Department
for Environment
Food & Rural Affairs

Pest specific plant health response plan:

Outbreaks of *Thrips palmi*

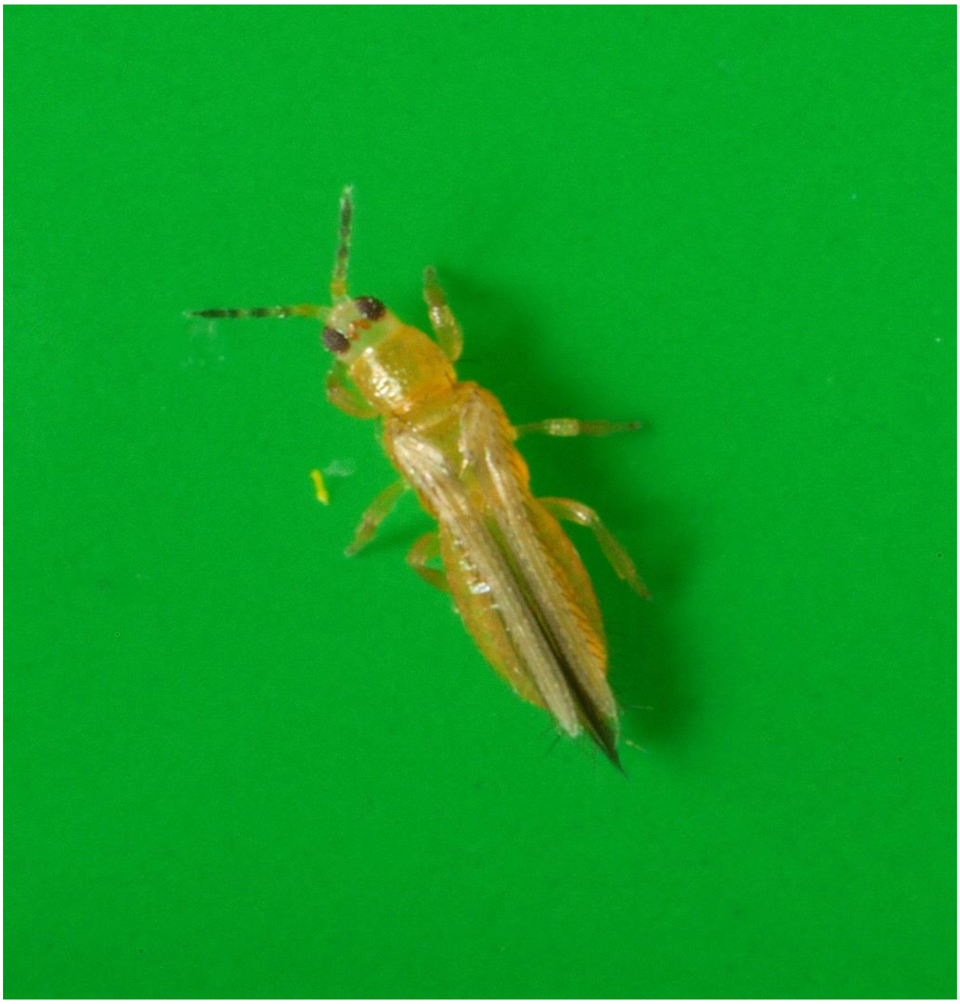

Figure 1. Adult *Thrips palmi* (approximately 1-1.3 mm in length) © Fera Science Ltd.

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Executive summary

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* Numbers relate to relevant points in 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 infestation of *Thrips palmi* is detected.

1.2 The plant health authorities in Northern Ireland, Scotland, Wales and the Crown Dependencies have been consulted on this plan and will use it as the basis for the action they will take in the event of *T. palmi* 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 responses 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 *T. palmi* and to make stakeholders aware of the planned actions.

2. Summary of threat

2.1 *Thrips palmi* is an insect pest native to South and Southeast Asia, and was described in 1925 from specimens collected in Sumatra and Java, Indonesia (Banks *et. al*, 1998; Karny, 1925). It has since spread widely through tropical and subtropical regions as shown in the distribution section of Appendix A. *Thrips palmi* has also been intercepted in a number of European countries due to the long-distance trade of host species, particularly in the Cucurbitaceae, Orchidaceae and Solanaceae. There have been a number of European outbreaks with the growing of host species under protection in Europe providing potential for the thrips to establish (Cannon *et al.*, 2007a).

2.2 *Thrips palmi* is highly polyphagous, having been recorded on over 200 plant species from more than 36 families, including a number of economically important protected crops, such as species in the Cucurbitaceae and Solanaceae, which are heavily damaged by the thrips (Collins, 2016). Protected crops at risk in the UK include aubergine, cucumber, lettuce, pepper and tomato. It is also damaging to ornamental crops, with the major family of economic significance being the Orchidaceae. It also infests a number of important UK ornamentals such as *Chrysanthemum* spp., *Cyclamen* spp., *Helianthus* spp. and *Nicotiana* spp. (Scrace, 2018), as well as a number of wild native species (EPPO, 2018a).

2.3 Symptoms are a consequence of feeding damage caused by the larval and adult stages of *T. palmi*. These stages utilise adapted mouth parts to pierce host cells and suck out their contents (Kawai, 1990b). This results in a speckled appearance to the leaves, which coalesce and merge to form silvery, shiny scars on above ground parts often close to the midrib and veins of leaves. Feeding by the thrips may also cause distortion, stunted leaves and terminals, chlorosis, and necrotic flowers and fruits, with heavily infested plants appearing silvered or bronzed (see figure 2 in appendix A) (EPPO, 2018a, 2018b; Fera, 2020).

2.4 The pest feeds gregariously and under protected conditions populations can increase rapidly leading to severe infestations and damage which can reduce the plants vigour, yield and marketability (Cannon *et al.*,2007b; Scrace, 2018). In addition to the immediate direct feeding damage there is also the risk of *T. palmi* being introduced with novel viruses. The species is one of only 0.2% of thrips species that are able to vector tospoviruses, which are responsible for a number of significant plant diseases (Jones, 2005).

2.5 Viruses which *T. palmi* have been shown to transmit include *Calla lily chlorotic spot orthotospovirus (*CCSV) (Persley *et al.,* 2006), *Groundnut bud necrosis orthotospovirus* (GBNV)*, Melon yellow spot orthotospovirus* (MYSV) and *Watermelon silver mottle orthotospovirus* (WSMV). They may also possibly transmit *Watermelon bud necrosis orthotospovirus* (WBNV) (Collins, 2016; Jones, 2005). The following combinations of host and *T. palmi*-spread virus could be of importance to the UK: carrot (GBNV), chillies (GBNV), cucumber (MYSV), onion (GBNV), pea (GBNV), potato (GBNV) and tomato (GBNV, WSMV) (CABI, 2019b, 2019c, 2019f, 2019g). Recent work suggests that *T. palmi* may be able to vector *Capsicum chlorosis orthotospovirus* (CaCV), a pest of peppers (CABI, 2019a), and that *T. palmi* can vector *Tomato spotted wilt orthotospovirus* (TSWV) (Chiaki *et al.*, 2020; Jones, 2005; Persley *et al.* 2006). TSWV is widespread throughout Europe and causes significant losses in a wide range of vegetable and ornamental crops (CABI, 2019e). If *T. palmi* is able to vector TSWV, its introduction could exacerbate existing problems in the UK tomato industry and cause further substantial economic impacts.

2.6 The major pathways of entry are plants for planting, cuttings and produce, which can be infested by eggs, larvae and adults, and soil, which can be infested by pupae (EFSA, 2019; van der Gaag *et al.*, 2019). Despite the polyphagous nature of *T. palmi*, the majority of EUROPHYT notifications made by the EU are from interceptions on cut flowers and produce of orchids, *Momordica* spp. and aubergines from outside of the EU. These may be considered the highest risk pathways as these interceptions are being made despite control measures being in place (EFSA, 2019).

2.7 The pest is commonly intercepted in the UK on a wide range of cut flowers, fruit and vegetables imported from the pest's known distribution (Cannon *et al.*, 2007a). In 2000 there was a UK outbreak of *T. palmi* in a glasshouse producing a year round crop of chrysanthemums. The origin of the outbreak could not be confirmed. Following an eradication campaign based on the use of systemic and foliar contact insecticides, sticky traps, plastic mulches and the fumigation of flowerbeds the outbreak was declared eradicated in 2001 following pest freedom in two complete cropping cycles (Cannon *et al.*, 2007b). As many of the insecticides used in this outbreak are no longer approved and have not been replaced, eradication of any future outbreak is likely to be more difficult.

3. Risk assessments

3.1 *Thrips palmi* has an unmitigated and mitigated UK Plant Health Risk Register score of 64 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=7359).

3.2 Pest risk analyses (PRA) have been carried out by Australia (Department of Agriculture and Water Resources, 2016), the European Food Safety Authority (EFSA, 2019) and the UK (MacLeod, 2001).

3.3 The UK PRA concluded that *T. palmi* has the potential to establish in the UK under protected conditions and may cause significant economic impacts particularly on protected Cucurbitaceae, Solanaceae and ornamentals crops.

4. Actions to prevent outbreaks

4.1 *Thrips palmi* is a GB Quarantine Pest (Schedule 1 of The Plant Health (Phytosanitary Conditions) (Amendment) (EU Exit) Regulations 2020) and is therefore prohibited from being introduced into, or spread within GB. Further pest and host specific requirements are listed in Schedule 7 *Thrips palmi* is also a GB Priority Pest meaning it is a GB quarantine pest which has been assessed to have the most severe potential economic, environmental and social impacts to GB.

4.2 *Thrips palmi* is listed in Annex IIA of Commission Implementing Regulation (EU) 2019/2072. Annex IIA is the list of Union Quarantine Pests which are absent from the Union territory, and as such they are prohibited from being introduced into, moved within or held, multiplied or released into the Union territory.

4.3 *Thrips palmi* is an EPPO A1 listed pest. These are pests that are absent from the EPPO region and recommended for regulation by EPPO member countries.

4.4 The Plant Health Service should be aware of the measures described in the current plan and be trained in responding to an outbreak of *T. palmi*. It is important that capabilities in detection, diagnosis, and risk management are available.

5. Response

Official action to be taken following the confirmation of *Thrips palmi* on imported plants and produce

5.1 If *T. palmi* 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. 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 rigid container, which is not liable to be crushed during transit, placed within two further layers of containment, and be clearly labelled.

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

5.3 If intercepted inland, and there is the potential for spread from the imported consignment, any host plants (including any fruit, which should be held) in the infested glasshouse should be inspected on the site (with fruit released if found free) and, if deemed necessary by the IMT, again in the following season for signs of pest presence. These surveys could require a number of visits and the installation and monitoring of sticky traps (see 5.25), dependent on the situation. These surveys could extend to host plants grown in other protected environments within 500 m of the infested site if considered appropriate by the IMT due to the risk of spread being high.

5.4 When there is a high risk of escape before destruction, fumigation and/or foliar insecticides may be used under guidance from the Defra Risk and Horizon Scanning team and detailed in a statutory plant health notice.

5.5 A UKPHINS notification should be made upon confirmation of an interception of live *T. palmi* where an import connection can be established.

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 confirmation of *T. palmi*. Details of recent past and future consignments from the same grower/supplier should also be obtained. Due to the resource required and level of risk involved, this should only be carried out for consignments which are not for consumption, such as finished plants and cuttings.

5.7 A pest factsheet to raise awareness of *T. palmi* and its symptoms should be distributed to packers/processors and importers where *T. palmi* has been found, and, where appropriate, 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/thrips-palmi-factsheet.pdf

5.8 General biosecurity measures and examples of successful control measures against *T. palmi* are highlighted in Appendix B and may be pro-actively used by the grower or as part of an outbreak management strategy.

Official action to be taken following the suspicion of a *Thrips palmi* outbreak

5.9 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, Fera Science Ltd and other organisations, may need to be set up to assess the risk and decide on a suitable response. 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.

5.10 The OTG will set an alert status, which will consider the specific nature of the outbreak. These levels, in order of increasing severity, are white, black, amber and red (more details of 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 *T. palmi* in a protected crop is likely to be given a black alert status. A black alert status refers to a significant plant pest with potential for limited geographical spread.

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

5.11 When *T. palmi* 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 to be agreed by the IMT.

5.12 There is potential for the pest to be carried on material, equipment and machinery, and therefore the movement of such items between infested and non-infested areas should be restricted.

5.13 The movement of personnel into an infested area such as a glasshouse should be restricted, especially during the early investigation phase and/or if *T. palmi* is detected. Personnel should follow good hygiene practice to reduce the risk of carrying the pest to other areas of the production facility. Workers should avoid wearing bright coloured clothing (particularly blue, white and yellow) which may attract the pest in case it facilitates spread to other areas (Joseph *et al.*, 2019; Sanderson, 2003).

Preliminary trace forward / trace backward

5.14 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 moving to and from the site. If applicable the relevant NPPO should be contacted.

5.15 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

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

- The origin of the host plants and suspected pathways.
- Details of other premises or destinations where the host plants/products have been sent, where *T. palmi* may be present.
- The layout of the premises and surrounding area (in relation to potential buffer zones of at least 500 m), including a map of the fields/cropping/buildings, at risk growers, and details of neighbouring crops, especially hosts in any commercial or non-commercial glasshouses.
- Details of the host variety, growth stage and any other relevant information.
- Description of the surrounding habitat, including all key hosts, such as those listed in Appendix A.
- 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, e-mail and telephone number of the person who found the pest and/or its symptoms, and the business owner.

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

5.18 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 (see 5.27).

Sampling

5.19 Plants should be visually inspected for speckled feeding damage, silvery scars near the midrib and veins, distortion, silvering or bronzing of leaves and deformed fruit.

5.20 Larvae and adults are mobile and should be looked for on all parts of the host plants, however, the undersides of leaves, or below the calyxes, should be inspected as a priority as most larvae are likely to be found here (Collins, 2016).

5.21 Sticky traps are commonly used to detect *T. palmi* given its small size and the inherent risk of non-detection. Some general points for successful use of *T. palmi* traps are included below.

- The most effective trap colours for *T. palmi* are blue and white. Yellow traps may catch thrips but these should be supplemented with blue or white traps for a more targeted approach.
- Traps should be positioned close to the top of the crop, as *T. palmi* is not an active flyer and traps may need to be repositioned as the crop grows.
- The recommended trap density for monitoring purposes by the PHSI is one trap for every 100-300 m^2. This may not be feasible for some protected sites, such as larger glasshouses, in which case a reduced rate may be used. In the previous UK outbreak in 2001 trap rates ranged between around one trap per 1,100-1,500 m^2, whilst EPPO (2009) recommend a minimum of 20/ha for monitoring purposes. Mass trapping, particularly using sticky trap rolls along the length of the crop can be particularly effective.
- Studies have shown that the use of aggregation pheromones can increase catches of *T. palmi* on sticky traps. Some pheromones available in UK can be found in Appendix A (Cultural control and sanitary measures).
- Traps should be monitored regularly to avoid an excess of non-target catch building up and pest deterioration which may impede successful and efficient laboratory identification. This was done fortnightly at the height of the previous UK eradication and should be done at least monthly for monitoring purposes.

5.22 Following the capture/putative identification of an adult, pupa, larva, and/or symptoms of the pest, 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, host variety and suspect pest.

Diagnostic procedures

5.23 Identification is difficult due to the pest's small size and similarities with other species of *Thrips,* particularly those that are yellow in colour. *Thrips palmi* can only be distinguished with confidence by means of laboratory diagnosis. This can be done using morphological features, although this can be difficult Molecular-based methods have been developed (EFSA, 2019) including Loop-mediated isothermal amplification (LAMP)- based identification systems for the detection of *T. palmi* in the field, (Blaser *et al.,* 2018).

5.24 The ISPM and EPPO diagnostic standards suggest that morphological identification is restricted to adults, as the keys for other life stages are not adequate. Keys listed in the standards for the identification of adults include Mound and Kibby (1998) and Moritz *et al.* (2004).

5.25 Four molecular assays have been developed for the identification of *T. palmi*, details of which can be found in the IPSM diagnostic protocol for *T. palmi* Karny (FAO, 2015), (available here: https://www.ippc.int/en/publications/586/). However, at present none of these have been fully validated for use in GB. Full DNA sequencing can be used for identification, but this is not a rapid assay.

5.26 Within protected cropping a non-specialist might misidentify *T. palmi* as species such as *T. tabaci* (onion thrips) and *Frankliniella occidentalis* (western flower thrips). In all instances thrips can only reliably be distinguished with confidence by laboratory morphological identification, LAMP or other lab-based molecular methods. Figure 4 in appendix A shows the similarities between these species.

Criteria for determining an outbreak

5.27 If *T. palmi* 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 pest 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

5.28 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. Guidance has been produced by the IPPC on the best practice when communicating with stakeholders and can be found here- https://www.ippc.int/en/publications/88510/.

5.30 The Defra pest factsheet to raise awareness of *T. palmi* and its symptoms should be distributed to relevant stakeholders in the locality of where *T. palmi* has been found. This could include nurseries, garden centres, landowners and importers, as appropriate. The pest factsheet can be found on the Plant Health Portal - https://planthealthportal.defra.gov.uk/assets/factsheets/thrips-palmi-factsheet.pdf

Demarcated zones

5.31 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 500 m 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. This could include other glasshouses or protected horticulture sites which are growing hosts of *T. palmi.* The buffer zone is relatively small due to the low risk of the pest establishing a population outdoors, and surveys within the buffer zone should focus on hosts under protection.

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

5.33 All batches of host plants under protected conditions in the infested and buffer zones should be visually inspected where feasible and suspect samples should be sent for diagnosis. Surveying rates should be determined by the IMT. Blue and white sticky traps should be used as in point 5.21.

5.34 The demarcated area should be adjusted in response to further findings. If *T. palmi* is found under protected conditions site outside of the infested zone, this should subsequently be designated as infested and the buffer zone adjusted accordingly.

Pest management procedures

Propagation sites and production sites of plants for planting

5.35 Host plants should not be moved off site, with the exception of plants being moved for destruction under statutory plant health notice.

5.36 Any infested plants should be removed and destroyed by incineration or deep burial under statutory plant health notice. If the IMT deem there to be an unacceptable risk of spread to other growing sites, the whole crop could be destroyed by incineration or deep burial.

5.37 Remaining plants in the infested zone will require treatment with a foliar insecticide (see Appendix B) under statutory plant health notice. The PHSI will suggest an appropriate insecticide treatment regime in consultation with the Defra Risk and Horizon Scanning team. These treatments may also be used on other susceptible hosts on the premises, depending on the circumstances of the outbreak.

- If the situation demands it, it may be necessary to require the use of pesticides even in organic crops or those where biological control agents are being used.
- Growers will be placed under notice to apply the recommended pesticides and make the applications using their own or contractor's equipment. Records of applications will be kept, including details of the amount of product and water use. All pesticide applications will be made in accordance with pesticide approvals and in accordance with HSE guidance.
- The pest is difficult to control using insecticides, as the majority of the lifecycle is underneath leaves, fruit, calyxes and similar. Therefore coverage levels may not be effective and visual inspections and sticky traps should be used to assess the efficacy of insecticide treatments.

5.38 It may be feasible to use an integrated pest management (IPM) approach under certain circumstances if deemed appropriate by the IMT. Successful control measures are highlighted in Appendix B and may be useful in developing an effective IPM strategy. If this approach does not reduce the infestation significantly the procedures may need to revert to an insecticide treatment regime as determined by the IMT.

Production sites of cut flowers and edibles

5.39 Host plants should not be moved off site, with the exception of plants being moved for destruction under statutory plant health notice.

5.40 If the IMT deem there to be a high risk of spread to other growing sites, the whole crop could be destroyed by incineration or deep burial before the end of the cropping season.

5.41 If the risk of spread is deemed low by the IMT it may be considered appropriate to continue growing the crop until the end of the season, in order for the produce from the infested crop to be sold directly to retail/wholesale.

5.42 In most scenarios, produce should not be moved to other production sites for packing. Any movements would be on a case by case basis subject to criteria set by the IMT.

5.43 The focus for pest management should initially be on the containment of the pest, keeping pest numbers at a very low level, with the focus shifting to eradication following the end of season or crop cycle. The management at this stage should be an IPM approach (see 5.38) and use a mixture of biocontrol and cultural methods as described in Appendix B, as deemed appropriate for the specific situation by the IMT.

5.44 Hot spots where there are high levels of infestation may require foliar insecticide treatments to reduce the spread of the pest. Decisions on the treatment of the hot spots will be determined by the IMT.

5.45 Plants exhibiting severe infestations, where the IMT consider that other treatments are not sufficient for control of *T. palmi*, should be removed and destroyed by incineration or deep burial.

Crops growing within the buffer zone (at least 500 m around the infested zone)

5.46 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 baited blue sticky traps, until the outbreak has been declared eradicated.

Post-crop clean up

5.47 Following the appropriate measures above (5.35-5.45) 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 or deep burial, including volunteers, weeds and waste under statutory plant health notice.

5.48 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 pest. The permanent facility should also be cleaned and or disinfected to remove any remaining life stages of the pest.

5.49 Given the potential for the pest to be physically transferred, best hygiene practice should be followed as in Appendix B.

5.50 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 *T. palmi*. 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 pest. Sticky traps, sticky trap rolls or pheromone baited blue sticky traps should be used to monitor the empty growing site.

5.51 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 *T. palmi.* This monitoring should include the use of sticky traps, sticky trap rolls, pheromone baited blue sticky traps or trap plants.

5.52 Official inspections, with the frequency determined by the IMT, should be carried out over the following growing season.

Disposal plan

5.53 When deciding on the most appropriate method(s) of disposal, several factors such as the likelihood of *T. palmi* 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 minimal 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.

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

5.55 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 such as using high pressure water or steam. 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

6.1 The minimum time period before *Thrips palmi* can be declared eradicated (by the Chief Plant Health Officer) will be the time necessary for two complete lifecycles of the pest, as based on the generation times found in Appendix A, 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 to consider any changes in legislation, control procedures, pesticides, sampling and diagnostic methods, and any other relevant amendments.

7.2 Lessons should be identified during and after any outbreak of *T. palmi* 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 *Thrips palmi*

Identity (EPPO, 2020; CABI, 2019d; Fera, 2020)

PREFERRED SCIENTIFIC NAME	AUTHOR (taxonomic authority)
Thrips palmi	Karny (1925)

CLASS: Insecta

ORDER: Thysanoptera

FAMILY: Thripidae

COMMON NAMES: Melon thrips, oriental thrips, palm thrips, southern yellow thrips.

SYNONYMS:
Thrips claurus (Moulton, 1928)
Thrips nilgiriensis (Ramakrishna, 1928)
Thrips gossypicola (Priesner, 1939)
Thrips leucadophilus (Priesner, 1936)
Chloethrips aureus (Ananthrakishnan & Jagadish, 1967)
Thrips gracilis (Ananthrakishnan & Jagadish, 1967)

Notes on taxonomy and nomenclature

Despite a large number of synonyms, *T. palmi* is consistently referred to by this preferred name and there is no issue with distinguishing the species from other *Thrips* spp. Although it is referred to as palm thrips it is not known to be associated with palm species. It is in fact named after a doctor from Sumatra, Indonesia, where the species was first described by Karny in 1925 (Karny, 1925).

Biology and ecology

Life Cycle

Adults emerge from pupae in the soil and migrate to young leaves, flowers and fruits where they begin to feed by piercing host cells and sucking out the contents. Soon after emergence they begin to mate and lay eggs on the leaves, fruits and flowers of the host (Cannon *et al.*, 2007; EPPO, 2018a; Kawai, 1990b). Females can reproduce both sexually and asexually, leading to rapid population increases. Asexual reproduction results in purely male progeny whereas sexual reproduction results in 70-80% female progeny (Cannon *et al.*, 2007b; EPPO, 2018a). Egg laying occurs within incisions on the leaves made by an ovipositor with a single egg laid in each incision (EFSA, 2019; Kawai, 1990b). This egg laying within leaves makes them difficult to detect (EFSA, 2019).

After hatching from the eggs, first instar larvae feed on the leaves of the host. First instar larvae develop into the larger, yellow second instar. Both first and second instars are mobile and cause direct feeding damage using their specialised sucking mouthparts, resulting in symptoms of distorted leaves with a speckled appearance, with specks coalescing to form the silvery scars synonymous with thrips damage.

Second instar larvae mature and drop to the ground where they develop into non-feeding pre-pupae and subsequent pupae. These are relatively sedentary stages, but continue to develop, becoming darker in colour, and develop wing pads before emerging as winged adults and completing their life cycle (Cannon *et al.*, 2007b; EPPO, 2018a; Kawai, 1990b).

The generation time of *T. palmi* has been shown to shorten as temperatures increase up to 25°C, at which net reproductive rates are optimal (EFSA, 2019; Kawai, 1990b). The EPPO datasheet suggests the lifecycle of *T. palmi* can last for around 17.5 days at this temperature, allowing for rapid population expansion, consistent with most phytophagous thrips species (EPPO, 2018a). Studies have calculated that the developmental thresholds of 194 day degrees above a thermal temperature of 10.1°C are required for egg to adult development (Cannon *et al.*, 2007b; McDonald *et al.*, 1999). Cold tolerance studies show that all stages of *T. palmi* will die if exposed to 8 days at 0 °C, 255 minutes at -5 °C or 35 minutes at -10 °C. While the UK climate could theoretically support 4-5 generations of the thrips, this is far fewer than the estimated 25-26 generations per year under optimal conditions (25-30°C) (Banks *et al.,* 1998; EFSA, 2019). Survival outdoors over winter in the UK is also doubtful, and establishment is therefore likely to be limited to protected crops (Cannon *et al.*, 2007b; EFSA, 2019; Kawai, 1990b, McDonald *et al.*, 1999)

Hosts/crops affected

Thrips palmi is highly polyphagous, having been recorded on over 200 plant species from more than 36 families, including a number of economically important protected crops, such as species in the Curcubitaceae including cucumbers and aubergines, and the Solanaceae including tomatoes and peppers, which are heavily damaged by the thrips (Collins, 2016). It is also damaging to ornamental crops with the major family of economic significance being the Orchidaceae. It also infests a number of important UK ornamentals such as *Chrysanthemum* spp., *Cyclamen* spp., *Helianthus* spp. and *Nicotiana* spp. (Scrace, 2018), as well as a number of weed species (EPPO, 2018a), but other than *Chrysanthemum* spp., *T. palmi* has thus far not been intercepted or detected on any of these hosts in the UK.

The pest is regularly intercepted in the UK on a range of cut flowers, fruit and vegetables, usually imported directly from the pest's natural range (Cannon *et al.* 2007a). A host list based on those listed by CABI and EPPO is given in table 1.

Table 1. Host list of *Thrips palmi* (Source: EPPO global database (2020). An up-to-date host list can be found here https://gd.eppo.int/taxon/THRIPL/hosts.

Host	Common name	Host type
Abelmoschus esculentus	Okra	Host
Allamanda oenotherifolia	Golden trumpet bush	Host
Allium cepa	Onion	Host
Allium porrum	Leek	Host
Amaranthus dubius		Host
Amaranthus spinosus		Host
Apium graveolens	Celery	Host
Arachis hypogaea	Peanut	Host
Arachnis	Scorpion orchids	Host
Arracacia xanthorrhiza	Arracacha	Host
Arundina graminifolia	Bamboo orchid	Host
Basilicum polystachyon	Musk basil	Host
Benincasa hispida	Winter melon	Host
Bougainvillea sp.		Host
Brassica oleracea		Host
Brassica oleracea var. capitata	Cabbage	Host
Callistephus chinensis	China aster	Host
Canavalia ensiformis	Jack bean	Host
Capsella bursa-pastoris	Shepherd's purse	Wild/Weed
Capsicum annuum	Pepper	Host
Capsicum frutescens	Chilli pepper	Host

Host	Common name	Host type
Celosia argentea	Silver cock's comb	Host
Cerastium glomeratum	Sticky chickweed	Wild/Weed
Chrysanthemum	Chrysanths	Host
Citrullus lanatus	Watermelon	Host
Coriandrum sativum	Coriander	Host
Cosmos sulphureus	Sulphur cosmos	Host
Cucumis melo	Honeydew melon	Host
Cucumis sativus	Cucumbers	Host
Cucurbita maxima	Giant pumpkin	Host
Cucurbita moschata	Butternut squash	Host
Cucurbita pepo	Acorn squash	Host
Cyclamen persicum	Persian cyclamen	Host
Datura metel	Devil's trumpet	Host
Daucus carota	Carrot	Host
Dendrobium	Orchid	Host
Eleusine coracana	Finger millet	Host
Ficus benjamina	Weeping fig	Doubtful host
Ficus elastica	India rubber plant	Doubtful host
Fragaria vesca	Wild strawberry	Host
Gerbera jamesonii	Gerbera daisy	Host
Glebionis segetum	Corn marigold	Host
Glycine max	Soybean	Host
Gossypium hirsutum	Cotton	Host
Helianthus annuus	Sunflower	Host
Hippeastrum puniceum	Barbados Lilly	Host
Ipomoea batatas	Sweet potato	Host
Lactuca sativa	Lettuce	Host
Linum usitatissimum	Flaxseed	Host
Luffa acutangula	Luffa	Host
Luffa aegyptiaca	Luffa	Host
Mangifera indica	Mango	Host
Manihot esculenta	Cassava	Host
Momordica charantia	Bitter melon	Host
Nicotiana tabacum	Tobacco	Host
Ocimum basilicum	Sweet basil	Host
Ocimum sp.		Host
Ocimum tenuiflorum	Holy basil	Host
Persea americana	Avocado	Host
Petroselinum crispum	Parsley	Host
Phaseolus lunatus	Sieva bean	Host
Phaseolus vulgaris	Common bean	Host

Host	Common name	Host type
Phyllanthus emblica	Indian gooseberry	Host
Pisum sativum	Pea	Host
Plumbago auriculata	Cape leadwort	Host
Plumeria rubra		Host
Portulaca grandiflora	Moss rose	Host
Pyrus communis	Pear	Host
Raphanus sativus	Radish	Host
Rosa	Rose	Host
Rubus		Host
Salvia farinacea	Mealycup sage	Host
Sauropus androgynus	Star gooseberry	Host
Sesamum indicum	Sesame	Host
Solanum betaceum	Tree tomato	Host
Solanum lycopersicum	Tomato	Host
Solanum macrocarpon	African eggplant	Host
Solanum mauritianum	Wild tobacco	Host
Solanum melongena	Aubergine	Host
Solanum quitoense	Naranjilla	Host
Solanum torvum	Turkey berry	Host
Solanum tuberosum	Potato	Host
Solanum violaceum		Host
Sphagneticola trilobata	Yellow creeping daisy	Host
Stachytarpheta urticifolia	Nettleleaf velvetberry	Host
Strobilanthes calycina		Host
Tagetes patula	French marigold	Host
Vaccinium	Blueberries	Host
Vanda	Orchid	Host
Vicia sativa	Common vetch	Wild/Weed
Vigna mungo	Black gram	Host
Vigna radiata	Mung bean	Host
Vigna unguiculata	Cowpea	Host
Vigna unguiculata subsp. sesquipedalis	Asparagus bean	Host
Zantedeschia aethiopica	Calla lilly	Host
Zea mays	Maize	Host

Plant stages affected

Larval instars and adults feed on all growth stages of hosts.

Plant parts affected

Larval instars and adults feed on all above ground plant parts. Eggs will be laid into above ground plant tissues via an ovipositor. Pre-pupae and pupae can be found in the soil or on lower leaves (CABI, 2019d; Cannon *et al.,* 2007b; Collins, 2016; EPPO, 2018a; Fera, 2020; Kawai, 1990b).

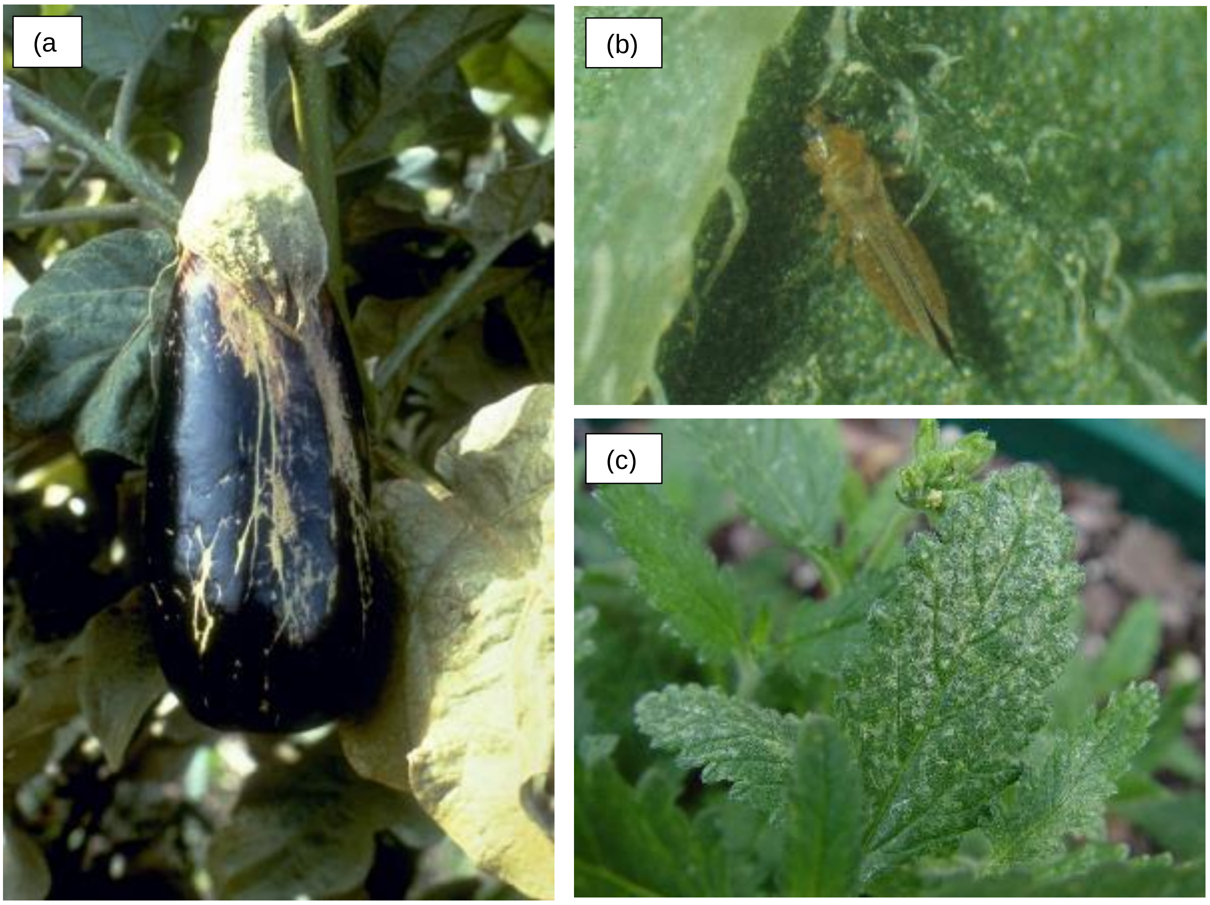

Figure 2. (a) *Thrips palmi* damage on Aubergine © EPPO (Guyot, 2019), (b) *Thrips palmi* feeding © Bugwood (Shepard *et al.*, 2008), (c) Typical thrips damage on Verbena sp. leaf © Bugwood (Hesselein, 2011).

Symptoms/signs – description

Symptoms are related to the feeding damage caused by the larval and adult stages of *T. palmi*. All of these stages utilise adapted mouth parts to pierce host cells and suck out their contents (Kawai, 1990b). This results in a speckled appearance to the leaves, which coalesce and merge to form silvery, shiny scars on above ground parts often close to the midrib and veins of leaves. The feeding may also cause distortion, stunted leaves and terminals, chlorosis, necrotic flowers and fruits, with heavily infested plants appearing silvered or bronzed (EPPO, 2018a, 2018b; Fera, 2020). The feeding damage is consistent with other thrips species and requires laboratory examination of specimens for distinctions to be made (Collins, 2016; Scrace, 2018). Some examples of thrips damage are shown in figure 2.

Morphology

Eggs: Bean-shaped, colourless to pale white in colour. This stage is cryptic and eggs are unlikely to be encountered (Capinera, 2000).

First instar larvae: Very small, translucent and lacking wings (Cannon *et al.*, 2007b, Capinera, 2000).

Second instar larvae: Similar to adults in form but smaller, lacking wings and genitalia and more yellow in colour than first instar larvae (Cannon *et al.*, 2007b, Capinera, 2000).

Pupae: Similar to second instar larvae in form but possessing wing pads (Capinera, 2000).

Adults: 1.0-1.3 mm in length with females on average larger than the males (EFSA, 2019). Adults are pale yellow or whitish in colour with a black line running along the back of the body. Wings are fringed and pale and numerous dark setae can be found on the body (Capinera, 2000).

Figure 3. *Thrips palmi* life stages (left to right) 1st instar larva, 2nd instar larva, pupa and adult. © Fera Science Ltd.

Identification is difficult due to the pest's small size and similarities with other species of *Thrips,* particularly those that are yellow in colour. *Thrips palmi* can only be distinguished with confidence by means of laboratory diagnosis. This can be done using morphological features, although this can be difficult and molecular-based methods have been developed (EFSA, 2019). There are four molecular assays published which are listed in the ISPM diagnostic protocol for *T. palmi*, including those by Walsh *et al.* (2005) designed as a species-specific assay for use by the phytosanitary authorities in England and Wales. The assays designed by Kox *et al.* (2005) and developed by Brunner *et al.* (2002) have been evaluated by screening them against predominantly European species of thrips (FAO, 2015).

Figure 4. Similarities between thrips species. (a) Adult *Thrips palmi* © Fera Science Ltd.; (b)adult *Frankliniella occidentalis* © David Cappaert, Bugwood.org.

Keys are available for second instar larvae, such as the key developed by Vierbergen *et al.* (2010), suggested by the EFSA pest categorisation. The ISPM and EPPO diagnostic standards state that morphological identification is restricted to adults, as the keys for other life stages are not adequate. Keys listed in the standards for the identification of adults include Mound and Kibby (1998) and Moritz *et al.* (2004), both listed in the ISPM diagnostic standard. A list of key diagnostic morphological characters of *T. palmi* adults that separate it from other species within the genus *Thrips* is provided in the EPPO diagnostic protocol (EPPO, 2018b).

Similarities to other species/diseases/plant damages

There are a number of both native and exotic species which are superficially similar to *T. palmi*. In particular *T. tabaci* (onion thrips) and *Frankliniella occidentalis* (western flower thrips) may be confused with *T. palmi* within protected cropping (Collins, 2016; EPPO, 2018a, 2018b; FAO, 2015).

In the UK, *T. flavus* (honeysuckle thrips) is a widespread flower thrips and can superficially be confused with *T. palmi* but is more often found outside of protected cropping whereas *T. palmi* is regarded as mainly posing a risk to protected crops within the UK (CABI, 2019d; Collins, 2016; EPPO, 2018a). In all instances thrips can only reliably be distinguished with confidence by laboratory diagnosis or molecular-based methods. In addition to this a list of diagnostic morphological characters which distinguish *T. palmi* adults from other *Thrips* spp. is provided in the EPPO diagnostic protocol (EPPO, 2018b). Figure 4 shows *T. palmi* and *F. occidentalis* which are superficially similar and given their small size could be confused by an untrained eye.

Detection and inspection methods

Visual inspection and sampling

Plants can be visually inspected for symptoms of thrips damage including speckled foliage, silver feeding scars near the midrib and veins, distortion, silvering or bronzing of leaves, and deformed fruit (see Figure 2). The undersides of leaves, or below the calyxes, should be inspected as a priority as most larvae are likely to be found here (Collins, 2016).

If larvae or adults are seen it may be necessary to remove them for sampling. This can be done by cutting out infested areas, removing adults individually with a paintbrush or beating plant parts onto small white plastic trays or sheets of white paper from which the pest can be collected. Plant parts could also be placed inside plastic bags for 24 hours with some filter paper to absorb condensation (EFSA, 2019; EPPO, 2018b; FAO, 2015). Diagnostic standards also recommend the use of a Berlese funnel where infested plant parts are sat on top of a sieved funnel with a container of ethanol below. By placing an electric lamp above the funnel most invertebrates will move down towards the container, trying to escape the heat and light where they can then be collected (EFSA, 2019; EPPO, 2018b; FAO, 2015).

Sticky traps

In low level infestations detection may be difficult due to the small size of the pest, the cryptic nature of eggs and pupae in leaves and soil respectively, and low population densities producing little or no detectable symptoms (EFSA, 2019; EPPO, 2018b; FAO, 2015). There are no recognised methods of extracting thrips pupae from the soil. In these instances, the use of sticky traps may be preferable for detecting adult presence, with blue and white being effective colours for trapping *T. palmi,* although yellow traps may also work (CABI, 2019d; EPPO, 2018b; FAO, 2015).

Loop-Mediated isothermal amplification (LAMP)

LAMP-based genetic identification systems have been developed in Switzerland to prevent the introduction of the three most commonly encountered regulated insect species including *T. palmi*. LAMP primers have been developed and were tested at Zurich airport under laboratory conditions and by plant health inspectors under field conditions. Assays were carried out on a Genie ® II system (OptiGene Ltd.) or 7500 Real-Time PCR System (Applied Biosystems, Carlsbad, CA, USA).

Of the 98 assays carried out under laboratory conditions 75 assays returned true positives, 22 returned true negatives and one assay returned a false negative. Of the ten assays carried out under field conditions by inspectors seven assays returned true positives, two returned true negatives and one returned a false negative. This gave test efficiencies of 99% and 90% respectively. Specificity was 100% for both laboratory based and field based assays, whilst sensitivity for *T. palmi* was 98.7% and 87.5% respectively (Blaser *et al.*, 2018).

These results indicate there may be some scope for the use of this technology in the UK for in-field detection of *T. palmi* in the future.

Distribution

Thrips palmi is present in Africa, Asia, North America, Oceania and South America. The distribution as of July 2021 is shown in figure 5. Full and up to date distribution data be found can at https://gd.eppo.int/taxon/THRIPL.

History of introduction and spread

Global spread

Thrips palmi is native to South and Southeast Asia, and was described in 1925 from specimens collected in Sumatra and Java, Indonesia. It has since spread widely through tropical and subtropical regions, causing particular issues in western Japan from 1978 onwards, where the pest spread to an extensive area of 20,000 ha by 1990, becoming a serious pest of both outdoor and protected crops (CABI, 2019d). In addition to this in 1977 an outbreak in watermelon plantations in the Philippines resulted in the destruction of nearly 80% of plantations in some regions. The pest has also spread to Australia, the Caribbean, South America and West Africa (Cannon *et al.*, 2007a).

Europe

Thrips palmi has been intercepted in a number of European countries due to the long distance trade of host species, particularly in the Curcubitaceae and Solanaceae. The growth of these species under protection in Europe presents a risk of introduction and establishment (Cannon *et al.*, 2007a, Kawai, 1990b).

Thrips palmi is intercepted commonly in EU member states with data showing a total of 2,175 EUROPHYT notifications made between 1995 and 2018. Of these notifications 89.7% are comprised of consignments of orchids, *Momordica* spp. (bitter gourd) and *Solanum melongena* (aubergine), with the majority of these notifications coming from Asian or South American countries (EFSA, 2019). There have been a number of European outbreaks, the majority of which have been in the Netherlands between 1988 and 1998 as well as in the UK (2000), Portugal (2004) and Germany (2014). All of these have been eradicated and *T. palmi* is considered absent from the EU (Cannon *et al.*, 2007a; Collins, 2016). The Portuguese finding was reported on outdoor crops of *Actinidia chinensis* but subsequent surveys the following year did not detect any further findings (Collins, 2016).

UK

In 2000 a Sussex glasshouse producing a year round chrysanthemum crop notified the UK PHSI of a thrips problem which was not being controlled with their usual measures. Samples were taken by the PHSI and diagnosed by Fera Science Ltd. As *T. palmi.* High populations of *T. palmi* were found in two separate glasshouses, but the origin of the outbreak could not be unconfirmed. Following an eradication campaign based on the use of systemic and foliar contact insecticides, sticky traps, plastic mulches and the fumigation of flowerbeds, the outbreak was declared eradicated in 2001 following pest freedom in two complete cropping cycles (Cannon *et al.*, 2007b).

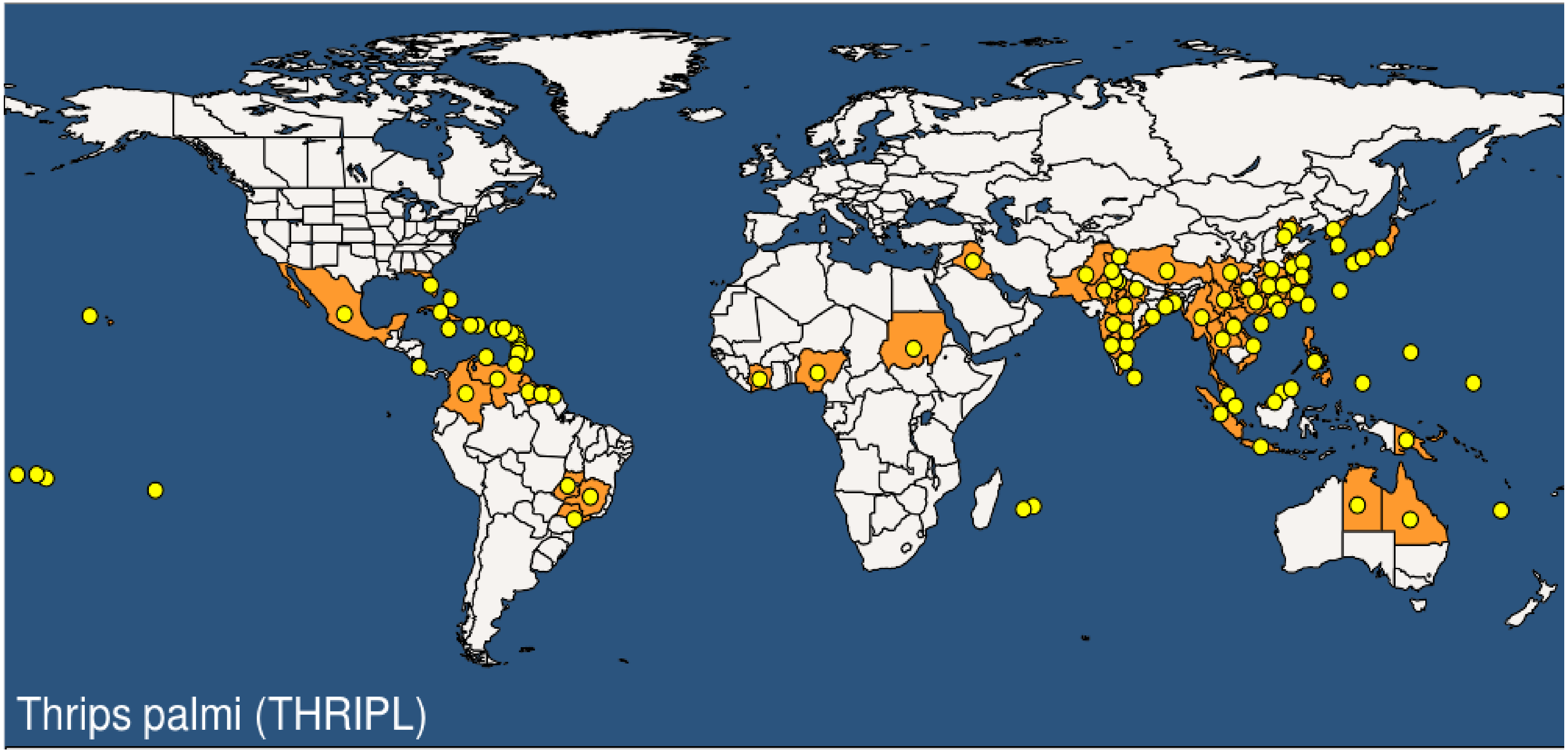

Figure 5. Distribution map of *Thrips palmi* (Source: EPPO, 2021). Up to date distribution data can be found at https://gd.eppo.int/taxon/THRIPL/distribution

Phytosanitary status

Table 2. Global categorisations of *Thrips palmi* (Adapted from EPPO, 2020)

Country/NPPO/RPPO	List	Year of addition
AFRICA		
East Africa	A1 list	2001
Egypt	A1 list	2018
Morocco	Quarantine pest	2018
Southern Africa	A1 list	2001
Tunisia	Quarantine pest	2012
AMERICA		
Argentina	A1 list	2019
Chile	A1 list	2019
Mexico	Quarantine pest	2018
Paraguay	A1 list	1993
Uruguay	A1 list	1993
ASIA		
Bahrain	A1 list	2003
Israel	Quarantine pest	2009
Jordan	A1 list	2013
Kazakhstan	A1 list	2017
EUROPE		
Azerbaijan	A1 list	2007
Georgia	A1 list	2018
Great Britain	Priority pest	2021
Moldova	A1 list	2006
Norway	Quarantine pest	2012

Country/NPPO/RPPO	List	Year of addition
Russia	A1 list	2014
Turkey	A1 list	2016
Ukraine	A1 list	2019
OCEANIA		
New Zealand	Quarantine pest	2000
RPPO		
CAHFSA	A2 list	1990
COSAVE	A2 list	2018
EAEU	A1 list	2016
EPPO	A1 list	1988
EU	A1 Quarantine pest (Annex II A)	2019

Means of movement and dispersal into the UK

Long distance spread

Modelling by van der Gaag (2019) found no quantitative data on dispersal distances of *T. palmi.* They suggest that thrips do not generally actively fly over large distances, with wider spread often being facilitated by air currents or wind. In the UK outbreak adults were caught outside of the infested glasshouse on two traps; one trap 1 m from the glasshouse and the other 10 m from the glasshouse. During monitoring of the 5 km buffer zone, 118 nurseries were monitored using sticky traps. No *T. palmi* were found, suggesting long distance spread via natural means is unlikely (Cannon *et al.*, 2007b). A paper by van der Gaag (2019) suggests it is unlikely that the pest would reach a suitable glasshouse unassisted, unless a glasshouse or susceptible consignment was located close to the incursion, as adults are unlikely to survive for long periods without host plants.

With this in mind the main pathway for long distance spread is likely to be human assisted spread via trade with eggs, larvae and adults being moved on infested plants for planting, cuttings or produce and pupae being transferred in soil (EFSA, 2019; van der Gaag, 2019). This is supported by the number of interceptions in the EU, with the majority being on orchids, bitter melon and aubergines (EFSA, 2019).

Local spread

Thrips palmi can actively fly over short distances facilitating spread to non-infested areas locally, and possibly also moving from treated areas to untreated areas. They can also be spread locally as contaminants on infested plant material, equipment and machinery. They are also attracted to bright coloured clothing (particularly blue, white and yellow) which can facilitate spread to other areas (Joseph *et al.*, 2019; Sanderson, 2003).

Control

In the UK outbreak of 2000, an emergency approval was granted by the UK Pesticide Safety Directive (PSD) for the use of Intercept™ granules to be used in peat based media for the propagation of chrysanthemum cuttings. The PHSI also made an application to the PSD for an emergency off-label use of Admire™ - a water dispersible granule on protected, all year-round chrysanthemums. The active ingredient of both products is imidacloprid and eradication was achieved by combining these treatments with Methyl bromide fumigation, propoxur smokes and the use of bait plants, plastic mulches and sticky traps. Of the insecticides used imidacloprid was deemed the most effective at reducing population levels, although this could also be due to it being the insecticide which was deployed most frequently (MacLeod *et al.*, 2004). However, imidacloprid is not approved for use in the UK.

Current mitigations

Thrips palmi is a GB quarantine pest (Annex 2 part A of The Plant Health (Phytosanitary Conditions) (Amendment) (EU Exit) Regulations) and is therefore prohibited from being introduced into, moved within or held, multiplied or released into GB. To comply with this third country imports of cut flowers of Orchidaceae, fruits of *Solanum melongena,* fruits of *Momordica* and plants for planting other than bulbs, corms, rhizomes, seeds, tubers and plants in tissue culture, require phytosanitary certificates with official statements to indicate the consignments freedom from *T. palmi*. The large number of interceptions reported to EUROPHYT under the EU legislation suggest this is not wholly effective. EFSA report that as the pest is polyphagous there is also scope for it being introduced on unregulated produce (EFSA, 2019), however, following changes in legislature produce now requires a phytosanitary certificate with the exception of fruits of *Actinidia* sp. (kiwi), *Ananas comosus* (pineapple), *Cocos nucifera* (coconut), *Diospyros* sp. (persimmon), *Durio zibenthinus* (durian), *Fortunella* sp. (kumquat), *Gossypium* sp. (cotton), *Mangifera* sp. (mango), *Musa* sp. (banana), *Passiflora* sp. (passionfruit), *Phoenix dactylifera* (dates), *Poncirus* sp. (trifoliate orange), *Psidium* sp. (guava), fruits and leaves of *Citrus* sp., leaves of *Murraya* spp. and grains of *Oryzae* sp. (rice). Of these *Gossypium hirsutum* and *Mangifera indica* are hosts of *T. palmi*.

Cultural control and sanitary measures

Whilst the most efficient method of *T. palmi* control is pesticide applications, several cultural methods have proved effective at suppressing populations. As they are unable to achieve eradication in isolation they are mainly used in Integrated Pest Management (IPM) programmes (Cannon *et al.*, 2007a).

General sanitary measures which are useful for thrips control include the removal of weeds/debris and screening openings such as ventilation and doors, although as *T. palmi* is unlikely to survive outside in the UK this may not be greatly cost beneficial (Mouden *et al.*, 2017). Overhead irrigation can be effective at washing adults off leaves and periods of intense rainfall have shown significant reductions in outdoor crops. Despite this as larvae have a preference for the underside of leaves its efficiency as a control measure may be limited and with crops often being subject to a strict irrigation schedule it may also not be possible.

Studies in Australia and Japan looked at several cultural methods, including crop rotation, UV absorbing vinyl film, blue sticky traps and silver films, all of which were found to be effective at reducing population density (Cannon *et al.*, 2007a; Kawai, 1990a; Young and Zhang, 1998). In particular silver materials were a deterrent to adults and provided the highest yield in pepper crops. Mulches including black plastic are also considered effective as they work to limit pupation in the soil and repel flying adults by interfering with visual cues used to locate favourable habitats (CABI, 2019d; Cannon *et al.*, 2007a). Black plastic mulches were used in the UK outbreak in October 2000 to limit the emergence of adults from the pupae in the soil (Cannon *et al.*, 2007b).

Sticky traps are an effective control measure and can be utilised in both surveillance and mass trapping. They were not a major measure in the UK outbreak as logistical issues due to heating pipes and overhead spraying systems constrained the measure to one of the two infested glasshouses (Cannon *et al.*, 2007b). Blue and white are recommended by the ISPM and EPPO diagnostic standards as the best colours, although they both mention yellow traps should also work (EPPO, 2018b; EFSA, 2019).

A study in 2014 was able to identify the aggregation chemical of *T. palmi* found in males but absent in females. This compound was synthetically produced and when tested in aubergine crops in Japan increased blue sticky trap yields from unbaited traps. The compound itself is similar to a previously identified pheromone of *F. occidentalis* and is named (*R*)-lavandulyl 3-methyl-3-butenoate (Akella *et al.*, 2014). Some commercial products available for use in the UK can be found below;

- Koppert - Lurem-TR (https://www.koppert.co.uk/lurem-tr/)

- Bioline AgroSciences - Thripline (https://www.biolineagrosciences.com/?products=thripline)

Another method of mass trapping is the use of susceptible and preferential hosts as trap plants. This has been shown to be a low-cost viable option for small farmers in Venezuela (Salas, 2004). The efficacy of this will be diminished if the preference for the crop is similar or larger than the trap plant, but they can be effective for monitoring at low densities and mass trapping at high densities. This method is used widely in Ontario, Canada, as an attract and kill strategy for the control of *F. occidentalis* in potted chrysanthemum and herb production. Flowering chrysanthemum with high attractiveness to the pest are placed throughout the crop and removed, destroyed and replaced on a biweekly basis (Brownbridge *et al.*, 2013). They can also be used for determining hot spots of *T. palmi* within a crop, allowing for targeted control methods towards specific areas of the crop to reduce population levels efficiently (Brownbridge *et al.*, 2013; Mouden *et al.*, 2017).

Biological control

Biological control agents (BCA) are used in the control of *T. palmi* around the world and utilised within IPM strategies (CABI, 2019d). One genus which seems to be an effective predator of *T. palmi* are *Orius* spp., which are predatory true bugs, with *O. sauteri, O. strigicollis* and *O. insidiosus* all mentioned in the literature as having significant impacts on *T. palmi* population density and being widely used in Japan and the Caribbean (Cannon *et al.,* 2007a; Paul and Khan, 2019). Of the *Orius* spp. only *O. laevigatus* and *O. majusculus* are available for use in the UK both for the control of thrips. There are no specific references in the literature to the predation of *T. palmi* by either *O. laevigatus* or *O. majusculus* so their efficacy may need to be confirmed.

Studies in Florida showed the potential of the predatory mites *Neoseiulus cucumeris* and *Amblyseius sirskii* to predate *T. palmi* and *F. schultzei*. Both predators were able to supress both species of thrips *in vitro,* although only *A. swirskii* was able to suppress populations in shade house studies and under field conditions, being able to do so even at the lower application rates tested (Kakkar *et al.*, 2016). The use of *A. swirskii* for the control of *T. palmi* is backed up by a number of studies, and the BCA is available for use in the UK, as is *N. cucumeris* (Kajita, 1986; Razzak *et* al., 2019; Shibao *et al.*, 2009, 2010). In addition to this there are a number of BCAs which target thrips or specifically *F. occidentalis* available for use in England, both available for use with and without a licence (Defra, 2019). Some may be useful in combating *T. palmi* outbreaks although further information would be required to confirm this.

In a similar manner to trap plants, banker plants can be placed throughout the crop to act as a reservoir for beneficial species. These can provide a continuous source of

BCAs over a growing cycle with the plants providing resources including pollen, oviposition sites and a stable habitat which may be absent within the economic crop. This strategy is used in Canadian horticulture in combination with *O. insidiosus* to combat *F. occidentalis*. The strategy must work in conjunction with the biology of the BCA as short cropping production may not allow the BCA population to build up, and if entire host plants are removed (as in ornamental production), this may remove a large proportion of BCA and any parasitoid eggs laid within the pest population. If the biology of the BCA is compatible with the crop then benefits could include reduced costs, enhanced effectiveness and preventative BCA uses (Brownbridge *et al.,* 2013).

The use of entomopathogenic fungi such as *Lecanicillium muscarium* and *Beauveria bassiana* also are reported to be effective. Studies show that *L. muscarium* causes significant mortality to both adults and larvae of *T. palmi*, whereas *B. bassiana* has been shown to be effective but only under certain conditions and in the absence of certain chemical insecticides. These could be factored into IPM strategies (Cannon *et al.*, 2007a). Both of these are available in the UK under the product names Mycotal™ and Botanigard WP™/Naturalis-L™ respectively (HSE, 2020).

Biological controls were considered but not used in the previous UK outbreak, as *T. palmi* specific BCAs were unavailable in the UK and the environmental impacts of insecticide use were low (Cannon *et al.*, 2007b).

Chemical control

Thrips palmi is considered difficult to control and the use of a solely chemical based strategy is likely to be ineffective. Difficulties include instances of pesticide resistance and inadequate cover due to the cryptic nature of *T. palmi*, which can be present on the underside of leaves, underneath the calyxes or similar. It has been reported that insecticide resistance seen in *T. palmi* populations (to organophosphates, carbamates and pyrethroids), could be due to this cryptic nature rather than genuine resistance (Cannon *et al.*, 2007a).

Many of the insecticides which have been shown to be effective against the pest are not registered for use or have been revoked, meaning they are unavailable for use in the UK. Some of the active ingredients which have been shown in the literature to be effective are listed in table 3, along with whether they are registered for UK use.

Impacts

Economic impact

Direct feeding by *T. palmi* results in typical sap sucker damage such as stunting, leaf deformation, silvery or bronze discolouration, chlorosis, and silvery scars on the host surface. The pest feeds gregariously and under protected conditions populations of the thrips can increase rapidly leading to severe infestations and damage which can reduce the plants vigour, yield and marketability (Cannon *et al.*, 2007b; Scrace, 2018).

In addition to the immediate direct feeding damage *T. palmi* can also transmit novel viruses. The species is one of only 0.2% of thrips species which is able to vector tospoviruses, the cause of a number of significant plant diseases (Jones, 2005). Tospoviruses are capable of infecting thrips, and once infected (primarily at first and early second larval stage), the thrips may be able to transmit the virus whilst feeding on hosts throughout the rest of its life. There are also reports that *T. palmi* feeds preferentially on tospovirus infected plants making *T. palmi* an efficient vector (Jones, 2005). If novel viruses were introduced with *T. palmi* or on associated hosts, other native species may then be able to vector these viruses resulting in additional impacts to UK horticulture (Cannon *et al.*, 2007b).

Table 3. List of active ingredients for the control of *T. palmi* (Source: adapted from Cannon *et al.* (2007a))

Active ingredient	Country of use	Crop	Registered for use in the UK?	References (as cited in Cannon *et al.* (2007a))
abamectin	Japan, Venezuala	N/A, Aubergine, Beans	Yes	Anon (1998) Bon and Rhino (1989) Cermeli *et al.* (2002) McHugh and Mau (1998)
aldicab	Japan	N/A	No	Chang (1991) Kawai (2001)
carbofuran	Japan	N/A	No	Chang (1991) Kawai (2001)
carbosulfan	Japan	N/A	No	Chang (1991)

Active ingredient	**Country of use**	**Crop**	**Registered for use in the UK?**	**References** **(as cited in Cannon *et al.* (2007a))**
				Kawai (2001)
cartap	Venezuala	Beans	No	Cermeli *et al.* (2002)
chlorfenapyr	USA	Peppers	No	Seal (1993; 1994; 2004)
chlorfluazuron	Venezuala	Beans	No	Cermeli *et al*. (1993)
diflurobenzon +paraffinic oil	Venezuala	Beans	No	Cermeli *et al.* (2002)
emamectin benzoate	N/A	N/A	No	N/A
flufenoxuron	Venezuala	Beans	No	Cermeli *et al*. (1993; 2002) Nagai *et al.* (1988)
imidiacloprid	India, Japan, Netherlands, USA, Venezuala	N/A, Beans, Ficus	No	Anon (1995) Cermeli *et al*. (1993; 2002) Murai (2001) Seal (1994) Sreekanth *et al.* (2004)
insecticidal soaps	Japan	N/A	Yes	Young and Zhang (1998)
methiocarb	Japan	N/A	No	Cooper (1991) Hsu *et al.* (2002)

Active ingredient	Country of use	Crop	Registered for use in the UK?	References (as cited in Cannon *et al.* (2007a))
				Sakimura *et al.* (1986) Takematsu *et al.* (1999)
oxamyl	Japan, Venezuala	N/A, Beans	No	Cermeli *et al*. (1993) Chang (1991) Kawai (2001)
pyriproxyfen	Venezuala	Beans	Yes	Cermeli *et al.* (2002) Nagai (1990)
spinosad	USA	Cucumbers, Peppers	Yes	Jones *et al.* (2005) McHugh and Mau (1998) Rodriguéz *et al.* (2003) Seal (1993; 1994; 2004)
thiacloprid	N/A	N/A	No	N/A
thiamthoxam	Brazil	Chrysanthemum	No	Takematsu *et al.* (1999)

Thrips palmi has been shown to transmit *Calla lily chlorotic spot orthotospovirus (*CCSV) (CABI, 2019b), *Groundnut bud necrosis orthotospovirus* (GBNV)*, Melon yellow spot orthotospovirus* (MYSV) and *Watermelon silver mottle* orthotospovirus (WSMV) and may possibly transmit *Watermelon bud necrosis orthotospovirus* (WBNV) (Collins, 2016; Jones, 2005). Host lists on CABI suggest that hosts of importance to the UK of these viruses include carrot (GBNV), chillies (GBNV), cucumber (MYSV), onion (GBNV), pea (GBNV), potato (GBNV) and tomato (GBNV, WSMV). Of these only cucumber is listed as a main host with the remaining hosts categorised as other and have all been reported from India (other being defined as other crops/plants attacked by the pest, but not as often or not as severely) (CABI, 2019b, 2019c, 2019f, 2019g). One paper has also showed that *T. palmi* may be able to vector *Capsicum chlorosis orthotospovirus* (CaCV), a pest of peppers (CABI, 2019a). Adults fed on infected pepper leaves were able to infect healthy seedlings 50% of the time 21 days after release (Chiaki *et al.*, 2020). A further concern is the implication that *T. palmi* can vector *Tomato spotted wilt orthotospovirus* (TSWV) (Jones, 2005; Persley *et al.*, 2006). TSWV is widespread throughout Europe and can cause significant losses in a wide range of vegetable and ornamental crops (CABI, 2019e). If *T. palmi* is able to vector TSWV, its introduction could exacerbate existing problems and cause further substantial economic impacts.

The introduction of *T. palmi* into the UK could result in a number of direct and indirect impacts, including crop losses in both yield and quality, additional pest control costs, additional labour costs, additional research to develop new plant protection strategies and technologies, further plant health certification costs and a reduced level of exports resulting in significant economic losses for UK horticulture (Cannon *et al.*, 2007b; MacLeod *et al.*, 2004).

The extra measures required for eradication of the UK outbreak in 2000 resulted in significant financial costs for both the grower and the PHSI with the eradication costs estimated at £55,600 for the grower and £178,450 overall. An assessment in 2004, estimated the economic impact of *T. palmi* to UK horticulture if it were to become established at up to £16.9-19.6 million over a 10 year period (dependent on rates of spread) representing a significant impact to the UK. This is significantly increased if there is a reduction in exports. The majority of exports of relevant hosts to the EU from the UK are to countries where *T. palmi* is mitigated for by legislative quarantine measures, and it is unclear if an outbreak or introduction of the thrips would result in a reduction of exports. However, if EU countries prohibited the movement of plants and plant products from the UK, the losses would be significant (MacLeod *et al*., 2004). This estimate may now be outdated due to changes and shifts within the industry but indicates at the potential economic impacts posed by the establishment of *T. palmi* in the UK.

Environmental impact

Thrips palmi is unlikely to survive outside in the UK and therefore the environmental impact is likely to be negligible.

Social impact

The major social impacts will likely come from the indirect impacts of crop losses on businesses.

9. Appendix B

General biosecurity advice and advisory measures for growers

Some measures which have proved effective in control strategies of *T. palmi* and other thrips pests are highlighted below.

- Sealing the infested area and other areas potentially at risk as far as practically possible to prevent the escape or further spread of *T. palmi*.

- Given the potential for the pest to be physically transferred, best hygiene practice should be followed as below:

    - Staff should be trained in advance to recognise the symptoms of a *T. palmi* infestation.

    - 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.

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

    - 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 measures such as high pressure water or steam cleaners.

    - Access to the working area should be restricted to essential staff trained in the recognition of *T. palmi* 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. Avoiding working in blue, white or yellow clothing may also decrease the risk of *T. palmi* being attracted and spread to other areas on clothing.

- Volunteer plants and weeds may act as reservoirs for *T. palmi*. Controlling these plants within and around the site 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). Some examples of potential host weed species include *Solanum nigrum* (black nightshade), *Capsella bursa-pastoris* (shepherd's purse), *Cerastium glomeratum* (mouse-ear chickweed) and *Vicia sativa* (common vetch) (EFSA, 2019).

- Measures to reduce the size of any potential populations which may be taken as a precaution include:

  - The use of sticky traps or sticky trap rolls is advised as it is an effective tool for both monitoring and mass trapping.

  - Screening openings such as ventilation and doors with the appropriately sized mesh can provide a physical barrier to reduce the likelihood of spread to other areas (adult *T. palmi* are around 1-1.3 mm in length). The pest is unlikely to survive outdoors, but this may reduce the risk of spread to any non-infested areas.

  - Overhead irrigation, if feasible, can help to wash adults from leaves. This may not be compatible or practical with the crop being grown or irrigation schedules. Also, with adults spending much of their time on the undersides of leaves it may not cause large population reductions but could be combined with other measures.

  - Black or silver plastic mulches and films have been used in previous outbreaks and control strategies to reduce the emergence of pre-existing pupae and prevent pre-pupae reaching the soil to pupate, causing a knock-on reduction in population levels. They can also repel flying adults by interfering with visual cues used by the pest to locate favourable habitats.

  - The use of preferential hosts as trap plants can be used as a mass trapping tool. These are placed amongst the crop and monitored to determine hot spots for treatments or removed on a regular basis to reduce population levels within the crop. This technique is used in Venezuela, utilising cucumber and bean plants to combat *T. palmi* (Salas, 2004) and in Canadian protected horticulture as part of IPM strategies, utilising flowering *Chrysanthemum* sp. against *Frankliniella occidentalis* (western flower thrips) (Brownbridge *et al*., 2013; Mouden *et al*., 2017). However, the efficacy of this strategy will be diminished if the trap plants are less attractive to *T. palmi* than the host crop.

- Biological control agents (BCA) are used in the control of *T. palmi* in its native range and are often utilised within IPM strategies. One genus which seems to be an effective predator of *T. palmi* is *Orius* (Hemiptera: Anthocoridae), with multiple species within the genus having significant impacts on *T. palmi* population density. *Orius laevigatus* and *O. majusculus* are available for use in UK for the control of thrips, although there are no specific references in the literature of predation on *T. palmi* by these species. The use of *Amblyseius swirskii* for the control of *T. palmi* is backed up by a number of studies and the BCA is available for use in UK. The mite *Neoseiulus cucumeris* (Acari: Phytoseiidae) has been reported as an effective predator of a number of thrips species including *Thrips tabaci* (onion thrips), *Frankliniella tritici* (flower thrips) and *Scirtothrips dorsalis* (chilli thrips). It has been shown to predate *T. palmi* in laboratory trials and is available for use in the UK. In addition to this there are a number of BCAs which target thrips or specifically *Frankliniella occidentalis* (western flower thrips) available for use in England, either with or without a non-native biological control licence. More information on these can be found in the guidance for the release of non-native biological control agents (https://secure.fera.defra.gov.uk/phiw/riskRegister/plant-health/non-native-biocontrol-agents.cfm).

- In a similar manner to trap plants, banker plants can be placed throughout the crop to act as a reservoir for beneficial species. These plants provide resources including pollen, oviposition sites and a stable habitat which may be absent within the crop. This strategy is used in IPM strategies in Canadian floriculture, using ornamental pepper plants to maintain *O. insidious* populations for the control of *F. occidentalis* (Brownbridge *et al.*, 2013).

- The use of the entomopathogenic fungi such as *Lecanicillium muscarium* and *Beauveria bassiana* are reported to be effective. Studies show that *L. muscarium* causes significant mortality to both adults and larvae of *T. palmi*, whereas *B. bassiana* has been shown to be effective under certain conditions and in the absence of certain chemical insecticides. This would have to be factored into any IPM strategy. Both of these are available in the UK (see Appendix A for further details (Biological control)).

- Many of the insecticides which have been shown to be effective against the pest are not registered for use or have been revoked, and therefore are unavailable for use in the UK. Any insecticidal treatments as part of outbreak management will be used under guidance by the Defra Risk & Horizon Scanning team.

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