immediate action to prevent further spread

To prioritize action during an outbreak the NPPO should follow EPPO Standard PM 9/18 *Decision-support scheme for prioritizing action during outbreaks* from the point at which an outbreak is suspected as a result of a finding in a crop, store or consignment moving in trade**.**

'*Candidatus* L. solanacearum' cannot be transmitted mechanically, but may be spread to new areas by the planting of infected material (e.g. potato tubers, tomato plants). For further efficient spread a vector is required. Adult *B. cockerelli* are unlikely to be carried on, for example, equipment, farm machinery and people, because they fly away when disturbed. However, eggs and nymphs of *B. cockerelli* can readily be carried on equipment, machinery and by farm workers and, if infected with '*Ca.* L. solanacearum', can effectively spread '*Ca.* L. solanacearum' to new areas.

The following scenarios may occur:

- *B. cockerelli* is found with or without '*Ca.* L. solanacearum' haplotypes A or B
- '*Ca.* L. solanacearum' haplotype A or B is found without *B. cockerelli*.

These scenarios may be further divided according to the plant species on which the pest (s) is found and whether it is found in a crop, in store or on a consignment.

The finding of *B. cockerelli* requires prompt action to contain and eradicate it. Eradication may only be possible if it is a single incursion which has been detected very early so it has not spread from the infested site. It is envisaged that the pests may be found on:

- Crops under field cultivation (e.g. potato, tobacco, tomato)
- Crops under glasshouse cultivation (e.g. pepper, tomato and potato minitubers)
- Harvested host plants or plant products in a store at the production site, in a packing house, or in a processing facility
- Consignments of potential host plants or plant products (including potato tubers) moving in trade (see 3.2.1) originating in areas where the pest is present.

The following sections describe the measures to be taken on suspicion and confirmation of the presence of the pest(s) under various scenarios. Measures are summarized in Fig 1.

3.5.1 Measures to be taken at suspicion of an outbreak of B. cockerelli and/or 'Ca. L. solanacearum' haplotypes A or B

An outbreak of *B. cockerelli* may be suspected because of plant symptoms or the finding of eggs, larvae or adult psyllids on plant foliage. The presence of '*Ca.* L. solanacearum' may be suspected because of symptoms in the plant foliage and, in the case of potato, symptoms of zebra chip in the harvested tubers.

Depending on the strength of the suspicion of pest presence and the risk of spread (e.g. level of containment, nearby host crops), a provisional regulated area should be established comprising:

- the potentially infested consignment, the lot, the crop
- the potentially infested production site (e.g. field, glasshouse) or premises where the infestation was found
- a potentially infested area. The size and what is covered by this area will have to be decided on a case by case basis.

Within this area, handling and movement of the host plants or plant products should be prohibited until a diagnosis is made. Restrictions should also be placed on the movement of staff, tools and machinery. Staff should be trained to implement good hygiene standards to prevent the potential spread of the vector, and tools and machinery should be disinfested if removed from site under suspicion (e.g. application of insecticide followed by steam cleaning or cleaning with detergent).

If initially only '*Ca.* L. solanacearum' is suspected, surveys should be conducted to check for the presence of *B. cockerelli* or other vectors**.** Because '*Ca.* L. solanacearum' is not mechanically transmitted, if it can be established that vectors are not present in the regulated area measures can be limited to ensuring that there is no further spread of the pathogen. If the initial suspicions of pest presence are not confirmed then any prohibitions should be lifted.

3.5.2 Measures to be taken after confirmation of an outbreak of B. cockerelli (with or without 'Ca. L. solanacearum' haplotypes A or B) in an infested crop (field or glasshouse)

3.5.2.1 Solanaceous crops or other potential host plants growing in a glasshouse or a field. If infestation by *B. cockerelli* (with or without '*Ca.* L. solanacearum' haplotypes A and B) is confirmed, the NPPO should:

Designate as 'infested':

- the host plants (including tubers) from which the sample was taken
- the site of production (e.g. field, glasshouse) where the infested host plants were found.

Designate as 'probably infested' an area of not less than 1 km around the site of production (e.g. the infested field) taking account of other pathways of spread, particularly within the place of production. If *B. cockerelli* is only detected in a glasshouse it should be sealed as far as is practically possible to prevent the psyllid spreading to the wider environment. If this can be achieved, based on a risk assessment, the radius of the probably infested area may be reduced below 1 km

Demarcate a regulated area which is composed of:

- the infested site of production
- the 'probably infested' area
- a buffer zone of at least 1 km around the probably infested area.

In determining the size and shape of the regulated area meteorological data, especially wind speed and direction, may be useful. The movement of any potential host plants of *B. cockerelli* and of '*Ca.* L. solanacearum' from the regulated area should be prohibited.

A delimiting survey should be conducted within the regulated area to determine the extent of infestation by inspecting all potential host plants for eggs, nymphs and adults that may be present on the foliage. The use of yellow sticky traps, water traps, suction traps or sweep nets is recommended in determining the infested area.

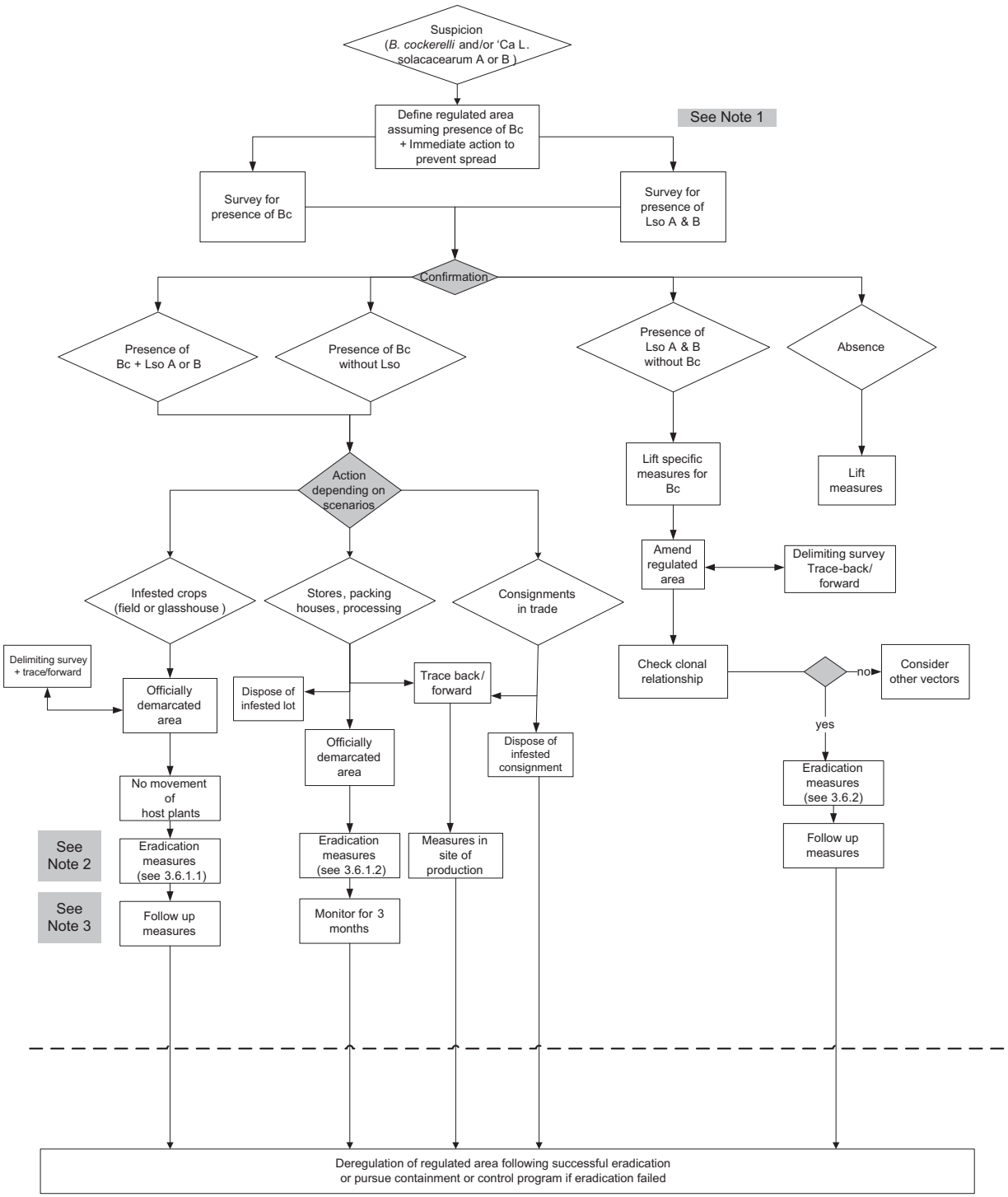
The boundaries of the regulated area should be adjusted depending on survey results. The results may indicate whether eradication is still possible.

The origin of the infestation should be investigated by traceback, investigating potential links in the case of seedling/transplant/produce links for solanaceous or other host crops.

Potential sources of *B. cockerelli* within the regulated area should also be investigated. However, since adults are strong flyers, particularly when assisted by the wind, it may not be possible to identify the source of any infestation in the regulated area, in which case specific surveys will be required outside of the regulated area.

Trace forward should be done for potentially infested material moved from the infested area prior to the regulated area being established and NPPO of other countries should be notified if this is relevant.

3.5.2.2 Stores, packing houses, and processing facilities. If infestation by *B. cockerelli* (with or without '*Ca.* L.



Note 1 – No movement of plant products - Restrictions on movement of staff, tools and machinery - good hygiene
Note 2 – Treat infested crop and all crops in infested and probably infested area – harvest host plants and destroy or process them – desinfest machinery
Note 3 – No host crops in infested and probably infested area for 2 years (except trap crops) – monitoring for 2 further years – host crops in buffer zones treated against psyllids.

Fig 1 Measures to be taken at suspicion and after confirmation of an outbreak of *B. cockerelli* with or without '*Ca.* L. solanacearum' haplotypes A or B.

solanacearum' haplotypes A or B) is confirmed, the NPPO should:

Designate as 'infested':

- the lot of host plants (or tubers) from which the sample was taken
- other plants (or tubers) within the facility/site unless the NPPO can exclude the possibility of the pest being present on them
- the facility/site where the infested host plants were found.

Designate as 'probably infested' an area surrounding the facility/site if there is a potential risk of the psyllid infestations having spread into the field.

Demarcate a regulated area which is composed of:

- the infested facility/site
- the 'probably infested' area
- a buffer zone if there is a potential risk of the psyllid infestations having spread into the field.

The size of this 'probably infested' area and buffer zone should be decided on a case by case basis.

A delimiting survey should be conducted. The boundaries of the regulated area should be adjusted depending on survey results. Traceback should be done to identify the source of the infestation. Where the site or place of production can be identified, measures should be applied accordingly.

3.5.2.3 Consignment(s) moving in trade. If *B. cockerelli* (with or without '*Ca.* L. solanacearum' haplotypes A and B) is confirmed on a consignment moving in trade the consignment should be designated as infested. Depending on where the consignment is located (port, rural area) the NPPO should amend the provisional regulated area established on suspicion so that it now comprises:

- the infested area
- a probably infested area
- a buffer zone.

The size of this 'probably infested' area and buffer zone should be decided on a case by case basis. A delimiting survey should be conducted. The boundaries of the regulated area may be adjusted depending on survey results. Other consignments from the same or related sources should be traced backwards and forwards and surveys carried out at the suppliers' and recipients' premises and intermediate points of handling such as ports of entry and packing stations to confirm whether the pests are present. If the consignment is from another country the NPPO of that country of origin and the consignor(s) should be notified.

3.5.3 Confirmation of 'Ca. L. solanacearum' haplotypes A or B only

If infestation by '*Ca.* L. solanacearum' haplotypes A or B is found (without *B. cockerelli*) the NPPO should:

Designate as 'infested':

- the host plants (including tubers and the lot or crop) from which the sample was taken
- the production site (e.g. field, glasshouse) where the infestation was found

Designate as 'probably infested' any potentially infested crop, lot or consignment if other vectors are identified.

Demarcate a regulated area which is composed of:

- the infested site of production
- the 'probably infested' area if other vectors are identified.

Traceback should be done. The boundaries of the regulated area may be adjusted depending on survey results.

Since '*Ca.* L. solanacearum' is not mechanically transmitted, if it can be established that vectors are not present in the regulated area measures can be limited to ensuring that there is no further spread of the pathogen.

3.6 Eradication and follow-up measures

3.6.1 Bactericera cockerelli with or without 'Ca. L. solanacearum' haplotypes A and B

3.6.1.1 Solanaceous crops or other potential host plants growing in the regulated area.

- The whole of the infested growing crop should be treated promptly with an approved insecticide (see Appendix 1). All other crops (not just host crops) in the regulated area (excluding the buffer zone) and other plants including weeds should be treated at appropriate intervals with an approved insecticide
- All host plants (including haulms, tubers and *Solanum* weeds) should then be harvested from the regulated area (excluding the buffer zone), sealed and transported to an approved facility for disposal or processing in such a way that there is no risk of spread, or destroyed *in situ* (e.g. by a foliar desiccant or by burning with appropriate machinery) (see Appendix 2 Treatment or disposal of infested material). Desiccated foliage with no remaining green material may be left *in situ* and does not require further treatment. Infested glasshouses and premises, and all machinery in contact with the infested and probably infested crops, should be disinfested.

Measures to be applied in the following years:

- After a finding in solanaceous crops or other potential host plants, no host crops of *B. cockerelli* should be grown in the infested site of production and the probably infested area for two consecutive years, during which time the crops, volunteers and weeds should be officially monitored. After this time solanaceous crops may be planted but these should be subject to monitoring for 2 years
- After a finding in potatoes, the infested field should be maintained for 3 years in bare fallow or in permanent pasture with frequent close cutting or intensive grazing. Alternatively cereals or other arable crops may be grown for 3 years provided control of potato volunteers can be achieved using selective herbicides. After 3 years either seed or ware potatoes may be produced, but these crops should be subject to monitoring during the growing season
- As an exception to this prohibition, small plots of solanaceous host crops may be grown as trap crops. These

should be inspected at appropriate times, treated with an insecticide and destroyed *in situ*. This will enable monitoring of the level of the pest and may aid in avoiding its dispersal
- Host crops grown within the buffer zone should be monitored for the presence of psyllids and treated with an approved insecticide
- Surveillance should be carried out in the regulated area for 4 years following the outbreak using visual inspections and appropriate traps. Where '*Ca.* L. solanacearum' (A or B) has been found in addition to *B. cockerelli*, monitoring may include testing of host crops/psyllids for presence of the pathogen.

3.6.1.2 Stores at the production site, packing houses and processing facilities.
- The infested plant material should be disposed of according to the measures described in Appendix 2 at an approved facility
- If the infested plant material is to be transported, it should be sprayed or fumigated prior to transportation with an approved insecticide to kill the psyllid. Containers should be sealed to prevent the escape of any surviving *B. cockerelli* during transportation
- The regulated area, including containers, machinery and buildings, should be disinfested
- Surveillance should be carried out in the regulated area using appropriate traps for 3 months or longer if appropriate.

3.6.1.3 Consignments moving in trade. Measures are the same as for stores (see 3.6.1.2).

3.6.2 'Candiatus L. solanacearum' haplotypes A or B in the absence of B. cockerelli

The following measures should be applied after an outbreak in a potato crop (e.g. when infection is linked to clonal material):
- If the infected crop is still growing, the potato haulm should be treated immediately with an effective insecticide and destroyed since there is still some uncertainty about the potential presence of unknown effective vectors
- Infested fields may be maintained for 3 years, either in bare fallow or in permanent pasture (with frequent close cutting, intensive grazing). Alternatively, cereals or other arable crops may be grown for 3 years provided control of potato volunteers can be achieved using selective herbicides
- Potatoes or other host crops of '*Ca.* L. solanacearum' should not be grown in the 'infested' fields until no volunteer potato plants have been found for two consecutive years
- Control of *Solanum* weeds should be carried out
- After this period either seed or ware potatoes or other host crops may be produced. The first production (growing crop and tubers) should be inspected for symptoms.

3.7 Possible control programme if eradication of B. cockerelli is not successful

A management plan and programme of phytosanitary measures should be drawn up to provide ongoing control of the pest in the event of failure of eradication of *B. cockerelli*. EPPO recommendations may be developed in future. Information from New Zealand and Australia is included in Appendix 3.

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References

Alfaro-Fernández A, Hernández-Llopis D & Font MI (2017) Haplotypes of '*Candidatus* Liberibacter solanacearum' identified in Umbeliferous crops in Spain. *European Journal of Plant Pathology* **149**, 127.

Antolinez C, Fereres A & Moreno A, (2017a) Risk assessment of '*Candidatus* Liberibacter solanacearum' transmission by the psyllids *Bactericera trigonica* and *B. tremblayi* from Apiaceae crops to potato. Scientific Reports 7. https://doi.org/10.1038/srep45534

Antolínez CA, Fereres A & Moreno A (2017b) Sex-specific probing behaviour of the carrot psyllid Bactericera trigonica and its implication in the transmission of 'Candidatus Liberibacter solanacearum'. *European Journal of Plant Pathology* **147**, 627–637.

Bertolini E, Teresani GR, Loiseau M, Tanaka FAO, Barbé S, Martínez C *et al.* (2014) Transmission of '*Candidatus* Liberibacter solanacearum' in carrot seeds. *Plant Pathology*. https://doi.org/10.1111/ppa.12245.

Cambra M, Bertolini E, Teresani G, Martinez C & Lopez MM (2014) Detection/zebra chip like symptoms first found in Spain 2013-2014. from the autonomous region of Castilla de Leon https://www.sasa.gov.uk/sites/default/files/6%20Current%20situation%20of%20%E2%80%98Ca%20Liberibacter%20%20solanacearum%E2%80%99%20in%20Spain.%20Mariano%20Cambra.pdf accessed on 01 June 2017

EPA (2016) Decision to To release from containment the psyllid parasitoid Tamarixia triozae into New Zealand to assist with the biological control of the tomato potato psyllid (Bactericera cockerelli) http://www.epa.govt.nz/search-databases/HSNO%20Application%20Register%20Documents/APP201955_APP201955_Decision_FINAL.pdf [Accessed on 01 June 2017]

EPPO (2012a) Final pest risk analysis for Candidatus Liberibacter solanacearum in Solanaceae. EPPO, Paris. Available at https://gd.eppo.int/taxon/LIBEPS/documents [accessed on 01 June 2017]

EPPO (2012b) Final pest risk analysis for Bactericera cockerelli. https://gd.eppo.int/taxon/PARZCO/documents [accessed on 01 June 2017]

EPPO (2013a) Data sheet of '*Ca.* Liberibacter solanacearum'. Available at https://gd.eppo.int/taxon/LIBEPS/documents [accessed on 01 June 2017]

EPPO (2013b) Data sheet of *Bactericera cockerelli*. Available at https://gd.eppo.int/taxon/PARZCO/documents [Accessed on 01 June 2017]

EPPO Standard PM 3/21 Post-entry quarantine for potato. (under revision). Available at eppo.int [Accessed 01 June 2017]

EPPO Standard PM 3/61 "*Pest free areas and pest-free production systems for quarantine pests of potato*. Available at https://gd.eppo.int/standards/PM3/ [Accessed on 01 June 2017]

EPPO Standard PM 3/64 *Intentional import of organisms that are plant pests or potential plant pests*. Available at https://gd.eppo.int/standards/PM3/ [accessed on 01 June 2017]

EPPO Standard PM 3/66 *Guidelines for the management of plant health risks of biowaste of plant origin*. Available at eppo.int. Available at https://gd.eppo.int/standards/PM3/[accessed on 01 June 2017]

EPPO Standard PM 9/10 *Generic elements for contingency plans*.

Hajri A, Loiseau M, Cousseau-Suhard P, Renaudin I & Gentit P. (2017) Genetic Characterization of 'Candidatus Liberibacter solanacearum' Haplotypes Associated with Apiaceous Crops in France. Plant Disease, in press, dx.doi.org/10.1094/PDIS-11-16-1686-REISPM 27 Diagnostic protocols for regulated pests DP 21: 'Candidatus Liberibacter solanacearum' https://www.ippc.int/static/media/files/publication/en/2017/04/DP_21_2017_En_2017-03-31.pdf [accessed on 01 June 2017]

Halbert SE & Munyaneza JE (2012) The potato psyllids and its associated pathogens. NPDN Protect US Module. http://entnemdept.ifas.ufl.edu/hodges/ProtectUs/presentations/potato_psyllids_7_6-12.pdf

Loiseau M, Renaudin I, Cousseau-Suhard P, Lucas PM, Forveille A & Gentit P (2017b) Lack of evidence of vertical transmission of 'Candidatus Liberibacter solanacearum' by carrot seeds suggests that seed is not a major pathway for transmission. *Plant disease*. https://doi.org/10.1094/PDIS-04-17-0531-RE.

Loiseau *et al.* (2017a) Transmission tests of 'Candidatus Liberibacter solanacearum' by carrot seeds. *Acta Horticulture* **1153**, 41–46.

Monger W, Nisbet C & Jeffries C. (2015) EUPHRESCO PHYLIB End of Project Meeting http://www.sasa.gov.uk/content/phylib-end-project-meeting [accessed on 01 June 2017]

Munyaneza JE, Mustafa T, Fisher TW, Sengoda VG & Horton DR (2016) Assessing the likelihood of transmission of *Candidatus* Liberibacter solanacearum to carrot by potato psyllid Bactericera cockerelli (Hemiptera:Triozidae). *PLoS ONE*. https://doi.org/10.1371/journal.pone.0161016

Nissinen AI, Haapalainen M, Jauhiainen L, Lindman M & Pirhonen M (2014) Different symptoms in carrots caused by male and female carrot psyllid feeding and infection by 'Candidatus Liberibacter solanacearum'. *Plant Pathology* **63**, 812–820.

Plant Health Australia (2011). Industry Biosecurity Plan for the Potato Industry. Threat Specific Contingency Plan: Zebra chip complex. Plant Health Australia, Deakin, ACT 2600. www.planthealth Australia.com.au. [accessed on 01 June 2017]

Potato New Zealand (2014) Oils and selective insecticides for tomato psyllid management in potato. Potato Update, Issue 4. http://potatoesnz.co.nz/?mdocs-file=6249 [accessed on 01 June 2017]

Teresani GR (2014) '*Candidatus* Liberibacter solanacearum': detection, characterization, new hosts and epidemiology. PhD thesis 234 pp. Poly technical University of Valencia.

Tomatoes New Zealand and Vegetables New Zealand (2016) The New Zealand Code of Practice for the Management of the Tomato/Potato Psyllid in Greenhouse Tomato and Capsicum Crops. 3rd Edition https://www.freshvegetables.co.nz/assets/Uploads/TPPsyllid-CoP-2016-Capsicums-and-tomatoes-PDF.pdf [accessed on 01 June 2017]

Wen A, Johnson C & Gudmestad NC (2013) Development of a PCR assay for the rapid detection and differentiation of '*Candidatus* Liberibacter solanacearum' haplotypes and their spatiotemporal distribution in the United States. *American Journal of Potato Research* **90**, 229–236. https://doi.org/10.1007/s12230-012-9293-9.

Other useful references

Collins L, Nissinen A, Pietravalle S & Jauhiainen L (2014) Carrot psyllid (*Trioza apicalis*) feeding behavior on carrot and potato: an EPG study. 2014 Zebra Chip Annual Reporting Session 9th-11th November 2014 Portland, Oregon. http://zebrachipscri.tamu.edu/files/2015/01/Nissinen_ZC_Poster_2014.pdf [Accessed on 01 June 2017]

Halbert SE, Munyaneza JE & Sobel L (2014) The potato psyllid and its associated pathogens. http://www.protectingusnow.org/. [Accessed 2017-06]

Pitman AR, Drayton GM, Simona J, Kraberger SJ & Genet RA (2011) Scott IAW (2011) Tuber transmission of 'Candidatus Liberibacter solanacearum' and its association with zebra chip on potato in New Zealand. *European Journal of Plant Pathology* **129**, 389–398.

Tahzima R, Maes M, Achbani EH, Swisher KD, Munyaneza JE & De Jonghe K (2014) First Report of '*Candidatus* Liberibacter solanacearum' on Carrot in Africa. *Plant Disease* **98**, 1426.

Teresani GR, Bertolini E, Alfaro-Fernández A, Martínez C, Tanaka FA, Kitajima EW *et al.* (2014) Association of '*Candidatus* Liberibacter solanacearum' with a vegetative disorder of celery in Spain and development of a real-time PCR method for its detection. *Phytopathology* **104**, 804–811.

Teresani G, Hernández E, Bertolini E, Siverio F, Marroquín C, Molina J *et al.* (2015) Search for potential vectors of '*Candidatus* Liberibacter solanacearum': population dynamics in host crops. *Spanish Journal of Agricultural Research.* **13**, e10–002. 11 pages (2015) eISSN: 2171-9292 https://doi.org/10.5424/sjar/2015131-6551

Wang J, Haapalainen M, Schott T, Thompson SM, Smith GR, Nissinen AI *et al.* (2017) Genomic sequence of'Candidatus Liberibacter solanacearum' haplotype C and its comparison with haplotype A and B genomes. *PLoS ONE* **12**(2), e0171531.

Appendix 1 – Control options

1. Chemical control

Effective control is dependent on the timely application of insecticides with good activity against *B. cockerelli* and other potential insect vectors. The NPPO should assess the portfolio of insecticides available to control *B. cockerelli* in advance of any outbreak because it is likely to influence the overall control strategy adopted. Furthermore, if there is a shortage of effective insecticides it may be possible to apply for emergency clearance so that more effective chemicals are available in a future outbreak situation. It is also important to have chemicals available with different modes of action in order to mitigate against any existing resistance and to help limit the development of resistance to ensure that control remains effective in the longer term.

For treatment of growing crops good insecticide coverage or an insecticide with translaminar activity is important because psyllids are commonly found on the underside of the leaves. Insecticides which are effective against adults

do not necessarily work against nymphs or eggs, therefore several different insecticides may need to be applied, although an insecticide with activity against all stages of the life cycle of *B. cockerelli* is preferable.

Insecticides approved in the United Kingdom, known to control one or more psyllid growth stages are listed in Table A1. In the USA abamectin and spirotetramat are widely used. Tolfenpyrad, cyazapyr and sulfoxaflor are effective alternatives.

2. Biological control

In New Zealand the release of the psyllid parasitoid *Tamarixia triozae* has been recently approved to assist with the biological control of *B. cockerelli* in field crops (EPA 2016), as well *Amblydromalus limonicus* predatory mite for greenhouses.

Appendix 2 – Treatment or disposal of infested material

1. Plants infested with *B. cockerelli*

Plant material can be collected and piled up in a heap on the infested field or in the infested glasshouse, covered to prevent escape of *B. cockerelli* and left at ambient temperatures for a period of at least 12 months or until well rotted.

Desiccated foliage with no remaining green material may be left in the field and does not require further treatment.

No plant material should be removed from the infested area unless it is securely enclosed during transportation to be disposed in a facility approved by the NPPO according to procedures recommended below, for example:

- deep burial
- incineration
- heat treatment of at least 70°C for 30 min throughout the material
- freezing small quantities at ≤−20°C throughout the material for 24 h.

Potato tubers or other solanaceous crops harvested from the infested field can also be submitted to industrial processing in such a way that there is no risk of dispersal or survival of the pest. This should be done under official supervision and only at a processing plant with appropriate waste facilities.

Machinery used in the disposal process should be thoroughly disinfested.

2. Plants infested with '*Ca.* L. solanacearum' only

In addition to the options mentioned above, infected material may be disposed of using, for example:

- industrial processing at a processing plant with appropriate waste facilities

Table A1. Insecticides approved in the UK (in 2016), known to control one or more psyllid growth stages. Registration in other EPPO countries may differ. Plant protection products should be used following the instructions on the label for the particular use in the country concerned

Active ingredient	Product	Insecticide class	Potato	Tomato	Aubergine	Pepper	Authorization expiry date
Esfenvalerate	Barclay Alphasect	3A	Label	Not authorized	Not authorized	Not authorized	30/04/2017
Lambda-cyhalothrin	Hallmark with Zeon Technology	3A	Label	Ex no. 2012/1994	Ex no. 2012/1994	Ex no. 2012/1994	30/06/2018
Acetamiprid	Gazelle	4A	Not authorized	Label	Label	Label	31/10/2019
	InSyst	4A	Label	Not authorized	Not authorized	Not authorized	31/10/2019
Thiacloprid	Calypso	4A	Not authorized	Ex no. 2014/2151	Ex no. 2014/2151	Ex no. 2014/2151	17/08/2018
	Biscaya	4A	Label	Not authorized	Not authorized	Not authorized	17/08/2018
Thiamethoxam	Actara	4A	Label	Not authorized	Not authorized	Not authorized	31/10/2020
Spinosad	Conserve	5	Not authorized	Label	Label	Label	31/10/2020
	Tracer	5	Ex no. 2890/014	Not authorized	Not authorized	Not authorized	31/10/2020
Abamectin	Dynamec	6	Not authorized	Label	Ex no. 2007/0421	Ex no. 2007/0422	31/12/2021
Pymetrozine	Plenum WG	9B	Label	Not authorized	Not authorized	Not authorized	30/06/2018
	Chess WG	9B	Not authorized	Ex no. 2007/0501	Ex no. 2007/0501	Ex no. 2007/0501	30/06/2018
Spiromesifen	Oberon	23	Not authorized	Label	Ex no. 2006/3645	Ex no. 2006/2149	30/04/2016

3A, pyrethroids; 4A, neonicotinoid; 5, nicotinic acetylcholine receptor allosteric modulator' 6, chloride channel activator; 9B, selective feeding inhibitor; 9C, selective homopteran feeding inhibitor; 23, inhibitors of acetyl CoA carboxylase.
Ex no., extension of authorization number.

- anaerobic digestion for production of biogas at an officially approved site
- fermentation and composting at an officially approved composting site following EPPO standard PM 3/66 *Guidelines for the management of plant health risks of biowaste of plant origin*
- fermentation of contaminated plants during silage production then feeding to animals
- steaming and feeding to animals.

Appendix 3 – Control programme against *B. cockerelli* developed in New-Zealand and Australia

1. Glasshouse crops

Tomatoes New Zealand and Vegetables New Zealand (2016) has published the New Zealand Code of Practice for the Management of the Tomato/Potato Psyllid in Greenhouse Tomato and Capsicum Crops. This has been used to describe some key elements for a control programme:

- The glasshouse should be designed to minimize the risk of entry of psyllids (appropriately sized insect screens, double-door entry system, with change of clothes at entry)
- All potential weed hosts and non-commercial ornamental plants should be removed from the place of production
- Clean and disinfect the greenhouse ensuring all plant material including weeds and volunteer plants is removed and destroyed before a new crop is planted
- Only source pest-free plants
- Drench or spray plants on arrival with an approved insecticide
- Establish a crop monitoring plan, and using trained staff, monitor the crop weekly, increasing to daily during periods of high pest pressure, marking infested plants and areas
- Set up sticky traps in the glasshouse (at least 10 per hectare), at greenhouse entrance (at least every 10 m^2), and outside
- Spot spraying may be effective in a glasshouse for controlling limited incursions
- Crop removal and actions between cropping cycles: before the end of a crop, close the glasshouse to contain the psyllids, thus preventing them from being spread into the wider environment. Apply a high-volume pesticide spray together with a surfactant or mineral spraying oil. Keep the greenhouse closed for 24 h before plant removal. Remove the plants securely (e.g. in covered bins) to land fill or composting. Check that all flying insect pests have been eradicated by hanging yellow sticky traps (at least 10 per hectare) and inspect daily. Use fog or spray insecticide if pests are present. Close the greenhouse ventilators and doors and allow a period for warming to accelerate pest eradication.

2. Field crops

Plant Health Australia (2011) has developed a management plan for *B. cockerelli* in anticipation of the pest, with or without '*Ca.* L. solanacearum', becoming established in the country. This includes application of a number of pesticides, with effect on different metabolic processes, to provide protection of potato crops at different developmental stages:

- Imidacloprid: applied in the planting furrow provides control for up to 42 days from planting, but with decreasing efficacy after 28 days
- Spirotetramat: applied as three spray applications at 7–14 day intervals depending on conditions, provides control of psyllids from 28 to around 55 days after planting
  - First spray application is at the beginning of stem formation (about 28 days after planting)
  - Second spray application around 7–14 days later
  - Third spray application around 7–14 days after the second application
- Spinosad applied as a spray application in two applications beginning at around 55 days after sowing provides psyllid control up to 70 days
- Remaining sprays include either organophosphates, carbamate or synthetic pyrethroids applied weekly, providing control for 30 days from weeks 70 to 100.

Potato New Zealand (2014) underlines the need to consider insecticide resistance management when choosing active substances. Oils may be used to reduce the number of insecticide sprays They note that monitoring should be conducted with traps, as well as using degree days to determine the start of the spray programme. Depending on the conditions, thiamethoxam may be used early in the season. A best practice programme then includes spirotetramat (2 applications), abamectin (4 applications), spinetoram (4 applications) and cyantraniliprole (3 applications).