Department
for Environment
Food & Rural Affairs

Pest specific plant health response plan:

Outbreaks of zebra chip disease (‘*Candidatus* Liberibacter solanacearum’) and its psyllid vector *Bactericera cockerelli* on glasshouse-grown crops

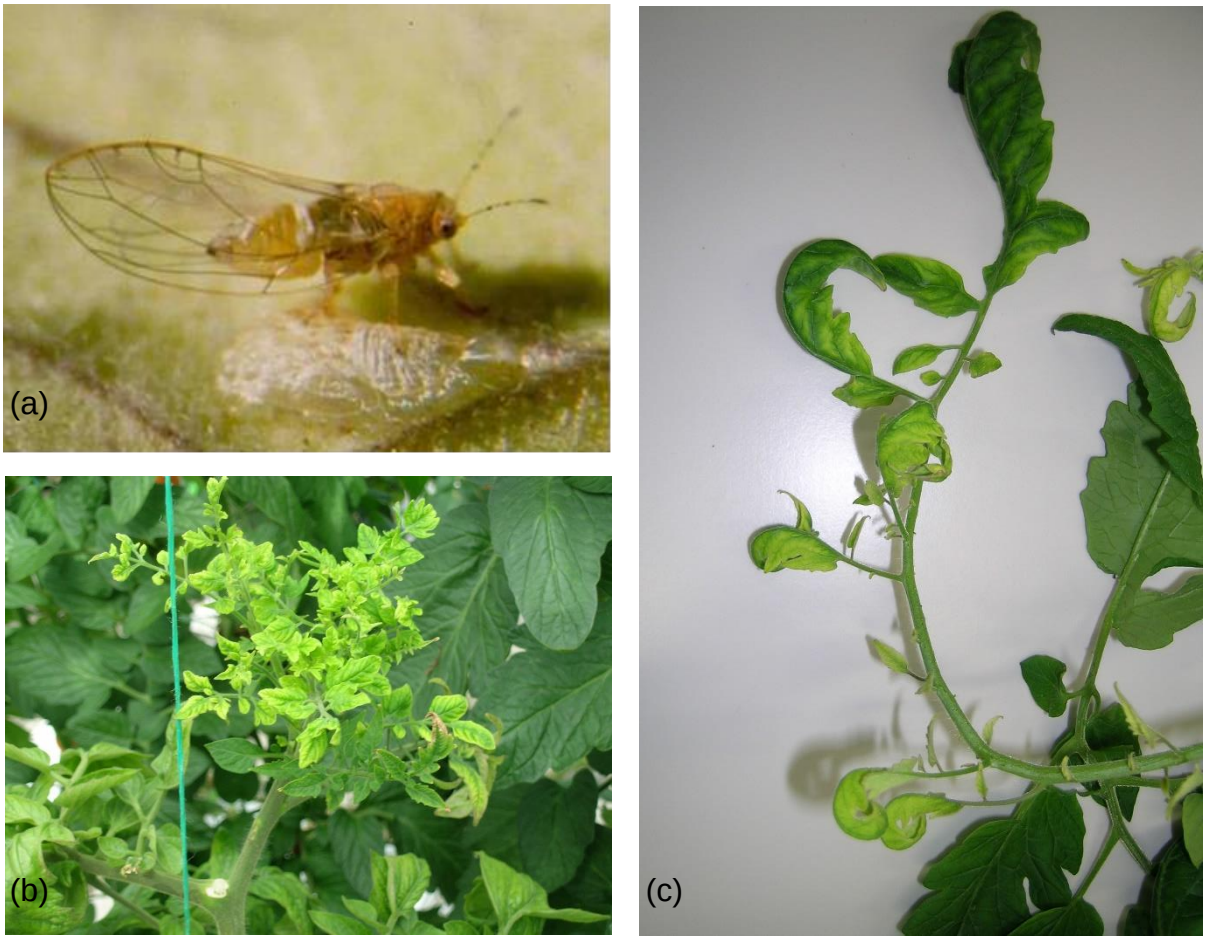

Figure 1. (a) Adult *B. cockerelli* (2.5-2.75 mm long). © Joseph E. Munyaneza, USDA ARS, Wapato, WA.; (b) and (c) symptoms on tomato ©

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Executive summary

Background	
Regulation	*Bactericera cockerelli* is a GB Quarantine pest whilst *'Candidatus* Liberibacter solanacearum' (Lso) is a regulated non quarantine pest.
Key Hosts (2.2)*	Potatoes, peppers, tomatoes and aubergines
Distribution of *B. cockerelli*	Australia, Canada, Colombia, Ecuador, El Salvador, Guatemala, Honduras, Mexico, New Zealand, Nicaragua, Peru, USA
Distribution of Lso haplotypes A and B	Canada, El Salvador, Guatemala, Honduras, Nicaragua, New Zealand, Norfolk Island, Central America, USA
Key pathways	Plants for planting, seed and produce
Industries at risk	Protected crops of solanaceous crops
Symptoms (5.24)	Chlorosis and purpling of the foliage, stunting, leaf distortion, plant rosetting, enlarged nodes, leaf scorching, deformed and poor quality fruit
Surveillance	
Demarcated zones (5.41)	Infested zone = Defined infested area e.g., glasshouse/premise Buffer zone = ≥ 1 km
Surveillance activities (5.20-5.23)	• Visual surveys of all batches of plants under protection in the infested and buffer zone. • Yellow and neon orange sticky trapping. • Leaf samples of infected/infested plants
Response measures	
Interceptions (5.1-5.8)	• Re-export or destruction via deep burial or incineration. • Visual surveys of site if intercepted inland. • Tracing exercises are carried out where required
Outbreaks (5.50-5.71)	Action taken will be dependent on the situation but may include: • Apply foliar insecticides • Destruction of crop if the vector is present • Glasshouse clean up • Monitoring and surveillance
Key control measures	
Biological	N/A
Chemical	Foliar contact insecticides
Cultural	Restrictions on movement of equipment and access to infested areas, removal of volunteers, good hygiene
Declaration of eradication	
Eradication can be declared following a year or one complete crop cycle after the removal of the infested crop.	

* Numbers refer to relevant points in plan.

Contents

1. Introduction and scope

1.1. This pest specific response plan has been prepared by the Defra Risk and Horizon Scanning team. It describes how the plant health service for England will respond if the solanaceous haplotypes of '*Candidatus* Liberibacter solanacearum' (Lso) and/or their psyllid vector *Bactericera cockerelli*, which together constitute the 'zebra chip' complex, are discovered on plants of potato (*Solanum tuberosum*), tomato (*Solanum lycopersicum*), pepper (*Capsicum annum*), aubergine (*Solanum melongena*) or other solanaceous hosts[1] in glasshouses in England. There is also a response plan specifically for findings in potato fields in England.

1.2. This document is restricted to activities specific to haplotypes A and B of Lso and their vector *B. cockerelli*.

1.3. The plant health authorities of Northern Ireland, Scotland, Wales and the Crown Dependencies have been consulted on this plan and will use it as the basis for the action they will take in the event of haplotypes A and B of Lso or their vector *B. cockerelli* being detected in their territories.

1.4. This document will be used in conjunction with the *Defra Generic Contingency Plan for Plant Health in England* (https://planthealthportal.defra.gov.uk/assets/uploads/Generic-Contingency-Plan-for-Plant-Health-in-England-FINAL-2.pdf), which gives details of the teams and organisations involved in pest response in England, and their responsibilities and governance. It also describes how these teams and organisations work together in the event of an outbreak of a plant health pest.

1.5. The aim of this response plan is to facilitate the containment and eradication of Lso and *B. cockerelli* in England and to make stakeholders aware of the planned actions.

2. Summary of threat

2.1. Lso is a rod-shaped unculturable Gram-negative bacterium with approximate dimensions of around 0.2 by 0.4 µm, and in infected plants is confined to the

[1] Hosts of Lso refer to all plants which can be infected by any of the haplotypes of the bacterium whilst hosts of *B. cockerelli* refers to those plant species on which the psyllid completes its life cycle or which are the preferred food sources of the psyllid. A list of known hosts of *B. cockerelli* can be found in Biosecurity Australia (2009).

phloem tissue (Leifting *et al.*, 2008). Outside of the phloem, it can only survive within a vector.

2.2. The plant disease known as ‘zebra chip’, caused by either of the two solanaceous haplotypes of Lso (A and B), was first reported on potato (*Solanum tuberosum*) in the early 1990s in the Americas (including Guatemala, Honduras, Mexico and the southwestern USA), and has since been found further north and east in the USA. In 2008, the pathogen (haplotype A) and its vector were also reported in New Zealand where they are causing economic losses in potato, pepper and tomato production. They have recently been found in *B. cockerelli* vectors (Figure 8) in Alberta, Canada, though no evidence of disease in potatoes has been found (Johnson *et al.*, 2017). Recent studies have described two new solanaceous haplotypes from the Americas, haplotypes F and G (Mauck *et al.*, 2019; Swisher-Grim & Garczynski, 2019). Findings of these and any other solanaceous haplotypes should be treated on a case by case basis.

2.3. Haplotypes A and B have been shown to be particularly damaging to the potato industry in the USA and New Zealand. They reduce yield and can kill plants, affect potatoes for the fresh market, and internal tuber discolouration can render harvested tubers unacceptable to the potato chip and crisp manufacturing industry, because chips made from infected tubers develop areas of brown discolouration after frying (figures 2 and 3). Besides causing disease in potato, Lso haplotypes A and B cause disease in a number of other solanaceous crops such as tomatoes and peppers. They also infect weeds such as *Solanum dulcamara* and *S. nigrum*, which can provide a reservoir for the bacterium.

2.4. The psyllid vector, *B. cockerelli*, transmits haplotypes A and B both transovarially through the eggs, as well as from plant to plant during feeding. *Bactericera cockerelli* is a serious pest in the absence of Lso, causing the condition ‘psyllid yellows’ in potato and some other solanaceous plants (e.g. tomato, aubergine and pepper) (Figure 6). Symptoms of psyllid yellows include yellowing, stunting, and leaf and tuber distortion, and psyllid sugars (wax coated honeydew droplets; see Figures 7 and 9). *Bactericera cockerelli* is distributed in North and Central America, as well as Western Australia, New Zealand and Norfolk Island.

2.5. Haplotypes C, D and E have been found in Europe, Morocco and Israel associated with plants from the family Apiaceae, including carrots, celery, parsley and parsnips. Haplotype C sequence type 1 (the most common sequence type infecting *T. apicalis* and carrot) has been found infecting volunteer potato plants and cultivated potato grown at the edge of a carrot field (Haapalainen *et al.*, 2018a, 2018b). Infected plants and tubers were asymptomatic. Haplotype E has also been detected in potatoes with zebra chip symptoms in Spain (Cambra, 2014; EPPO reporting service, 2017). A further haplotype, named haplotype U, has also been identified in the psyllid *Trioza urticae* and *Urtica dioica* (stinging nettle) in Finland (Haapalainen *et al.*, 2018) and Scotland (Sumner-Kalkun *et al.*, 2020a). These are all non-

solanaceous haplotypes, and further haplotypes are continually being discovered (Sumner-Kalkun *et al.*, 2020a).

2.6. These European haplotypes seem to pose little risk to potato because of the lack of a vector that is able to feed efficiently on the primary host and then on potato, resulting in very limited transmission of Lso to potato and then no further transmission between potato plants (EPPO, 2020). Furthermore, there is evidence that these haplotypes have been present in Europe for a long time, perhaps since the separation of the tectonic plates (Monger & Jeffries 2017) without damage to potato.

2.7. The psyllid, *Trioza apicalis* (Figures 4 and 5), has been recorded transmitting haplotype C, while the psyllid, *Bactericera trigonica*, has been recorded transmitting haplotypes D and E. *Trioza apicalis* is distributed in eastern Russia, Mongolia, and much of Europe, including the UK. While *Bactericera trigonica* is currently found sporadically over southern Europe, western Asia and northern Africa. It has not been recorded as established in the UK.

Figure 2. Zebra chip infected potato tuber. credit: Joseph E. Munyaneza, USDA ARS,Wapato, WA.

Figure 3. Zebra chip infected fried chips. credit: Joseph E. Munyaneza, USDA ARS,Wapato, WA.

Figure 4. Adult *Trioza apicalis* (male). © Joe Botting

Figure 5. Adult *Trioza apicalis* (female). © Joe Botting

2.8. *Bactericera cockerelli* has been intercepted four times in the UK, twice in 2017 and twice in 2018. These interceptions were made on *Solanum melongena* (aubergine) and *Capsicum* from Mexico. *Bactericera trigonica* has not been intercepted in the UK.

2.9. The first finding of Lso in the UK was in 2016, when haplotypes D & E were found on commercially available parsley seed, whose origin could not be established (Monger & Jeffries, 2016). There is evidence to suggest it has been present in the UK for much longer, being found in follow up surveys on historic seed collections of the Apiaceae (Monger & Jeffries, 2018). Since 2016, the PHSI have made six confirmed findings of Lso in the UK, twice in 2017, twice in 2018 and twice in 2020. Four of these findings were on parsley seed, one was on *Pastinaca* (parsnip) seed (haplotype E), and the other was on *Daucus carota* (carrot) seed. There was also a further interception of a '*Candidatus* Liberibacter spp'. (likely to be Lso) on carrot seed in 2017.

2.10. In Scotland Lso haplotype C has been found infecting symptomless carrot crops and *Anthriscus sylvestris* (cow parsley) (Sumner-Kalkun *et al.*, 2020a) and in adult *Trioza anthrisci* from suction traps, carrot crops and cow parsley between 2015 and 2016 (Sjölund *et al*., 2017; Sumner-Kalkun *et al.*, 2020a). *Trioza anthrisci* is morphologically very close to *Trioza apicalis*.

3. Risk assessments

3.1. Lso (haplotypes A & B) and *B. cockerelli* have an unmitigated and mitigated UK Plant Health Risk Register score of 75. Overall scores range from 1 (very low risk) to 125 (very high risk). These scores are reviewed as and when new information becomes available (https://planthealthportal.defra.gov.uk/pests-and-diseases/uk-plant-health-risk-register/viewPestRisks.cfm?cslref=26791 and https://planthealthportal.defra.gov.uk/pests-and-diseases/uk-plant-health-risk-register/viewPestRisks.cfm?cslref=27077). *Trioza apicalis* and *B. trigonica* are currently not on the Risk Register.

3.2. In 2012, EPPO published risk assessments (EPPO, 2012a, b) and data sheets (Munyaneza, 2013a, b) on solanaceous Lso and its vector, outlining their biology and distribution, and identifying and evaluating economic risks and management options should the pathogen and/or vector establish in the EPPO region.

3.3. Fera Science Ltd.carried out a Rapid Pest Risk Analysis for Lso and *B. cockerelli* in 2015 (Fera, 2015).

3.4. The risk assessments concluded that if Lso along with *B. cockerelli* were introduced into the region, they would have a high chance of establishment wherever host plants were present, and that eradication or containment would be difficult, due to the likelihood that they would not be detected before becoming established and

causing damage. If introduced together, the damage caused by Lso and *B. cockerelli* was assessed as being significant to host crops.

4. Actions to prevent outbreaks

4.1. *Bactericera cockerelii* is a GB quarantine pest (Schedule 1 of The Plant Health (Phytosanitary Conditions) (Amendment) (EU Exit) Regulations 2020) and is therefore prohibited from being introduced into, or spread within, GB. *Bactericera cockerelli* is also a GB Priority Pest meaning it is a GB quarantine pest which has been assessed to have the most severe potential economic, environmental and social impacts to GB.

4.2. Lso is listed in Schedule 4, Parts 4E, 4F and 4H of The Plant Health (Phytosanitary Conditions) (Amendment) (EU Exit) Regulations 2020, as a Regulated Non-Quarantine Pest (RNQP) on tomato seed and plants (*Solanum lycopersicum)* and seed potatoes (*Solanum tuberosum*). All commodities have a 0% tolerance.

4.3. Prohibitions also exist for the import into GB of solanaceous host plants of *B. cockerelii* and Lso in Schedule 6 of the same regulations, as well as further pest and host specific requirements in Schedules 5 and 7.

4.4. *Bactericera cockerelli* is an EU Union Quarantine Pest and is therefore prohibited from being introduced into, or spread within, the Union Territory. Lso is listed as an RNQP on seed potatoes under EU plant health legislation with a 0% tolerance. Also nuclear potato stocks must be derived from mother plants tested as free from Lso (Commission Implementing Directive (EU) 2020/177).

4.5. Lso (Solanaceae haplotypes) (e.g., A and B) and *B. cockerelli* are A1 listed pests in the EPPO region and are therefore recommended for regulation by EPPO member countries. *Trioza apicalis* and *B. trigonica* are not EPPO listed.

4.6. The National Regulatory Control System PM 9/25 (2) *Bactericera cockerelli* and '*Candidatus* Liberibacter solanacearum' provides guidance on excluding *B. cockerelli* and Lso haplotypes A and B from the EPPO region, and eradicating incursions of *B. cockerelli* and Lso (EPPO, 2020). It also includes measures to take against European Lso haplotypes present in the EPPO region. There is evidence that these haplotypes have been present in Europe for a long time (Monger & Jeffries 2018).

4.7. The Plant Health Service (including APHA, Defra and Fera Science Ltd) should be aware of the measures described in this plan and be trained in responding to an outbreak of Lso and/or its vectors. It is important that capabilities in detection, diagnosis, and risk management are available.

5. Response activities

Official action to be taken following the suspicion or confirmation of Lso (haplotypes A & B) and/or *B. cockerelli* on imported plants, including seeds

Holding consignments at point of entry, including packhouses

5.1. If Lso (haplotypes A & B) and/or any of the development stages of *B. cockerelli*, are suspected by the Plant Health and Seeds Inspectorate (PHSI) to be present in a consignment moving in trade, the PHSI must hold the consignment until a diagnosis is made. Ideally, the consignment should be placed in a sealed cold store and any opened containers should be resealed. Other consignments that are at risk of cross-contamination should also be held prior to a risk assessment on whether cross-contamination has or could have potentially occurred. Samples should be sent to Fera Science Ltd., Plant Clinic, York Biotech Campus, Sand Hutton, York, YO41 1LZ (01904 462000) in a sealed bag or container, within at least two other layers of containment, which are not liable to be crushed during transit.

5.2. When an infestation of Lso (haplotypes A & B) and/or *B. cockerelli* is confirmed, the PHSI should advise the client of the action that needs to be taken by way of an official plant health notice.

5.3. If *B. cockerelli* is present, the consignment should be destroyed by either incineration, deep burial or re-exported in a sealed container (as in 5.72). For re-export, the consignment should be sent back to the place of production and the relevant NPPO notified. If it is not possible to organise destruction by deep burial or incineration, suitable alternatives should be discussed with the Defra Risk and Horizon Scanning team.

5.4. Consignments that have tested positive for Lso (haplotypes A & B), but where *B. cockerelli* is not found should also be destroyed by either incineration, deep burial or re-exported in a sealed container due to the potential for *B. cockerelli* to be present. However, solanaceous fruit (without green parts), where *B. cockerelli* has been shown to be definitely not present, may be allowed for processing at approved facilities or for retail following discussion with the Defra Risk and Horizon Scanning team.

5.5. For interceptions inland where there is a risk of escape, any host plants (including any tubers or fruit, which should be held) should be surveyed on the site or in the immediate vicinity in the summer and again in the following year for signs of pest presence. If the site is in an area where hosts are grown, at least two

fields/nurseries closest to the site and a field/nursery on the prevailing wind side should be surveyed. Waste disposal processes and areas should also be inspected.

5.6. A UKPHINS (UK Plant Health Interception Notification System) notification should be made upon confirmation of an interception of Lso (haplotypes A & B) and/or *B. cockerelli*. UKPHINS is the IT system for recording findings and non-compliance in order to maintain records and notify other National Plant Protection Organisations (NPPO) of plant health issues.

5.7. If all or part of the consignment has been distributed to other premises prior to diagnosis, trace forward and trace back inspections should take place upon suspicion or confirmation of Lso (haplotypes A & B) and/or *B. cockerelli*. Details of recent past and future consignments from the same grower/supplier should also be obtained and a decision on action taken on a case by case basis.

5.8. A pest alert to raise awareness of Lso (haplotypes A & B) and *B. cockerelli* and their symptoms should be distributed to packers/processors and importers where Lso (haplotypes A & B) and *B. cockerelli* have been found, and to those associated with the infested premises. The pest alert is found on the plant health portal – https://planthealthportal.defra.gov.uk/assets/factsheets/Bactericera-cockerelli-pest-alert-v3.pdf.

Official action to be taken following the suspicion of Lso (haplotypes A & B) and/or *B. cockerelli* at a place of production

5.9. The occurrence of Lso (haplotypes A & B) in glasshouse-grown crops is likely to be confined to a main host such as tomato, pepper, aubergine, and potato minitubers.

5.10. Suspected outbreaks will be assessed on a case by case basis. An Outbreak Triage Group (OTG), chaired by the Chief Plant Health Officer (CPHO) or their deputy and including specialists from APHA, Defra and other organisations, should be set up to assess the risk and decide on a suitable response. Where appropriate, the OTG will also decide who will be the control authority, and the control authority will then nominate an incident commander. An Incident Management Team (IMT) meeting, chaired by the Incident Commander, will subsequently convene to produce an Incident Action Plan (IAP). See the *Defra Generic Contingency Plan for Plant Health in England* for full details.

5.11. The OTG will set an alert status, which will consider the specific nature of the outbreak. These levels, in order of increasing severity, are white, black, amber and red (more details of these levels can be found in table 2 of the *Defra Generic Contingency Plan for Plant Health in England*). Under most scenarios, an outbreak of Lso (haplotypes A & B) under protection is likely to be given a black alert status, which is used for a significant plant disease that has the potential for geographic

spread. However, this can be downgraded to a white alert status (limited geographic spread) in the absence of *B. cockerelli*.

Restrictions on movement of material, equipment and machinery to and from the place of production

5.12. Lso (haplotypes A & B) and *B. cockerelli* are associated with plants for planting, fruit, vegetables and tubers, and living parts of plants (excluding plants for planting and fruit, vegetables and tubers, e.g. cut foliage), so these should be restricted from leaving the site, except for when they are being sent for destruction by deep burial or incineration (as in 5.72). There is some limited evidence that haplotypes of Lso can be seed transmitted (Bertolini *et al.*, 2015), therefore if haplotype A or B is suspected, movement of seed could also be restricted as a precaution.

5.13. Movement of material, equipment and machinery, which may result in the movement of life stages of *B. cockerelli* between infested and non-infested areas, should also be restricted. However, if movement is necessary, the material, equipment and machinery should be thoroughly cleaned at the designated outbreak site to remove any life stage of *B. cockerelli*.

5.14. Movement of personnel into the affected glasshouse should be severely restricted especially during the early investigation phase and/or if *B. cockerelli* is detected. Personnel should be briefed on the importance of good hygienic practice to reduce the risk of carrying psyllid eggs/nymphs to other areas of the production facility (see 5.15).

General biosecurity advice and advisory measures for growers

5.15. The glasshouse and other glasshouses at risk should be sealed to prevent the escape of *B. cockerelli*.

5.16. Although Lso has not been demonstrated to be transmitted mechanically, it can be mistaken for other diseases for which mechanical transmission is possible. Psyllid eggs and nymphs can also be transferred mechanically, and therefore hygiene best practice should be followed as below:

- Training staff to identify symptoms of Lso (haplotypes A & B) and basic characteristics of psyllids and to follow best practice procedures.
- Using disposable garments (including overshoes), which will be destroyed after working on an infected/infested lot or only used in the infected area.
- Using disposable gloves that can be destroyed following work on a particular crop, between different areas within a crop, or between plants, or only used in infected area.

- Restricting the use of equipment and machinery to one location. If equipment or machinery must be moved between locations, then they should be thoroughly cleaned before being moved using measures such as high water pressure or steam cleaners.
- Restricting access to the working area. The fewer people entering a particular lot, the less chance of psyllid vectors harbouring Lso (haplotypes A & B) will be introduced. Wherever possible, employees should work in the same areas or number of rows each day rather than swapping around work areas. Only trained staff should be able to access restricted areas, and there should be a sign in/sign out sheet to record movements.
- Wherever possible, working in uninfested areas initially and finishing in areas that could be infested during work shifts.

5.17. Volunteer plants and weeds, particularly solanaceous perennials, may act as reservoirs for Lso (haplotypes A & B), either as primary hosts (e.g. *Solanum dulcamara* and *S. elaeagnifolium*) or in *B. cockerelli* when it overwinters on these weed hosts. Other weed hosts of Lso (haplotypes A & B) may be present in Europe. Controlling these plants within and around glasshouses reduces the chance of the crop becoming infected and reduces the risks of survival and persistence in the event of an outbreak. Volunteer plants and weeds can be controlled mechanically (e.g. hoeing), chemically (e.g. herbicides), and manually (e.g. roguing).

Preliminary trace forward / trace backward

5.18. If an infested consignment is considered as being the source of the suspect outbreak, investigations regarding the origins of infested consignments will be undertaken to locate other related and therefore potentially infested consignments moving to and from the site. If applicable the relevant NPPO should be contacted. This process is particularly important for propagation or seed potato stocks.

5.19. In addition to tracing investigations relating to consignments, trace forward/back investigations linked to equipment, machinery and personnel in the infested premise should also be made.

Confirming a new outbreak

How to survey to determine whether there is an outbreak

5.20. Information to be gathered by the PHSI on the suspicion of an infestation of Lso (haplotypes A & B) and/or *B. cockerelli*, in accordance with ISPM 6; guidelines for surveillance (https://www.ippc.int/en/publications/615/):

- The origin of the host plants and associated pathways.

- Details of other premises or destinations where the host plants/products have been sent, where Lso (haplotypes A & B) and/or *B. cockerelli* may be present.
- The layout of the premises and surrounding area (in relation to potential buffer zones of at least 1 km), including a map of the fields/cropping/buildings, at risk growers, and details of neighbouring crops, especially any commercial or non-commercial hosts in fields, allotments, gardens or glasshouses.
- Details of the host variety, growth stage and any other relevant information.
- Description of the surrounding habitat, including all hosts e.g. *Convolvulus arvensis* (bindweed).
- Area and level of infection/infestation, including life stages and a description of symptoms (photos should be taken).
- The location of any known populations, including grid references.
- The date and time the sample was taken, how it was identified and by whom.
- Current treatments/controls in place e.g. chemical treatments.
- Details of the movement of people, equipment, machinery etc. to and from the infested area.
- Cultural, biosecurity and working practices.
- The name, address, email and telephone number of the person who found the pest and/or its symptoms, and the business owner.

5.21. This information should be included on the plant pest investigation template (see the *Defra Generic Contingency Plan for Plant Health in England* for more details https://www.gov.uk/government/publications/contingency-plan-for-plant-and-bee-health-in-england).

5.22. Further to information gathering, samples of other infected or infested plants should be taken to confirm the extent of the infection/infestation e.g. in associated glasshouses. This initial survey will be used to determine if it is an isolated finding or an established outbreak.

5.23. Finance for the surveys will depend on the individual circumstances of the outbreak, and will be subject to discussion, usually between Defra policy and the PHSI.

Sampling

Lso (haplotypes A & B)

5.24. Although symptoms may vary slightly between solanaceous host plants, above ground symptoms associated with Lso (haplotypes A & B) to look out for generally include chlorosis and the purpling of foliage, stunting of plants, erectness of new foliage, leaf distortion (e.g. cupping or curling), shortened and thickened internodes

resulting in plant rosetting, enlarged nodes, leaf scorching, and deformed and poor quality fruit (see figures 4 and 5). These symptoms can be confused with other diseases caused by phytoplasmas, viruses etc.

5.25. In addition to crop plants, a survey of solanaceous weeds on and around the affected facility should be carried out to assess the extent of the outbreak. Although it is known that diseased plants may sometimes fail to exhibit symptoms of the disease, finding the disease in a weed implies the presence of a vector, as spread from crop plants to weeds would otherwise not be possible.

5.26. Lso (haplotypes A & B) is not normally distributed uniformally throughout the plant, and is often present in low levels, leading to difficulty in confirming its presence. To minimise this problem, representative sections of all plant parts should be sampled. For minitubers, sections of tubers should be sampled where applicable (if symptomatic) as Lso (haplotypes A & B) titre is often higher in tuberous tissue.

5.27. Symptomatic parts of the plant (e.g. leaves, fruit, stems and tubers) should be placed in a sealed bag or container and sent for diagnosis as in point 5.1.

Bactericera cockerelli

(Adapted from Plant Health Australia Threat Specific Contingency Plan – Plant Health Australia, 2011)

5.28. *Bactericera cockerelli* can cause ‘psyllid yellows’, which is associated with the stunting and yellowing of plants, and the distortion of leaves (see figure 6). As for other sap sucking insects, *B. cockerelli* egests excess water and sugar in the form of honeydew, but before the honeydew is expelled, the psyllid also coats the honeydew in wax. These wax covered honeydew droplets are called psyllid sugars (see figure 7, 9).

5.29. While life stages of the psyllid are small, with adults around 2.5 mm in length (Figure 8, 9), they can be sampled throughout the affected premises by examining leaves from a number of plant species/varieties with a hand lens and collecting leaves with as many life stages as possible (or placing them in glass/plastic vials). Leaves from separate plant species and from different areas of the production facility should be packed separately and appropriately labelled (with information on the location within the facility and life stages seen). Random sampling of eggs, nymphs and adults on leaves of the crop can help to determine the composition of the psyllid populations.

5.30. Yellow, neon green or neon orange sticky traps have been shown by Al-Jabar and Cranshaw (2007) to be effective for catching adults in glasshouses. Yellow pan water traps can also be used to capture adults.

- Sticky traps should be placed near to the tops of plants, should be partially shaded and should be facing north to give the best capture rates.

- Water pan traps. The inside of the containers should be painted either yellow or orange and should contain a solution of 70% ethanol and water (1:10), with a few drops of liquid detergent to help break the surface tension when the psyllid lands on the water. The pan water traps should be checked regularly to ensure the water has not evaporated and should be changed every few days before the specimens deteriorate.
- Sticky traps should be placed at a density of at least one trap per quarter of the glasshouse, but possibly more depending on the size of the glasshouse. These should ideally be placed near the edge of the glasshouse.
- Sticky and water traps should be sent weekly to Fera for analysis.

5.31. A large number of samples should be collected with as many life stages of the population as are available. Of the three psyllid life stages (egg, nymph, adult), only the adults are identifiable to species level using morphological features, and males are easier to identify to species level than females. As species of *Bactericera* known to occur in the UK are not known to be associated with solanaceous plants, identification of males or females to this genus in a solanaceous crop will suggest the presence of *B. cockerelli*. In non-solanaceous crops, only one native species of *Bactericera* (*B. crithmi*) is associated with the Apiaceae, so findings of psyllids on Apiaceae crops may indicate *B. crithmi, B. nigricornis*, *B. tremblayi* or *B. trigonica*, which are hosts of European haplotypes of Lso on Apiaceae in some EU countries. *Bactericera crithmi* is not known to be a host of Lso.

5.32. Leaves and young shoots with feeding damage should be stored between sheets of newspaper to allow slow drying and sent to the laboratory with names and contact details of the sender and recipient.

5.33. Adults and nymphs can be stored short term in 70% ethanol but this makes the use of subsequent molecular diagnostic techniques more difficult. Alternatively, adults can be collected, killed by freezing and stored frozen, followed by dry mounting. Specimens to be used for diagnostic purposes should be kept cool during transport to the laboratory and then stored dry in a freezer at - 20 to - 80°C after arrival at the laboratory.

Figure 6. Early zebra chip symptoms showing leaf discolouration. credit: Joseph E. Munyaneza, USDA ARS,Wapato, WA.

Figure 7. Lso infected plant showing leaf discolouration. credit: Joseph E. Munyaneza, USDA ARS,Wapato, WA.

Figure 6. Psyllid yellows symptoms caused by *B. cockerelli*. © Kiwicare

Figure 7. Psyllid sugars excreted by *B. cockerelli*. © Plant & Food Research.

Figure 8. Adult *B. cockerelli*. credit: Joseph E. Munyaneza, USDA ARS, Wapato, WA.

Figure 9. Adult *B. cockerelli* on leaf with yellow eggs and white frass. credit: Joseph E. Munyaneza, USDA ARS, Wapato, WA.

Diagnostic procedures

5.34. Diagnosis of Lso (haplotypes A & B) is based on PCR, and is detailed in the IPPC protocol (https://www.ippc.int/en/publications/84157/). There is currently no EPPO diagnostic protocol available for Lso (haplotypes A & B).

5.35. Identification to haplotype requires the amplification and sequencing of three genomic regions. These sequences are then aligned to reference sequences for the five haplotypes.

5.36. Morphological identification of adult *B. cockerelli* is based on the protocol produced by Yen and Burckhardt (2012) and by comparing specimens with verified slide-mounted material obtained from New Zealand deposited in the Fera reference collections. *'Bactericera cockerelli* can also be identified using a taq-man real-time PCR assay by SASA. Further assays are being developed for *T. apicalis* and other potential vectors (Sumner-Kalkun *et al.*, 2020).

Criteria for determining an outbreak

5.37. If Lso (haplotypes A & B) and/or *B. cockerelli* is detected at a port or confined to a particular consignment with no risk of spread (e.g., tomato seed), then an outbreak should not be declared. If it is found to have spread or likely to have spread beyond its original consignment, for example if *B. cockerelli* is found across multiple lots in a glasshouse, then an outbreak should be declared.

Official action to be taken following the confirmation of an outbreak

5.38. The scale of the outbreak will determine the size and nature of the IMT and action.

Communication

5.39. The IMT will assess the risks and communicate details to the IPPC and EPPO, in accordance with ISPM 17: pest reporting (https://www.ippc.int/en/publications/606/), as well as within Government to Ministers, senior officials, devolved administrations, and other government departments and agencies (e.g., the Environment Agency) on a regular basis as appropriate; and to stakeholders.

Surveillance and demarcated zones

5.40. After an outbreak has been detected, a demarcated area should be established that includes:

- An infested zone (i.e. the infested premises). This may include other premises in which staff/growers have visited or worked in, premises in which stock has been sent or received, and/or any other premises where there is a perceived risk.
- A buffer zone, which should extend out to at least 1 km from the infested zone, but may extend out further, particularly if *B. cockerelli* is found. This will be influenced by the local climatic and meteorological conditions.

5.41. Initial maps of outbreak sites should be produced by officials.

5.42. All host plants in the infested and buffer zones should be visually inspected and any suspect samples should be sent for diagnosis. Traps should be used as described in 5.30.

5.43. The demarcated area should be adjusted in response to further findings. If Lso (haplotypes A & B) and/or *B. cockerelli* is found within a glasshouse outside the infested zone, this should subsequently be designated as infested and the buffer zone changed accordingly.

Decontamination procedures

5.44. Within the infested zone, all non-disposable material, equipment and machinery, should be thoroughly cleaned to remove any life stages of the pest before movement to un-infested areas.

5.45. Any waste (plant or other potentially infested material) should be removed and destroyed (via deep burial, incineration or other appropriate methods) (as in 5.72-5.74).

Tracing forwards/backwards

5.46. Refer to section 5.18-5.19.

5.47. Once other sites that are potentially infested by Lso (haplotypes A & B) and/or *B. cockerelli* have been identified, these should be inspected as per 5.20-5.33.

5.48. The Defra pest alert to raise awareness of Lso (haplotypes A & B) and/or *B. cockerelli* and its symptoms should be distributed to growers of host plants, to packers/processors and importers, and other areas at risk. The pest alert can be found on the Plant Health Portal - https://planthealthportal.defra.gov.uk/plant-health-api/api/pests/26791/notices/6685/documents/4189/document

Pest management procedures

Infested zone (Lso (haplotypes A & B) with *B. cockerelli*)

5.49. The whole crop should be treated as soon as possible with a foliar insecticide if *B. cockerelli* is present. The PHSI will advise on an appropriate insecticide treatment regime in consultation with the Defra Risk and Horizon Scanning team. These treatments should also be used on other susceptible hosts in the glasshouse.

- Prior to any pesticides being used, the risk posed by the pesticide to people and the environment will be assessed.
- Any applications should be made following the advice on the product label and be in accordance with HSE guidance.
- If the crop is organic, pesticides will still have to be used if the situation demands it.
- Growers will be placed under notice to apply the recommended pesticides and make the applications using their own or contractor's equipment. Records of applications will be kept, including details of the amount of product and water use.

5.50. Use of contact insecticides requires good coverage of the foliage as psyllids are found primarily on the undersides of leaves. Moreover, different chemicals are required for adults, nymphs and eggs, making selection of chemicals difficult, and necessitating knowledge of psyllid growth stages present in the crop in order to apply the appropriate chemicals at appropriate times in the growing season.

- Sticky traps and pan water traps (or other appropriate traps) should be used to assess the efficacy of insecticide treatments.

5.51. Following insecticide use, all susceptible host crops including volunteers in the glasshouse should be destroyed by incineration or deep burial (as in 5.72). If possible, host crops in the vicinity of the glasshouse should also be treated and destroyed.

5.52. Once the infected/infested crop has been removed, all remaining material e.g., string, plastic flooring and growing media, should be destroyed or recycled and the facility thoroughly cleaned with water and detergent to remove any remaining plant material and finally disinfected with a suitable disinfectant.

5.53. No host plants should be grown in the infested glasshouse for the maximum recorded development time + period of female longevity for *B. cockerelli*. This will depend on the climatic conditions within the glasshouse, particularly the temperature. Any volunteer plants should be removed.

5.54. Inspections, with the frequency determined by the IMT, should be carried out over the following growing season.

Infested zone (Lso (haplotypes A & B) in the absence of *B. cockerelli*)

5.55. Points 5.50 – 5.51 should be followed to knock down other potential vectors.

5.56. If other potential vectors are present, points 5.52-5.53 should be followed as a precaution.

5.57. If no other potential vectors are present, crops may be allowed to grow until the end of the season.

5.58. All infected plants should be destroyed, and if there are several infected plants in a lot, the whole lot should be destroyed. Host crops in the vicinity of the glasshouse should also be treated and destroyed.

5.59. Plants should be monitored weekly until the end of the growing season.

5.60. Harvesting of fruit may be allowed but should only be sent for retail if agreed by the IMT.

5.61. All susceptible host crops in the glasshouse should be destroyed by incineration or deep burial (as in 5.72).

5.62. Once the infected/ infested crop has been removed, all remaining material e.g., string, plastic flooring and growing media, should be destroyed, recycled or thoroughly cleaned with water and detergent to remove any remaining plant material and finally disinfected with a suitable disinfectant. The permanent facility should also be cleaned and disinfected.

5.63. No host plants should be grown in the infested glasshouse for a period covering the lifespan of adult potential vectors in the absence of host plants. This will depend on the climatic conditions within the glasshouse, particularly the temperature. Any volunteer plants should be removed.

5.64. Inspections, with the frequency determined by the IMT, should be carried out over the following growing season.

Measures to be taken in the case of detection of infection/infestation in fruit after harvest (e.g. during processing/packaging and grading)

5.65. The following should be designated as infested:

- The lot from which the sample was taken.
- The waste from the infested lot, such as processed waste.
- The equipment and other articles (e.g. machinery and packing material) which have been in contact with the lot).
- The glasshouse where the lot was grown.

5.66. As in 5.41, a buffer zone should be created that extends out to at least 1 km from the infested glasshouse.

5.67. Areas where potentially infested equipment, waste, and other articles, have been used should be surveyed, and any fruit harvested from these areas should be inspected.

5.68. Points 5.2 - 5.5 and 5.7 - 5.8 should be followed, but only destruction rather than re-export should be considered.

5.69. Refer to infested zone pest management procedures should Lso (haplotypes A & B) and/or *B. cockerelli* be found in a glasshouse.

Crops growing within the buffer zone (at least 1 km around the infested zone) in the year of the outbreak

5.70. If no infestation is found in host crops growing in the buffer zone following surveillance, then they should be treated with a programme of foliar insecticides under notice until harvest and monitored for any sign of Lso (haplotypes A & B) and/or *B. cockerelli*. Monitoring should include the use of sticky, water pan or other appropriate traps.

Disposal plan

Infested plant material

5.71. When deciding on the most appropriate method(s) of disposal, factors such as the likelihood of *B. cockerelli* adults being present, the level of handling and transportation required, all need to be taken into account. For all methods, measures need to be taken to ensure that there is no risk of spread during transport and treatment or disposal. Material that can be moved safely should be destroyed by incineration at a licensed facility (if in small quantities) or deep burial. Disposal and/or destruction should be under the approval of the PHSI, with any supervision decided on a case by case basis. If the material has to be moved off the premises, it should be contained within at least two layers if possible, and placed in a sealed vehicle for transport. Deep burial may be done at an approved landfill site, or on the site or nearby farm, but only in agreement with the local Environment Agency. Incineration must comply with appropriate waste management regulations, Environment Agency in England, Scottish Environment Protection Agency and Natural Resources Wales.

5.72. Aside from incineration and deep burial, other viable methods of destruction may include anaerobic digestion and recycling (e.g., of rockwool slabs for non-horticultural use). However, these and any other methods should be agreed by the IMT.

5.73. All objects designated as ‘infested’, such as equipment, machinery, storage facilities that may be contaminated with infested plant material should be thoroughly cleansed to remove the pest e.g. using high pressure water. This should be carried out at the outbreak site or a site nearby in agreement with a Plant Health and Seeds Inspector. Any waste material generated should be bagged and sent for deep burial or incineration (as in 5.72).

Review measures in the case of prolonged official action

5.74. Monitoring of the affected premises and demarcated areas should take place. In the following year, this should take place monthly throughout the growing season. Plants should be visually inspected and any plants showing suspect symptoms should be tested. Any volunteer plants should be removed and destroyed by incineration or deep burial. Monitoring should also include the use of sticky, water pan or other appropriate traps for *B. cockerelli*.

5.75. The EPPO protocol states that if continuing official action is required within the demarcated area over a prolonged period, a review of eradication and containment measures should be undertaken regularly to determine the success and cost-effectiveness of measures in the longer term. This review will involve consultation with stakeholders and should include:

- Evaluation of the effectiveness of current measures
- Evaluation of the economic impact and cost-effectiveness of continuing existing measures
- Consideration of further measures to strengthen containment and eradication actions
- Consideration of statutory obligations and impact on import and export procedures
- Consideration of alternative approaches, including pursuing measures to contain the pest rather than eradication or even the cessation of statutory action.

In circumstances where it is considered that the pest cannot be eradicated or contained and official action is no longer considered appropriate, stakeholders should be consulted and a timetable and mechanism for the removal of official measures, and for the dissemination of pest management information, should be agreed.

6. Criteria for declaring eradication / change of policy

6.1. Lso (haplotypes A & B) and/or *B. cockerelli* can be declared eradicated (by the Chief Plant Health Officer) if it has not been found for a year (or for a single cycle of the crop) after the infected/infested crop was removed.

7. Evaluation and review of the contingency plan

7.1. This pest specific contingency plan should also be reviewed regularly to consider changes in legislation, control procedures, pesticides, sampling and diagnosis methods, and any other relevant amendments.

7.2. Lessons should be identified during and after any Lso (haplotypes A & B)/*B. cockerelli* outbreak or non-Lso (haplotypes A & B)/*B. cockerelli* outbreak, including what went well and what did not. These should be included in any review of the contingency plan leading to continuous improvement of the plan and response to outbreaks.

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