Department
for Environment
Food & Rural Affairs

Pest specific plant health response plan:

Outbreaks of Zebra chip disease (‘*Candidatus* Liberibacter solanacearum’) and/or its psyllid vector *Bactericera cockerelli* in potato crops

Fig. 1. (a) Zebra chip infected potato tuber; (b) Zebra chip infected potato plant; (c) *Bactericera cockerelli* and (d) Zebra chip infected fried chips. © Joseph E. Munyaneza, USDA ARS, Wapato, WA

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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	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	Seed and ware potatoes
Industries at risk	Potato growers and packers
Symptoms (2.5)	Internal tuber discolouration, reduction in yield, host mortality
Surveillance	
Demarcated zones (5.38-5.43)	Infested zone = Infested field(s) Buffer zone = ≥ 2 km
Surveillance activities (5.38-5.44)	• Visual surveys will be carried out in the infested and buffer zone • Sampling using vacuums, sweep nets and sticky traps • Symptomatic plants sampled • Further general surveys on hosts grown outside of the buffer zone or in areas where potentially infested machinery has been used
Response	
Interceptions (5.1-5.8)	• Consignment should be destroyed or re-exported if live or dead larvae or feeding damage is seen. • Surveillance of the site following inland interceptions • Tracing exercises carried out where required • UKPHINs notification to be made.
Outbreaks (5.46-5.53)	• Crop in infested zone to be treated with a foliar insecticide. • Destruction of haulm if pest levels are low • Weeds and host debris to be treated with herbicide • Buffer zone crops to be treated with a programme of insecticides • Post-harvest inspection of tubers
Key control measures	
Biological	N/A
Chemical	Insecticide and herbicide applications
Cultural	Cleaning of equipment and machinery, removal and destruction of waste and infested tubers
Declaration of eradication	
Eradication can be declared if no pest is detected during annual surveys for two years after the infested material was destroyed if no volunteers have been identified.	

* 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 (A and B) of '*Candidatus* Liberibacter solanacearum' (Lso) and/or their psyllid vector *Bactericera cockerelli*, which together constitute the 'zebra chip' complex, are discovered in potato (*Solanum tuberosum*) fields in England.

1.2. The plant health authorities in 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 that Lso haplotypes A and B and/or *B. cockerelli* are detected in their territories.

1.3. This document is restricted to activities specific to haplotypes A and B of Lso and their vector *B. cockerelli* and will be used in conjunction with *Defra 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.

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

1.5. If Lso haplotypes C, D, E and/or other non-solanaceous haplotypes are identified in potato crops in the absence of a suitable vector for transfer to potatoes, action will be considered separately.

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 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.

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.

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

2.9. 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

4. 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.

3.1. In 2012, EPPO published risk assessments (EPPO, 2012a, b) and data sheets (Munyaneza, 2013a, b) on Lso haplotypes A and B and their 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.

3.2. The Food and Environment Research Agency (Fera) carried out a Rapid Pest Risk Analysis in 2015 for Lso and *B. cockerelli* (Fera, 2015).

3.3. The risk assessments concluded that if Lso haplotypes A and B, along with *B. cockerelli* were introduced, they would have a high chance of establishment, 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.

5. 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 cockerelii* 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.

6. 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 ports 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 by the PHSI to Fera Science Ltd., Plant Clinic, York Biotech Campus, Sand Hutton, York, YO41 1LZ (01904 462000; email: plantclinic@fera.co.uk) 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 or deep burial (as in 5.65) or re-exported in a sealed container. 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 (see 5.66).

5.4. Consignments in which the pathogen is confirmed but are found to be free of *B. cockerelli* (based on inspection) should also be destroyed by either incineration or deep burial (as in 5.65) or re-exported in a sealed container. 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 of *B.cockerelli*, any host plants 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. There would not be a risk if the fruit was imported without green parts. If the site is in an area where host crops

are grown, at least two fields/horticultural holdings closest to the site and an additional field/horticultural holding downwind of the prevailing wind should be surveyed. Waste disposal processes and areas should also be inspected at the site of interception.

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 *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/or *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 in the local area and those associated with the infested premises. The current pest alert is found on the plant health portal - https://planthealthportal.defra.gov.uk/assets/factsheets/Zebra-chip-pest-alert-v8.pdf.

Official action to be taken following the suspicion of Lso (haplotypes A & B) at a place of production

5.9. Suspect 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 at strategic and operation levels. Where appropriate the OTG will also decide who will be the 'control authority' (responsible body for the outbreak), and the control authority will then nominate an incident commander. For an outbreak of Lso (haplotypes A & B) and/or *B. cockerelli* in potatoes, APHA will likely be the control authority. An Incident Management Team (IMT) meeting, chaired by the Incident Commander, will subsequently convene to produce an Incident Action Plan (IAP) to outline the operational plan. See the *Defra Generic Contingency Plan for Plant Health in England* for full details.

5.10. The OTG will determine the alert status, which will consider the specific nature of the outbreak. These alert levels, in order of increasing severity are white, black, amber and red (more details of these 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) in a potato field is likely to be given an amber alert status, which is used for a serious plant pest/disease that has the potential for relatively slow but extensive geographic spread leading to host death and/or major economic, food security or environmental impacts. However, this can be downgraded to a white alert status (limited geographic spread) in the absence of *B. cockerelli*.

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

5.11. Lso (haplotypes A & B) and *B. cockerelli* are associated with potato plants and tubers, so these should be restricted from leaving the site, except when they are being sent for destruction by deep burial or incineration (as in 5.67).

5.12. 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*.

5.13. Movement of personnel into the affected field 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 hygiene practice to reduce the risk of carrying psyllid eggs/nymphs to other areas of the site.

General biosecurity advice and advisory measures for growers

5.14. Psyllid eggs and nymphs can 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 (see 4.15 for links to further information).
- Using disposable garments (including overshoes), which will be destroyed after working on an infested field or only used in the infested 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 the 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 e.g. with high water pressure, steam cleaners etc.
- The fewer people entering a particular field, the less chance of psyllid vectors harbouring Lso (haplotypes A & B) will be introduced. 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.

5.15. Volunteer host 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 for *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 reduces the chance of the crop becoming infected and reduces survival and persistence in the event of an outbreak. Volunteer plants and weeds can be controlled mechanically (e.g. hoeing, roguing, flame weeding) and chemically (e.g. herbicides). For a list of host species of Lso and *B.cockerelli*, consult the EPPO Global Database (https://gd.eppo.int/taxon/LIBEPS/hosts and https://gd.eppo.int/taxon/PARZCO/hosts) and EPPO PRAs, considering that this lists hosts of all Lso haplotypes (https://gd.eppo.int.taxon/LIBEPS/documents and https://gd.eppo.int/taxon/PARZCO/documents).

Preliminary trace forward / trace backward

5.16. 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 of products moving to and from the site. If applicable the relevant NPPO should be contacted.

5.17. In addition to tracing investigations relating to consignments, trace forward/back investigations linked to equipment and machinery used in the infested premise should also be made if *B. cockerelli* was present or is suspected to have been present in the outbreak site.

Confirming a new outbreak

How to survey to determine whether there is an outbreak

5.18. Information to be gathered by the PHSI on suspicion of an outbreak 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), 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 (e.g. *Convolvulus arvensis* [bindweed]), allotments, gardens or glasshouses.
- Details of the host variety, growth stage and any other relevant information.
- Area and level of infection/infestation, including life stages and a description of symptoms (photos should be taken).
- The locations where Lso (haplotypes A & B) and/or *B. cockerelli* have been detected, 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.

5.19. This information should be included on the plant pest investigation template..

5.20. 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 fields. This initial survey will be used to determine if it is an isolated finding or an established outbreak.

5.21. 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)

5.22. 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 6 and 7). These symptoms can easily be confused with other diseases caused by phytoplasmas, viruses etc.

5.23. In addition to crop plants, a survey of solanaceous weeds on and around the affected field 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.

5.24. Lso (haplotypes A & B) is not normally distributed uniformly throughout the plant, and is often present in low titre, leading to difficulty in confirming its presence. To minimise this problem, whole symptomatic plants should be taken if small enough, or representative sections should be taken, ideally three to five leaves and/or stems, from symptomatic parts of the plant (ISPM, 2017). Five to ten symptomatic plants would be sufficient to confirm an outbreak. Whole tubers or sections of tubers should be sampled where applicable (if symptomatic) as Lso (haplotypes A & B) titre is often higher in tuberous tissue.

5.25. Whole plants or 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 the Plant Health Australia Threat Specific Contingency plan – Plant Health Australia, 2011)

5.26. While all life stages of the psyllid are small, with adults around 2.5 mm in length (Figures 8 and 9), they can be sampled throughout the affected field 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 or plastic vials). Leaves from separate plant species and from different areas should be packed separately and appropriately labelled (with information on the location within the facility and life stages seen).

5.27. In field grown crops, adult psyllids can also be vacuum collected using suction devices for insects (where found), or collected by the use of a sweep net, which should have a very fine mesh. Adult psyllids normally congregate in the upper plant foliage and it is only necessary for the net to touch the tips of the leaves to disturb the psyllids, facilitating collection.

5.28. Sticky traps (yellow, neon green or neon orange) and yellow pan water traps can also be used to capture adults, but these may be more liable to be affected by wind, rain and windblown soil and debris. They also need to be placed to avoid damage by any farm operations, such as spraying.

- 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 field, but possibly more depending on the size of the field. These should ideally be placed near the edge of the field.
- Sticky and water traps should be sent to Fera weekly for analysis.

5.29. 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 from a solanaceous crop to this genus 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 they are either *B. crithmi*, or the non-native psyllids *B. nigricornis*, *B. tremblayi* or *B. trigonica*, which are hosts of haplotypes of Lso on Apiaceae in some EU countries*. Bactericera crithmi* is not known to be a vector of Lso.

5.30. 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. They should be sent in containers as described in 5.1.

5.31. Adults and nymphs can be stored short term in 70% ethanol. 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

5.32. Diagnosis of Lso (haplotypes A & B) is based on PCR, and is detailed in the IPPC protocol (https://www.ippc.int/static/media/files/publication/en/2017/04/DP_21_2017_En_2017-03-31.pdf).

5.33. Identification to haplotype requires the amplification and sequencing of three genomic regions. These sequences are then aligned to reference sequences for the five haplotypes. However, it should be noted that action would be taken based on confirmation of Lso in potato and suspicion of haplotype A and B, and haplotype identification would take place subsequent to this due to the time and difficulty in identifying to haplotype.

5.34. 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

5.35. If Lso (haplotypes A & B) and/or *B. cockerelli* is detected at a location other than at a port or confined to a particular consignment with no risk of spread then an outbreak should be declared. For example, if they are identified in a potato field, then this would be classified as an outbreak. However, if they are restricted to recently imported potatoes within a cold store then this would be classified as an interception. If only symptoms of Lso (haplotypes A & B) and/or *B. cockerelli* are found, then the outbreak should be treated as suspected until either the presence of Lso (haplotypes A & B) is confirmed by testing or live stages of *B. cockerelli* are found.

Official action to be taken following the confirmation of an outbreak

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

Communication

5.37. The IMT will assess the risks and communicate details to the IPPC, EU (via a Europhyt notification) and EPPO, in accordance with ISPM 17: pest reporting (https://www.ippc.int/en/publications/606/), as well as to Defra 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

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

- An infested zone (i.e. the field or crops that are known to be infested). This will also include field margins or uncropped areas if infestation is found on solanaceous weed species, and/or any other premises where there is a perceived risk.
- A buffer zone, which should extend out at least 2 km from the infested zone, but may extend out further depending on the characteristics of the outbreak, particularly if *B. cockerelli* is found. This will be influenced by the local climatic and meteorological conditions. The buffer zone should be split into an inner buffer zone of at least 1 km and an outer buffer zone extending at least 1 km from the inner buffer zone.

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

5.40. All host crops in the infested and buffer zones should be visually inspected and a representative sample of symptomatic plants should be sent for diagnosis. Vacuum collection, sweep nets, and/or sticky traps should also be used as described in 5.27-5.28.

5.41. Further general surveys will be carried out on hosts grown outside of the buffer zone, as *B. cockerelli* has the potential for long distance spread.

5.42. If it is considered possible that the pests have spread to distant fields on machinery or by other means, these fields should also be surveyed.

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 field outside the infested zone, this should subsequently be designated as infested. If the pests are found within uncropped areas outside the infested zone then any field directly adjacent to these areas should normally be designated as infested.

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 5.65-5.67).

Pest management procedures

Infested zone

5.46. The whole crop should be treated as soon as possible with a foliar insecticide if *B. cockerelli* is present (and should be carried out as a precaution even if *B. cockerelli* is not found). The PHSI will advise on an appropriate treatment regime in consultation with the Defra Risk and Horizon Scanning team.

- 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. In some cases there may be a requirement to carry out a Local Environment Risk Assessment for Pesticides (LERAP), depending on the product used and the situation of the finding.
- If the crop is organic, pesticides will still have to be used.
- 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 used.

5.47. The use of contact insecticides requires good coverage of the foliage as psyllids are found primarily on the undersides of leaves. Different chemicals are also better at targeting particular life stages of the psyllid.

5.48. Bee advisors and local beekeepers should be contacted to inform them of any insecticide applications and their timing. Bee inspectors should be able to provide contact details.

5.49. Visual inspection, vacuum traps and/or sweep nets (or other appropriate traps) should be used to assess the efficacy of insecticide treatments.

5.50. When the level of adult psyllids is low (none found), the potato haulm and tubers should be destroyed regardless of crop stage (using methods in point 5.64-5.66) to

eliminate the food supply of *B. cockerelli* and thereby reduce its ability to survive and multiply.

5.51. If the level of adults is high (some found), the potato haulm should **not** be destroyed due to the high risk of adults dispersing to hosts in other fields/sites.

5.52. Even if the number of adults is low when the haulm is destroyed, there is still a risk of some adults spreading further afield. Several rows of crop should therefore be left at the edge of the field to act as a trap. These should be treated regularly (e.g. weekly) with insecticide and destroyed later in the season.

5.53. Host plants, such as solanaceous weeds, and host debris in the infested zone, and uncropped areas, field boundaries and hedgerows in the immediate vicinity of the infested zone should be destroyed by herbicide or mechanical means.

Measures to be taken in the case of detection of infection with Lso (haplotypes A & B) and/or infestation with *B. cockerelli* in tubers after harvest (e.g. during storage processing/packaging and grading)

5.54. 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 field where the lot was grown.

5.55. As in 5.38, a buffer zone should be created that extends out to at least 2 km from the infested field, and restriction measures and surveillance should be carried out as described earlier in the plan.

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

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

5.58. Refer to points 5.46-5.53 should Lso (haplotypes A & B) and/or *B. cockerelli* be subsequently found in a potato field.

Crops growing within the buffer zone in the year of the outbreak

5.59. If no infestation by *B. cockerelli* 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 vacuum traps, sweep netting or other appropriate techniques.

5.60. Growers of non-potato crops, which contain host volunteers or weeds may be restricted under notice from undertaking any husbandry or harvesting of the crops until they have been inspected and found free of the pests.

5.61. Potato tubers should also be inspected during and/or immediately after harvesting. This will also apply to non-potato crops in fields or other areas containing volunteer potato plants or solanaceous weeds.

5.62. In the inner buffer zone (at least 1 km from the infested zone), potatoes must not be used as farm saved seed and should only be sent for processing or packing with suitable waste disposal facilities.

5.63. In the outer buffer zone (at least 1 km from the inner buffer zone), potatoes do not need to be sent for processing or packing with suitable waste disposal facilities, but should only be marketed as ware potatoes and must not be used as farm saved seed.

Disposal plan

Infested plant material

5.64. The primary means of destruction of potato plants in a field is through herbicide application. The Defra Risk and Horizon Scanning team will advise on the most appropriate approved treatments.

Infested harvested tubers/soil/plant debris

5.65. 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 and supervision of the PHSI. If the material has to be moved off the premises, it should be contained within at least one sealed layer, and two layers if possible, and should not split open prior to being buried or incinerated. 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.

5.66. Other possible methods of destruction for potato tubers should be considered on a case by case basis and include heat sterilization, industrial processing (under official supervision), fermentation and composting, steaming and feeding to animals, and anaerobic digestion (minimum temperature of 55°C for 24 h without interruption with a hydraulic dwell time in the reactor of at least one day).

5.67. 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 5.65).

Measures in subsequent seasons

Infested zone

5.68. No host crop should be planted for at least two years following the year of the outbreak and until no volunteer plants have been found for two consecutive years (under notice). Trap crops planted in the year following the outbreak are exempt from this rule.

5.69. If trap crops are used, these should be planted early in the season to ensure they are present before the emergence of adults in spring. If possible, trap crops could be used in combination with a chemical attractant. These plants should be inspected regularly during spring and summer (e.g. fortnightly) and sprayed with an appropriate insecticide program as discussed with the Defra Risk and Horizon Scanning team (see 5.46).

5.70. Any volunteer plants should be destroyed early in the season following the outbreak. If the population of volunteer plants is low, they can be removed by hand, but if the population of volunteer plants is high, they are best controlled by an application of an effective herbicide (see 5.64). Solanaceous weeds should also be controlled in a similar way.

5.71. 'Infested' fields may be maintained in permanent pasture with frequent close cutting or intensive grazing. This option has the advantage of providing effective control of potato volunteers and solanaceous weeds.

5.72. The frequency of inspections and insecticide treatments will be determined by the IMT.

5.73. Following two years without volunteer plants, only ware potatoes or a trap crop should be produced in the following season, with the crop and any harvested tubers inspected for Lso (haplotypes A & B) and *B. cockerelli*. If there are no finds of the

pest following this, then either seed or ware potatoes can be produced on the field the following year.

Buffer zone (at least 2 km around the infested zone)

5.74. In the inner buffer zone, host crops should not be planted outdoors for at least two years if *B. cockerelli* is found in the infested zone (under notice). Volunteer plants and weeds should be destroyed. Following this period, only ware potatoes should be produced with the growing crop and harvested tubers inspected for Lso (haplotypes A & B) and *B. cockerelli*. If there are no finds of the pest, then either seed or ware potatoes can be produced on the field.

5.75. If *B. cockerelli* is not found in the year of the outbreak, then host crops may be planted outdoors in the following year, but these crops should be inspected. However, if the finding of Lso (haplotypes A & B) in the outbreak year is towards the end of the season, then the following year should be treated as if *B. cockerelli* is present and restrictions and surveys implemented, as surveys during the outbreak year would not have been sufficient to rule out the presence of *B. cockerelli*.

5.76. The frequency of inspections will be determined by the IMT.

5.77. Host crops planted in protected environments such as glasshouses should be monitored, and if Lso (haplotypes A & B) and/or *B. cockerelli* are found, the site (which may include outdoor fields) should be designated as infected/infested and an appropriate management regime commenced.

5.78. In the outer buffer zone, host crops should be surveyed for Lso (haplotypes A & B) and/or *B. cockerelli*.

Review of measures in the case of prolonged official action

5.79. 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.

5.80. 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) after at least two years during which no volunteers have been identified in the infested zone (and inner buffer zone as appropriate) and no host plants have been found to be infected/infested with Lso (haplotypes A & B)/*B.cockerelli*.

7. Evaluation and review of the contingency plan

7.1. This pest specific contingency plan should 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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