Department
for Environment
Food & Rural Affairs

Pest specific plant health response plan:

Outbreaks of *Anthonomus eugenii*

Figure 1. Adult *Anthonomus eugenii*. © Fera Science Ltd

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Executive summary

Background	
Regulation	GB Quarantine pest
Key Hosts (2.2)*	Peppers
Distribution	Belize, Canada, Costa Rica, Dominican Republic, El Salvador, French Polynesia, Guatemala, Honduras, Jamaica, Mexico, Nicaragua, Panama, Puerto Rico, USA
Key pathways	Produce
Industries at risk	Protected crops of key hosts
Symptoms (2.3)	Fruit: deformation, discolouration, browning of the core, premature ripening and abscission of the developing fruit. Wounds created by adult feeding and oviposition also facilitate the entry of the fungus *Alternaria alternata*, which can develop internally and cause fruit rot .
Surveillance	
Demarcated zones (5.36)	Infested zone = Defined infested area e.g., glasshouse Buffer zone = ≥ 1 km
Surveillance activities (5.27-30)	• Visual surveys of fruit. • Yellow sticky trapping.
Response measures	
Interceptions (5.1-5.8)	• Destruction via deep burial or incineration. • Visual surveys of production sites if intercepted inland. • Tracing exercises are carried out where required
Outbreaks (5.40-5.50)	• Foliar insecticide treatment of plants • Removal and destruction of fruit • Destruction of infested plants. • Post-crop clean up measures. • Host crop free period with monitoring carried out.
Key control measures	
Biological	N/A
Chemical	A treatment regime will be developed in consultation with the nursery or grower
Cultural	Removal of infested fruit, sticky traps, good hygiene
Declaration of eradication	
Anthonomus eugenii can be declared eradicated if it has not been found for six months after the infested crop is removed.	

* 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 *Anthonomus eugenii* (pepper weevil) is discovered.

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 *A. eugenii* being detected in their territories.

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

1.4. The aims of this response plan are to facilitate the containment and eradication of *A. eugenii* and to make stakeholders aware of the planned actions.

2. Summary of threat

2.1. From its probable origin in Mexico, *A. eugenii* has spread to Central America and the Caribbean, the southern states of the USA, and to French Polynesia and Hawaii (CABI, 2018). The beetle was also introduced into Canadian protected pepper crops in 1992 and 2009/2010 (EPPO, 2019), into Dutch protected pepper crops in 2012 (EPPO Reporting Service, 2012), and into both protected and field pepper crops in Italy in 2013 (EPPO Reporting Service, 2014a). *Anthonomus eugenii* has since been eradicated from Canada, Italy and the Netherlands (EPPO Reporting Service, 2014a, b, 2019; EPPO, 2019).

2.2. The main hosts of *A. eugenii* are *Capsicum* spp., and include *C. annuum* (sweet), *C. frutescens* (chilli pepper) and wild *Capsicum* spp. (EPPO, 2019). Other known solanaceous host plants for the larval stages include *Solanum melongena* (aubergine), *Physalis philadelphica* (tomatillo), and wild solanum species (Patrock and Schuster, 1992; Capinera, 2017). In addition, adults may feed on *Datura stramonium* (jimsonweed), *Nicotiana alata* (sweet scented tobacco), *Calibrachoa parviflora*, *Physalis pubscens* (hairy groundcherry), and *Solanum lycopersicum* (tomato), but oviposition and development has not been recorded on these species (Elmore *et al.*, 1934; Patrock and Schuster, 1992).

2.3. Larvae feed inside flower buds and developing fruit on the seeds and other tissues and this can cause fruit deformation, discolouration, including browning of the core, and premature ripening and abscission of the developing fruit (Capinera, 2017). Wounds created by adult feeding and oviposition also facilitate the entry of the fungus *Alternaria alternata*, which can develop internally and cause fruit rot (Bruton *et al.*, 1989).

2.4. Significant yield losses as a result of damage caused by the weevil have been reported on several occasions from North America (Elmore *et al.*, 1934; Costello and Gillespie, 1993; Riley and King, 1994; Riley and Sparks, 1995). The time and monetary costs associated with the implementation of weekly spraying programmes to control *A. eugenii* have also been considerable (van der Gaag and Loomans, 2013).

2.5. While *Capsicum* and *Solanum* plants for planting (e.g. aubergine and wild *Solanum* plants) present a possible pathway, solanaceous plants for planting from third countries other than Albania, Algeria, Andorra, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Canary Islands, Egypt, EU Member States, Faroe Islands, Georgia, Iceland, Israel, Jordan, Lebanon, Libya, Liechtenstein, Moldova, Monaco, Montenegro, Morocco, North Macedonia, Norway, parts of Russia, San Marino, Serbia, Switzerland, Syria, Tunisia, Turkey and Ukraine are prohibited from entry into GB. None of the exempt countries are included in the distribution of *A. eugenii*. The more likely pathway of introduction is through the trade in *Capsicum* and *Solanum* spp. fruit from territories where the weevil is known to occur, and then the subsequent movement onto nearby *Capsicum* crops or other suitable host plants. In 2014, EU measures were introduced requiring that fruit of *Capsicum* from countries where the weevil is distributed must either come from a pest free area or a pest free place of production, but the weevil has still been intercepted on numerous occasions in *Capsicum* fruit. These measures have been retained in GB legislation.

2.6. As of October 2021, *Anthonomus eugenii* has been intercepted 18 times since September 2014 in the UK, and all the findings were in *Capsicum* fruit arriving from Mexico (12 times) and the Dominican Republic (6 times). In most instances, these interceptions were as larvae and pupae inside fruit, but also on a number of occasions, these interceptions were as live and active adults outside of fruit.

3. Risk assessments

3.1. *Anthonomus eugenii* has an unmitigated and mitigated UK Plant Health Risk Register score of 36 and 24, 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=13339).

3.2. Pest risk analyses have been carried out by Canada, the Netherlands and the UK (Ameen, 2010; Baker *et al.*, 2012; van der Gaag and Loomans, 2013).

3.3. These analyses concluded that *A. eugenii* has the potential to establish and cause significant economic damage to protected pepper crops, because the weevil's biology and cryptic nature make it difficult to control.

4. Actions to prevent outbreaks

4.1. *Anthonomus eugenii* 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. There are also further pest specific requirements in Schedule 7.

4.2. *Anthonomus eugenii* is an EU Quarantine Pest (Annex II Part A) and is therefore prohibited from being introduced into, or spread within the Union Territory.

4.3. *Anthonomus eugenii* is an EPPO A1 listed pest and is therefore recommended for regulation by EPPO member countries.

4.4. The Plant Health Service (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 *A. eugenii*. It is important that capabilities in detection, diagnosis, and risk management are available.

5. Response

Official action to be taken following the suspicion or confirmation of *Anthonomus eugenii* on imported plants, including fruit

5.1. If *A. eugenii* is suspected by the Animal and Plant Health Agency, Plant Health and Seeds Inspectorate (APHA PHSI) to be present in a consignment moving in trade, the PHSI must hold the consignment until a diagnosis is made. Ideally, the consignment should be placed in a sealed cold store and any opened containers should be resealed (which could be via wrapping in plastic if this facility is available). Other consignments 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. Larvae can be cannibalistic and should therefore be sent individually. Absorbent paper should also be included with samples where possible, as larvae can drown in the fluid from the fruit.

5.3. When an infestation of *A. eugenii* is confirmed, the PHSI should advise the client of the action that needs to be taken by way of an official plant health notice. The consignment should be double bagged and destroyed by either incineration or deep burial.

5.4. Where there is a high risk of escape before destruction, fumigation may be used under guidance from the Defra Risk and Horizon Scanning team.

5.5. A UKPHINS (UK Plant Health Interception Notification Scheme) notification should be made upon confirmation of an interception of live *A. eugenii*. 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 intercepted inland, any host plants (including any fruit, which should be held) should be surveyed on the site and in the immediate vicinity in the summer (with fruit released if found free) and again in the following year for signs of pest presence. When a site is in an area where hosts are grown, a survey of protected environments should be established within 1 km of the infested site. The size of the survey area will be influenced by the local climatic and meteorological conditions, and the density of host crops. Waste disposal processes and areas should also be inspected to ensure best practice is followed.

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

5.8. A pest factsheet to raise awareness of *A. eugenii* and its symptoms should be distributed to packers/processors and importers where *A. eugenii* has been found, and to those in the local area and those associated with the infested premises. The pest factsheet can be found on the Plant Health Portal - https://planthealthportal.defra.gov.uk/assets/factsheets/anthomonus-eugenii-jan-2016.pdf.

Official action to be taken following the suspicion of an *Anthonomus eugenii* outbreak

5.8. Suspect outbreaks will be assessed on a case by case basis. An Outbreak Triage Group (OTG), chaired by the Chief Plant Health Officer (CPHO) or their deputy and including specialists from APHA, Defra and other organisations, should be set up to assess the risk and decide on a suitable response at strategic and operation levels.

Where appropriate, the OTG will also decide who will be the control authority, and the control authority will then nominate an Incident Controller. An Incident Management Team (IMT) meeting, chaired by the Incident Controller, will subsequently convene to produce an Incident Action Plan (IAP) to outline the operational plan. See the *Defra Generic Contingency Plan for Plant Health in England* for full details.

5.9. The OTG will set an 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, a suspected infestation of *A. eugenii* in a protected pepper crop is likely to be given a black alert status. A black alert status refers to a plant pest with potential for limited geographical spread leading to moderate economic, environmental or social impacts.

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

5.10. When *Anthonomus eugenii* is found in association with plants for planting, fruit and flowers of its host plants, these should be prevented from leaving the site, other than for destruction by deep burial, incineration or another approved method.

5.11. There is potential for the weevil to be carried on material, equipment and machinery, and therefore the movement of such items between infested and non-infested areas should be restricted. If, however, movement of any such items is necessary, they should be thoroughly cleaned at the designated outbreak site to remove any life stage of *A. eugenii*.

5.12. The movement of personnel into an infested area such as a glasshouse should be restricted, especially during the early investigation phase and/or if *A. eugenii* is detected. Personnel should be briefed on the importance of good hygiene practice to reduce the risk of carrying the weevil to other areas of the production facility.

Precautionary measures

5.13. The infested area and other areas potentially at risk should be sealed as far as practically possible to prevent the escape or further spread of *A. eugenii*.

5.14. Given the potential for the weevil to be physically transferred, best hygiene practice should be followed as below:

5.15. Staff should be trained in advance to recognise the symptoms of an *A. eugenii* infestation.

5.16. Disposable protective garments (including overshoes) should be available and worn when working on an infested lot and these should be appropriately disposed of after use or left in the infested area for future use prior to eventual disposal.

5.17. Wherever possible, work should be carried out within uninfested areas, before working in areas that could be infested.

5.18. The movement of equipment and machinery between locations should be avoided when possible. If equipment and machinery must be moved between locations, it must first be thoroughly cleaned using high water pressure, steam cleaners etc.

5.19. Access to the working area should be restricted to essential trained staff only. Wherever possible, staff should work in the same areas or number of rows each day and there should be a sign in/sign out sheet to record all movements.

5.20. Volunteer plants and weeds, particularly wild *Solanum* species, may act as reservoirs for *A. eugenii*. Controlling these plants within and around glasshouses reduces the chance of the crop becoming infested and reduces the risk of survival and persistence of the pest in the event of an outbreak. Volunteer plants and weeds can be controlled mechanically (e.g. hoeing), chemically (e.g. herbicides), and manually (e.g. roguing).

5.21. All fallen fruit and other debris that may harbour the weevil should also be regularly removed and destroyed.

Preliminary trace forward / trace backward

5.22. If an infested consignment is considered as being the source of the suspect outbreak, investigations regarding the origins of infested consignments will be undertaken to locate other related and therefore potentially infested consignments of products moving to and from the site. If applicable the relevant NPPO should be contacted.

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

Confirming a new outbreak

How to survey to determine whether there is an outbreak

5.24. Information to be gathered by the PHSI on the suspicion of an infestation of *A. eugenii*, in accordance with ISPM 6; guidelines for surveillance (http://www.acfs.go.th/sps/downloads/13717_ISPM_6_E.pdf):

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

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

5.26. 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

5.27. Fruit should be visually inspected for oviposition punctures (difficult to detect), exit holes, discoloration and deformation. Premature ripening and early abscission of developing fruit are also indicative of the weevil infestation. Fruit suspected to be infested should be cut open and inspected for the presence of larvae, pupae, adults and feeding damage.

5.28. Adults are mobile and should be looked for on all parts of the host plants.

5.29. Yellow sticky traps are commonly used to detect the pepper weevil, and these are often accompanied by a lure; adults are attracted to host plant volatiles, feeding damage and/or the male's aggregation pheromone (Eller *et al.*, 1994; Addesso and McAuslane (2009), Addesso *et al.*, 2010). Yellow sticky traps with a two component lure are sold by Great Lakes IPM (https://www.greatlakesipm.com/monitoring/ready-to-use-kits/row-amp-field-crops/gltr442408-trece-pherocon-pepper-weevil-pew-kit-8-station). It is suggested that trap lures are replaced every four weeks and that traps should be deployed at a minimum rate of one trap per ha. In the Netherlands, 10 traps were set up per ha when they had an outbreak of the weevil (van der Gaag and Loomans personal communication 2019). Pepper weevil lures are also sold by Alpha Scents, Inc. (https://www.alphascents.com/pepper-weevil-lure.html). Pheromone based traps have been found to be less effective in a crop that are in bloom (van der Gaag and Loomans, 2013).

5.30. Following the capture/putative identification of an adult, pupa, larva, and/or symptoms of the weevil, samples should be sent for confirmatory diagnosis as in point 5.1-5.2. Each sample should be labelled with full details of the sample number, location (including grid reference if possible), variety, and suspect pest.

Diagnostic procedures

5.31. There are no morphological characters that can be used to specifically identify this species in any of its life stages. This is because the genus *Anthonomus* is a vast and diverse group of weevils that are not all completely known. In addition, other weevil species of the same size do occur on the same hosts as *A. eugenii*. As a consequence, DNA sequencing is used to provide confirmed diagnoses.

Criteria for determining an outbreak

5.32. If *A. eugenii* 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 if the weevil is found across multiple lots in a glasshouse or packhouse, then an outbreak should be declared.

Official Action to be taken following the confirmation of an outbreak

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

Communication

5.34. The IMT will assess the risks and communicate details to the IPPC, EU 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.

5.35. A pest factsheet to raise awareness of *A. eugenii* and its symptoms should be distributed to packers/processors and importers where *A. eugenii* has been found, and to those in the local area and those associated with the infested premises. The pest factsheet can be found on the Plant Health Portal - https://planthealthportal.defra.gov.uk/pests-and-diseases/pest-and-disease-factsheets/notifiable-pests/.

Demarcated zones

5.36. Once an outbreak has been confirmed, a demarcated area should be established that includes:

- A **defined infested zone** (i.e. the infested glasshouse)
- A **buffer zone**, which should extend out to at least 1 km from the infested zone, but may extend out further. The size of the buffer zone will be influenced by the local climatic and meteorological conditions, and the density of host crops. The buffer zone may include other premises in which staff/growers have visited or worked in, premises in which stock has been sent or received, and/or any other premises where there is a perceived risk.

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

5.38. All host plants under protected conditions in the infested and buffer zones should be visually inspected and any suspect samples should be sent for diagnosis. Yellow sticky traps with lures should also be used as described in point 5.29. Any host plants outdoors in the vicinity of protected host crops should also be surveyed, as they could act as a reservoir for the beetle.

5.39. The demarcated area should be adjusted in response to further findings. If *A. eugenii* is found within a glasshouse outside of the infested zone, this should subsequently be designated as infested and the buffer zone changed accordingly.

Pest Management procedures

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

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

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

- If the crop is organic, pesticides will still have to be used if the situation demands it.

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

- The weevil is difficult to control using insecticides, as the majority of its lifecycle is protected within the fruit (Ostojá-Starzewski *et al.*, 2016). Insecticides can still have some effect, however, when the adults leave the fruit to feed and mate. Use of contact insecticides requires good coverage of the foliage, buds, flowers and fruit.

- Visual inspection and pheromone yellow sticky traps should be used to assess the efficacy of insecticide treatments.

5.41. Following insecticide use, immature fruit, and ideally all fruit, should be removed and destroyed by incineration or deep burial to reduce the population of the weevil and minimise the risk of spread when the whole crop is removed.

5.42. All susceptible host crops in the glasshouse should then be removed and destroyed by incineration or deep burial, including volunteers, weeds and waste. If possible, host crops in the vicinity of the glasshouse (e.g. out to 50 m) should also be treated and destroyed. If there is a large volume of material, plants could be shredded first to reduce the population and minimise the risk of spread. In the Netherlands, crops were removed at night (when adults are less likely to be mobile) to further minimise the risk of spread (van der Gaag and Loomans, 2013). In exceptional circumstances, there may be justification not to remove the whole crop, but this should be decided by the IMT.

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

5.44. No host plants should be grown in the infested glasshouse for a period covering the lifespan of adult *A. eugenii* in the absence of host plants. This will depend on the climatic conditions within the glasshouse, particularly the temperature. If possible, the temperature should be raised to speed up the lifecycle of the beetle. In the Netherlands, the glasshouse was left for two weeks at ~ 20°C (van der Gaag and Loomans personal communication 2019). Pheromone yellow sticky traps should be used to monitor the empty glasshouse.

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

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

5.46. The following should be designated as infested:

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

5.47. As in 5.36, a buffer zone should be created that extends out to at least 1 km from the infested glasshouse.

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

5.49. Refer to the pest management procedures section if *A. eugenii* is found in a glasshouse.

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

5.50. If no infestation is found in host crops growing in the buffer zone following surveillance, they should continue to be monitored with the use of pheromone yellow sticky traps and there should be a crop-free period between crops. A programme of foliar insecticides until harvest is also advised. The programme of foliar insecticide treatments should be within legally specified safe use guidelines and compatible, where possible, with any existing biological control programmes.

Disposal plan

5.51. When deciding on the most appropriate method(s) of disposal, several factors such as the likelihood of *A. eugenii* adults being present, the level of handling and transportation required and climatic conditions 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, treatment or disposal. This may include keeping the distance of travel to a minimum. Material that can be moved safely should be destroyed by incineration at a licensed facility (if in small quantities) or by deep burial. Disposal and/or destruction should be under the approval of the PHSI, with any supervision decided on a case by case basis. If the material has to be moved off the premises, it should be contained within at least two layers if possible, and placed in a sealed vehicle for transport. Deep burial may be done at an approved landfill site, on the outbreak site or another suitable site nearby, but only in agreement with the local Environment Agency. Incineration must comply with appropriate waste management regulations i.e. as specified by the Environment Agency in England.

5.52. Other viable methods of destruction should be agreed by the IMT.

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

6. Criteria for declaring eradication / change of policy

6.2. *Anthonomus eugenii* can be declared eradicated (by the Chief Plant Health Officer) if it has not been found for six months after the infested crop is removed.

7. Evaluation and review of the contingency plan

7.1. This pest specific contingency plan should be reviewed regularly in order to consider any 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 *A. eugenii* or other pest), including what went well and what did not. These should be included in any review of the contingency plan leading to continuous improvement of the plan and response to outbreaks.

8. Appendix A

Data sheet for Anthonomus eugenii

Identity

PREFERRED SCIENTIFIC NAME	AUTHOR (taxonomic authority)
Anthonomus eugenii	Cano, 1894

CLASS: Insecta
ORDER: Coleoptera
SUBORDER: Polyphaga
SUPERFAMILY: Curculionoidea
FAMILY: Curculionidae
SUBFAMILY: Curculioninae

SYNONYMS
Anthonomochaeta aeneotinctus (Champion, 1894)
Anthonomus aeneotinctus (Champion, 1903)

COMMON NAMES
Pepper weevil (English)
Paprikarüssler (German)
Pfefferkäfer (German)
Barrenillo del Chile (Spanish)
Picudo del Chile (Spanish)
Biber goz kurdu (Turkish)

Notes on taxonomy and nomenclature

The genus *Anthonomus* contains many serious plant pests, including the boll weevil and the strawberry blossom weevil. It is a large genus of more than 749 species (Ostojá-Starzewski *et al.*, 2016). Fifty-eight of these species are found in the Palaearctic region and 13 occur naturally in the British Isles (Ostojá-Starzewski *et al.*, 2016).

Biology and ecology

Life history

Adults usually spend the winter on weeds, such as wild *Solanum* spp., and old pepper plants (CABI, 2018). The overwintering adults do not diapause but are still able to survive for 10 months (CABI, 2018). The adults feed throughout the year on buds, blossoms, fruit and leaves (Patrock and Schuster, 1992; Baker *et al.*, 2012; van der Gaag and Loomans, 2013).

Within 2 days of mating, females begin to lay eggs (Ostojá-Starzewski *et al.*, 2016). Females lay eggs singly within immature fruit, flower buds, and occasionally open flowers, mature fruit, and stalks (Patrock and Schuster, 1992; Ostojá-Starzewski *et al.*, 2016). Within fruit, females show a preference towards the upper portion of the fruit, particularly the calyx and peduncle (Seal and Martin, 2016). It is speculated that the calyx may be easier for the adults to lay eggs into and heals quicker following egg laying (Toapanta *et al.*, 2005). The puncture wounds created by egg laying are sealed by an anal secretion produced by the females (Elmore *et al.*, 1934). Over their oviposition period, which is around 51 days, females can oviposit between 340 and 600 eggs (Toapanta *et al.*, 2005; Ostojá-Starzewski *et al.*, 2016).

Larvae hatch from eggs within 2.5 – 5 days (Burke and Woodruff, 1980). Emerging larvae are aggressive and, within the majority of buds and fruit, only one larva will survive (Ostojá-Starzewski *et al.*, 2016). Although, large fruit may be able to support more than one larva in some cases (Ostojá-Starzewski *et al.*, 2016). The weevil has three larval instars, which feed on seeds and other tissue within the buds and fruit, and develop in around 6 – 12 days (Elmore and Campbell, 1951; Burke and Woodruff, 1980; Costello and Gillespie, 1993). Mature larvae form a pupal cell within the bud or fruit from their anal secretions, and pupate (Ostojá-Starzewski *et al.*, 2016). Pupation often lasts between 3 and 6 days (Burke and Woodruff, 1980). Adults eclose inside the bud or fruit, and feed for several hours or days before emergence (Riley and Sparks, 1995). Newly emerged adults are light brown and darken to greyish black after 2-3 days (Riley and Sparks, 1995).

The length of the lifecycle varies between 12.9 days at 30°C and 41.8 days at 15°C on Jalapeno pepper (Toapanta *et al.*, 2005). Based on these development times, Toapanta *et al.* (2005) was able to estimate that the weevil has a lower developmental threshold of 9.6°C and a day degree requirement of 256.4 days. In subtropical areas, this allows the weevil to complete 5 – 8 generations per year (van der Gaag and Loomans, 2013).

The lifecycle of the weevil at 21°C is illustrated below (Figure 2).

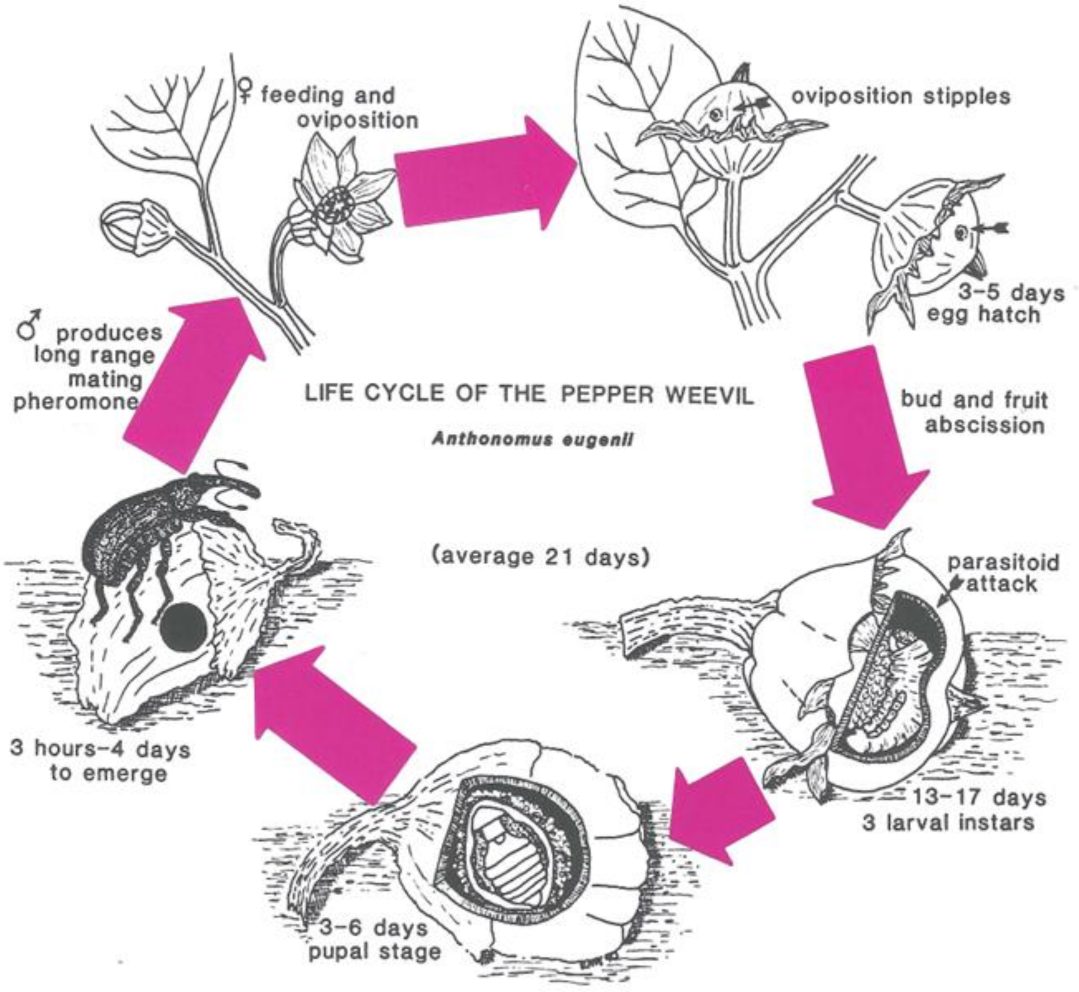

Figure 2. Life cycle of *Anthonomus eugenii* at 21°C (Riley and Sparks, 1995).

Chemical cues

Long range cues

Adults are attracted to volatiles of their host plants and those of plants that they feed on, but do not oviposit on, such as tomato. This suggests that there are further contact or short-range cues involved in the acceptability of host plants for oviposition (Addesso and McAuslane, 2009). Young females (2 days old) have also been shown to be attracted to lima bean, a plant which is neither used for oviposition or feeding, though this may be explained by young females having undeveloped neural receptors that are not yet sensitive enough to differentiate between volatile mixes (Addesso and McAuslane, 2009).

Attraction to host plant volatiles is enhanced by feeding damage, particularly when adults are actively feeding on the plants (Addesso *et al.*, 2010). This could either be due to an increase in host plant volatiles emitted or due to a qualitative difference between volatile profiles (Addesso *et al.*, 2010). Adults preferred plants that had been fed on for two days rather than plants that had only been fed on for one hour, likely as a result of attraction to compounds induced after one hour, and also preferred damaged fruit over damaged flowers (Addesso *et al.*, 2010). Fruit may be preferred as they are larger and last longer than flowers on a plant when damaged (Addesso *et al.*, 2010).

The final long range cue that has so far been identified is the male aggregation pheromone, which is composed of six male-specific compounds: (*Z*)-2-(3,3-dimethylcyclohexylidene) ethanol, (*E*)-2-(3,3-dimethylcyclohexylidene) ethanol, (*Z*)-(3,3-dimethylcyclohexylidene) acetaldehyde, (*E*)-(3,3-dimethylcyclohexylidene) acetaldehyde,(*E*)-3,7-dimethyl-2,6-octadienoic acid (geranic acid), and (*E*)-3,7-dimethyl-2,6-octadien-1-ol (geraniol) (Eller *et al.*, 1994). The aggregation pheromone is produced throughout a male's life, though is less pronounced in the first few days and towards the end of their life (21 days onwards), and is primarily produced during the photophase (light period), particularly just after noon, before tailing off towards dusk (Eller and Palmquist, 2014). Interestingly, the amount of pheromone released per male is reduced in groups of males (Eller and Palmquist, 2014). Only males and virgin females are attracted to this pheromone, whereas mated females are not, as they are primarily searching for an oviposition site (Addesso *et al.*, 2010).

Short range cues

Addesso *et al.* (2007) have shown that the anal secretion used to plug up oviposition wounds acts as a deterrent to other *A. eugenii* weevils, despite only covering 0.01-0.04% of the fruit. There are some adults that ignore this cue, however, but this could be due to an inability to detect the cue, adults with a higher egg load being less discriminatory, there being a lack of egg free plants, and/or a loss of sensitivity due to repeated exposure.

Hosts/crops affected

The main hosts of *A. eugenii* are *Capsicum* spp., including *C. annuum* (sweet pepper), *C. frutescens* (chilli pepper) and wild *Capsicum* spp. (EPPO, 2019). Other solanaceous plants, such as *Solanum melongena* (aubergine), *Physalis philadelphica* (tomatillo), and wild solanum species, are also recorded as hosts (Patrock and Schuster, 1992; Capinera, 2017;). In addition, adults may feed on *Datura stramonium* (jimsonweed), *Nicotiana alata* (sweet scented tobacco), *Calibrachoa parviflora*, *Physalis pubscens* (hairy groundcherry), and *Solanum lycopersicum* (tomato), but oviposition and development has not been recorded on these species (Elmore *et al.*, 1934; Patrock and Schuster, 1992).

Plant stage affected

Anthonomus eugenii affects the plant during fruit production and destroys seeds.

Plant parts affected

Fruit and seeds.

Symptoms/signs - description (Ostoja-Starzewski *et al.*, 2016)

Adults will feed on the aerial parts of the host creating small circular or oval feeding punctures (2-5mm across). On leaves these punctures could be mistaken for slug or caterpillar damage and on fruits they appear as a dark speckling. The larvae develop and feed inside flower buds and fruits, consuming both the seeds and flesh. As they feed both adults and larvae can cause yellowing followed by bud and fruit drop, fruit distortion and premature ripening. Laval feeding activity within larger fruit often results in the core becoming brown and mouldy. In addition punctures can allow the entry of the fungus *Alternaria alternata*, resulting in further damage

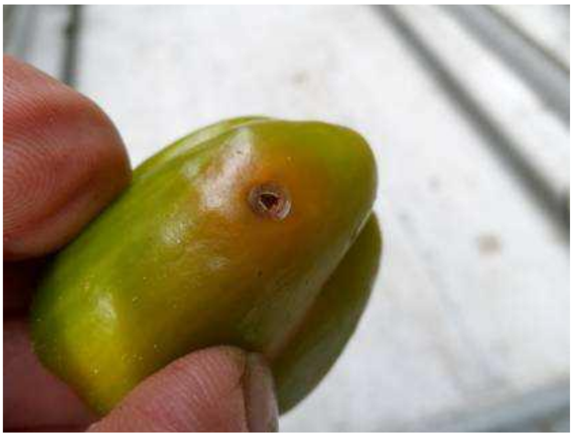

Figure 3. Adult exit hole on pepper fruit. NVWA.

Figure 4. Larval damage in pepper fruit. *John L. Capinera, University of Florida, http://edis.ifas.ufl.edu/pdffiles/IN/IN55500.pdf*.

Detection and inspection methods

Fruit can be visually inspected for oviposition punctures and exit holes, although these are difficult to detect. Discoloration, deformation, premature ripening and early abscission of developing fruit and flower buds are the most obvious signs of the weevil infestation (Capinera, 2017; CABI, 2018).

Yellow sticky traps are commonly used to detect the pepper weevil. Yellow is preferred over other colours, including light and dark green, red, grey, blue and black (Segarra Carmona and Pantoja, 1988). If traps are used in field crops, they are best placed 10 – 60 cm above the soil, where one 375 cm^2 trap can catch as many weevils as can be detected by inspecting 50 buds (Capinera, 2017). Yellow sticky traps may also be improved with lures. Muniz-Mereno *et al.* (2014) has demonstrated that weevils of both sexes are attracted to a combination of host volatiles ((Z)-beta-ocimene, D-limonene and 2-isobutyl-3-methoxypyrazine). The addition of either (Z)-3-hexenyl acetate or terpinolene further increased the attractiveness of the combination to both males and females, while the addition of (E)-beta-ocimene increased the attractiveness of the combination to males. In the same study, males showed an increased response to a mixture of host volatiles together with the aggregation pheromone.

Morphology

Egg: White in colour when first laid, before turning yellow (Capinera, 2017). It is oval in shape and is approximately 0.53 mm in length and 0.39 mm wide (Capinera, 2017). Eggs cannot be identified. Image provided by Seminis, 2019.	
Larva: White or yellow to grey, with a yellow-brown head and dark mouthparts (CABI, 2018). It lacks thoracic legs, but it has a few large hairs or bristles (Capinera, 2017). The first instar is about 1 mm in length, the second is about 1.9 mm in length, and the third is about 3.3 mm in length (Capinera, 2017). Image provided by Lyle Buss UF/IFAS.	
Pupa: It resembles the adult in form, but the wings are not yet developed and the rostrum (snout) is held under the body (Ostojá-Starzewski *et al.*, 2016). Initially white in colour, before darkening to yellow-brown with brown eyes (Capinera, 2017). Large setae (hairs) are found across the head, prothorax and abdomen (CABI, 2018). Image provided by Lyle Buss UF/IFAS.	
Adult: The body is dark brown to black in colour, and is covered in yellow scale like hairs (Ostojá-Starzewski *et al.*, 2016). The body is arched and has a long rostrum that is approximately 1.5 mm in length (Capinera, 2001; Ostojá-Starzewski *et al.*, 2016). Antennae are expanded at the tips (Capinera, 2017). Adults are 2-3.5 mm in length, and 1.5-1.8 mm in width (Capinera, 2017). Image provided by Fera Science Ltd.	

Distribution

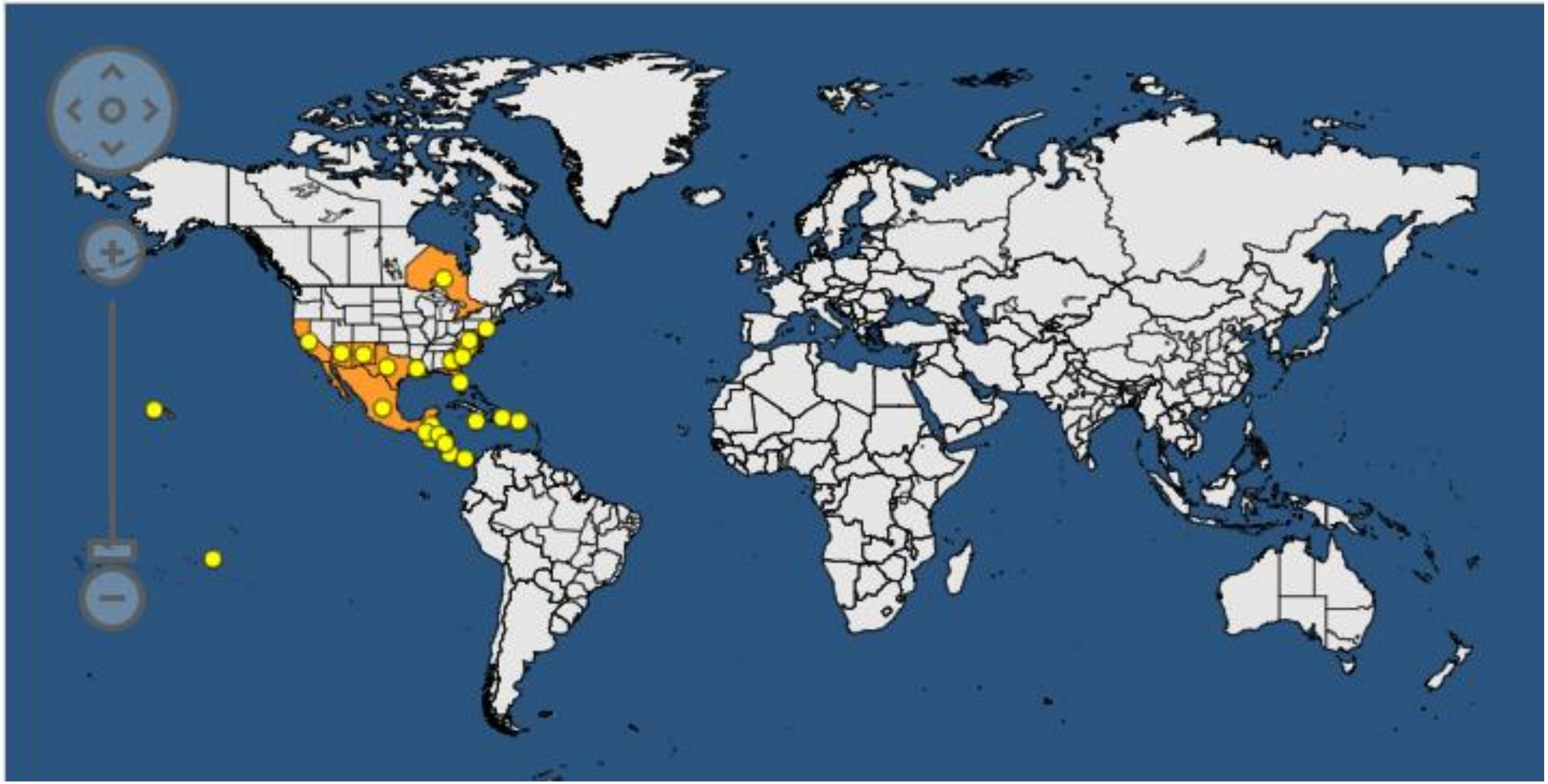

Figure 5. *Anthonomus eugenii* distribution as of October 2021. (Source: EPPO Global database). The link below provides up to date distribution data

https://gd.eppo.int/taxon/ANTHEU/distribution

History of introduction and spread

Global spread

From its probable origin in Mexico, the beetle has since spread to Central America and the Caribbean, the southern states of the USA, French Polynesia and Hawaii. It was also introduced into Canadian protected pepper crops in 1992 and 2009/2010, but these outbreaks were eradicated (Costello and Gillespie, 1993; EPPO, 2019). More recently, the beetle has been introduced into Europe; in the Netherlands in 2012, and Italy in 2013 (EPPO Reporting Service 2012, 2014b).

Netherlands

In July 2012, the beetle was observed in one pepper glasshouse in Westland (Zuid-Holland), and in three nearby glasshouses during follow up surveys (EPPO Reporting Service, 2012). Small and prematurely aborted fruit were observed in the affected glasshouses (EPPO Reporting Service, 2012). Eradication measures were subsequently applied, including the application of pesticides, the destruction and removal of affected plants and associated growing medium, and surveillance out to 1 km from the infested zone (EPPO Reporting Service, 2012).

In January 2013, the beetle was found in two further glasshouses, and surveillance efforts were increased, with a buffer zone of 2.5 km used (EPPO Reporting Service, 2014c; van der Gaag and Loomans, personal communication 2019). Surveillance was carried out in a 4 x 9 km area around the infested zone, covering over 50 pepper facilities. Pheromone traps were used to detect the beetle, including within tomato and ornamental Solanaceae glasshouses within 2 x 3 km of the infested zone. Eradication measures of pesticide application and destruction were also implemented as in 2012, and, as there had been no further findings, the beetle was declared eradicated in December 2013 (EPPO Reporting Service, 2014c).

Italy

Anthonomus eugenii was identified in the municipalities of Fondi and Monte San Biagio (Latina, Lazio region) in 2013 on pepper crops under protection and in the field (EPPO Reporting Service, 2014b). As in the Netherlands, fruit had prematurely fallen, but there were also signs of oviposition and exit observed on the fruit, as well as larvae and secondary rot found in the fruit (EPPO Reporting Service, 2014b). Eradication measures in this case included destruction of affected plants, surveillance, a prohibition on growing *Capsicum* spp. and an information campaign to growers and other stakeholders (EPPO Reporting Service, 2014b). There have been no records of the weevil since 2016, and in 2020 the NPPO of Italy declared that *A. eugenii* had been successfully eradicated from Italy (Lazio Region, 2019; EPPO reporting service, 2020).

Phytosanitary status

Anthonomus eugenii is a GB quarantine pest (Schedule 1), which means that it is prohibited from being introduced into, or spread within GB. It is also present on several other phytosanitary lists (see Table 1).

Table 1. Global phytosanitary categorisation of *A. eugenii*.

Country/NPPO/RPPO	List	Year of addition
	AFRICA	
East Africa	A1 list	2001
Morocco	Quarantine pest	2018
	AMERICA	
Argentina	A1 list	2019
Chile	A1 list	2019
Paraguay	A1 list	1993
Uruguay	A1 list	1993
	ASIA	
Jordan	A1 list	2013
	EUROPE	
GB	Quarantine Pest	2020
Turkey	A1 list	2016
	RPPO	
COSAVE	A1 list	2018
EPPO	A1 list	1995
EU	A1 Quarantine pest (Annex II A)	2019

Means of movement and dispersal

Natural dispersal

Although natural spread is considered to be limited in *A. eugenii*, it does have the capacity to spread locally and between nearby glasshouses. In a mark recapture study, Riley (1990) detected marked adults 50 m from the release point two weeks after release, while in the Netherlands, six glasshouses within 1.5 km of each other were found to be infested in 2012, likely as a result of natural dispersal, though human assisted movement could not be excluded (van der Gaag and Loomans, 2013).

Movement in trade

Long distance spread

While *Capsicum* and *Solanum* plants for planting (e.g. aubergine and wild *Solanum* plants) present a possible pathway, solanaceous plants for planting from third countries other than Albania, Algeria, Andorra, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Canary Islands, Egypt, EU Member States, Faroe Islands, Georgia, Iceland, Israel, Jordan, Lebanon, Libya, Liechtenstein, Moldova, Monaco, Montenegro, Morocco, North Macedonia, Norway, parts of Russia, San Marino, Serbia, Switzerland, Syria, Tunisia, Turkey and Ukraine are prohibited from entry into GB. The more likely pathway of introduction is through fruit of *Capsicum* and *Solanum* spp. The beetle spends a large proportion of its lifecycle within the fruit and the beetles have been demonstrated to survive at 2°C for more than 100 days, far longer than would be required when transported in chilled conditions by plane (Costello and Gillespie, 1993; van der Gaag and Loomans, 2013). In the UK, as of October 2021, *A. eugenii* has been intercepted 18 times in *Capsicum* fruit from Mexico (12 times) and the Dominican Republic (6 times) since September 2014, and in a few of these instances, live and active adults were detected. This is despite EU measures requiring that *Capsicum* fruit from countries where the weevil is distributed must come from a pest free area or pest free place of production. Given that packhouses and growers do occur on the same sites in the UK, or in close proximity, there is a risk of introduction from commercially traded fruit, particularly if unwanted fruit is discarded in the open (Baker *et al.*, 2012).

Local spread

There is potential for the beetle to hitch hike on people's clothes, on packaging material and on machinery, but there is no evidence to confirm this as yet (van der Gaag and Loomans, 2013).

Control

Cultural controls and sanitary methods

There are few cultural controls available for *A. eugenii*. In a study of 35 varieties of pepper, Berdegue *et al.* (1994) found little difference in their susceptibility to the weevil. Although, varieties which readily shed their fruit when infested with the weevil tend to experience less damage (Ostojá-Starzewski *et al.*, 2016). Weevil numbers can also be suppressed by removing and destroying fallen fruit, introducing crop free periods, and removing solanaceous host plants and weeds (Capinera, 2017).

Wu *et al.* (2019) has demonstrated that double stranded RNA of Snf7 and V-ATPase-A injected into the weevil results in significant mortality, and could therefore potentially be used in the future as a management option. Addesso *et al.* (2014) also demonstrated that a plant terpenes product, Diatomaceous Earth and Kaolin Clay were able to reduce the damage caused by the pepper weevil in laboratory and field trials.

Biological control

Central and southern Mexico is considered to be the origin of domesticated pepper plants, and as such is seen as the native region of the pepper weevil and the best place to search for natural enemies. Several parasitoids have so far been found to be associated with the weevil in Mexico, including *Catolaccus hunteri*, *Triaspis eugenii*, *Urosigalphus* sp., *Aliolus* sp., *Bracon* sp. including *Bracon mellitor*, *Euderus* sp., *Sympiesis* sp., *Ceratoneura* sp., *Eupelma* sp., *Eupelmus* sp., *Pteromalus hunteri*, *Telenomus* sp. and *Baryscapus hunteri* (Rodriguez-Leyva *et al.*, 2007, 2012; Perez-Perez *et al.*, 2013). A similar composition of parasitoids was also found in Canada (Labbé *et al.*, 2018).

In a survey carried out in Mexico by Rodriguez-Leyva *et al.* (2007), *C. hunteri*, *T. eugenii* and *Urosigalphus* sp. represented 96% of all recovered parasitoids. *Catolaccus hunteri* is also common in the US, and is seen as a potential candidate for biological control (Ostojá-Starzewski *et al.*, 2016). This parasitoid generally prefers mature larvae, though it can also feed and lay eggs on young pupae, but is unable to lay its eggs in larger fruit and so is restricted to flower buds and the smallest fruits. Despite this impediment, Schuster (2007) demonstrated that both weekly releases of this parasitoid in organically grown bell pepper at first bloom, and weekly releases in nightshade during autumn/winter followed by weekly releases in adjacent bell pepper in spring, reduced the number of fruit that became infested by the pepper weevil.

Because of their abundance in Mexico, Rodriguez-Leyva *et al.* (2007) also considered *T. eugenii* and *Urosigalphus* sp. to be potential candidates for biological control. These two species have the benefit of being egg parasitoids and are therefore not restricted in where they can lay their eggs, as pepper weevil eggs are generally laid near the surface of the fruit. Parasitism rates of 18-40% have been recorded for *T. eugenii* in the field (Mariscal *et al.*, 1998).

Economic thresholds

The point at which economic damage occurs was initially calculated as 0.01 beetles per plant or one beetle per 100 plants in Puerto Rico (Segarra-Carmona and Pantoja, 1988). However, using one beetle per 100 plants as an economic threshold for applying insecticides to a crop was not considered to be sufficient to prevent significant yield loss by Riley *et al.* (1992). Instead, a more conservative threshold of one beetle per 400 plants was suggested, as it controlled the beetle and reduced the number of insecticide applications by 12. Cartwright *et al.* (1990) also investigated a threshold of one beetle per 100 plants, and while it did give better yields than a weekly spraying programme, it was not as good as a threshold of 1-5% bud cluster damage, which gave higher yields to a weekly spraying programme, whilst also reducing the number of insecticide applications by 10.

Chemical control

Anthonomus eugenii is difficult to control using insecticides, as the majority of its lifecycle is protected within the fruit (Ostojá-Starzewski *et al.*, 2016). Insecticide programmes are still commonly used to control the adult weevil, however, as this life stage leaves the fruit to feed and mate. Insecticides are often applied weekly and as many as 15 sprays can be used to control an infestation of the weevil in North America (CABI, 2018). A number of chemicals have shown efficacy against the weevil, including fenvalerate, oxamyl, pyrethrin, cyantraniliprole, thiamethoxam, chlorpyrifos, methamidophos, endosulfan, cyfluthrin, azinphos-methyl, methomyl, acetamiprid and lambda-cyhalothrin (Armstrong, 1994; Garcia Nevarez *et al.*, 2012; Servin-Villegas *et al.*, 2008; Caballero *et al.*, 2015; Ostojá-Starzewski *et al.*, 2016). Of these, only pyrethrin, acetamiprid and lambda-cyhalothrin are approved for use on pepper in the UK (HSE, 2019). In the Netherlands, a regime composed of deltamethrin and a neonicotinoid was used (van der Gaag and Loomans personal communication 2019).

It should be noted that these insecticides should not be used too often as the pepper weevil can develop resistance, as it has done for Carbaryl in Benito Juárez, San José Viejo, and particularly San Juan de los Planes where Carbaryl has been used extensively (Servin *et al.*, 2002). Resistance to thiamethoxam, chlorpyrifos ethyl, malathion and oxamyl has also been observed in La Cruz de Elota in Mexico (Avendano-Meza *et al.*, 2015).

Impacts

Economic impact

Yield losses attributed to the beetle have been reported by a number of authors. Riley and King (1994) estimated that the beetle caused average crop losses in the USA of 10%, Riley and Sparks (1995) reported losses of 50% and even the loss of whole pepper fields, while Costello and Gillespie (1993) reported serious losses in glasshouse peppers in British Columbia. Elmore *et al.* (1934) also reported that $500,000 was lost to the beetle in Californian pepper crops. Even where the beetle is kept at bay, the monetary cost of implementing control measures, such as the application of pesticides, can be great (van der Gaag and Loomans, 2013). The use of insecticides against the beetle may also disrupt existing integrated management systems and may increase problems with other pests (van der Gaag and Loomans, 2013).

Environmental impact

The beetle can have an indirect negative impact on arthropod biodiversity because of the increased use of insecticides used to control it.

Social impact

There is no evidence of social impacts, apart from the indirect impacts of crop losses on businesses (van der Gaag and Loomans, 2013).

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