Department
for Environment
Food & Rural Affairs

Pest specific plant health response plan:

Outbreaks of *Clavibacter sepedonicus* (potato ring rot)

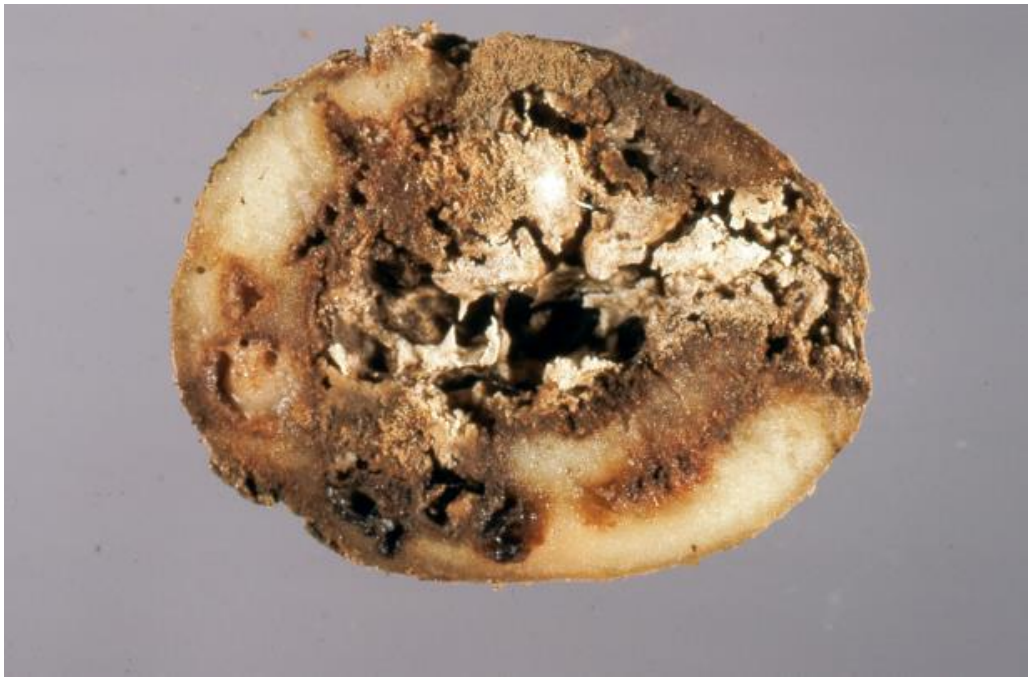

Figure 1. Late stages of rotting caused by *Clavibacter sepedonicus* (potato ring rot). © Fera Science Ltd.

This document is also available on our website at:

https://planthealthportal.defra.gov.uk/pests-and-diseases/contingency-planning/

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1. Introduction and scope

1.1. This pest specific response plan has been prepared by the Defra Risk and Policy team. It describes how the Plant Health Service for England will respond if an outbreak of *Clavibacter sepedonicus* (potato ring rot) is discovered.

1.2. The plant health authorities in Northern Ireland and Wales have been consulted on this plan and will use it as the basis for the action they will take in the event of potato ring rot being detected in their territories.

1.3. Scotland has its own contingency plan, which closely aligns with this contingency plan (https://www2.gov.scot/Publications/2005/05/16142418/24194).

1.4. This document will be used in conjunction with the *Defra Contingency Plan for Plant and Bee Health in England* (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/593508/generic-contingency-plan-plant-bee-health-england.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 aims of this response plan are to facilitate the containment and eradication of potato ring rot and to make stakeholders aware of the planned actions.

2. Summary of the threat

2.1. Potato ring rot is a short, non-motile, Gram-positive rod shaped bacterium, which causes disease in potato (Hayward and Waterston, 1964). There has been a single finding in tomato (*Solanum lycopersicum*) from a substrate crop in the Flanders region of Belgium, but this was limited to a row of 10 plants and additional inspection resulted in no further findings (CABI, 2018; Van Vaerenbergh *et al.*, 2016). Potato ring rot has also been isolated under natural conditions from sugar beet seed and roots, but no symptoms were observed (Bugbee and Gudmestad, 1988). Transmission in sugar beet has also not been reproducible under European conditions or with commonly grown varieties (Elphinstone, 2010).

2.2. It is unclear where the disease first originated, but potato ring rot is generally associated with cooler climates and has been reported from large areas of North America (Canada and the USA), China, Russia and northern Europe (Elphinstone, 2010). The disease has spread within Europe, with a number of outbreaks recorded in recent years, including in the warmer climes of Crete (Greece) (EPPO, 2018; Goumas *et al.*, 2001).

2.3. Potato ring rot causes wilting, reduced yield, and in severe cases, the death of the plant (Figure 7, CABI, 2018; EPPO, 2018). In tubers, specifically, infection causes rotting of the vascular tissue and cortex, and later the discolouration and cracking of the outer skin (Figure 2-6, Elphinstone, 2010; EPPO, 2018).

2.4. The bacterium is associated with, and can be spread by, the potato plant and tuber. The risk of entering with these commodities is reduced by the prohibitions on entering the EU of solanaceous plants for planting from third countries other than European and Mediterranean countries, seed potatoes from third countries other than Switzerland, and ware potatoes from third countries other than Algeria, Egypt, Israel, Libya, Morocco, Syria, Switzerland, Tunisia and Turkey, or other European third countries recognised as being free from potato ring rot

or which have measures to mitigate the entry of potato ring rot that are equivalent to those of the EU (Annex III, Council Directive 2000/29/EC). Seed potatoes entering from the EU must also come from advanced breeding selections, have been produced within the EU, been maintained under appropriate conditions, and tested for harmful organisms using appropriate methods (Annex IV part A section 2, Council Directive 2000/29/EC), and meet the requirements of Council Directive 2002/56/EU, which includes information on certification schemes to ensure healthy plant material. The most likely route of entry is therefore with ware potatoes coming from the EU.

2.5. There has been one outbreak of potato ring rot in seed potatoes in the UK, in 2003 in a farm in Wales (EPPO Reporting Service, 2004). This outbreak was subsequently eradicated (Giltrap, 2009). This was followed by outbreaks of potato ring rot in ware potatoes in Herefordshire and Lincolnshire in 2004 (John Elphinstone Personal Communication 2019). There have also been 14 interceptions of potato ring rot in England since 2001. The latest interceptions in 2017 and 2018 were both in ware potatoes from Poland (var. Innovator).

3. Risk assessments

3.1. Potato ring rot has an unmitigated and mitigated UK Plant Health Risk Register score of 125 and 40, respectively. These scores are reviewed as and when new information becomes available (https://secure.fera.defra.gov.uk/phiw/riskRegister/viewPestRisks.cfm?cslref=10954).

3.2. The impact to potato crops is considered to be large should it enter the UK, especially for seed potatoes.

4. Actions to prevent outbreaks

4.1. Potato ring rot is a IAII EU listed pest and is therefore banned from being introduced into and spread within all member states.

4.2. Potato ring rot is on the EPPO A2 list and is therefore recommended for regulation by EPPO member countries.

4.3. The Plant Health Service (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 potato ring rot. It is important that capabilities in detection, diagnosis, and risk management are available.

Prohibitions

Plants of Solanaceae

4.4. Plants of Solanaceae intended for planting, other than seeds, ware and seed potatoes, and other stolon- or tuber-forming plants for planting, are prohibited from third countries other than European and Mediterranean countries (Annex III, Council Directive 2000/29/EC).

4.5. Prohibited solanaceous plants can be imported and held under a plant health licence in quarantine conditions (usually for research purposes). Once work on the plants has been

completed, destruction of the plants is normally required. However, given adequate testing, the plants can, in some cases, be released from the terms of the licence if they are shown to be free of pests and pathogens.

Potato

4.6. The import of *Solanum tuberosum* tubers for propagation (seed potatoes) into the EU from third countries other than Switzerland is prohibited under Annex III, Council Directive 2000/29/EC. There is a derogation to bring in tubers for trial, scientific or varietal selection purposes (Commission Directive 2008/61/EC), but they must be placed under quarantine conditions and tested for pests before being used for propagation purposes. There is also derogation for Canadian seed potatoes. This allows Greece, Spain, Italy, Cyprus, Malta and Portugal to import, under specified conditions, seed potatoes originating from certain provinces of Canada: http://eurlex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32014D0368&from=ENhttp://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32011D0778&from=EN.

4.7. Ware potatoes and their hybrids are prohibited from third countries, with the exception of Algeria, Egypt, Israel, Libya, Morocco, Syria, Switzerland, Tunisia and Turkey, and other European third countries which are recognised as being free from *C. sepedonicus*, or in which provisions recognised as equivalent to those of the EU territory for mitigating the risk of spreading *C*. *sepedonicus* have been fulfilled (Annex III, Council Directive 2000/29/EC).

Measures

Plants of Solanaceae

4.8. Plants with roots, planted or intended for planting, grown in the open air must have an official statement that the place of production is known to be free from *C. sepedonicus* (Annex IV part A section I, point 33, and Annex IV part A section II, point 24, Council Directive 2000/29/EC).

4.9. Plants of stolon or tuber-forming species of *Solanum* L., or their hybrids, intended for planting other than those tubers of *Solanum tuberosum* L. specified in points 18.1, 18.1.1 or 18.2 of Annex IV part A section II of Council Directive 2000/29/EC, other than culture maintenance material being stored in gene banks or genetic stock collections, and other than seeds of *Solanum tuberosum* L. specified in point 18.3.1, shall have been held under quarantine conditions and shall have been found free of any harmful organisms in quarantine testing (Annex IV part A section II, point 18.3, Council Directive 2000/29/EC).

Potato

4.10. Tubers of *Solanum tuberosum* coming from third countries must originate in countries known to be free from *C. sepedonicus* or have provisions recognised as equivalent to the EU territory for mitigating *C. sepedonicus* (Annex part IV A section I, point 25.2, and Annex IV A section II, point 18.1, Council Directive 2000/29/EC).

4.11. Seeds of *Solanum tuberosum* L., other than those specified in point 18.4 of Annex IV part A section II of Council Directive 2000/29/EC must have an official statement that they derive from plants in line with 18.1, 18.1.1, 18.2 and 18.3 and originate in areas known to be free from *C. sepedonicus* (Annex IV part A section II, point 18.3.1, Council Directive 2000/29/EC).

4.12. Tubers of *Solanum tuberosum* L., other than those mentioned in points 18.1, 18.1.1, 18.2, 18.3 or 18.4 of Annex IV part A section II of Council Directive 2000/29/EC, shall have Union provisions to combat *C. sepedonicus* (Annex IV part A section II, point 18.5, Council Directive 2000/29/EC).

4.13. Within the EU, potato tubers for planting must come from advanced breeding selections, have been produced within the EU, been maintained under appropriate conditions, and tested for harmful organisms using appropriate methods (Annex IV part A section 2, Council Directive 2000/29/EC).

4.14. Seed potatoes can only be marketed in the EU if they meet the requirements of Council Directive 2002/56/EU (includes information on certification schemes to ensure healthy plant material).

Inspections

4.15. In annex V of the EU Directive 2000/29/EC, a plant health inspection is required in the country of origin or the consignor country originating in the EU before being permitted to enter the community and which must be accompanied by a plant passport for the following hosts of potato ring rot:

- Plants of stolon- or tuber-forming species of *Solanum* L. or their hybrids, intended for planting (Part A, point 1.3)

- Plants of Solanaceae, other than those referred to in point 1.3 of Part A, Annex V of Council Directive 2000/29/EC, intended for planting, other than seeds (Part A I, point 2.2)

4.16. A plant health inspection is required in the country of origin or the consignor country before being permitted to enter certain protected zones, and which must be accompanied by a plant passport valid for the appropriate zone when introduced into or moved with that zone for the following hosts of potato ring rot:

- Tubers of *Solanum tuberosum* L., intended for planting (Part A II, point 1.5)

4.17. A plant health inspection is required in the country of origin or the consignor country before being permitted to enter the EU from third countries for the following hosts of potato ring rot:

- Tubers of *Solanum tuberosum* L. (Part B I, point 4)

4.18. In response to other pests and diseases of potato, such as *Ralstonia solanacearum* (brown rot) and *Epitrix* potato flea beetles, seed and ware potatoes are surveyed.

Notification schemes

4.19. All EU seed potato importers must provide a written notification to an inspector, at least 2 days prior to the intended date of introduction into England of the potatoes.

4.20. For EU seed consignments being used for ware production, a random sample of 210 tubers (ideally taken from at least 5 containers) should be selected. This is required for one variety per grower.

4.21. All EU consignments destined for entry into the Seed Potato Certification Scheme will need sampling and testing, even if previous consignments of the same stock have been sampled

and tested elsewhere. A random sample of 410 tubers (ideally taken from at least 5 containers) should be selected.

4.22. For Poland and Romania, all importers of ware and seed potatoes must provide a written notification to an inspector, at least 2 days prior to the intended date of introduction into England of the potatoes. There has been a 50% inspection rate, with an attempt to inspect the widest range of grower/variety combinations as possible. A random sample of 210 tubers is taken. Specific measures are applied to Poland and Romania because of the high risk of introducing potato ring rot; there are regular findings of potato ring rot in national surveys.

4.23. Polish consignments must be accompanied by an official ring rot certificate which is issued by the Polish Plant Health Authority and which confirms that additional inspections and testing have been undertaken prior to movement. All movements of authorised consignments are notified to the APHA in advance by the Polish Plant Health Authority. There are currently no imports from Romania.

Communication

4.24. All stakeholders, particularly those involved in the production and processing of potatoes, should be provided with details of the disease and available control methods. A factsheet is available for potato ring rot on the EPPO Global Database (https://gd.eppo.int/taxon/CORBSE/documents) and on the UK Plant Health Information Portal (https://planthealthportal.defra.gov.uk/assets/factsheets/ringrot.pdf).

5. Response activities

Official action to be taken following the suspicion of an interception of potato ring rot

5.1. If potato ring rot is 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. 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 the Plant Clinic, Fera Science Ltd., National Agri-Food Innovation 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. All other material that has come in contact with the suspected tubers, such as equipment, vehicles, machinery and storage facilities, should also be designated as contaminated until testing has been completed.

Official action to be taken following the confirmation of an interception of potato ring rot

5.3. When infection with potato ring rot is confirmed, the PHSI should advise the client of the action that needs to be taken by way of an official plant health notice.

5.4. The consignment should be destroyed by either incineration, deep burial or one of the other methods described in point 5.51. If it is not possible to organise destruction via one of these methods, a suitable alternative should be discussed with the Defra Risk and Policy team.

5.5. Contaminated materials, such as equipment, vehicles, machinery and storage facilities should be cleansed and disinfected as in point 5.52.

5.6. A Europhyt notification should be made upon confirmation of an interception of potato ring rot.

5.7. In the event that all or part of the consignment has not been held and has been distributed to other premises prior to diagnosis, trace forward and trace back inspections should take place upon suspicion or confirmation of potato ring rot. 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 factsheet to raise awareness of potato ring rot and its symptoms should be distributed to packers/processors and importers where potato ring rot has been found. The current factsheet is found on the plant health portal - https://planthealthportal.defra.gov.uk/assets/factsheets/ringrot.pdf.

Official action to be taken following the suspicion of a potato ring rot outbreak

5.9. Suspicion of potato ring rot is likely to occur following positives in real-time Taqman PCR and pastrik conventional PCR. A further eggplant bioassay is required for official confirmation, but given the confidence of the other two tests, a suspicion should be treated as if confirmed.

5.10. A Contingency Core Group (CCG), 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. This may include gathering more information on the suspected outbreak, such as the completion of an outbreak assessment, notification of ministers and senior officials, and agreeing a communications strategy. The CCG 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 ring rot in potatoes, the 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 and Bee Health in England* for full details.

5.11. The CCG will set an alert status (using the factors to consider document, appendix IV of the Defra *Generic Contingency Plan for Plant and Bee Health in England*), which will take into account the specific nature of the outbreak. Under most scenarios, an outbreak of potato ring rot in a potato field is likely to be given an amber alert status, which is used for a serious plant 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) depending on the extent of spread.

Restrictions on the movement of material

5.12. Potato ring rot is associated with potato plants and tubers, so potentially infected or contaminated potato plants or tubers should be restricted from leaving the infected site (e.g. farm), except when they are being sent for disposal. Potato plants and tubers may also be moved under exceptional circumstances under notice in consultation with the Risk and Policy team, provided there is no identifiable risk of potato ring rot spreading.

5.13. Potato ring rot bacteria can adhere to inorganic surfaces, so the movement of material, equipment, vehicles and machinery should also be restricted to prevent the movement of potato ring rot from infected to non-infected areas. However, if movement is necessary, the material, equipment, vehicles and machinery should be thoroughly cleansed and disinfected at the designated outbreak site to eliminate the bacterium as in point 5.52.

5.14. Movement of personnel into the affected field or production site poses a risk of spread, as potato ring rot can be transferred on clothing. Personnel should therefore be briefed on the importance of good hygiene practice to reduce the risk of spread, and movement into the affected field or production site should be minimised as best as possible.

Precautionary measures (grower)

5.15. To prevent the mechanical transfer of potato ring rot, hygiene best practice should be followed as below:

- Training staff to identify symptoms of potato ring rot.
- Using disposable garments (including overshoes), which will be destroyed after working on an infected field or production site, or which should only be 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 the infected area.
- Avoid using the same equipment and machinery for seed and ware potatoes when growing, packing or processing, particularly from different growers, as there is a higher risk of cross-contamination.
- Avoid cutting tubers, as this increases the risk of spreading potato ring rot through potato stocks.
- Take care when handling potatoes, as any damage can act as openings for the bacterium.
- The fewer people entering a particular field or infected area, the less chance of potato ring rot being spread. 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 during work shifts, uninfected areas should be worked in first before finishing in areas that could potentially be infected. There should be no movement between infected crops and those assumed to be uninfected.
- Maintain records of cleansing and disinfection, and the date and location of potato stocks.

5.16. Volunteer host plants may act as reservoirs for potato ring rot if they originate from an infected crop. Controlling these plants reduces the chance of the crop becoming infected and reduces survival and persistence in the event of an outbreak. Volunteer plants can be controlled mechanically (e.g. by hoeing, roguing, flame weeding) and chemically (e.g. using herbicides). Any disposal required should be as in point 5.51.

Preliminary trace forward / trace backward

5.17. Information obtained regarding the origins of suspected infected consignments should be used to locate other related and therefore potentially infected consignments. The relevant NPPO should be contacted and delivery notes requested upon confirmation of potato ring rot. Information should also be obtained on the destination to which suspect consignments have been sent. This process is particularly important for propagation or seed potato stocks.

5.18. In addition to tracing investigations relating to consignments, trace forward/back investigations linked to equipment, vehicles and machinery used in the infected field or production site should also be carried out.

Confirming a new outbreak

How to survey to determine whether there is an outbreak

5.19. Information to be gathered by the PHSI on suspicion of an outbreak of potato ring rot, in accordance with ISPM 6; guidelines for surveillance (http://www.acfs.go.th/sps/downloads/13717_ISPM_6_E.pdf), includes:

- The origin of the host plants and associated pathways.
- Details of other premises or destinations where the host plants/products have been sent, where potato ring rot may be present.
- The layout of the premises and surrounding area (in relation to potential demarcated areas), 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.
- Details of all potato stocks on site, particularly identifying any potatoes which are clonally related to a known infected stock or a stock grown on contaminated premises.
- Area and level of infection, including a description of symptoms (photos should be taken).
- The locations where potato ring rot has 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 infected area, and the associated premises.
- 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/person responsible for the infected premise and crops/consignments.

5.20. This information should be included on the plant pest investigation template (see Appendix III of the Defra *Generic Contingency Plan for Plant and Bee Health in England*).

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

5.22. 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

5.23. Potato tuber coring kits can be obtained from the bacteriology laboratory in Fera.

5.24. Buffer provided in the kits should be refrigerated prior to use and ice packs should be frozen prior to sending the samples to the laboratory.

5.25. Ensure that samples arrive at the laboratory the day after sampling, ideally by 9am. Inform the laboratory of the number and expected date of arrival of the samples before 5pm the day prior to arrival at the latest.

5.26. To prevent cross-contamination, use a new pair of disposable gloves, a new sterile corer, a new sterile collection tube and a fresh tube of sterile buffer for each sample.

5.27. Do not package any other sample types with core samples or tuber samples for this survey, as these samples do not pass through the plant clinic.

5.28. Instructions for taking cores from potato tubers:

- Wear disposable gloves.
- Select samples of 200 tubers randomly from the entire lot to be sampled.
- Attach a sterile stainless steel corer to the empty 50 ml screw cap tube.
- Remove as much soil as possible from the heel end of each tuber (e.g. using a new disposable cloth, glove or paper towel for each sample) and locate the point of attachment with the stolon.
- Remove cores from the point of attachment of each tuber in the sample and collect in the tube (each core must contain vascular tissue from the point of attachment). When 200 cores have been collected, their volume should exceed the 40 ml graduation mark.
- Unscrew the corer and replace it in the original transport pot for return with the sample.
- Add buffer to cover the cores, shake and top up to the 45 ml mark leaving an air space at the top of the tube. Discard any unused buffer.
- Replace cap and seal tightly.
- Include sample information as needed on the sample tube label, including the sample ID number, date of coring and the inspector name.
- Maintain the samples refrigerated or in a cooled box until packaging for sending to the laboratory.
- Always place the cored sample against the ice-pack in the transport package, also include the used corer in the package, and return overnight to the laboratory using the correct label.
- If several core samples are sent together in an outer bag or box, ensure that the ‘Potato cores’ label will be visible and easily identifiable upon arrival at the laboratory.
- Collect cored tubers from each sample and store separately in labelled secure bags for further reference until results are known.

5.29. If the tubers are too difficult to sample in the field, the tubers can be sent to the lab for processing (using the tuber label). As previously, Fera should be informed prior to arrival at the laboratory. Cores and tubers are sent to different parts of the laboratory.

5.30. A higher sampling density may be required during trace-back during outbreaks to give greater confidence in detecting an infection of ring rot. See ISPM 31 for details

(https://www.ippc.int/static/media/files/publication/en/2016/01/ISPM_31_2008_En_2015-12-22_PostCPM10_InkAmReformatted.pdf).

Diagnostic procedures

5.31. Identification of potato ring rot is carried out in line with Commission Directive 2006/56/EC (https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32006L0056&from=en) and following additional guidelines given in the EPPO Diagnostic Protocol PM7-59.

5.32. In Fera, initial tests include immunofluorescence microscopy (monoclonal antibody) and real-time (Taqman) PCR. These provide a first indication of whether the sample is positive for potato ring rot.

5.33. Identification of the ring rot bacterium is confirmed by a Pastrik conventional PCR test.

5.34. To confirm potato ring rot, according to Commission Directive 2006/56/EC, an eggplant bioassay is carried out. This takes 2-4 weeks depending on the inoculum load and subsequent symptom development. Identification of potato ring rot from the bioassay is carried out using immunofluorescence microscopy and Pastrik conventional PCR.

5.35. The variety of the potatoes can be confirmed by DNA microsatellite analysis at SASA, should there be suspicion of misidentification or mixing of varieties.

Criteria for determining an outbreak

5.36. If potato ring rot 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 it is identified in a potato field, then this would be classified as an outbreak. However, if it is restricted to recently imported potatoes within a cold store then this would be classified as an interception. If only symptoms are found, then the outbreak should be treated as suspected until it is confirmed by testing.

Official Action to be taken following the confirmation of an outbreak

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

Communication

5.38. 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/) and EU council Directive 93/85/EEC, as well as to Defra Ministers, senior officials, devolved authorities, and other government departments and agencies (e.g., the Environment Agency) on a regular basis as appropriate; and to stakeholders.

5.39. Notification to other member states and the EU Commission should include the variety of the potato lot, the type (ware, seed, etc.) and where applicable the seed category of the potatoes. When investigations have been completed, further information should be notified to other member states and the EU Commission as follows:

- The date that contamination was confirmed.
- Brief description of the investigation carried out to identify the source and the possible spread of the contamination, including the level of sampling undertaken.
- Information on the identified or presumed source(s) of contamination.
- The extent of designated contamination, including the number of places of production and the number of lots with an indication of the variety, and category (if seed potatoes).
- The area demarcated, including the number of places of production not designated as contaminated but included in the area.
- Any other information relating to the outbreak as the Commission may require.

5.40. If there is a risk of contamination of potatoes coming from or moving into another member state(s), the member state(s) should be informed by the member state in which potato ring rot was found of the:

- Variety of the potato lot.
- The name and address of the consignor and the consignee.
- The date of delivery of the potato lot.
- The size of the potato lot delivered.
- A copy of the plant passport or at least the plant passport number where appropriate, or where appropriate the registration number of the grower or merchant and a copy of the delivery notice.

Demarcated zones

5.41. As in Article 5 (1) (a) of EU Council Directive 93/85/EEC designate as **contaminated** the tubers or plants, consignment and/or lot, and the machinery, vehicle, vessel, store, or units thereof, and any other objects including packaging material, from which the sample was taken, and, where appropriate, the place(s) of production and fields(s) from which the tubers or plants were harvested.

5.42. As in Annex III of EU Council Directive 93/85/EEC designate the extent of **probable contamination** as the following:

- Tubers or plants grown at a place of production designated as contaminated.
- Places of production with some production link to the tubers or plants designated as contaminated, including those sharing production equipment and facilities directly or through a common contractor.
- Tubers or plants produced in the place(s) of production referred to in the previous bullet point, or present in such place(s) of production during the period when the tubers or plants designated as contaminated were present on the place of production referred to in the first bullet point.
- Premises handling potatoes from the places of production referred to in the previous bullet points.
- Any machinery, vehicle, vessel, store, or units thereof, and any other objects including packaging material, that may have come into contact with the tubers or plants designated as contaminated.
- Any tubers or plants stored in, or in contact with, any of the structures or objects listed in the previous bullet point, prior to the cleansing and disinfection of such structures and objects.
- Those tubers or plants with a sister or parental clonal relationship to the tubers or plants designated to be contaminated and for which, although they may have tested negative

for the organism, it appears that contamination is probable through a clonal link. Variety testing may be undertaken to verify the identity of the contaminated and clonally related tubers or plants.

- Places of production of the tubers or plants referred to in the previous bullet point.

5.43. A demarcated area should be established based on the designation of contamination (point 5.41), the designation of probable contamination (point 5.42), and the possible spread of the organism based on the proximity of other places of production growing potatoes or other host plants, and the common production and use of seed potato stocks.

5.44. Initial maps of outbreak sites should be produced by either the PHSI or the Risk and Policy team. Grower contact details will be available from the Agriculture and Horticulture Development Board (AHDB) buyers and grower levy payers list.

5.45. As in Article 6 of the EU Council Directive 93/85/EEC, testing must be carried out on potato stocks which are clonally related to those involved in the contamination to determine the probable primary source of infection, and testing must be carried out to determine the extent of probable contamination, preferably in order of degree of risk. This will include places of production that are in proximity to contaminated and probably contaminated premises.

5.46. The demarcated area should be adjusted in response to further findings.

Pest management procedures

5.47. If there are potato plants still being grown in fields designated as contaminated or probably contaminated, the plants should either be cut or left in the field and ploughed into the soil or treated with an approved herbicide/desiccant. Plant material and tubers should not be removed to minimise the risk of spreading potato ring rot. All the equipment and machinery used to cut the crop or to plough it into the soil must be cleansed and disinfected as in point 5.52.

5.48. Any other tubers or plants designated as contaminated or probably contaminated must not be planted and must either be destroyed or disposed of using one of the options outlined in point 5.51.

5.49. Any machinery, vehicle, vessel, store, or units thereof, and any other objects including packaging material, designated as contaminated or probably contaminated must either be destroyed as in point 5.51 or cleansed and disinfected as in point 5.52.

Disposal plan

Infected plant material

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

Infected tubers/soil/plant debris

5.51. 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. The vehicle used for transport must be cleaned and disinfected after use. The following disposal methods are approved for potato ring rot contaminated material:

- **Deep burial** (minimum 2 m with immediate backfill), which can be done at an approved landfill site, or on the site or nearby farm, but only in agreement with the local Environment Agency, who is satisfied that there will be no risk of contaminating ground water.

- **Incineration**, which must comply with appropriate waste management regulations, Environment Agency in England, Scottish Environment Protection Agency and Natural Resources Wales.

- **Use as animal feed** following boiling for at least 30 minutes.

- **Approved commercial composting** using a validated process (PAS 100) with regular mixing, at least 50% moisture content, pH 7 and a two-week sanitation period with peak temperatures of 55°C (or 1 week with peak temperatures of 65°C). If temperature requirements cannot be met, then additional heating to 70°C for 4 hours either before or after composting would be required. In addition, the final compost should not be used on arable land.

- **Approved mesophilic anaerobic digestion** using a validated process (PAS 110) at temperatures of ≥ 37°C for 6 or more days. Because potato ring rot can survive for more than 24 h at these temperatures, continuous processes should not be used. Instead, it should be a batch process to ensure all of the material is treated for at least 6 days. Pasteurisation, either before or after digestion, at 70°C for at least 1 hour is recommended to ensure complete kill of the bacteria. In addition, the digested material should not be used on arable land.

- **Direct feeding of small quantities to cattle** (without cooking). Feeding should take place on hard-standing to avoid the risk of potatoes returning to arable land. The manure should be collected and stored (composted) for a period of 2 months and not returned to arable land. As an additional precaution, potatoes could be used in silage production prior to feeding to cattle.

- **Direct and immediate delivery for industrial processing** to a site which operates officially approved waste disposal facilities and which has a system of disinfection of storage areas and departing vehicles.

- Treatment of liquid washing or drainage effluent will be decided on a case by case basis, but will likely include an **approved treatment to remove all solids, followed by a treatment to kill the bacteria, such as heat or UV treatment.**

5.52. All objects designated as ‘contaminated’ or ‘probably contaminated’, such as equipment, vehicles, machinery, boxes and storage facilities, should be thoroughly cleansed and disinfected to eliminate the risk of spread of potato ring rot. 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 disposed of as in 5.51. Boxes could also be left in the open air for several months to expose the bacterium to the weather, but the boxes must not be used for storage of seed potatoes.

Measures in subsequent seasons

Contaminated fields or units of protected cropping

5.53. Measures for contaminated fields must follow either I or II:

I. For the next three years from the start of the next growing season, growers must eliminate volunteer potato plants and other naturally found host plants (see point 5.47 for guidance on destruction). In addition, no potato tubers, plants or true seeds, or other naturally found host plants of the organism or crops for which there is an identified risk of the organism spreading, shall be planted.
    - Following this period and if the field has been found free from volunteer potato plants and other naturally found host plants during official inspections for at least two consecutive years prior to planting, potatoes (officially classified seed potatoes) may be grown for ware production, but the harvested tubers must be tested for potato ring rot.
    - Following the growing of potatoes for ware production and an appropriate rotation cycle, either ware or seed potatoes may be grown and an official survey carried out. The official survey will include visual inspection of plants and tubers, and sampling of tubers for testing (as in points 5.23-5.35).

II. For the next four years from the start of the next growing season, growers must eliminate volunteer potato plants and other naturally found host plants of the organism (see point 5.47 for guidance on destruction). In addition, the field must be maintained either in bare fallow or in permanent pasture with frequent close cutting or intensive grazing.
    - Following this period and if the field has been found free from volunteer potato plants and other naturally found host plants during official inspections for at least two consecutive years prior to planting, either ware or seed potatoes (officially classified seed potatoes) may be grown, but harvested tubers must be tested for potato ring rot.

In other fields on contaminated premises

5.54. On the condition that the volunteer potato plants and other naturally found host plants of potato ring rot have been eliminated, officially classified seed potatoes may be planted for ware production only. The PHSI should inspect the growing crop and any volunteer plants should be tested for infection. Harvested tubers must be inspected and tested for potato ring rot.

5.55. In the second and third year following confirmation of potato ring rot, officially classified seed potatoes may be grown for seed production as well as ware production. Measures must be taken to eliminate any volunteer potato plants and other naturally found host plants of potato ring rot, and harvested tubers must be tested for potato ring rot.

5.56. Following the designation of premises as contaminated and in each of the subsequent growing years, up to and including the first permissible potato cropping season on the fields designated as contaminated, growers must cleanse and disinfect all potato machinery, equipment and storage facilities on the premises.

5.57. In a unit of production where the complete replacement of growing medium is possible, no tubers, plants or true seed must be planted unless the production unit has been subjected to

measures to eliminate potato ring rot and to remove all host plant material, which includes a complete change in growing medium and cleansing and disinfection of the production unit and all equipment, and has been granted approval for potato production by the PHSI. Potato production must be from officially classified seed potatoes, or mini-tubers or micro plants from tested sources.

Other areas of the demarcated area

5.58. Any premises growing, storing or handling potatoes (including those of contractors) will be supervised and controlled under notice.

5.59. All machinery, equipment and storage facilities involved with potato production must be cleansed and disinfected, as in point 5.52.

5.60. Growers must plant only officially classified seed potatoes, or seed potatoes once-grown under official control, for all potato production. Seed potato crops grown in places of production designated as probably contaminated must be tested at harvest.

5.61. Ware potatoes and seed potatoes must be handled separately on all premises within the demarcated area, or there must be a system of cleansing and disinfection in place between the handling of ware and seed potato stocks.

5.62. An official survey will be carried out. The official survey will include visual inspection of plants and tubers, and sampling of tubers for testing (as in points 5.23-5.35).

5.63. A programme should be established to replace all seed potato stocks over an appropriate period of time.

6. Criteria for declaring eradication / change of policy

6.1. Potato ring rot can be declared eradicated (by the Chief Plant Health Officer) in potato after:

- at least 5 years if the contaminated field(s) is left in bare fallow or permanent pasture for 4 years with at least two consecutive years without volunteer potato plants or naturally found host plants prior to planting of ware or seed potatoes.
- at least 6 years if the contaminated field(s) is not left in bare fallow or permanent pasture for 3 years, with at least two consecutive years without volunteer potato plants or naturally found host plants prior to planting of ware potatoes in the first potato cropping season, and following a rotation of ideally two years (and must be two years for seed) prior to planting of ware or seed potatoes in the second potato cropping season.

7. Evaluation and review of the contingency plan

7.1. The Defra *Generic Contingency Plan for Plant and Bee Health in England* requires that the pest specific plan is reviewed following an outbreak. This pest specific contingency plan should also be reviewed regularly to take into account 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 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.

8. Appendix A

Data sheet for potato ring rot

Identity

PREFERRED SCIENTIFIC NAME	AUTHOR (taxonomic authority)
Clavibacter sepedonicus	(Spieckermann and Kotthoff 1914) Davis *et al.* (1984) Oren and Garrity (2018)

CLASS: Actinobacteria
ORDER: Micrococcales
FAMILY: Microbacteriaceae

SYNONYMS

Aplanobacter sepedonicum (Spieckermann and Kotthoff 1914) Smith 1920
Bacterium sepedonicum Spieckermann and Kotthoff 1914
Clavibacter michiganense sepedonicum
Clavibacter michiganense subsp. *sepedonicum*
Clavibacter michiganensis sepedonicum
Clavibacter michiganensis subsp. sepedonicus
Clavibacter sepedonicus nom. Illegit
Corynebacterium michiganense pv. *sepedonicum* (Spieckermann & Kotthoff) Dye & Kemp 1977
Corynebacterium michiganense subsp. *sepedonicum* (Spieckermann and Kotthoff 1914) Carlson and Vidaver 1982
Corynebacterium sepedonicum (Spieckermann and Kotthoff 1914) Skaptason and Burkholder 1942
Mycobacterium sepedonicum (Spieckermann and Kotthoff 1914) Krasil'nikov 1949
Phytomonas sepedonica (Spieckermann and Kotthoff 1914) Magrou 1937
Pseudobacterium sepedonicum (Spieckermann and Kotthoff 1914) Krasil'nikov 1949

COMMON NAMES

Bacterial ring rot of potato (English)
Bactériose annulaire de la pomme de terre (French)
Bacteriosis anular de la papa (Spanish)
Bacteriosis anular de la patata (Spanish)
Bakterielle ringfäule: Kartoffel (German)
Bakterienringfäule: Kartoffel (German)
Flétrissement bactérien de la pomme de terre (French)
кольцевая гниль картофеля (Russian)
Ljust ringröta (Swedish)
Marciume anulare della patata (Italian)
Podredumbre anular de la papa (Spanish)
Podredumbre anular de la patata (Spanish)

Podridão-anelar-bacteriana-da-batata (Portuguese)
Pourriture annulaire de la pomme de terre (French)
Ringbakteriose: Kartoffel (German)
Ringrot (Dutch)
Ring rot of potato (English)
Vascular wilt of potato (English)

Notes on taxonomy and nomenclature

Potato ring rot is a short, non-motile, Gram-positive rod shaped bacterium (Hayward and Waterston, 1964), and is currently placed within the *Clavibacter* genus. The *Clavibacter* genus originally contained 6 species, including *Clavibacter michiganensis*, *C. iranicum*, *C. rathayi*, *C. toxicus*, *C. tritici* and *C. xyli*, but *C. iranicum*, *C. rathayi*, *C. toxicus* and *C. tritici*, and *C. xyli*, were subsequently moved into the genera *Rathayibacter* and *Leifsonia*, respectively, leaving *C. michiganensis* as the only species in the genus *Clavibacter* (Zgurskaya *et al.*, 1993; Suzuki *et al.*, 1999; Evtushenko *et al.*, 2000).

Clavibacter michiganensis is subdivided into nine subspecies based on their biology and host range (Li *et al.*, 2018):

- *Clavibacter michiganensis* subsp. *insidiosus* (causes wilting and stunting in alfalfa)
- *Clavibacter michiganensis* subsp. *michiganensis* (causes bacterial canker of tomato)
- *Clavibacter michiganensis* subsp. *nebraskensis* (causes wilt and blight of maize)
- *Clavibacter michiganensis* subsp. *sepedonicus* (potato ring rot)
- *Clavibacter michiganensis* subsp. *tesselarius* (freckles and leaf spots in wheat)
- *Clavibacter michiganensis* subsp. *phaseoli* (causes bacterial bean leaf yellowing)
- *Clavibacter michiganensis* subsp. *capsici* (causes bacterial canker in pepper)
- *Clavibacter michiganensis* subsp. *californiensis* (isolated from tomato and pepper seed from California)
- *Clavibacter michiganensis* subsp. *chilensis* (isolated from tomato and pepper seed from Chile)

There are other strains of the genus *Clavibacter* that have been isolated as epiphytes and endophytes on asymptomatic plant species, but these are generally classified as *Clavibacter* sp.

Most recently, based on genome classification of the phylum *Actinobacteria*, Nouioui *et al*. (2018) proposed raising the subspecies *capsici*, *nebraskensis* and *sepedonicus* to species, and the names *Clavibacter capsici*, *Clavibacter nebraskensis* and *Clavibacter sepedonicus* were formerly accepted (Oren and Garritty, 2018).

Biology and ecology

Life cycle

The most likely route of introduction of the bacterium is the planting of infected seed tubers (CABI, 2018; EPPO, 2018). Once planted, the bacterium builds up rapidly and moves into the stems and petioles via the vascular tissue (CABI, 2018; EPPO, 2018). The bacterial load generally increases throughout the growing season and can move into the developing tubers through the stolons within

8 weeks (EPPO, 2018). Over the winter, the bacterium survives within plant debris, and volunteer plants, but does not survive well in the soil (CABI, 2018). The bacterium can remain infective within potato stems for 63 months (Nelson, 1984). Infection does not necessarily result in symptom development and latent infections are possible for up to three generations of the potato crop (Franc, 1999). Ring rot disease eventually develops when the bacterial load reaches a threshold population, which is influenced by environmental conditions and differential host response in different potato cultivars (Inglis *et al.*, 2013).

The potato ring rot bacterium prefers cooler temperatures, optimally between 21 and 23°C, and this is reflected in its northerly distribution (CABI, 2018; see Figure 2). The bacterium prefers cold dry conditions, with moist conditions and repeated cycles of wetting and drying decreasing the ability of the bacterium to survive (Inglis *et al.*, 2013).

Modes of transmission

1. **Seed tuber transmission** is the primary route (as described above).
2. Transfer of the bacterium from infected to healthy tubers via **direct** contact during handling. Wounds are necessary to infect, but less than 300 bacteria are required to infect a seed piece (Nelson, 1982). The operation of cutting, grading and handling seed tubers is therefore an ideal means of spreading the bacterium within potato lots (Elphinstone, 2010). Transmission between plants in the field is thought to be low (Elphinstone, 2010).
3. Transfer of the bacterium via **indirect contact on machinery, equipment** etc. The bacterium produces extracellular polysaccharides that protect the bacteria and allows it to adhere and survive for long periods on inorganic surfaces (Inglis *et al.*, 2013). It can survive for at least a month, and much longer if it dries rapidly and conditions continue to be cold and dry (Defra, 2018). It has been recorded surviving in a desiccated state on equipment and in dust in stores for several years (APHA, 2016). Infection can therefore occur during routine cutting, planting, harvesting and grading operations, if the machinery becomes contaminated (Inglis *et al.*, 2013).
4. Infection of healthy plants **via infected volunteer plants**. As mentioned, the bacterium can persist over winter in infected volunteer plants, which can be a source of inoculum for subsequent crops.
5. **Contaminated potato waste**.
6. **Transmission in water**. The bacterium can survive for 35-52 days in sterile water and less time in unsterile water, but there are no known aquatic hosts which allow the bacterium to build up its population in natural water systems (Elphinstone, 2010). Infection of healthy tubers has been demonstrated, however, following washing in contaminated water (Defra, 2018).
7. **Insect transmission**. *Leptinotarsa decemlineata* (Colorado beetle), *Myzus persicae* (potato peach aphid), and potato flea beetles have been shown to transfer the bacteria between potato plants experimentally (Stevenson *et al.*, 2001), but this is unlikely to be a significant pathway in the field.

Hosts/crops affected

Potato ring rot only causes disease symptoms under natural conditions in potato (*Solanum tuberosum*), with the exception of a finding in tomato (*Solanum lycopersicum*) from a substrate crop in the Flanders region of Belgium, but this was limited to a row of 10 plants and additional

inspection resulted in no further findings (CABI, 2018; Van Vaerenbergh *et al.*, 2016). Potato ring rot has also been isolated under natural conditions from sugarbeet seed and roots, but no symptoms were observed (Bugbee and Gudmestad, 1988). Reports from the USA of infection and seed transmission in sugar beet have not been reproducible under European conditions or with commonly grown sugar beet varieties (Elphinstone, 2010). In addition to tomato and eggplant, infections can be artificially introduced into several wild *Solanum* species following stem or root inoculations (Knorr, 1948; Zizz and Harrison, 1991; van der Wolf *et al*., 2005; CABI, 2018). Similarly, artificial infections were introduced into stinging nettle (*Urtica dioica*) following root and stem inoculations, leading to symptoms of wilting, chlorosis or leaf necrosis (van der Wolf *et al*., 2005).

Plant stage affected

Flowering, fruiting, vegetative and post-harvest stages are all affected.

Plant parts affected

Tubers, leaves, roots, seedlings, stems and accompanying soil are all affected.

Symptoms/signs - description

Whole plant

Symptoms are variable, but generally start to appear towards the end of the season as wilting of the lower leaves which progresses upwards until the whole plant is wilted (CABI, 2018; EPPO, 2018; Figure 7). Leaves also roll inwards and upwards and show areas of discolouration, such as chlorosis between the veins (EPPO, 2018; Inglis, 2013; Figure 7). As the disease progresses, leaves can become brown and necrotic, and the whole plant can die prematurely (EPPO, 2018). In certain cultivars, rosette symptoms with short internodes can also develop, but in the absence of wilting (CABI, 2018).

Tubers

Symptoms initially develop as glassy, creamy-yellow to dark patches in the vascular tissue at the stolon end (Elphinstone, 2010; EPPO, 2018; Figure 2). The rotting extends around the vascular ring and eventually moves into the cortex of the tuber, where hollowing can develop (Elphinstone, 2010; Figures 3, 4 and 5). When the tuber is cut and squeezed, bacterial ooze can be expelled (Elphinstone, 2010; Figure 3). External symptoms are also evident in advanced infections as reddish-brown blotches and cracking (EPPO, 2018). The latter can leave tubers susceptible to infection by secondary rot microorganisms and lead to the mummification of the tuber (Elphinstone, 2010; Figure 6).

Figure 2. Early tuber symptoms. Vascular tissue has a glassy, watersoaked appearance. © Fera

Figure 3. Bacterial ooze emerging from the vascular ring of an infected tuber. © Fera

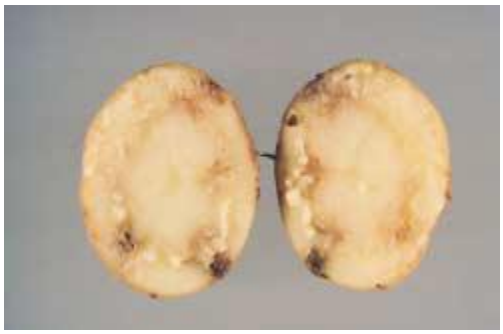

Figure 4. Cheese-like rot of the vascular ring. © Fera

Figure 5. Later stage of infection, showing extensive tuber rot and breakdown with internal hollowing. © Fera

Figure 6. Severe infection, shown as cracking and mummification of the tuber. © Fera

Figure 7. Wilting and yellowing of an infected potato leaf. © Fera

Similarities to other species/diseases/plant damages

Plant symptoms of potato ring rot may be confused with those of potato blight (*Phytophthora infestans*), wilt (*Verticillium albo-atrum*), stem canker (*Rhizoctonia solani/Thanatephorus cucumeris*) and drought (EPPO, 2018). While early tuber symptoms are similar to brown rot (*Ralstonia solanacearum*) (EPPO, 2018).

Detection and inspection methods

Detection of potato ring rot can be difficult due to the bacterium having a latent period, expressing symptoms late in the season after natural senescence, and due to its similarity to other wilting/rotting diseases and conditions (CABI, 2018). Inspection of plants in the field is therefore usually not advised. Instead, tuber sampling and laboratory testing is required, with a range of techniques used, including immunofluorescence microscopy (monoclonal antibody), real-time Taqman PCR and conventional PCR, and host testing in line with EU Council Directive 93/85/EEC and EPPO Standard PM 7/59.

Distribution

History of introduction/spread

The disease was first described in 1905 in Germany (Appel, 1906), but it is unclear where the disease first originated. Potato ring rot is generally considered to be associated with cooler climates and has been reported from large areas of North America (Canada and the USA), China, Russia and northern Europe (Elphinstone, 2010). The disease has spread within Europe, with a number of outbreaks recorded in recent years, including in the warmer climes of Crete (Greece) (EPPO, 2018; Goumas *et al.*, 2001).

Table 1. Distribution of potato ring rot as of 2018.

(P) present, (W) widespread, (L) localized, (O) occasionally present, (D) reported in the past, no longer present, (E) eradicated, (I) absent, intercepted only		
COUNTRY/REGION	**DISTRIBUTION** (see codes above)	**REFERENCES**: please write (name, date) citation here and include full bibliographic details in reference list
ASIA	P	
CHINA	L	Zhang and Huang (1990)
Anhui	P	Zhang and Huang (1990)
Hebei	P	Zhang and Huang (1990)
Heilongjiang	P	Zhang and Huang (1990)
Henan	P	Zhang and Huang (1990)
Jiangsu	P	Zhang and Huang (1990)
Ningxia	P	Zhang and Huang (1990)
Shaanxi	P	Zhang and Huang (1990)
Yunnan	P	Zhang and Huang (1990)
Zhejiang	P	Zhang and Huang (1990)
JAPAN	P	EPPO (2018)
KAZAKHSTAN	P	EPPO (2018)
KOREA, DPR (NORTH)	P	EPPO (2018)
KOREA, REP (SOUTH)	P	EPPO (2018)
NEPAL	P	EPPO (2018)

PAKISTAN	P	EPPO Reporting Service (2010a); Bhutta (2008)
TAIWAN	P	EPPO (2018)
UZBEKISTAN	P	EPPO (2018)
AFRICA	Absent	
NORTH AMERICA	P	
CANADA	W	Conners (1967); McDonald and Borrel (1991)
Alberta	P	EPPO (2018)
British Columbia	P	EPPO (2018)
Manitoba	P	EPPO (2018)
New Brunswick	P	EPPO (2018)
Newfoundland	P	EPPO (2018)
Nova Scotia	P	EPPO (2018)
Ontario	P	EPPO (2018)
Prince Edward Island	P	EPPO Reporting Service (2003a)
Québec	P	Paquin and Genereux (1976)
Saskatchewan	P	EPPO (2018)
MEXICO	L	Rueda *et al.* (2009)
USA	L	Kennedy and Alcorn (1980)
Colorado	P	Westra *et al.* (1994)
Idaho	P	Bishop *et al.* (1988)
Kansas	P	EPPO (2018)
Maine	P	Manzer *et al.* (1979); Manzer and McKenzie (1988); Westra *et al.* (1994)
New York	P	Westra *et al.* (1994)
North Dakota	P	Christie *et al.* (1991); Gudmestad *et al.* (1991); Westra *et al.* (1994)
Oregon	P	Bugbee and Gudmeestad (1988); Westra *et al.* (1994)
Washington	P	Westra *et al.* (1994)
Wisconsin	P	Westra *et al.* (1994)
CENTRAL AMERICA & THE CARIBBEAN	Absent	
SOUTH AMERICA	Absent	
EUROPE	P	
AUSTRIA	E	EPPO Reporting Service (2001a, 2004a, 2006a)
BELARUS	P	EPPO Reporting Service (2000a); Ivanyuk (1998)
BELGIUM	E	EPPO Reporting Service (2014a, 2016a)
BOSNIA AND HERZOGOVINA	Absent	EPPO (2018)
BULGARIA	P	EPPO Reporting Service (2004b, 2006b)
CROATIA	Absent	EPPO Reporting Service (2004c)
CYPRUS	Absent	EPPO Reporting service (2001b, 2008)
CZECHIA	L	EPPO Reporting Service (2001c)
DENMARK	E	EPPO Reporting Service (2013a)
ESTONIA	L	EPPO Reporting Service (2001d, 2002a)
FINLAND	L	Seppanen and Heinamies (1972); EPPO Reporting Service (1999a; 2001e, 2004d, 2012, 2013b, 2014b; 2016b)
FRANCE	E	EPPO (2018)
GERMANY	P	EPPO Reporting Service (2000b, 2001f, 2001g, 2002b, 2003b, 2005a); Müller (2009)
GREECE	W	Goumas *et al.* (2001)
HUNGARY	P	EPPO Reporting Service (2015a)
IRELAND	Absent	EPPO (2018)
ITALY	Absent	EPPO Reporting Service (2000c)
LATVIA	L	EPPO Reporting Service (1999b, 2002c, 2003c, 2004e, 2015b)

LITHUANIA	L	EPPO Reporting Service (1999c, 2000d, 2000e, 2003d, 2004f, 2005b, 2011, 2015c, 2016b, 2017)
MALTA	Absent	Vella *et al.* (2009)
NETHERLANDS	P	EPPO Reporting Service (1999d, 2000f, 2003e)
NORWAY	L	EPPO Reporting Service (2013c); Perminow *et al.* (2012)
POLAND	L	Golenia and Pajewska (1977)
ROMANIA	L	EPPO Reporting Service (1996); EPPO (2018)
RUSSIA	W	EPPO Reporting Service (2015d); Zinnikov and Sinkevich (2015)
Central Russia	P	EPPO (2018)
Northern Russia	P	EPPO Reporting Service (2015d); Zinnikov and Sinkevich (2015)
Western Russia	P	EPPO (2018)
SLOVAKIA	P	EPPO Reporting Service (1999e; 2002d; 2004g; 2014c)
SLOVENIA	Absent	EPPO Reporting Service (1995)
SPAIN	E	EPPO Reporting Service (2001g; 2005c); EPPO (2018)
Islas Baleares	Absent	EPPO (2018)
Islas Canárias	Absent	EPPO (2018)
SWEDEN	L	EPPO Reporting Service (2002e; 2002f)
TURKEY	P	Altundağ *et al.* (2009); EPPO (2018); EPPO Reporting Service (2010b)
UKRAINE	W	Melnik et al. (2009)
UNITED KINGDOM	E	EPPO Reporting Service (2003f, 2004h); Giltrap (2009); EPPO (2018)
England	E	EPPO Reporting Service (2003f, 2004h); Giltrap (2009); EPPO (2018)
Scotland	Absent	EPPO (2018)
OCEANIA	Absent	

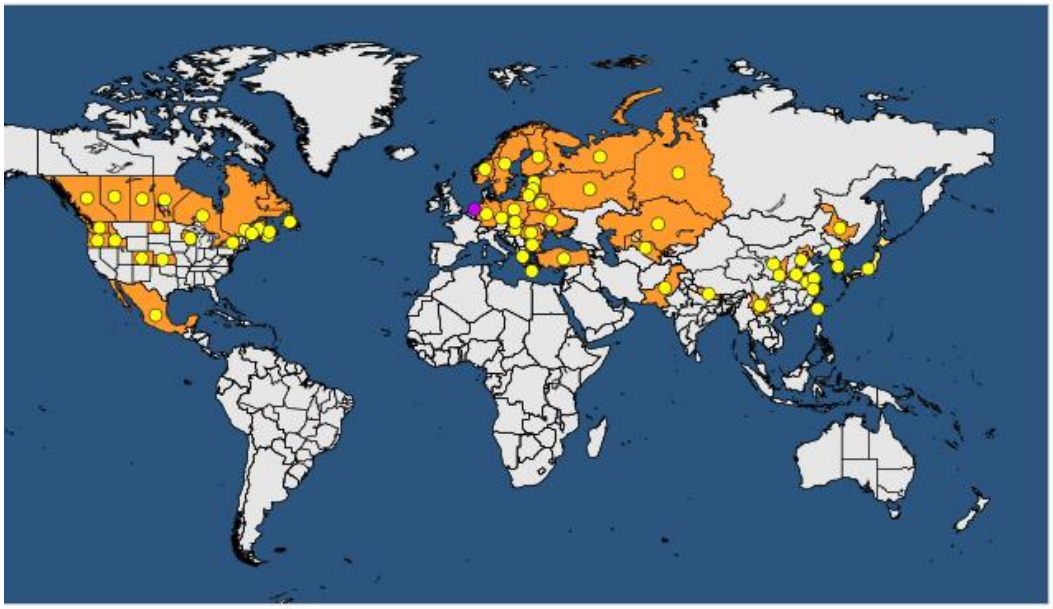

Figure 2. Global distribution of potato ring rot. Yellow dot = present, purple dot = transient, under eradication (EPPO, 2018).

Phytosanitary status

Potato ring rot is a IAII EU listed pest. It is also on the EPPO A2 list and is therefore recommended for regulation by EPPO member countries.

A full table of country and regional categorisations is provided below:

Country/Region	List	Year of addition
East Africa	A1 list	2001
Southern Africa	A1 list	2001
Argentina	A1 list	1995
Brazil	A1 list	1992
Canada	A2 list	1995
Chile	A1 list	1992
Paraguay	A1 list	1992

Uruguay	A1 list	1992
Bahrain	A2 list	2003
Israel	Quarantine pest	2009
Jordan	Quarantine pest	2007
Azerbaijan	A1 list	2007
Norway	Quarantine pest	2012
Russia	Regulated non-quarantine pest	2014
Turkey	A1 list	2007
Ukraine	Regulated non-quarantine pest	2010
New Zealand	Quarantine pest	2000
APPPC	A2 list	1988
CAN	A1 list	1992
COSAVE	A1 list	1992
EPPO	A2 list	1975
EU	Annex IAII	1992
IAPSC	A1 list	1989

Means of movement into the UK

Solanaceous plants for planting are prohibited from third countries other than European and Mediterranean countries (Annex III, Council Directive 2000/29/EC). Seed potatoes from third countries other than Switzerland are also prohibited, as are ware potatoes from third countries other than Algeria, Egypt, Israel, Libya, Morocco, Syria, Switzerland, Tunisia and Turkey, and other European third countries which are recognised as being free from potato ring rot or in which provisions recognised as equivalent to those of the EU territory for mitigating against potato ring rot have been fulfilled (Annex III, Council Directive 2000/29/EC). Given that potato ring rot is present across most of Europe, there is potential for the disease to enter via potato plants for planting, seed and ware potatoes from European countries.

Within the EU, seed potatoes must come from advanced breeding selections, have been produced within the EU, been maintained under appropriate conditions, and tested for harmful organisms using appropriate methods (Annex IV part A section 2, Council Directive 2000/29/EC). Seed potatoes can also only be marketed in the EU if they meet the requirements of Council Directive 2002/56/EU, which includes information on certification schemes to ensure healthy plant material. The risk posed by seed potatoes is therefore reduced, and the most likely route of entry is through ware potatoes. Recently, the UK has had interceptions of potato ring rot on ware potatoes (var. Innovator) from Poland, where potato ring rot is present at high levels in localized areas.

Control

There are currently no forms of biological or chemical control for potato ring rot, and there are no varieties that are resistant to the disease (EPPO, 2018). Some American varieties have been classed as tolerant, but these are not now widely used and are not encouraged because they may act as symptomless carriers of the disease (CABI, 2018; EPPO, 2018).

The main form of control is exclusion. Potato ring rot free stock can be established via micro propagation under aseptic conditions and laboratory testing (CABI, 2018). When obtaining disease free material, use of certification schemes, sourcing of material from reputable suppliers, laboratory testing, and good record keeping, are recommended (EPPO, 2018). Monitoring of crops and tubers for symptoms is also advised.

Appropriate sanitation procedures are also important for minimising introduction and spread of the disease, and these include advice to:

- Avoid sharing machinery, equipment, containers and vehicles where possible to avoid the spread of the disease by contact. Likewise, avoid the use of picker type planting machinery.
- Clean and disinfect machinery, equipment, containers, vehicles and storage facilities regularly. Appropriate disinfectants include quaternary ammonium compounds and chlorine (bleach) (EPPO, 2018).
- Careful handling of potatoes to avoid any damage, as wounds can act as an entry point for the disease (Elphinstone, 2010). Similarly, whole rather than cut seed tubers should be used (CABI, 2018).
- Avoid planting on infected land/implement a crop rotation (CABI, 2018).
- Avoid using the same machinery for grading/processing of different tuber lots to prevent cross-contamination (Elphinstone, 2010).
- Remove volunteer plants, which can act as reservoirs for the disease (Elphinstone, 2010).
- Dispose of waste appropriately, using deep burial, incineration or other approved methods (Inglis *et al.*, 2013).
- Disinfect and change wash water between different tuber lots, as contaminated wash water has been shown to transmit the disease (Elphinstone, 2010).
- Plant seed tubers from different sources separately where possible to avoid any cross-contamination (Inglis *et al.*, 2013).

Phytosanitary measures

See section 4.

Impact

Crop losses of 50 and 47% have been reported from the USA and Russia respectively (Easton, 1979; Muller and Ficke, 1974). Crop losses of 30% have also been recorded from France (Lansade, 1950), but generally infection and loss is lower in the EPPO region because seed tubers are usually not cut and picker type style planters are not used, minimising spread of the disease (EPPO, 2018). In addition to direct yield losses, economic losses are also incurred through cleaning, disinfection, waste disposal and the purchasing of new seed material, as well as the loss of certification status (CABI, 2018).

A cost benefit analysis conducted by Defra in 2000 showed that the benefit: cost ratio of excluding potato ring rot from England was 29.8: 1 over a 30 year period (Elphinstone, 2010).

9. References

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