Department for Environment Food & Rural Affairs

Pest specific plant health response plan:

Outbreaks of *Beet curly top virus* and its vector *Circulifer tenellus* in protected tomato and pepper crops

Figure 1. Tomato plant infected with *Beet curly top virus* © Bob Hammon, Colorado State University, Bugwood.org

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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.

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Executive summary

Background	
Regulation	GB Quarantine pest
Key Hosts	Beet crops, tomato and peppers
Distribution	Argentina, Bolivia, Canada, Costa Rica, Cote d'Ivoire, Cyprus, Egypt, India, Iran, Italy, Japan, Mexico, Türkiye, Uruguay, USA
Key pathways	Plants for planting
Industries at risk	Sugar and fodder beet, beetroot, tomato and pepper growers
Symptoms (2.3*)	• Erect, rigid and stunted hosts with brittle stems • Initial rolling of leaves with transparent veins, with leaves and calyxes becoming thickened • Reduced vigour and death of seedlings • Premature ripening of fruit
Surveillance	
Demarcated zones (5.31)	Infected zone = the infected glasshouse(s) Buffer zone = ≤ 1 km
Surveillance activities (5.18-5.22)	Visual surveillance; sweep netting and trapping for vector; and asymptomatic sampling in the demarcated zones.
Response measures	
Interceptions (5.1-5.7)	Destruction is via deep burial or incineration, although other methods may be considered by the IMT. Tracing exercises are carried out where required and an UKPHINs notification should be made. Further surveillance of the area for inland findings.
Outbreaks (5.37-5.52)	• Treatment of crop to control the vector • Removal and destruction of infected and nearby hosts • Movement restrictions • Post-crop clean up measures • Fruit may be permitted to move to retail/wholesale, or to packhouses if adequate hygiene measures are in place
Key control measures	
Biological	N/A
Chemical	Foliar insecticide treatments for control of vector
Cultural (5.14)	• Working from healthy areas to infected areas • Clean tools and equipment regularly • Restricting access • Removal and destruction of debris and volunteers
Declaration of eradication	
The outbreak can be declared eradicated if BCTV and/or *C. tenellus* has not been found for a year (or for a single cycle of the crop) after the infected crop was removed.	

*Numbers refer to relevant points in the plan

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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 infection of beet curly top virus (BCTV) or infestation of its vector *Circulifer tenellus* (beet leafhopper) is discovered in a glasshouse crop.

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 BCTV 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 aims of this response plan are to facilitate the containment and eradication of BCTV and to make stakeholders aware of the planned actions.

2. Summary of the threat

2.1. *Beet curly top virus* is the type species of the *Curtovirus* genus in the Geminiviridae family. Beet curly top virus (BCTV) and its vector are believed to have originated in the eastern Mediterranean basin and spread from there to the USA, where it was one of the first viral plant diseases to be recognised in the field after being detected in Nebraska in 1888. Since then, the disease has spread extensively across the USA and to arid and semi-arid regions of Africa, Asia and Europe.

2.2. BCTV has a very broad host range and can infect over 300 species in 44 families. Many of these hosts may remain asymptomatic, but the virus can infect several hosts of concern including beans (*Phaseolus vulgaris*), cucurbits (*Cucurbitaceae*), pepper (*Capsicum annuum*), potato (*Solanum tuberosum*), beet crops including sugar beet, fodder beet and beetroot (*Beta vulgaris*), tomato (*Solanum lycopersicum*), and wild hosts such as *Beta maritima* and common weeds such as *Amaranthus* spp. and *Chenopodium* spp. (a more comprehensive host list can be found on the EPPO Global database - https://gd.eppo.int/taxon/BCTV00/hosts). The virus can cause severe disease infections in beet crops, (which can be considered the primary host), peppers and tomatoes.

2.3. Infection of beets with BCTV results in curly top disease which gives hosts severely stunted growth with crinkled, rolled and chlorotic foliage with blistered and swollen veins on the underside of leaves and can cause mortality in younger plants. As the disease matures, wart-like growths appear on the veins of the lower leaves and eventually leaves become dark green, thick, crisp and brittle whilst root hair proliferation occurs, leading to woolly or hairy roots. In some cases, clear coloured ooze may be seen from the petioles, midribs or veins which can become black and sticky eventually forming a brown crust on plant surfaces. Harvested beet tubers show black longitudinal concentric rings (EFSA, 2017; CABI, 2021a; EPPO, 2022b).

2.4. BCTV is vectored by the beet leafhopper (*Circulifer tenellus*), although a second species, *C. opacipennis*, is suspected to be a vector. For the purpose of this plan and given the uncertainties around *C. opaciennis* as a vector, *C. tenellus* will be considered as the only vector of BCTV. There is one report of seed transmission in petunia, so this may be a possibility although further work is required to reduce the uncertainty. No other modes of transmission are currently known for BCTV. The vectors can spread the virus both via contaminated mouthparts and by circulative non-propagative transmission. Following a short latent period in the vector, the virus can be effectively transmitted into new host plants. Beet curly top virus can be transmitted in a persistent (circular) manner and carried for up to 30 days by the vector, although its transmission efficiency declines over this time and the virus does not replicate within the vector.

2.5. BCTV can be disseminated locally by *C. tenellus* and over long distances in host material or possibly within the vector, which has been reported to travel tens of miles and even hundreds of miles on some occasions. *Circulifer tenellus* has been observed on cars, so there is capacity for the pest to hitchhike. However, given the distance from the UK of areas where the distribution of the vector and virus overlap, this is an unlikely pathway into the UK. Given the wide host range there is potential for BCTV to be introduced on a number of hosts.

2.6. As of February 2024, there have been no interceptions or outbreaks of BCTV or its vector *C. tenellus* in the UK.

3. Risk assessments

3.1. *Beet curly top virus* has an unmitigated and mitigated UK Plant Health Risk Register score of 60 and 40, respectively. Overall scores range from 1 (very low risk) to 125 (very high risk). These scores are reviewed as and when new information becomes available (https://planthealthportal.defra.gov.uk/pests-and-diseases/uk-plant-health-risk-register/viewPestRisks.cfm?cslref=13).

3.2. *Circulifer tenellus* has an unmitigated and mitigated UK Plant Health Risk Register score of 40. Overall scores range from 1 (very low risk) to 125 (very high risk). These scores are reviewed as and when new information becomes available (https://planthealthportal.defra.gov.uk/pests-and-diseases/uk-plant-health-risk-register/viewPestRisks.cfm?cslref=2793).

3.3. Pest categorisation has been carried out by the European Food Safety Authority (EFSA, 2015), and a Pest Risk Analyses has been carried out by Poland (EPPO, 2017).

3.4. Based on the EPPO summary, the Polish PRA concluded that whilst the likelihood of BCTV spread in Poland was low, climate change may improve conditions for the vectors and increase the likelihood of impacts on cultivated and non-cultivated hosts. EFSA concluded that the virus can be expected to establish and spread within the EU where the vector is present and cause severe impacts in sugar beet, tomato and other crops, therefore meeting the criteria to qualify as a Union quarantine pest.

4. Actions to prevent outbreaks

4.1. Beet curly top virus is a GB Quarantine Pest (Annex 2 of The Plant Health (Phytosanitary Conditions) (Amendment) (EU Exit) Regulations 2020) and is therefore prohibited from being introduced into, or spread within, GB.

4.2. *Circulifer tenellus* is a GB Quarantine Pest (Annex 2 of The Plant Health (Phytosanitary Conditions) (Amendment) (EU Exit) Regulations 2020) and is therefore prohibited from being introduced into, or spread within, GB.

4.3. Beet curly top virus is an EU Union Quarantine Pest and is therefore prohibited from being introduced into, or spread within, the Union Territory.

4.4. 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 BCTV. It is important that capabilities in detection, diagnosis, and risk management are available.

5. Response activities

Official action to be taken following the suspicion or confirmation of an interception of BCTV

5.1. If BCTV and/or *C. tenellus* 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. BCTV is not tuber borne, and there are uncertainties around its transmission via seed, so the most likely pathway will be consignments of host plant for planting material. The vector could potentially hitchhike on plants for planting or produce (see 2.5), but is likely to disperse if disturbed, and as such the risk of this is considered low. Ideally, the consignment should be placed in a sealed cold store and any opened containers should be resealed (which could be via wrapping in plastic if this facility is available). Other consignments of host plants of significance that are at risk of cross-contamination should also be held pending a risk assessment on whether cross-contamination has or could have potentially occurred. Samples should be sent to Fera Science Ltd., Plant Clinic, York Biotech Campus, Sand Hutton, York, YO41 1LZ (01904 462000), in a sealed bag or container, within at least two other layers of containment, which are not liable to be crushed during transit.

5.2. If *C. tenellus* is intercepted inland and there is the potential for spread from the imported consignment, host plants at risk of contamination should be surveyed on the site and again in the following year for signs of the presence of BCTV and/or *C. tenellus*. When the site is in an area where hosts are grown, the survey should include an area extending to 1 km of the affected site. The size of the survey area will be influenced by the local climatic and meteorological conditions, and the density of host crops.

5.3. When a finding of BCTV and/or *C. tenellus* is confirmed, the PHSI should advise the client of the action that needs to be taken by way of an official notice. The consignment should be destroyed by either by incineration, deep burial, another approved method (such as heat sterilization, industrial processing (subject to adequate disposal of waste water), fermentation and composting, steaming and feeding to animals, and anaerobic digestion), or re-exported in a sealed container. The method of destruction/re-export will be chosen on a case by case basis.

5.4. If *C. tenellus* is present, where there is a high risk of escape before destruction or re-export, fumigation and/or insecticides may be used under guidance from the Defra Risk and Horizon Scanning team.

- Prior to any insecticides being used, the risk posed by the insecticides to people and the environment will be assessed.

- Any applications should be made following the advice on the product label and be in accordance with HSE guidance. In some cases, there may be a requirement to carry out a Local Environment Risk Assessment for Pesticides (LERAP) depending on the product used and the situation of the finding.

- If the situation demands it, it may be necessary to require the use of insecticides even for growers where only biological control agents are being used.

- Growers will be placed under notice to apply the recommended insecticides and make the applications using their own or contractor’s equipment. Records of applications will be kept, including details of the amount of product and water used.

- Sticky traps should be monitored to determine the efficacy of the treatments.

5.5. A UKPHINS (UK Plant Health Interception Notification System) notification should be made upon confirmation of an interception of BCTV or its vector *C. tenellus.* UKPHINS is the IT system for recording findings and non-compliance in order to maintain records and notify other National Plant Protection Organisations (NPPO) of plant health issues.

5.6. If all or part of the consignment has been distributed to other premises prior to diagnosis, trace forward and trace back inspections should take place upon suspicion or confirmation of BCTV and/or *C. tenellus*. Details of recent past and future consignments from the same grower/supplier should also be obtained.

5.7. A pest alert to raise awareness of BCTV and/or *C. tenellus* and its symptoms should be distributed to packers/processors and importers where BCTV and/or *C. tenellus* has been found, and to those in the local area and those associated with the infested premises.

Official action to be taken following the suspicion of a BCTV outbreak

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

5.9. The OTG will determine the alert status, which will consider the specific nature of the outbreak. These alert levels, in order of increasing severity, are white, black, amber and red (more details on these levels can be found in table 2 of the *Defra Generic Contingency Plan for Plant Health in England*). Under most scenarios, an infection of BCTV in a glasshouse crop of tomatoes or peppers is likely to be given a black alert status. A black alert status refers to a significant plant pest/disease with potential for limited geographical spread.

Restrictions on movement of material

5.10. BCTV is primarily associated with plants for planting. There are uncertainties surrounding seed transmission of the virus and it is not known to be tuber borne.

Therefore, plants for planting should be prevented from leaving the affected glasshouse (and wider site if considered a risk), other than under a statutory plant health notice for destruction by deep burial, incineration or another approved method.

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

5.12. Movement of people into the affected area should be restricted, especially during the early investigation phase. Personnel should be briefed on the importance of good hygiene practice, to reduce the risk of carrying life stages of *C. tenellus* to other areas of the site or to other sites.

Preliminary trace forward / trace backward

5.13. If an infested consignment or batch is considered as being the source of the suspect outbreak, investigations regarding the origins of infested consignments will be undertaken to locate other related and therefore potentially infested consignments moving to and from the site.

General biosecurity advice and advisory measures for growers

5.14. The main means of transmission is by vector, but hygiene best practice, should be followed to minimise the likelihood of mechanical spread. Measures could include:

- Training staff to identify symptoms of BCTV and *C. tenellus*, and to follow best practice procedures.
- Using clothes (including overshoes), which will either be destroyed (via incineration or deep burial) or washed following work on a particular lot. This prevents spread between lots.
- Using disposable gloves that will be destroyed (via incineration or deep burial) following work on a particular crop, between different areas within a crop or between plants (reducing spread).
- Washing hands with soap before and after entering a new glasshouse or compartment (reducing spread).
- Restricting the use of equipment, particularly knives, to one location, to prevent the virus spreading to other locations.
- Avoiding the use of leaf blowers that may spread the vector.

- Chemical disinfection of knives and pruning instruments (between crops, areas within a crop or plants to reduce spread).
- Cleaning and disinfection of machinery between crops. As with handheld equipment, machinery is another means of mechanical transmission. Disinfection and cleaning of machinery with high water pressure, steam cleaners or other methods may therefore reduce spread. Records of this should be maintained.
- Maintaining the working direction. If human-assisted spread of a pathogen occurs, it will occur in the direction that the human is working. Working in the same direction reduces the extent of the spread and allows measures to be carried out in a more concentrated way.
- Restricting access to the working area. The fewer people entering a particular lot, the less chance there is that BCTV or its vector *C. tenellus* will be introduced. Wherever possible, employees should work in the same areas or number of rows each day rather than swapping around work areas.
- Installing yellow sticky traps to monitor for and trap *C. tenellus* is advised.
- Volunteer host plants, weeds and crop debris (see 2.2) may act as reservoirs for BCTV and *C. tenellus*. Controlling these plants within and around the affected area reduces the chance of cultivated crops become infected and reduces the risk of survival and persistence of the pests in the event of an outbreak. Volunteer plants and weeds can be controlled mechanically (e.g. hoeing), chemically (e.g. herbicides), and manually (e.g. rogueing), disinfecting any equipment after use.

Confirming a new outbreak

How to survey to determine whether there is an outbreak

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

- The origin of the host plants and associated pathways, date of planting and plans for the date of succeeding crops
- Details of other premises or destinations where the potentially infected host plants have been sent
- The growing system being used, i.e. rockwool, nutrient film technique or soil grown
- Details of how waste material is disposed of

- The layout of the premises and surrounding area, including a map of the fields/cropping, at risk growers, and details of neighbouring crops, especially any commercial or non-commercial hosts in glasshouses and field grown
- Details of the host grown including cultivar or variety, growth stage and any other relevant information
- Description of surrounding habitat, including all potential hosts and weeds
- Area and level of infection, including a description of the symptoms seen (photos should be taken) and the location within the affected premise e.g. whether it is widespread across the planting, clustered in hotspots, or whether it is related to specific operations
- The date and time the sample was taken
- Current treatments/controls in place
- Details of the movement of people, equipment, machinery etc. to and from the infected area
- Cultural, biosecurity and working practices
- The name, address, email and telephone number of the person who found the pest and/or its symptoms, and the business owner

This information should be included on the plant disease investigation template.

5.16. Further to information gathering, surveys of other host plants should be carried out to confirm the extent of the infection e.g. in surrounding glasshouses, field grown crops etc. This should include samples and photographs of suspect plants where possible. This initial survey will be used to determine if it is an isolated finding or an established outbreak.

5.17. 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

5.18. Tomato and pepper plants can be visually examined for symptoms of BCTV which are described in more detail in 2.3 and Appendix A but may include:

- Stunted, erect hosts
- Brittle stems
- Initial rolling of leaves with transparent veins, with leaves and calyxes becoming thickened
- Premature ripening of fruit

5.19. The identity of BCTV should be confirmed using molecular testing.

5.20. Visual inspection for *C. tenellus* may be carried out but it may be difficult due to the size of the pest. Using yellow sticky traps has been found to be effective when traps are placed at ground level. If the crop is raised on benches, traps may be best placed level with the base of the stem.

5.21. Following the capture/putative identification of BCTV and/or *C. tenellus* samples should be sent for confirmatory diagnosis as in point 5.1. Each sample should be labelled with full details of the sample number, location (grid reference), plant variety and suspect pest. Care should be taken to avoid cross contamination between samples, for example samples in separate bags and the changing of disposable gloves and disinfection of equipment between sampling.

5.22. Symptomatic samples should be taken, and any asymptomatic samples should focus on young leaves, sepals/calyces and fruit rather than mature leaves.

Diagnostic procedures

5.23. A range of diagnostic techniques are available for BCTV. These include PCR, Southern Blot, Western Blot, Tissue-Blot Immunoassay and ELISA. Fera Science Ltd. use a specific ELISA test for the detection of BCTV. Confirmation would be carried out using High Throughput Sequencing (HTS) to obtain a whole genome.

5.24. There are three morphological types of *Circulifer tenellus* - a summer morph, a winter morph and a migratory morph (CABI, 2019). Identification to species level is tricky for *Circulifer* spp., due to morph variation and morphological convergence between species within the genus (EFSA, 2015). *Circulifer tenellus* adults are around 2.7-3.8 mm (females) or 2.5-3.6 mm (males) in length and brown or straw-like in colour with variable dark markings (EPPO, undated). These markings can be seen through the transparent forewings and overwintering individuals may also have dark coloured patterns across the head, thorax and forewings (see figure 3). Nymphs of the species appear similar to these overwintering adults, but with longer more pointed heads and lacking wings (CABI, 2019). Morphological and molecular methods will be used to identify *C. tenellus.*

Criteria for determining an outbreak

5.25. An outbreak will be declared if there is evidence showing that BCTV and/or *C. tenellus* has established in a glasshouse crop.

5.26. If BCTV and/or *C. tenellus* is detected at a port or confined to a particular consignment with no risk of spread, then an outbreak should not be declared. If it is found to have spread or likely to have spread beyond its original consignment, for example across multiple batches in a glasshouse, then an outbreak should be declared.

5.27. BCTV in the absence of *C. tenellus* has limited potential for spread. However, given the uncertainties in seed transmission, the presence of the virus is a strong indicator the vector is also present. Outbreaks of BCTV alone should therefore not be managed differently to outbreaks of BCTV where the vector is known to be present.

Official Action to be taken following the confirmation of an outbreak

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

Communication

5.29. 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.

5.30. A generic communications plan is available for use across all plant health outbreaks. This will be owned by APHA and FC communications teams and is intended to provide consistency across outbreaks. This plan aligns with the Plant Biosecurity strategy and 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

Demarcated zones

5.31. Once an outbreak has been confirmed, a demarcated area must be established around known infested plants. This will include two zones:

- A defined **infected zone** (i.e. the infected glasshouse(s)).
- A **buffer zone**, which will initially be at least 1 km from the infested zone. The buffer zone may include other premises in which stock has been sent or received, and/or any other premises where there is a perceived risk. This could

include other glasshouses, protected horticulture sites or farms growing hosts of BCTV.

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

5.33. All batches of host plants in the demarcated area should be visually inspected where feasible, and suspect samples should be sent for diagnosis. Surveying rates should be determined by the IMT. Yellow sticky traps can be used for monitoring and surveillance in glasshouse and protected crops as in 5.20.

5.34. The demarcated area should be adjusted in response to further findings. If BCTV is found within an area outside the infected zone, this should subsequently be designated as infected.

5.35. Surveys of the demarcated area will be carried out annually for at least two years after the year of the outbreak, with visual surveys of field crops in the buffer zone performed during spring or summer when the plants are in active growth.

5.36. Movement of potentially infested material out of the demarcated area should be prevented. The PHSI will contact stakeholders within the demarcated areas to inform them of the requirements that will apply to them (see Pest Management Procedures). Controls on the movement of specified plants will be implemented by statutory plant health notices.

Pest management procedures

Scenario 1: Outbreak in a fruit production crop

5.37. BCTV is primarily spread by the vector, and therefore the control of *C. tenellus* is important to prevent spread to nearby healthy crops. Therefore, all host plants in the infected zone should be treated as soon as possible with a foliar insecticide to treat for *C. tenellus* in the crop. Recommendations will be made on an appropriate insecticide treatment regime in consultation with the Defra Risk and Horizon Scanning team, and applications should be made in line with 5.4.

5.38. Bio-secure working practices as described in 5.14 should be followed.

5.39. There are no chemical or biological methods for controlling BCTV. Therefore, the only effective method of eradication is destruction. Following insecticide use, all infected plants, at risk plants along the row that are within 20 m of the infected plants, plants an equivalent distance in rows either side of the infected row, and volunteer plants should be destroyed; and if there are several outbreaks within the same crop, it is advised that the whole crop is destroyed.

5.40. Any remaining host plants should not be moved off site, with exception of plants being moved for destruction under statutory plant health notice.

5.41. As BCTV is phloem limited, movement of fruit presents a low risk. Therefore, marketable fruit may be harvested, if deemed appropriate by the IMT. Movement restrictions will not apply to:

- fruit that is being sold directly to retail/wholesale
- fruit that is moving to other production sites for packing under statutory plant health notice, provided there are deemed to be suitable hygiene measures in place to prevent infection of growing crops.

5.42. If no infestation is found in host crops growing in the vicinity following visual surveillance, they should continue to be monitored with visual inspections, asymptomatic sampling and vector trapping (as in 5.14) until the post-crop clean up, with the frequency to be determined by the IMT.

Scenario 2: Outbreak in a breeding or propagation nursery

5.43. Follow points 5.37-5.38.

5.44. All plants in the lot should be destroyed, even if the outbreak is only found in a single spot, because of the potential for the virus to be present in or spread throughout the whole lot.

Post-crop clean up

5.45. All remaining susceptible host crops left in the infested zone following the end of season or cropping cycle should be removed and destroyed by incineration, deep burial or another accepted alternative. This will include volunteers, weeds and waste and should be done under a statutory plant health notice.

5.46. Once the plant material has been removed, all remaining material e.g. string, plastic flooring and growing media, should be destroyed, recycled (if there is no risk of escape), or reused, if thoroughly cleaned with water and detergent to remove any remaining plant material and life stages of the vector. The permanent facility should also be cleaned and disinfected to remove any remaining life stages of the vector.

5.47. A host crop-free period will be specified under a statutory plant health notice. The length of this period will be determined by the IMT in discussion with the grower but should be at least the period covering the lifespan of *C. tenellus*. This will depend on the environmental conditions within the infested zone, particularly the temperature. If possible, the temperature should be raised to speed up the lifecycle of the vector. Sticky traps or sticky trap rolls should be used to monitor the empty growing site.

5.48. After the new host crop has been planted following the host crop-free period, regular monitoring should be carried out to ensure there are no surviving *C.*

tennellus. This monitoring should include visual inspections, asymptomatic sampling and vector trapping (as in 5.14).

5.49. Official visual inspections and asymptomatic sampling, with the frequency determined by the IMT, should be carried out over the following growing season to check for the presence of BCTV.

Disposal plan

5.50. The primary means of disposing of infected material and plants is through incineration (licensed) and deep burial. Deep burial may be done at an approved landfill site, or on the site or nearby farm, if practical and in agreement with the local Environment Agency. Incineration must comply with appropriate waste management regulations, Environment Agency in England, Scottish Environment Protection Agency and Natural Resources Wales. If the material has to be moved off the premises, it should be contained within at least two sealed layers, if possible (e.g. small plant within two plastic bags).

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

5.52. Any disposal of waste material must be done in accordance with the relevant legislation. Growers need to obtain permission for exemptions from the Agricultural Waste Regulations from the Environment Agency. No charges are made for these exemptions. Further information on activities that require a permit and those which require the registration of an exemption can be found on the EA website at: https://www.gov.uk/topic/environmental-management/environmental-permits.

6. Criteria for declaring eradication / change of policy

6.1. The outbreak can be declared eradicated (by the Chief Plant Health Officer) if BCTV and/or *C. tenellus* have not been found for a year (or for a single cycle of the crop) after the infected crop was removed.

7. Evaluation and review of the contingency plan

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

7.2. Lessons should be identified during and after any outbreak of BCTV and/or *C. tenellus* or any other pests, 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.

6. Appendix A

Data sheet for beet curly top virus

Identity

PREFERRED SCIENTIFIC NAME	AUTHOR (taxonomic authority)
Beet curly top virus	ICTV
Circulifer tenellus	(Baker)

Beet curly top virus

CLASS: Repensiviricetes
ORDER: Geplafuvirales
FAMILY: Geminiviridae
GENUS: Curtovirus
SPECIES: *Beet curly top virus*
VIRUS NAME: beet curly top virus

SYNONYMS
BCTV
beet curly top curtovirus
potato green dwarf virus
sugar beet curly leaf virus
sugar beet virus 1
tomato yellows virus
western yellow blight virus

COMMON NAMES
Curly leaf of sugar beet, curly top of beet, curly top of sugar beet, green dwarf of potato, yellows of tomato

Circulifer tenellus

CLASS: Insecta
ORDER: Hemiptera
FAMILY: Cicadellidae
GENUS: *Circulifer*
SPECIES: *tenellus*

SYNONYMS
Eutettix tenellus Baker
Neoaliturus tenellus (Baker)
Thamnotettix rubicundula Van Duzee

COMMON NAMES
Beet leafhopper

Notes on taxonomy and nomenclature

Beet curly top virus is the type species of the *Curtovirus* genus in the Geminiviridae family. The demarcation of genera in this family is split under several criteria including insect vectors, host range, symptom phenotype, coat protein serology, *trans*-replication of genomic components, genome organisation and genome sequence (EFSA, 2017; ICTV, 2022b). The Curtoviruses are vectored by leaf hoppers and infect a variety of vegetable crops, whilst the genomes usually have seven genes (ICTV, 2022b). Recent revisions of the Curtoviruses have meant that several formerly distinct species have been reassigned to the species *Beet curly top virus*.

The disease has undergone a number of taxonomic changes, with the disease in the USA thought to be caused by three separate strains – CFH, Worland and Cal/Logan. These were renamed as separate species – Beet severe curly top virus (CFH), Beet mild curly top virus (Worland) and BCTV (Cal/Logan). However, the ICTV demarcation criteria for the genus *Curtovirus* states that isolates with a greater than 94% sequence identity are considered to be variants of the same strain, and isolates with 77% or less sequence identity are considered different species. Due to this, a number of previously named species are now considered strains of BCTV (Varsani *et al.*, 2014; Strausbaugh *et al.*, 2017). Of these the BCTV (Cal/Logan) strain is less widely distributed in the USA and most damage is now attributed to the other strains (Harveson, 2015).

Another species, *Beet curly top Iran virus* (BCTIV) causes a similar leaf curl disease of sugar beet in Iran, but the virus belongs to a different genus – the *Becurtovirus* within the Geminiviridae and is distinguishable from BCTV in a diagnostic laboratory (EFSA, 2017). Both BCTV and BCTIV are present in Iran, and whilst symptoms are similar there is a slight delay in expression in plants infected with BCTIV (Motazeri *et al.,* 2016).

Biology and ecology

Biology of BCTV

BCTV is primarily spread after being ingested by leafhopper vectors. CABI (2021) and EPPO (2022b) note two vectors in the same genus - *Circulifer tenellus* or *C. opacipennis*, although EFSA (2017) states the former as being the only known vector. Chen and Gilbertson (2016) note that BCTV is only transmitted by species in the genus *Circulifer,* primarily by *C. tenellus* but possibly by *C. opaciennis*. The virus is also noted by EPPO (2022b) as not being easily mechanically transmitted. Anabestani *et al.* (2017) found seed transmission between 38.2-78.0% in petunia seedlings *in vitro,* but there are no other confirmed reports of seed transmission. No other modes of transmission are currently known for BCTV, and therefore given the uncertainties around seed transmission it is assumed that spread is primarily via insect vectors, of which *C. tenellus* is currently considered to be the only known vector of BCTV.

The vector can spread the virus both via contaminated mouthparts and by circulative persistent transmission (EPPO, 2022b). Short acquisition periods are required for the latter, and following a short latent period in the vector the virus can be effectively transmitted into new host plants. Beet curly top virus can be carried for up to 30 days by the *C. tenellus*, although its transmission efficiency declines over this time and the virus does not replicate within the vector. This represents a persistent circulative but non-propagative mode of transmission as there is no transmission to the progeny of the host (EFSA, 2017).

Many strains which vary in virulence, symptomology and host range have been reported, particularly from North America (EPPO, 2022b).

Lifecycle of *Circulifer tenellus*

Circulifer tenellus is a cicadellid in the sub-family Deltocephalinae. Insects from the Deltocephalinae are typically phloem sap feeders and are responsible for vectoring bacteria and plant viruses (EFSA, 2015).

The *C. tenellus* life cycle consists of an egg, five nymphal instars and a winged adult stage and can complete between one and six generations per year depending on climatic conditions. In the spring, overwintering females oviposit on the leaves of hosts (TSU, 2022) laying around 1 to 200 eggs in the veins and petioles. Developmental time can vary from 19 to 119 days to reach the adult stage, which can survive for up to five months feeding on various herbaceous plants and shrubs, although the average survival time is around two months (EFSA, 2015).

Following harvest *C. tenellus* adults, primarily mated females (EFSA, 2015), migrate to weeds where they overwinter until spring (Natwick, 2016).

Hosts/crops affected

BCTV

Beet curly top virus has a broad host range infecting over 300 species in 44 families. Many of these hosts may remain asymptomatic, but the virus can infect several hosts of concern including beans (*Phaseolus vulgaris*), cucurbits (*Cucurbitaceae*), pepper (*Capsicum annuum*), potato (*Solanum tuberosum*) beet crops including sugar beet, fodder beet and beetroot (*Beta vulgaris*), tomato (*Solanum lycopersicum*) and wild hosts such as *Beta maritima* and common weeds such as *Amaranthus* spp. and *Chenopodium* spp. The virus can cause severe disease in crops of beet crops (which can be considered the primary host), peppers and tomatoes (Severin, 1927; EFSA, 2017; EPPO, 2022).

A more comprehensive host list can be found on the EPPO Global database – https://gd.eppo.int/taxon/BCTV00/hosts.

Sugar beet is a biennial plant which is grown as an annual for sugar production. In the UK it is drilled in the spring (between late February and early April), putting on growth in the summer and being harvested between September and March. Enforced drilling is desirable as proven through good seed priming and seed treatments. The crop is topped before harvest, with harvesting happening soon after or being processed simultaneously using specialist machinery to prevent a reduction in sugar quantity. The process is similar in fodder beet, but the sowing date is often later, and tubers may remain in the ground for longer (Sheaffer & Moncada, 2012; pers. communication, Ian Munnery, 2024).

Circulifer tenellus

Adult *C. tenellus* are highly polyphagous, feeding on a range of herbaceous plants and shrubs in the Amaranthaceae, Brassicaceae, Chenopodiaceae and Fabaceae families. Immature stages can also survive on hosts in other families (EFSA, 2015).

A more comprehensive host list can be found on the EPPO Global database – https://gd.eppo.int/taxon/CIRCTE/hosts.

Plant stage affected

All stages affected.

Plant parts affected

Leaves, stems, roots, tubers.

Symptoms/signs

Beet crops (sugar beet, fodder beet and beetroot)

Infection with BCTV results in curly top disease which gives hosts severely stunted growth with crinkled, rolled and chlorotic foliage with blistered and swelled veins on the underside of leaves (EFSA, 2017; CABI, 2021a). Younger plants and seedlings often die when infected (EFSA, 2017).

Initial symptoms are the inward rolling of leaf margins and chlorosis of veins on younger leaves. As the disease matures, wart-like growths appear on the veins of the lower leaves and eventually leaves become dark green, thick, crisp and brittle whilst root hair proliferation occurs, leading to woolly or hairy roots. In some cases, clear coloured ooze may be seen from the petioles, midribs or veins which can become black and sticky eventually forming a brown crust on plant surfaces. Harvested tubers show black longitudinal concentric rings (EPPO, 2022b).

Tomato

Infections in tomato begin with an inward rolling of leaflets along the midrib which often curve down to give a drooping appearance. In field grown tomatoes, leaves become chlorotic with purple veins. However, in glasshouses, the veins become transparent and this purple venation is not apparent. Leaves become thick and crispen, whilst the desiccation of the pith leaves stems hollow and brittle. Overall plants become erect, rigid and stunted, with calyxes becoming large and thickened and the fruits ripening prematurely. As the infection progresses, the plant becomes necrotic and may eventually die. Young plants which are infected are usually killed (Heflebower *et al.*, 2008; EPPO, 2022b).

Figure 2. Symptoms of BCTV on whole plant and sugar beet tuber © Oliver T. Neher, The Amalgamated Sugar Company, Bugwood.org

Morphology

BCTV

Beet curly top virus has a monopartite single-stranded DNA genome of about 2.9-3.0 kilobases. Small geminate particles 18-22 nm in diameter, single or paired (EPPO, 2022b).

Circulifer tenellus

There are three morphological types – a summer morph, a winter morph and a migratory morph (CABI, 2019). Identification to species level is tricky for *Circulifer* spp., due to morph variation and morphological convergence between species within the genus (EFSA, 2015). *Circulifer tenellus* adults are around 2.7-3.8 mm (females) or 2.5-3.6 mm (males) in length and brown or straw-like in colour with variable dark markings (EPPO, undated). These markings can be seen through the transparent forewings, and overwintering individuals may also have dark coloured patterns across the head, thorax and forewings (see figure 3). Nymphs of the species appear similar to these overwintering adults, but with longer more pointed heads and lacking wings (CABI, 2019).

Detection and inspection methods

Visual inspection

Plants can be visually inspected for symptoms of BCTV, particularly given the symptoms (as described in the symptoms/signs section above) are similar on the different hosts in the virus's range. For instance, in both field grown crops such as sugar and fodder beet and protected crops such as tomatoes, the initial symptoms to look for are inward rolling of younger leaves before leaves become thickened and other symptoms such as stunting and chlorosis develop as the infection progresses. Any samples taken should be confirmed using molecular testing (EPPO, 2022b).

Figure 3. *Circulifer tenellus* adults. © Paul Langlois, Museum Collections: Cicadas, Planthoppers, & Allies, USDA APHIS PPQ, Bugwood.org

Sweep nets

The vector *C. tenellus* is found on the underside of leaves but is quick to disperse if the plants are disturbed (CABI, 2021a). Sweep nets can be used to assess the population levels (Meyerdirk & Oldfield, 1987 via CABI, 2021a).

Trapping

Trapping is a more efficient way of detecting and quantifying vector populations (CABI, 2021a). Studies by Meyerdirk & Oldfield (1985) found that the leafhopper was most attracted to yellow sticky traps placed at ground level. This was found to be an efficient way of surveying for adults. In glasshouse crops it may be more suitable to place these at the top of the pot rather than the floor, depending on the setup of the crop.

Distribution

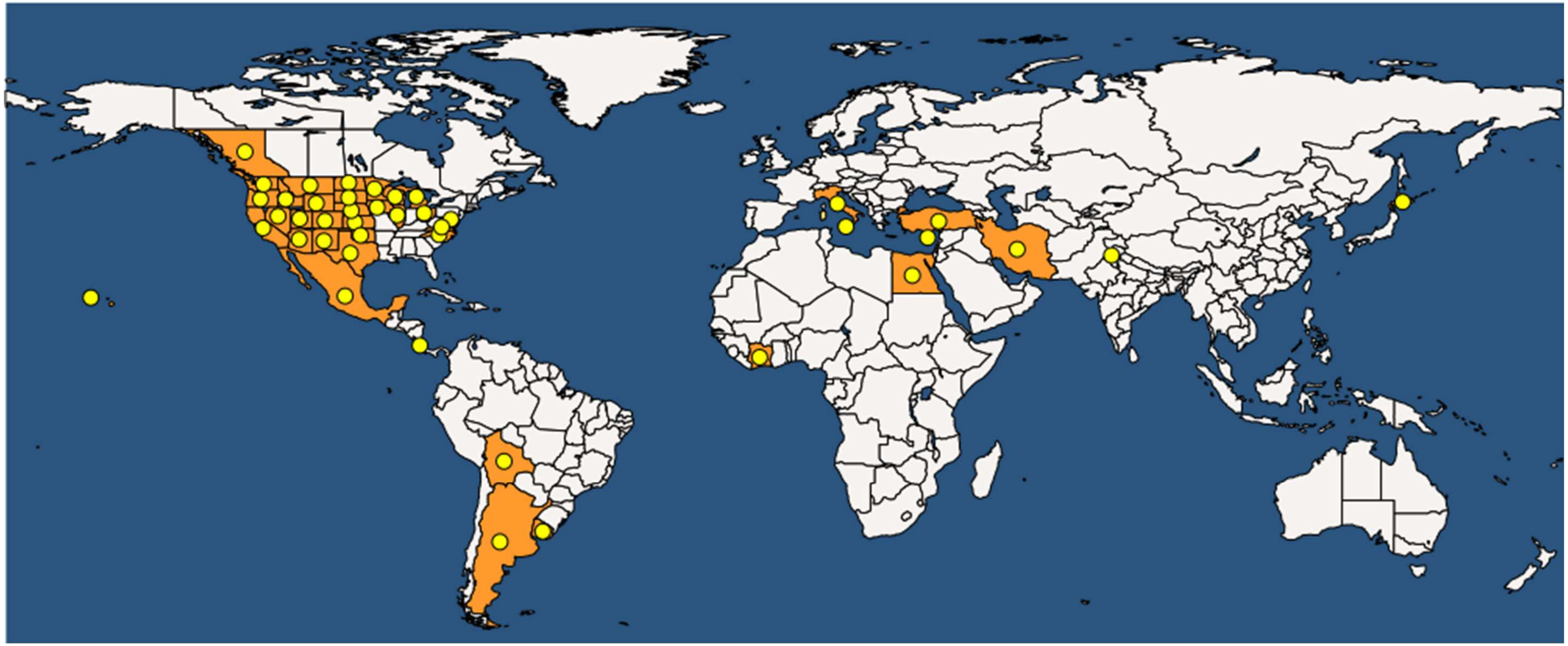

Figure 4. Beet curly top virus distribution as of March 2024. (Source: EPPO, 2022a). The link below provides up to date distribution data.
https://gd.eppo.int/taxon/BCTV00/distribution

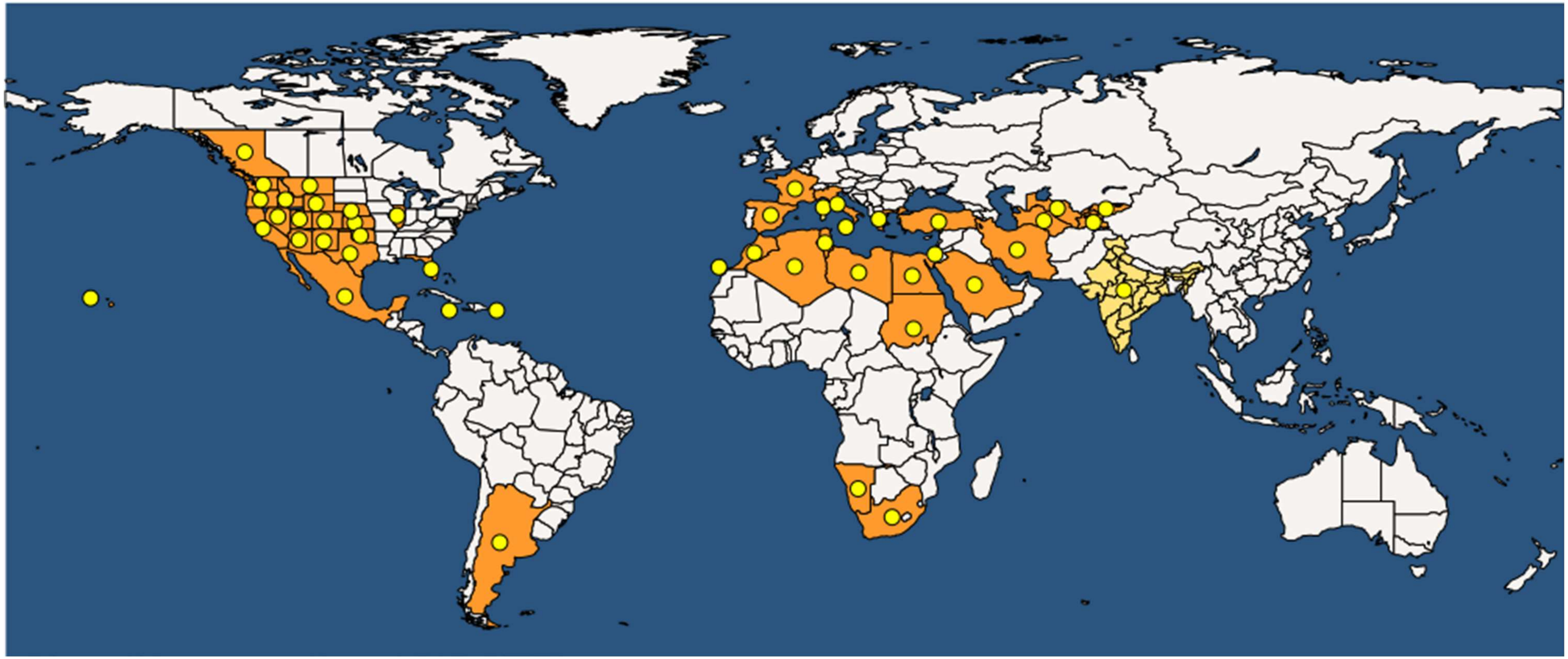

Figure 5. *Circulifer tenellus* distribution as of March 2024. (Source: EPPO, 2022c). The link below provides up to date distribution data.
https://gd.eppo.int/taxon/CIRCTE/distribution

History of introduction/spread

BCTV and its vector are believed to have originated in the eastern Mediterranean basin and spread from there to the USA (Bennet, 1971 as cited by CABI, 2021a), where BCTV was one of the first viral plant diseases to be recognised in the field, being detected in Nebraska in 1888 (Ağca & Yeşil, 2019). However, the disease was not conclusively shown to be caused by a virus until 1974 following improvements in virus purification (Harveson, 2015). Despite this, and prior to determining the causal agent as a virus, the disease was well documented in the USA due to severe losses of sugar beet in California and Utah from the 1890s onwards, suggesting it was widely distributed before it was recognised as a distinct disease. Additionally, there are potentially observations of the disease prior to 1888, but the symptoms seen were presumed to be other known diseases or disorders (Harveson, 2015). Describing curly top disease as a distinct disease may have been partly due to the first report of leafhoppers on beet crops in 1895, before Boucquet and Hartung proved the link between the disease and the vector in 1915 (Harveson, 2015).

According to EPPO (2022a), the virus is now present in the American states of Arizona, California, Colorado, Hawaii, Idaho, Illinois, Iowa, Kansas, Maryland, Michigan, Minnesota, Montana, Nebraska, New Mexico, North Carolina, North Dakota, Ohio, Oregon, South Dakota, Texas, Utah, Virginia, Washington, Wisconsin and Wyoming. The disease has also spread to arid and semi-arid regions of Africa, Asia and Europe (Ağca & Yeşil, 2019), presumably with infected plants or potentially vectors as the disease has not been shown to be seed-borne (CABI, 2021a).

Phytosanitary status

Beet curly top virus and *C. tenellus* are GB quarantine pests (Schedule 1), which means that they are prohibited from being introduced into, or spread within, GB. They are both also present on several other phytosanitary lists. Table 1 provides the global categorisation of BCTV in other countries, regions and RPPOs, whilst table 2 provides the global categorisation of *C. tenellus*.

Table 1. Global phytosanitary categorisation of *Beet curly top virus* (Source EPPO, 2022a).

Country/NPPO/RPPO	List	Year of addition
AMERICA		
Brazil	A1 list	2018
Canada	Quarantine pest	2019
Chile	A1 list	2019

Country/NPPO/RPPO	List	Year of addition
USA	Quarantine pest	2018
ASIA		
Israel	Quarantine pest	2009
Joran	A1 list	2013
EUROPE		
Türkiye	A1 list	2016
UK	Quarantine pest	2020
RPPO/EU		
EU	A1 Quarantine pest	2019

Table 2. Global phytosanitary categorisation of *Circulifer tenellus* (Source EPPO, 2022a).

Country/NPPO/RPPO	List	Year of addition
AMERICA		
Chile	A1 list	2019
EUROPE		
Türkiye	A2 list	2016
UK	Quarantine pest	2020

Means of movement and dispersal into the UK

Beet curly top virus can be moved locally by *C. tenellus* and over long distances as infected host material or possibly within the vector (EPPO, undated; EFSA, 2015; CABI, 2021a).

An EFSA pest categorisation (2015) summarises the dispersion capacity of *C. tenellus* from the data of Severin (1933). Reports from the USA suggest that the movements are seasonal with adults dispersing in spring and returning in autumn, travelling relatively long distances (tens of miles), although dispersal of up to 300 km has been observed and the insect is reported to be capable of flying over hundreds of miles (Texasinvasives.org, 2022 as cited by EFSA, 2015), although this is debated. The EFSA categorisation also notes that *C. tenellus* has been observed on cars so there is capacity for the pest to hitchhike. However, given the distance from the UK of areas where the distribution of the vector and virus overlap, this is an unlikely pathway into the UK.

The virus is phloem limited and not known to be seed or tuber borne (CABI, 2021a) and therefore infected host material would comprise of solely plants for planting. This may also contain eggs of *C. tenellus* which are inserted into the leaves. Due to this, there are special requirements in The Plant Health (Phytosanitary Conditions) (Amendment) (EU Exit) Regulations 2020 for plants for planting, other than seeds of *Beta vulgaris* coming from any third country where BCTV is known to occur, and thus some mitigation is in place against introduction into the UK. However, given the wide host range there is potential for BCTV to be introduced on other hosts.

Control

Whilst BCTV threatened the viability of the sugar beet industry in the USA in the late 19th Century, a combination of measures has achieved adequate control of the pathogen, allowing the industry to continue (Wisler & Duffus, 2000). Despite these control measures being adopted before the causal agent was known, these are still used in the USA today, and a number of these are discussed below.

Resistance

Breeding for resistance in the USA began in 1918, as a collaborative effort between the USDA and the Spreckles Sugar Company. This work received funding from the US Congress and the first curly top-resistant sugar beet variety was released in 1933, and following this in 1947, a permanent research laboratory dedicated to BCTV was established (Wisler & Duffus, 2000).

Resistant cultivars often only provide a low to mid level of resistance (Strausbaugh *et al.*, 2017), and as such other measures such as vector control are considered important, especially when young plants are exposed to a large viruliferous vector population (Wisler & Duffus, 2000). In the USA it has been established that it is also crucial to monitor the composition and prevalence of strains and variants in different areas, as this will affect the resistant cultivars which can provide the most effective protection (Strausbaugh *et al.*, 2017). The presence of both BCTV and BCTIV in Iran makes breeding for resistance difficult, and this may be further exacerbated by differences in the Iranian and American strains of BCTV, which show variation in response to resistant lines of beet (Motazeri *et al.*, 2016). There is currently no known breeding programme in the UK.

The breeding process can be accelerated by gene editing, although there are considerable costs associated with this.

Cultural controls and sanitary methods

As above the use of certified seed is key, but according to Wisler & Duffus (2000), the timing of planting is also significant. Rapid early growth is desired, as when the sugar beet grow and shade the soil they become less susceptible to attack from the vector. This is due to the leafhoppers preferentially feeding in sunny locations, and as such advice for gardeners in the USA is to plant susceptible crops in the shade or use netting to make these plants less desirable (Goldberg & Lujan, 2021). This may differ in the UK due to the growing conditions and seasons and be difficult to implement in a commercial crop. However, nearly all commercial sugar beet seed is primed and drilled early in the season to accelerate growth. This combined with the adoption of high seed rates helps to increase soil shading and produce mature plants earlier in the season which are less susceptible to attack from pest and disease. In contrast, fodder beet is unprimed and drilled later which may make the crop more susceptible to infection (Ian Munnery, pers. communication, 2024).

As with other viruses it is important to remove infected plants quickly, as well as any volunteers or weeds which could provide natural reservoirs for the vector. As the virus is so polyphagous, there are many wild hosts which can become infected and act as a source of inoculum for commercial crops. Preferential wild hosts can cause increases in populations of *C. tenellus* which can subsequently lead to severe infections of BCTV in crop hosts. Before the agricultural development of the western USA, many of the preferred wild hosts of *C. tenellus* were not present. As the land use changed and species such as mustards (*Brassica* spp.), filaree (*Erodium cicutarium*) and *Plantago* spp. replaced the previous plant cover, *C. tenellus* were able to reach huge populations causing an increase in impacts of BCTV. Using this idea in reverse, the replanting of 100,000 ha in Idaho with *Agropyron cristatum*, on which *C. tenellus* does not reproduce, has anecdotally reduced the populations of the vector and reduced losses to sugar beet by over $1 million per annum (Wisler & Duffus, 2000).

Monitoring for the presence of vectors such as *C. tenellus* is important. As leafhoppers are often found on the undersides of leaves and petioles and are disturbed easily, using a sweep net is a quick, easy and cheap way of assessing population levels. This can also be done using yellow sticky taps placed in the crop (CABI, 2021). Other methods include using inverted leaf blowers with a fine mesh sleeve fitted, but this may have higher cost implications (Rondon & Murphy, 2016).

Biological control

There are currently no commercially available biological controls for BCTV.

CABI (2019b) lists the following as natural enemies of *C. tenellus – Anagrus atomus, A. nigriventris, Aphelinoidea turanica, Erynia radicans* and *Gonatocerus capitatus*. Of these, *A. atomus* and *E. radicans* are both present in the UK, and *A. atomus* appears to have previously been available for use commercially, although none of the mentioned products could be found. None of the other species are listed as available for use as a non-native biological control agent in the UK (Defra, 2022).

Chemical control

There are no chemical controls available for BCTV.

Insecticide control of *C. tenellus* has been an important control measure in the USA since the introduction of the Curly Top Virus Control Programme in 1943. This has included aerial spraying of vast amounts of non-crop areas (EFSA, 2015). At the time of publication, Wisler & Duffus (2000) reported that the estimated cost of spraying (malathion) for control of *C. tenellus* in California was $1.3 million. There are also issues around the environmental costs with respect of the wide scale insecticidal sprays, and despite the measures there are still occasional outbreaks (EFSA, 2015).

Seed treatments may be considered more important, especially given the susceptibility of young plants of resistant cultivars to BCTV infection (Wang *et al.*, 1999; Strausbaugh *et al.*, 2017). Neonicotinoid seed treatments are used frequently in the USA, and various field studies have shown their use can provide effective control and increase yield in comparison to untreated crops (Strausbaugh *et al.*, 2006; 2014; 2016). They may also provide some benefit in reducing unintended effects in comparison with foliar applications (CABI, 2021a).

One of these studies combined the seed treatment with a foliar treatment, applied before and after the release of viruliferous *C. tenellus*. The seed treatments (Poncho, Poncho Beta and Poncho Votivo) reduced symptoms by 26-42% and the pyrethroid foliar applications (Asana and Mustang) reduced symptoms by 22-56%. The authors conclude that the seed treatment provides a good mitigation against the infection of young plants whilst the foliar insecticides can extend the treatment through the midseason period (Strausbaugh *et al.*, 2014). These pesticides are not available for use in the UK.

The EFSA pest categorisation (2015) suggests that systemic insecticide applications are more effective for the control of *C. tenellus* than contact-based applications, but there are many variables which can affect the treatment. This is backed up by studies by Hammon & Franklin (2012) who assessed the percentage of BCTV infection on field grown tomatoes which were given a foliar treatment, a soil injection treatment or left untreated. Both foliar and soil treatments were made using the active ingredient dinotefuran and in all the tomato varieties tested, the soil treatment had the lowest percentage of BCTV seen.

Impacts

Damage from direct feeding of *C. tenellus* is relatively minor, but the transmission of BCTV to sugar beet crops can result in significant impacts (EFSA, 2015; Natwick, 2016). Due to this, the impact section will focus solely on the impacts of BCTV.

Economic impact

The majority of economic impacts are reported from the USA, whereas BCTV reports from countries bordering the Mediterranean and in the Middle East suggest the virus causes minor losses in sugar beet crops (EPPO, undated; Briddon *et al.*, 1998), aside from reports of up to 50% losses in sugar beet crops from Türkiye (Ağca & Yeşil, 2019).

These reported impacts are mostly from crops of sugar beet and tomato, although a range of other crops are also affected such as chilli and basil with the former having reported losses of up to 50% in New Mexico (EFSA, 2017).

Sugar beet

Around 20% of global sugar production comes from sugar beet (Ağca & Yeşil, 2019), and losses due to BCTV can be severe, with seedlings being killed off and mature plants suffering dwarfing, leaf distortions and chlorosis, blistering and swelling of the veins, reducing the vitality of the plant and reducing the marketable yield (EFSA, 2015). This is exacerbated by the virus also affecting the sugar content of both susceptible and resistant cultivars (EPPO, undated).

In semiarid regions such as the western USA, it is considered a serious yield-limiting disease (Strausbaugh *et al.*, 2017), with much of the damage seen in the 1900s attributed to the importation of seed from Europe due to convenience and lower costs. As BCTV was not present in Europe, the plants were highly susceptible to the disease resulting in high losses. This almost eliminated sugar beet production in the western USA in the 1920s-1930s (Strausbaugh *et al.*, 2017) and, subsequently, emphasis was put on domestic seed production which increased yield and resulted in the production of curly top resistant seed (Harveson, 2015).

Currently the use of low to intermediate resistant cultivars and neonicotinoid treated seed provides effective control in the USA. However, much of the production area remains at high risk from strains of BCTV. Losses from BCTV are in the millions on an annual basis, and if noenicitinoids were withdrawn from use, it is assumed that losses in the western states would be unsustainable (WAAESD, 2021).

Tomato

Economic losses can also be severe in tomato crops due to plant death, reduced vigour and the premature ripening of fruit with an odd taste (Heflebower *et al.*, 2008; EPPO, 2022b).

One of the most severe outbreaks in the USA was in 2013 when over 1 million tons of field grown tomatoes were affected, resulting in losses of around $100 million. This was attributed to the spinach curly top strain of BCTV (Chen *et al.*, 2017).

Environmental impact

The 2017 EFSA report notes that the virus can infect common weeds such as *Amaranthus* spp. and *Chenopodium* spp. In addition, as the virus is polyphagous it may infect a range of wild species. However, no significant environmental impacts are noted in the literature and this is reflected in the UK Plant Health Risk Register environmental impact score of 1 out of 5.

Infections in the wider environment may provide a further source of inoculum which allows for the re-infection of crops (EFSA, 2017). Control of this to manage BCTV infections in commercial crops could have environmental impacts.

Social impact

There are potential social impacts on gardeners and allotment holders who may be affected by the broad host range of the virus. In the USA the disease is often troublesome in these environments due to the presence of alternate hosts and an increased likelihood of infected source plants (Goldberg & Lujan, 2021).

In addition to this there may be an impact for agricultural/horticultural workers if production sites are affected and there are subsequent knock-on effects for jobs.

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