Department
for Environment
Food & Rural Affairs

Pest specific plant health response plan:

Outbreaks of *Meloidogyne chitwoodi*

Figure 1. Potato tuber showing feeding damage by *Meloidogyne chitwoodi*. Photograph courtesy of Fera Science Ltd.

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This publication is available at

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

This contingency plan has been undertaken taking into account the environmental principles laid out in the Environment Act 2021. Of particular relevance are:

The prevention principle, which means that any policy on action taken, or not taken should aim to prevent environmental harm.

The precautionary principle, which assists the decision-making process where there is a lack of scientific certainty.

Any enquiries regarding this document should be sent to us at:

The UK Chief Plant Health Officer

Department for Environment, Food and Rural Affairs

Room 11G32

York Biotech Campus

Sand Hutton

York

YO41 1LZ

Email: plantpestsrisks@defra.gov.uk

www.gov.uk/defra

Executive summary

Background	
Regulation	GB Quarantine pest
Key Hosts (2.1)*	Potatoes, tomatoes
Distribution	Present in four continents: North America, South America, Africa, and Europe. See appendix A for the full distribution.
Key pathways	Seed and ware potatoes.
Industries at risk	Potato growers and packers.
Symptoms (2.3)	Gall formations on roots and tubers
Surveillance	
Demarcated zones (5.30)	• Infested - Potato lot/s from which the positive sample/s of *M. chitwoodi* were taken from. • Possibly infested - Additional fields at the growing site where the infested lot was grown. • Contaminated - Equipment and other objects or areas used to handle or which have come into contact with either infested or possibly infested plants or soil.
Surveillance activities (5.27-5.37)	• Visual surveys will be carried out in the vicinity of the first findings • Following this, surveys should be extended to potato fields from the same lot determined by tracing activities • Surveys should then focus on fields in the vicinity in which host crops are growing or have recently been grown
Response measures	
Interceptions (5.1-5.5)	• Consignment should be destroyed or re-exported if live nematodes are found • Tracing exercises carried out where required • UKPHINs notification to be made
Outbreaks (5.37-5.45)	This is dependent on the growth stage and outbreak situation. Measures could include: • Herbicide treatments • Removal and destruction of volunteers and weeds • Monitoring of pest levels • Harvesting restrictions, destruction of infested tubers
Key control measures	
Chemical	Herbicide and nematicide applications
Cultural	Cleaning of equipment and machinery, removal and destruction of waste, destruction of infested tubers, trap crops.
Declaration of eradication	Eradication can be declared if no pest is detected during annual surveys for five years after the infested material was destroyed. This should include two years with no volunteers and a following year with only a ware or trap crop.

*numbers refer to relevant points in the 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 an infestation of *Meloidogyne chitwoodi* (Columbia root-knot nematode) is detected.

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 of *M. chitwoodi* being detected in their territories.

1.3. This document will be used in conjunction with the *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 *M. chitwoodi*. This plan focuses on a potential infestation of *M*. *chitwoodi* in a potato crop although it may be applicable to other host crops with some alterations in the event of a finding in association with another host. The likelihood of a finding in a tomato crop was considered, however due to current growing practises in GB which predominantly use hydroponic systems with inert growing media such as rockwool or coir the risk of a finding was deemed low. Any findings would be treated on a case-by-case basis depending on the host and situation surrounding the finding.

2. Summary of threat

2.1. *Meloidogyne chitwoodi* is a root-knot nematode which is an important pest of *Solanum tuberosum* (potato) and *S. lycopersicum* (tomato). The area of origin of *M*. *chitwoodi* is unknown, although it was first described in 1980 from the Pacific Northwest of the USA, gaining its common name, Columbia root-knot nematode, from the Columbia River in this region (Holden *et al.*, 1980). Following its description in the USA, *M*. *chitwoodi* was first detected in Europe in the Netherlands in the 1980s, however evidence from old illustrations and specimens suggest its presence may predate this by 50 years (EPPO, 2020). *Meloidogyne chitwoodi* is currently reported as present in Africa (Mozambique, South Africa), Europe (Belgium, France, Germany, Lithuania, Netherlands, Portugal, Romania, Spain, Sweden, Switzerland, Türkiye), North America (Mexico, USA) and South America (Argentina, Chile) (EPPO, 2020). It is suspected that *M*. *chitwoodi* may have a wider distribution than currently known.

2.2. *Meloidogyne chitwoodi* is polyphagous with a host range extending across many plant families. The two major hosts noted for this nematode are *S*. *tuberosum* and *S*. *lycopersicum*. A detailed host list is provided in Appendix A.

2.3. Juvenile *M*. *chitwoodi* enter the host through wounds or epidermal cells which have yet to undergo suberization. The nematodes move into the cortical region and stimulate giant cell and gall formation on roots and tubers. As a result of the formation of these galls, paired with internal necrotic damage caused by *M*. *chitwoodi*, the marketability of tubers is severely affected. Visual symptoms covering as little as 5% of the tuber lead to an unacceptable product for marketing. In addition to visual damage, yield losses caused by *M. chitwoodi* have resulted in this species becoming a major nematode pest in the Pacific Northwest states of the USA.

2.4. Based on their biology, *M. chitwoodi* nematodes are most likely to be associated with imports of seed and ware potatoes with soil attached (EPPO, 2020). Infested seed potatoes are likely to be from EU member states where *M*. *chitwoodi* is reported from (appendix A) or Switzerland. Seed potatoes are prohibited from all other third countries, except Liechtenstein where *M. chitwoodi* has not been recorded. Infested ware potatoes are likely to originate from the EU member states where *M*. *chitwoodi* is reported from (appendix A), Switzerland or Türkiye. The import of ware potatoes from countries other than EU member states, Algeria, Bosnia and Herzegovina, Egypt, Israel, Libya, Liechtenstein, Morocco, Serbia, Switzerland, Syria, Tunisia and Türkiye are prohibited. Those EU member states which are currently known to have *M*. *chitwoodi* and provide the main trade in ware potatoes to the UK are Belgium, France, Netherlands, and Spain. However, it is important to be aware that *M. chitwoodi* could be present in further countries and be currently unreported. In 2022 *M*. *chitwoodi* was newly reported in three European countries: Lithuania, Romania and Switzerland (EPPO, 2024). In 2024 *M*. *chitwoodi* was also reported for the first time in Denmark.

2.5. In the UK, as of November 2023, there have been seven interceptions of *M*. *chitwoodi* all on ware potatoes originating from the Netherlands between 1996 and 1999.

3. Risk Assessments

3.1. *Meloidogyne chitwoodi* has a mitigated UK Plant Health Risk Register score of 40 (moderate risk). 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/index.cfm).

3.2. Finland have performed a pest risk analysis (PRA) for *M*. *chitwoodi* in 1995 (Tiilikkala *et al.*, 1995) and the UK a *prima phacie* pest risk assessment (MacLeod, 2012). The Finnish PRA highlighted the risk of *M*. *chitwoodi* extending its range in Europe and that the low winter temperatures may limit the formation of dense populations of the pest in Finland but were not enough to prevent establishment. The UK assessment concluded that the overall risk posed by this pest was medium due to a high introduction potential and a low-medium impact caused by the pest.

4. Actions to prevent outbreaks

4.1. *Meloidogyne chitwoodi* 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. Further pest and host specific requirements are listed in Schedules 6-8.

4.2. *Meloidogyne chitwoodi* is an EPPO A2 listed pest. The EPPO A2 list contains species that are present in the EPPO region and are recommended for regulation.

4.3. The Plant Health Service for England (including the Animal and Plant Health Agency (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 *M*. *chitwoodi* as appropriate.

5. Response

Official action to be taken following the suspicion of or confirmed interceptions of *M. chitwoodi* on imported plants, including tubers and seeds

Holding consignments at interception points, including packhouses

5.1. If *M. chitwoodi* is suspected by the Plant Health and Seeds Inspectorate (PHSI) to be present on a consignment moving in trade, the PHSI should hold the consignment (ideally in a sealed cold store or covered in a way as to prevent cross contamination with other goods) until a diagnosis is confirmed. Samples should be submitted by the PHSI to Fera Science Ltd., Plant Clinic, York Biotech Campus, Sand Hutton, York, YO41 1LZ (01904 462000) in a sealed bag or container, within at least two other layers of containment, which are not liable to be crushed during transit. If an infestation of *M. chitwoodi* is confirmed, the PHSI will advise the client of the action that needs to be taken by way of an official Statutory Plant Health Notice. The consignment should be destroyed by either deep burial or re-exported to the place of origin in a sealed container (see also 5.48-5.52). Defra's Risk and Horizon Scanning team can advise on alternative methods of destruction if necessary.

5.2. Host plants (including any tubers, which should be held) should be surveyed on the site or in the immediate vicinity for signs of pest presence (see 5.16-5.20).

5.3. An UKPHINS notification should be made upon confirmation of an interception of *M*. *chitwoodi*. UKPHINS is the IT system for recording findings and non-compliance in order to maintain records and notify other National Plant Protection Organisations (NPPOs) of plant health issues.

5.4. In the event that 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 *M. chitwoodi*. Details of recent past and future consignments from the same grower/supplier should also be obtained.

5.5. If fields have been planted using the same lot of potatoes which are suspected to be infested with *M*. *chitwoodi*, these fields should also be surveyed and sampled. Waste disposal processes and areas should likewise be inspected.

Official action to be taken following the suspicion of an *M. chitwoodi* outbreak

5.6. Suspected outbreaks will be assessed on a case-by-case basis. An Outbreak Triage Group (OTG), chaired by the CPHO or deputy and including specialists from APHA, Defra and other organisations, should subsequently be set up to assess the risk and decide on a suitable response. This may include gathering more information on the suspected outbreak, notification of ministers and senior officials, and agreeing a communications strategy. An Incident Management Team (IMT) meeting, chaired by the Incident Controller, will follow the OTG. This will produce an Incident Action Plan to outline the operational plan. See the *Defra Contingency Plan for Plant Health in England* for full details.

5.7. The OTG will determine an alert status, which will take into account the specific nature of the outbreak. These alert levels, in order of increasing severity, are white, black, amber and red (more details on these levels can be found in table 2 of the *Defra Generic Contingency Plan for Plant Health in England).* Due to the potential for spread, if an infestation of *M. chitwoodi* is suspected in a potato field, an amber alert status is likely to be given by the PHSI. An amber alert status refers to a serious plant pest/disease with potential for relatively slow, but extensive geographical spread leading to host death and/or major economic, food security or environmental impacts. However, this is partly dependent on the situation and a black alert status could also be used for more restricted and confined outbreaks. This describes a plant pest with potential for limited geographical spread leading to moderate economic, environmental or social impacts.

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

5.8. As well as host material, *M. chitwoodi* eggs, juveniles and adults can be transferred with non-host material, equipment and machinery which has been contaminated with infested soil (EPPO, 2020). Therefore, the movement of plant material, equipment and machinery from infested areas (i.e. the field where the nematode was found) should be restricted. However, if movement is necessary, the equipment and

machinery should be thoroughly cleaned or disinfected within the field to remove any soil and life stage of *M. chitwoodi* nematodes prior to movement.

5.9. Any waste (plant or other potentially infested material) should be removed and destroyed (via deep burial, incineration or other appropriate methods prescribed in 5.48-5.52).

Preliminary trace forward / trace backward

5.10. If an infested consignment is considered as being the source of the outbreak, investigations regarding the origins of infested consignments will be undertaken to locate other related and therefore potentially infested consignments of tubers or plants moving to and from the site. If applicable NPPOs should be contacted. This process is particularly important for propagation or seed potato stocks as these are planned to be planted in the field unlike ware potatoes for consumption.

5.11. 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 be carried out.

Confirming a new outbreak

How to survey to determine whether there is an outbreak

5.12. Information to be gathered by the PHSI on the suspicion of an infestation of *M. chitwoodi*, in accordance with ISPM 6; guidelines for surveillance (https://www.ippc.int/en/publications/615/)

- The origin of the potatoes and seed lot numbers.
- Details of other premises or destinations where the potatoes have been grown or sent, where the nematodes may be present.
- The layout of the premises and surrounding area, including a map of the fields/cropping/buildings, at risk growers, details of field ownership/rental and details of neighbouring crops, especially any commercial or non-commercial solanaceous crops in fields, allotments, gardens or glasshouses.
- Details of the crop variety, growth stage and any other relevant information.
- Description of the surrounding habitat and field margins.
- Level of infestation, including a description of symptoms (as well as photos if possible). These would include galling damage on the tubers, and galls on roots.
- 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 on the movement of people, equipment, machinery etc. to and from the infested area.
- Cultural and working practices.

- If in a store, details of consignments stored next to the suspect consignment.

5.13. Further to information gathering, samples of other nematodes and tuber feeding damage should be taken to confirm the extent of the infestation e.g. in surrounding lots or fields. This initial survey will be used to determine if it is an isolated finding or an established outbreak (see 5.16-5.20).

5.14. If at a processor/packer, any host plants (including any tubers, which should be held) should be surveyed on the site or in the immediate vicinity and again in the following year for signs of pest presence (see 5.16-5.20). Waste disposal processes and areas should likewise be inspected.

5.15. 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

5.16. *Meloidogyne chitwoodi* has a soil-borne life stage and can also be present in plant roots and tubers, therefore a combination of sampling techniques is required for both host material and soil.

5.17. The EPPO standard PM 9/17 (1) should be followed for sampling requirements (EPPO, 2013). This standard outlines how soil sampling should be performed directly after the growing of a host crop. This is of particular importance for *M*. *chitwoodi* as the chances of detecting *M*. *chitwoodi* decreases rapidly in the absence of a host. Populations of *M*. *chitwoodi* have been recorded as decreasing by 80% within one month following a potato harvest (EPPO, 2024). Sampling consists of taking a composite soil sample for each hectare in a grid pattern of 10 by 10 metres, or in a grid pattern of 10 by 20 metres if a ‘good host plant’ has been grown in the field. The standard suggests that potato, *Daucus carota* subsp. *sativus* (carrot) and *Scorzonera hispanica* (black salsify) are considered ‘good host plants’ (EPPO, 2013). Each core should contain 40 ml of soil from the top 25 cm of soil. The total soil sample should be 4000 ml of soil per hectare in the case of a 10 x 10 grid, or 2000 ml per hectare when a 10 x 20 grid is applied (EPPO, 2013). A sub sample of the total sample is then processed and tested in the laboratory (EPPO, 2016).

5.18. This standard also outlines how in season sampling of host plants should occur, targeting areas with sandy or sandy-loam soils which are preferable to the nematodes. In an area of 1 ha, 60 plants (including roots) should be sampled at random, with the entirety of the plants sent to the laboratory for diagnosis (EPPO, 2013).

5.19. Tuber inspections are best undertaken on tubers during harvesting, grading or in store because a large number of tubers can be inspected more easily than when the growing crop is *in situ*. Tuber symptoms are also likely to be more evident later in the growing season. Tubers discarded on grading or packing lines should be targeted

for inspection as tubers rejected have a higher likelihood of infestation. A post-harvest sample of 200 tubers of the whole lot should be sent for diagnosis at the laboratory.

5.20. Following a suspected finding of *M*. *chitwoodi* or *M*. *chitwoodi* symptoms, samples should be sent for diagnosis as in point 5.1. Each sample should be labelled with full details of sample number, location (including grid reference if possible) and variety.

Diagnostic procedures

5.21. The identification of *M*. *chitwoodi* is based on a combination of morphological, biochemical and/or molecular analysis. EPPO diagnostic protocol PM 7/41 is recommended for the identification of *M. chitwoodi* and *M. fallax* (EPPO, 2016). Morphological features used to distinguish between similar *Meloidogyne* species such as *M*. *chitwoodi*, *M*. *fallax* and *M*. *minor* are adult stylet length and shape, and second juvenile features including body length, tail length and hyaline tail length.

Criteria for determining an outbreak

5.22. If *M. chitwoodi* is detected at a location and is not confined to a particular consignment(s) then an outbreak should be declared. For example, if *M*. *chitwoodi* 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. Suspect material should be diagnosed according to EPPO standard 7/41 and movement of any material should be prohibited pending the results of these tests.

Official Action to be taken following the confirmation of an outbreak

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

Communication

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

5.25. The Defra plant pest factsheet should be distributed to relevant stakeholders in the locality of where the nematodes have been found to raise awareness of *M. chitwoodi* and its symptoms. The plant pest factsheet can be found on the Plant Health Portal

– https://planthealthportal.defra.gov.uk/pests-and-diseases/pest-and-disease-factsheets/notifiable-pests/.

5.26. A generic communication plan is available for use across all plant health outbreaks. This is owned by APHA and the Forestry Commission and is intended to provide consistency across outbreaks. This plan can be tailored to the outbreak, using pest and outbreak specific information. It includes a list of key stakeholders and templates for:

- Core narratives
- Press releases
- Reactive lines
- Frequently asked questions

Surveillance and demarcated zones

5.27. The aim of surveillance is to investigate the extent of the outbreak, so the distribution of *M*. *chitwoodi* in an outbreak site is understood and can be delimited and a demarcated zone established to prevent further spread of the pest.

- The use of buffer zones in the context of an outbreak of *M. chitwoodi* are not considered appropriate due to the sedentary nature of the pest and as spread is primarily mediated through human-assisted movement on planting material, machinery and other equipment.

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

5.29. Surveys should be conducted surrounding the finding. These surveys should focus on fields in the vicinity which are growing or have recently grown host crops and in addition fields where the same machinery has been used as the infested field. This should then be followed by trace back and trace forward activities to determine the source of infestation and any additional sites which may be infested. As part of general good hygiene measures field operations in the infested fields should be carried out last to minimise the risk of spread of *M*. *chitwoodi*.

5.30. After an outbreak has been detected, areas, premises and material should be described according to the probability of infestation in line with EPPO's National regulatory control systems PM 9/17 (1) *Meloidogyne chitwoodi* and *Meloidogyne fallax* (EPPO, 2013). This will influence the safeguarding measures taken on the areas or material, these will include the following categories:

- 'Infested'
    - Potato lot/s from which the positive sample/s of *M*. *chitwoodi* were taken from
    - Plant products originating from an infested field which have been in contact with soil. Those not in contact with soil can still be marketed (e.g. tomato fruits, cereals).

- Field of production where the positive sample/s were taken from.
- Waste produced from an infested lot or field.
- Any other objects including packaging material, from which the sample was taken.

- ‘Possibly infested’
  - Additional fields at the growing site where the infested lot was grown, but which have not yet been tested. Once these tests have been performed a field can change status to either ‘infested’ or ‘pest not detected’.
- ‘Contaminated’
  - Equipment and other objects or areas used to handle, or which have come into contact with either infested or possibly infested plants or soil.

5.31. Following official confirmation of a diagnosis of *M*. *chitwoodi* according to EPPO Standard PM 7/41 a demarcated area should be established. This should initially include both infested and possibly infested areas. If investigations confirm that *M*. *chitwoodi* is not present in possibly infested areas, the demarcated area can be updated accordingly. The demarcated area may include additional sites of production if machinery is shared, or the same lots or potatoes have been planted in different locations.

5.32. Areas where machinery used was the same as that for infested areas, and any other areas where there is a perceived risk to host crops, should also be surveyed and should be included within the initial demarcated area. If resources are limited, priority should be given to areas where there has been movement of large quantities of soil from infested areas, though this should be agreed by the IMT on a case-by-case basis.

5.33. All host plants in the infested fields should be visually inspected, samples taken, and suspect samples and soil samples sent for diagnosis (see 5.16-5.20).

5.34. Potato fields which have been planted using the same lot as the infested field(s) should also be surveyed and be part of the demarcated area.

5.35. The categories attributed to different areas and material should be adjusted in response to further findings. If *M. chitwoodi* is found within a field outside the infested area, this should subsequently be designated as infested, consequently altering the infested, possibly infested, contaminated areas/material and overall demarcated area. If infested fields are dispersed across the landscape and not adjacent to one another, this could lead to fragmented infested areas, delimited by natural boundaries. If *M*. *chitwoodi* is found within uncropped areas outside the infested area, then any fields directly adjacent to these areas should normally be designated as infested.

5.36. If the surveillance programme uncovers that *M*. *chitwoodi* is more widespread than initially thought, eradication may be deemed to be no longer feasible. If this is the case, a change in approach will be initiated. This will aim towards slowing the spread of *M*. *chitwoodi* rather than eradication. This decision will be made by the IMT. The plan for slowing the spread of *M*. *chitwoodi* sits outside this contingency plan which from here focuses on eradiation.

5.37. Material designated as contaminated in 5.30 should be cleaned prior to leaving infested or possibly infested fields. This should be done so with high pressure water or steam to remove all debris from the contaminated material.

Pest Management procedures

Scenario 1: Outbreak in a potato crop at an early stage of growth (i.e. prior to tuber formation)

5.38. The whole crop should be treated *in situ* as soon as possible with a herbicide to limit the number of nematode generations and hence population levels. The Defra Risk and Horizon Scanning team should be consulted about the most appropriate treatments.

- Prior to any herbicide being used, the risk posed by the herbicide to people and the environment will be assessed (see 5.47).

5.39. Host plants, such as weeds, and other plant material in the infested area, and uncropped areas, field boundaries and hedgerows in the immediate vicinity of the infested area should be destroyed by herbicide or mechanical means (such as ploughing).

Scenario 2: Outbreak in a growing potato crop (tubers have developed)

5.40. This is the same as for scenario 1.

5.41. The crop should not be harvested due to the risk of spread. Destruction of tubers in a way that does not risk further spread (e.g. exposure to frost) should be considered, and will be decided by the IMT. Measures should be taken to reduce potential volunteer problems in the following year. This may include the application of a herbicide to the growing crop to prevent sprout development of volunteers. Any volunteer potato plants that grow in the field should be destroyed soon after emergence.

Scenario 3: Measures to be taken in the case of detection of infestation in tubers after harvest (e.g. in a grower's potato store or during processing/packaging when the tubers can be traced back to a known crop or farm)

5.42. The following should be designated as infested:

- The lot from which the sample was taken and lots that *M. chitwoodi* may have spread to.
- The waste from the infested lot, such as soil and processed waste, including waste water from processing.
- 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.

5.43. As in point 5.30, materials and areas should be designated to different categories according to likelihood that the pest is present: infested, possibly infested or contaminated.

5.44. Areas where machinery used was the same as that for the infested potatoes or field, and any other areas where there is a perceived risk, should also be surveyed. If resources are limited, priority should be given to areas where there has been movement of large quantities of soil from the infested area.

5.45. There is the risk that other potato stocks may have become infested after harvest. This could have been through the transfer of soil in grading lines or storage boxes. Any tubers in storage should therefore be inspected for symptoms and for the presence of *M. chitwoodi* and designated as possibly infested. These stocks designated as possibly infested will fall under the same restrictions as other possibly infested fields, sites and material which has been identified.

Crops growing in neighbouring fields in the year of the outbreak

5.46. If no infestation is found in the potato crops growing in neighbouring fields following surveillance (5.27-5.37) they should undergo continued monitoring for any sign of *M. chitwoodi* for the remainder of the growing season. Potato tubers should also be inspected during and/or immediately after harvesting.

Disposal plan

The main risk of spreading *M*. *chitwoodi* is due to the movement of soil, soil adhered to plant products/plants for planting and also waste which has originated from plants (e.g. peelings from tubers, tubers which have been graded out).

Infested growing host crops

5.47. The primary means of destruction of potato plants in a field is through herbicide application. The Defra Risk and Horizon Scanning team should be consulted for appropriate treatments. Removal of the destroyed haulm in a way that does not risk further spread (e.g. ploughing back into the field) should be considered, and will be decided by the IMT.

- 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.

Prior to any herbicides being used, the risk posed by the herbicide to people and the environment will be assessed. The treatment should only be applied if it is determined that there will be no unacceptable risks to people and the environment.

Infested tubers/soil/plant debris

5.48. *Meloidogyne chitwoodi* may be present with the harvested tubers, associated soil and plant debris. It is important that all material is disposed of appropriately so as to eliminate the pest. When deciding on the most appropriate method(s) of disposal, factors such as 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. Standard methods of disposal include:

- 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.

5.49. Approved methods for disposal of soil and waste highlighted in PM 9/17 (1) include:

- Disposal of soil and waste on land which is not used for agricultural purposes

- Composting soil and waste, with verification that there is no risk of spreading *M*. *chitwoodi*. This should be done in accordance with the EPPO standard on phytosanitary procedures PM 3/66 (3) which outlines requirements for treating biowaste to ensure it is free of pests and diseases (EPPO, 2022).

- Heat treatment of soil and waste at the appropriate temperature to kill the pest, with verification that there is no risk of spreading *M*. *chitwoodi*

- Removal of soil from tubers and plants at the place of production before delivery to a processing plant, ensuring all soil remains on the field in which the plants were produced. Or if agreed and adequate hygiene measures are in place potatoes can be lifted, moved to processors where waste water, unsuitable tubers, and any other waste will be dealt with in an appropriate manner.

5.50. Alternative methods of disposal not considered in PM 9/17 (1)

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

5.51. Alongside the above approved methods any waste water which is created from processing or packaging of processed potatoes, other host plants or soil attached to other plants should be treated appropriately and not used for irrigation of plants for planting.

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

5.52. All objects designated as ‘contaminated’, such as equipment, machinery, storage facilities that may be contaminated with infested soil or potato material should be thoroughly cleaned (e.g. using water at high pressure) to remove the pest and any soil.

Measures in subsequent seasons

Infested areas

5.53. Once infested crops and/or tubers have been removed and disposed of, infested fields should be left fallow for a period of at least two years. This would help reduce populations levels further. This fallow period of two years is preferred due to the effectiveness of this action during outbreaks of *M*. *chitwoodi* and *M*. *fallax* in France. However, if the site is at particularly high risk of diffuse pollution running into water courses alternatives will be considered to adhere to The Reduction and Prevention of Agricultural Diffuse Pollution (England) Regulations 2018.

5.54. 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 5.47). Solanaceous weeds should also be controlled in a similar way.

5.55. According to the EPPO National regulatory control system for *M*. *chitwoodi* and *M*. *fallax* the fallow period of at least two years (in 5.53), which is initiated once infested plants and /or tubers have been removed and disposed of, this could be followed by a combination of measures. These measures may include: a three year period where only non-hosts are cultivated, heat treatment of the soil, inundation of the soil or treatment with nematicides if suitable (EPPO, 2013). Successful eradication will not be a result of one of these treatments but a combination of them and good hygiene/cultural practices.

6. Criteria for declaring eradication / change of policy

6.1. *Meloidogyne chitwoodi* can be declared eradicated (by the Chief Plant Health Officer) in potato after at least five years during which time no *M. chitwoodi* nematodes have been found. These five years must include two consecutive years without volunteer plants and a year with either a ware potato crop or trap potato crop.

7. Evaluation and review of the contingency plan

7.1. This pest specific contingency plan should 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 after an outbreak of *M. chitwoodi*, 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

Datasheet for *Meloidogyne chitwoodi*

Identity

CLASS: Chromadorea
ORDER: Rhabditida
FAMILY: Meloidogynidae
GENUS: *Meloidogyne*
SPECIES: *Meloidogyne chitwoodi*

Authority: Golden, O.Bannon, Santo & Finley 1980

SYNONYMS
Meloidogyne chitwoodii

INTERNATIONALLY USED COMMON NAME/S & INTERNATIONAL LANGUAGE

Columbia root-knot nematode (English, US)

nématode cécidogène du Columbia (French)

Notes on taxonomy and nomenclature

In the *Meloidogyne* genus there are over 100 described species (Ye *et al.*, 2019). Although this number is likely to increase, in 1988 only 68 species were noted in this genus (Luc *et al.*, 1988). The genus consists of certain extremely polyphagous species which are sedentary endoparasites.

Meloidogyne chitwoodi can be further divided into races, race 1 and race 2, each with subtly different host ranges (EPPO, 2020). Race 1 is reported to have a global distribution whereas race 2 is thought to be restricted to the Pacific Northwest of USA.

Biology and ecology

Life history

The life cycle and life forms of *M. chitwoodi* is typical of that of other *Meloidogyne* species. Males of the species are vermiform (worm-like) in shape whereas as mature adult females are pear shaped. Under favourable conditions it takes between three and five weeks to complete a life cycle (EPPO, 2020).

The development through the live stages of *M*. *chitwoodi* commences within the egg, which has been laid by the previous generation either into the soil or on the root surface. Within the egg the first stage juveniles moult to form second stage juveniles, which then hatch from the eggs. The hatching of them is primarily determined by temperature and moisture levels, although it is proposed that root exudates could stimulate hatching (James *et al.*, 2019). Second stage juveniles are motile and vermiform in shape allowing them to migrate through the soil. At this life stage, the only infectious life stage of this species, the nematode can enter the host's roots through unsuberized (before the thickening of cell walls) epidermal cells or unhealed wounds (EPPO, 2020). The juveniles then move within the host to the cortical tissue where a feeding site is established by injecting pharyngeal gland secretions into the host which result in the formation of galls. Within these galls the nematodes feed, increasing in size until they become sessile and commence three moults in quick succession to become adults. *Meloidogyne chitwoodi* reproduce via parthenogenesis, meaning a male *M*. *chitwoodi* is not required. Females which are embedded in the host tissue and immobile lay egg masses in gelatinous sacs which are protected by modified host cells.

Meloidogyne chitwoodi overwinters as either eggs or in its juvenile stages and is cold tolerant. Second stage juveniles are thought to be able to survive for approximately one year, whereas as eggs of *M*. *chitwoodi* may remain viable for up to four years (EPPO, 2020). This is a key difference in comparison to potato cyst nematodes (*Globodera rostochiensis* and *Globodera pallida*) which can persist as viable eggs contained within a cyst for up to 40 years (Ewing *et al.*, 2021). *Meloidogyne chitwoodi* is cold tolerant and able to survive long periods of freezing temperatures, metabolism is activated once the temperature increases above 5°C. The first generation of the year requires 600-800 degree days (above the 5°C threshold) to complete a life cycle and after this generations require 500-600 degree days (Khan *et al.*, 2014). The presence of a suitable host is important for the survival of *M*. *chitwoodi*, with populations reducing by 70-90% over a three month period when a suitable host is removed (EPPO, 2020).

Hosts/crops affected

Meloidogyne chitwoodi is polyphagous with a host range extending across many plant families (CABI, 2022). Although *M. chitwoodi* hosts of most significance are *Solanum tuberosum* (potato) and *S. lycopersicum* (tomato). It is important to note the host status varies between plant species, with a range from excellent host to poor/non-host (Ferris *et al.*, 1993). The host list reported here is not thought to be complete, new hosts are frequently described for both *M*. *chitwoodi* and other root knot nematodes.

Abelmoschus esculentus, Acer campestre, Acer palmatum, Acer platanoides, Actaea racemosa, Aegilops cylindrica, Allium cepa, Allium moly, Allium porrum, Anthemis arvensis, Apium graveolens, Arachis hypogaea, Arrhenatherum elatius, Asclepias syriaca, Astragalus cicer, Astragalus falcatus, Avena sativa, Beta vulgaris, Borago officinalis, Brassica juncea, Brassica napus, Brassica rapa, Bromus tectorum, Capsella bursa-

pastoris, Capsicum annuum, Capsicum, Chenopodium album, Cichorium endivia, Cichorium intybus var. foliosum, Cichorium intybus, Cirsium arvense, Cirsium vulgare, Citrullus lanatus, Clematis, Coronilla varia, Cynodon dactylon, Dactylis glomerata, Dahlia, Dasiphora fruticosa, Daucus carota (race 1 only)*, Delphinium, Dicentra formosa, Echinochloa crus-galli, Elymus repens, Eragrostis curvula, Eragrostis orcuttiana, Eragrostis tef, Erica cinerea, Fagopyrum, Festuca rubra, Fragaria chiloensis, Galinsoga parviflora, Geranium sp., Gladiolus, Gossypium hirsutum , Helianthus annuus, Hordeum vulgare, Hosta sieboldiana, Iris x germanica, Iris xiphium, Lamium amplexicaule, Lamprocapnos spectabilis, Lilium hybrids, Lolium arundinaceum, Lolium multiflorum, Lolium perenne, Lonicera xylosteum, Lotus corniculatus, Lupinus albus, Medicago falcata, Medicago sativa* (race 2 only)*, Medicago scutellata, Melilotus officinalis, Mentha spicata, Mentha x gentilis, Mentha x piperita, Nicotiana, Oenothera glazioviana, Panicum capillare, Persicaria maculosa, Petroselinum crispum, Phacelia tanacetifolia, Phaseolus vulgaris, Pisum sativum, Poa annua, Poa pratensis, Raphanus sativus subsp. oleiferus, Raphanus sativus, Salsola kali, Scorzonera hispanica, Secale cereale, Senecio vulgaris, Setaria helvola, Sinapis alba, Solanum lycopersicum, Solanum melongena, Solanum nigrum, Solanum tuberosum, Sonchus arvensis, Sorghum bicolor, Stellaria media, Tagetes patula, Taraxacum officinale, Trifolium pratense, Trifolium repens, Triticum aestivum, Triticum, x Triticosecale, Valeriana officinalis, Vicia sativa, Vigna unguiculata, Vitis labrusca, Vitis vinifera, Zea mays*

Symptoms/signs - description

Infection by *M*. *chitwoodi* can result in severe losses in quality in potato tubers. Despite these losses in quality, which can lead to complete rejection of a crop, yield reduction is minimal.

Above ground symptoms of *M*. *chitwoodi* infection are often inconspicuous and vary depending on the level of infestation (CABI, 2022). Symptoms include stunting, lack of vigour and wilting. Infected tubers also have varying symptoms dependent on level infestation and cultivar grown, when galls are visible, they are small and raised, can be concentrated in one area or located near eyes or lesions. When infected tubers are cut into the tissue under galls is brown and necrotic, within this tissue shining, white, pearl shaped adult females can be observed.

Morphology

Eggs

79 – 92 µm long, 40 – 46 µm wide (Holden *et al.*, 1980).

Second larvae

Note: the first larval stage develops into the second larval stage whilst still within the egg.

Vermiform, 336 – 417 µm long, 12.5 – 15.5 µm wide (Holden *et al.*, 1980).

Adult Male

Vermiform, 887 - 1268 µm long, 22 – 37 µm wide (Holden *et al.*, 1980).

Adult Female

Pear shaped, pearly white 430- 740 µm long, 344 – 518 µm wide (Holden *et al.*, 1980).

Similarities to other species/diseases/plant damages

Symptoms on potatoes caused by *M*. *chitwoodi* (Figure 2) can be confused for those caused by *M*. *fallax,* the false Columbia root-knot nematode, which is present (restricted distribution) in GB and is an RNQP. Additional information for *M*. *fallax* can be found on the factsheet (https://planthealthportal.defra.gov.uk/pests-and-diseases/pest-and-disease-factsheets/). Despite this potential confusion with similar symptoms there is an identification guide in the EPPO Diagnostic Standard PM 7/41 *Meloidogyne chitwoodi* and *M*. *fallax* (EPPO, 2016). In this Standard the tools required for accurate identification are outlined including morphological differences and molecular diagnostics required to distinguish between *M*. *chitwoodi* and two similar nematode species *M*. *fallax* and *M*. *minor*.

Figure 2. Potato infected with *Meloidogyne chitwoodi*. Image courtesy of Fera Science Ltd.

Detection and inspection methods

EPPO also provides guidance on the sampling of both potatoes and soil which is provided in EPPO Standards: 3/71 General crop inspection procedure for potatoes, 3/69 *Meloidogyne chitwoodi* and *M*. *fallax*: sampling potato tubers for detection (EPPO, 2007; 2019).

History of introduction/spread

The timings, history of introduction and even current distribution of *M*. *chitwoodi* are difficult to ascertain with it likely that this nematode has gone undetected for a number of years in many countries and may still be undetected in some.

The first record of *M*. *chitwoodi* is from its description in 1980, where it was isolated from a potato in Quincy, Washington, USA (Holden *et al.*, 1980). When this species was formerly described it was also known to be present in other areas of the Pacific Northwest including the states of Idaho and Oregon (EPPO, 2024). Later in the 1980s *M*. *chitwoodi* was detected in the Netherlands, although following a review of old nematode illustrations it is thought it was present in the 1930s (Visser & Wesemael, 2021). In 1996 *M*. *chitwoodi* was detected for this first time in Belgium, although again its presence is thought to predate this due to the high genetic distances observed between populations and the infested soil was sampled from an oak forest (Visser & Wesemael, 2021). In recent years across Europe *M*. *chitwoodi* has been found for the first time in Sweden (2018), Spain (2021), Romania (2022) and Lithuania (2022). The findings in Sweden, Spain and Romania were on potatoes, whereas the Lithuanian finding was from a soil sample where perennial grasses had been grown since 2019. In 2024 *M*. *chitwoodi* was also reported for the first time in Denmark on potatoes.

Distribution

Meloidogyne chitwoodi now shows a globally scattered distribution (Figure 3), present in four continents: North America, South America, Africa and Europe.

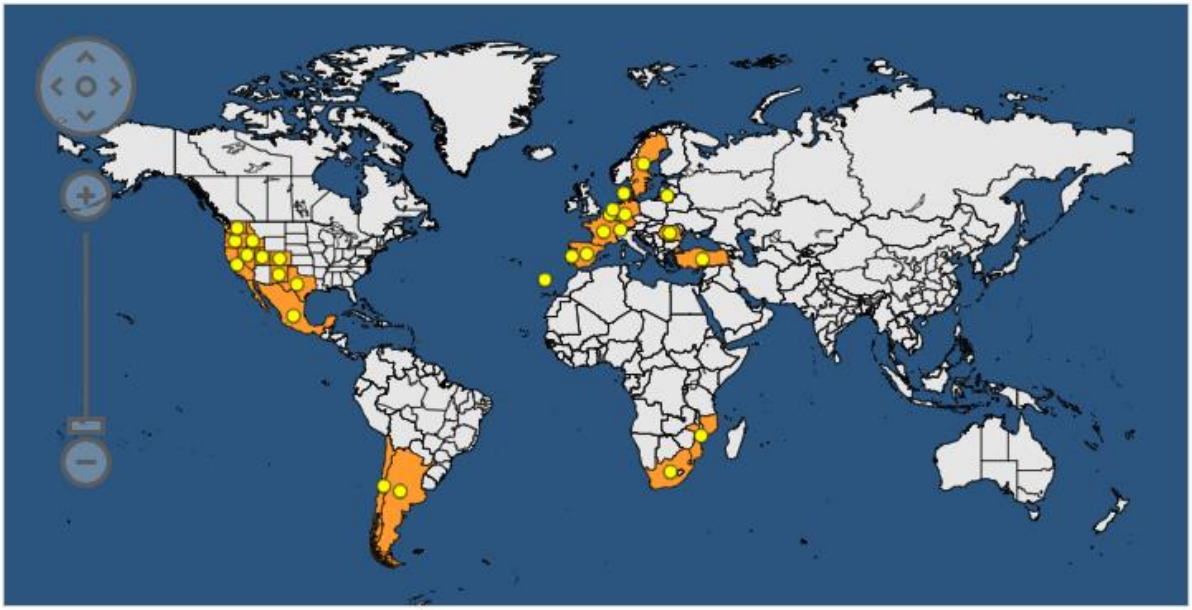

Figure 3. Global distribution of *Meloidogyne chitwoodi* as of February 2024 (full distribution details can be found here: https://gd.eppo.int/taxon/MELGCH/distribution). Yellow dots represent countries/regions where the pest is present. ©(EPPO, 2024).

Phytosanitary status

Meloidogyne chitwoodi is a GB Quarantine pest listed in Annex 2 (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. It is also found on a number of other quarantine lists, this table may be incomplete so correspondence with the relevant NPPOs should be attained for confirmation on this pests status (Table 1).

Table 1. Global categorisations of *Meloidogyne chitwoodi* (Adapted from (EPPO, 2024)).

Country/NPPO/RPPO	List	Year of Addition
AFRICA		
Egypt	A1 list	2018
Morocco	Quarantine pest	2018
AMERICA		
Brazil	A1 list	2018
Canada	Quarantine pest	2019
Mexico	Quarantine pest	2018
Uruguay	A1 list	1995
ASIA		
Bahrain	A1 list	2003
Israel	Quarantine pest	2009
Kazakhstan	A1 list	2017
EUROPE		
Azerbaijan	A1 list	2007
Georgia	A1 list	2018
Moldova	Quarantine pest	2017
Norway	Quarantine pest	2012
Russia	A1 list	2014
Ukraine	A1 list	2019
United Kingdom	A1 list	2020
RPPO/EU		
APPPC	A1 list	1992
COSAVE	A2 list	2018
EAEU	A1 list	2016
EPPO	A2 list	1995

EU	A2 Quarantine pest (Annex II B)	2019

Means of movement and dispersal into the UK

Natural dispersal

The natural dispersal of *M*. *chitwoodi* is very limited. The second juvenile stage is the only stage thought to move any distance within the soil, even this is very limited to tens of centimetres. Therefore, the most likely method of dispersing *M*. *chitwoodi* is through human-mediated movement of infected or material contaminated with *M*. *chitwoodi*.

Control

Chemical control

Chemical control in the form of the application of nematicides may reduce the impact caused by *M*. *chitwoodi* on potato crops. Although nematicides are frequently being removed from the approved list due to potential damage caused to non-target nematodes. Two nematicides currently available for use in GB and NI (until 2026). The use of nematicides alone is unlikely to reduce levels of infestation by enough to eradicate or lower densities enough so quality of potato is maintained. In order to attain such reduced levels of *M*. *chitwoodi* a range of control methods are required (James *et al.*, 2019). Herbicides can also be used to control the host plants which in turn controls nematode levels.

Cultural controls and sanitary methods

Meloidogyne chitwoodi has a wide host range which limits the ability to control population levels through rotating with non-host crops. Leaving fields fallow over the winter has been reported to reduce populations by 90%, however there is conflict between this and the use of green manure crops over winter which aim to reduce erosion, nitrogen leaching whilst increasing organic matter additions back to the soil (James *et al.*, 2019). The effective management of *M*. *chitwoodi* once fields have become infested with this nematode is very difficult and methods are still under development. The most effective method is growing potato cultivars which are resistant to *M*. *chitwoodi*, work on this has been ongoing for decades. Now a small number of cultivars are available which have resistance to *M*. *chitwoodi*, they are also thought to be resistant to *M*. *fallax*.

Impacts

Economic impact

The main economic impact associated with *M*. *chitwoodi* infection is in relation to the quality and therefore marketability of the crop rather than yield loss, which is rarely

observed (EPPO, 2024). Marketability is reduced through the internal necrosis of potato tissue and galling on tuber surfaces. When visible symptoms reach 5% of the total surface of ware potatoes this makes the crop unmarketable, highlighting the importance of *M*. *chitwoodi* free fields for production.

Economic costs are also incurred as a result of inspections, increased costs are associated with soil sampling and diagnostics in attempts to prevent the introduction or reduce the spread of pests, and this is no different for *M*. *chitwoodi*. Despite the fact the costs of preventative measures are likely outweighed by the potential costs of *M*. *chitwoodi* introduction to production areas, they are still worth considering. The success of measures such as preventative soil sampling are highlighted by the reduction in vegetables rejected for canning due to root-knot nematode damage from 7% to 1.5% when soil sampling was initiated in the Netherlands (Wesemael *et al.*, 2011). In addition to these costs if *M*. *chitwoodi* is detected in GB or NI safeguarding measures will be taken to contain or eradicate the pest. This will have economic impacts on growers which have areas or material which fall within certain categories such as infested, possibly infested or contaminated.

Environmental impact

The overall impact is largely economic and derived from the direct effects of the nematodes on the quality of potato crops. However, where *M*. *chitwoodi* is present, nematicides and/or herbicides may be used to control them, and this may have a potentially significant effect on non-target, potentially beneficial nematodes and plants.

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11. Authors and reviewers

Authors:

Aaron Hoyle (Defra)

Reviewers:

Laura Stevens (Defra) & Tom Prior (Fera Science Ltd.)