Department
for Environment
Food & Rural Affairs

Rapid Pest Risk Analysis (PRA) for:

Pochazia shantungensis (and *P. chinensis*)

March 2025

Summary and conclusions of the rapid PRA

This rapid PRA shows:

Pochazia shantungensis is a hemipteran insect which is thought to be native to eastern China. It is now also found in South Korea, Japan and scattered locations in southern Europe. There are apparently established populations in parts of southern France, Pistoia in Italy, Sochi in Russia and around Istanbul in Türkiye. There have been detections of the pest in other parts of Europe, often linked with recently imported plants. In 2024 it was intercepted in England and Wales for the first time, with findings of the pest in multiple consignments of plants (hardy ornamental stock (HONS)) from Italy.

Pochazia shantungensis feeds on sap (phloem) of plants. Although the English name brown-winged cicada is commonly used, this insect is not a cicada and “brown-winged planthopper” would be more appropriate. The insects feed on a very wide range of plant species, both herbaceous and woody. Adults lay eggs deep inside young twigs of woody plants, and the pest overwinters as eggs in the twigs. There are one or two generations per year in the current range. *Pochazia chinensis* is a very closely related species which was described in 2024 based on molecular differences. Before that analysis, it was regarded as conspecific with *P. shantungensis*. As nearly all published information may refer to either species, this PRA does not attempt to distinguish between them and information presented for *P. shantungensis* may refer to either species (or both).

Likelihood of entry

Plants for planting are considered **very likely** to allow entry of *P. shantungensis*, with **high confidence**. Movement of infested planting material has been linked to outbreaks and transient incursions in mainland Europe. All life stages (but particularly nymphs and eggs) have been intercepted multiple times in England and Wales on Italian planting material. Movement and disturbance caused by cutting and packing plant parts was thought likely to cause nymphs and adults to leave both cut flowers and fresh produce. Entry on **cut flowers and branches** was considered **very unlikely** with **medium confidence** as eggs could be laid in some stems. Entry on **fresh produce** was considered **very unlikely** with **high confidence** as eggs would not be associated with these commodities. Entry as a **contaminating pest (hitchhiking)** was considered **unlikely** with **medium confidence**: both adults and nymphs are very mobile, so locating a suitable growing host after arrival was not considered limiting, but the numbers of insects associated with any one consignment is likely to be low.

Likelihood of establishment

While there is uncertainty over the exact climatic conditions *P. shantungensis* requires in order to complete development, **establishment outdoors** in the UK is considered **unlikely** with **medium confidence**. The insect appears to require long periods at temperatures higher than those typically experienced in the UK to complete its lifecycle. The UK has a temperate oceanic climate, with relatively cool summers, and any heatwaves are usually relatively short in duration. Nymphs would hatch from eggs considerably later in the year than in any part of the current range, and nymphs are not considered able to complete development to adult before winter.

Suitable woody hosts for egg laying are not commonly grown long-term in commercial protected cultivation. The pest may be able to establish in specialist tropical or subtropical botanical collections, but there are no records of it establishing in protected cultivation anywhere in its current range. Overall, **establishment in protected cultivation** is considered **unlikely** with **medium confidence**.

Economic, environmental and social impact

Impacts in **South Korea** are considered to be **large**, with **medium confidence**. High populations of *P. shantungensis* can occur and the damage caused by egg laying can cause the twigs to die, or a reduction in fruit quality due to blocked nutrient flow. Other impacts occur from reduction in sap from feeding of both adults and nymphs, egestion of honeydew, and growth of sooty moulds on the honeydew. Impacts in **other parts of the current distribution** are considered to be **small**, with **medium confidence**. There has been damage in China, but few data are available. There are no reports of impacts from other countries where *P. shantungensis* has recently established, though newly invasive populations may take some years to build up to a level where damage occurs.

Potential impacts in the **UK** are considered **very small** with **high confidence**. The pest is considered unlikely to establish outdoors, and any impacts would be from transient populations which would not persist (for example, introduction of late instar nymphs which are able to develop to adult and lay eggs; but the next year, those eggs could not develop all the way to adult). Even if establishment was possible, it is likely the pest would be restricted to only the very warmest areas of the UK and even there, be under significant stress from the relatively cool UK summers. It is very unlikely that high populations capable of causing unacceptable economic impacts could occur. If the pest were introduced to a glasshouse where woody plants are grown, localised damage could occur, but the pest would probably be restricted to a single site unless infested plant material was moved.

Endangered area

As *P. shantungensis* is not expected to establish in any part of the UK and would not cause unacceptable impacts, there is no endangered area.

Risk management options

Preventing entry would be difficult. The very wide host range and presence in parts of Europe means there is a large volume of potentially infested planting material imported into the UK, as evidenced by the high number of intercepted consignments containing the pest detected in 2024.

Various control methods are used in parts of China and South Korea, ranging from insecticides to cultural controls such as pruning. There has been a lot of research in South Korea into plant-based extracts as alternatives to chemical controls.

Key uncertainties and topics that would benefit from further investigation

More details about the temperature requirements of this pest are needed. Some data are available, especially on egg hatching, but they are often contradictory and there are no complete lifecycle data available.

Data on any future spread into more temperate areas with cooler summers would be critical to many assumptions in this PRA regarding environmental tolerances and degree day accumulation required for development. In particular, monitoring any new distribution records of populations in Japan and France would be informative, as in both countries the pest could spread northwards with relatively few geographical barriers such as mountain ranges.

As this PRA needed to be completed within a short deadline, machine translation (mostly using the website https://www.deepl.com/) was used for papers in Korean and Chinese. Where the PRA relies on information only in the text (rather than interpreting tables or figures) such instances are clearly identified. It would be useful to have professional translation of at least some sections of important papers to capture nuances and also to be sure the interpretation of graphs, tables and figures is correct.

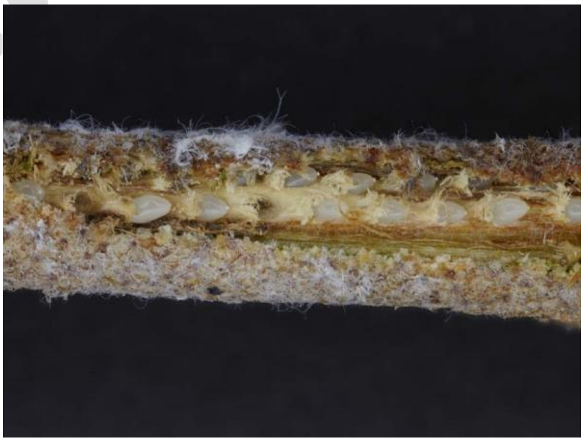
As the pest is not expected to establish in the UK, data on natural spread is relatively unimportant in this PRA and will not affect the conclusions. However, data on the flight capacity of adults is sparse. Adults can fly tens of metres but it is unclear if they will undertake longer flights.

Images of the pest

Adult *Pochazia shantungensis* with a 5th instar nymph © Chris Malumphy

First instar *Pochazia shantungensis* nymph reared from eggs laid into *Prunus lusitanica* © Fera Science Ltd

Fifth instar nymph of *Pochazia shantungensis* © Fera Science Ltd



***Pochazia shantungensis* eggs laid in *Elaeagnus* from Italy** © Fera Science Ltd

Is there a need for a detailed PRA or for a more detailed analysis of particular sections of the PRA? If yes, select the PRA area (UK or EPPO) and the PRA scheme (UK or EPPO) to be used.

This is a pest which is only known to have become invasive since around 2009 in South Korea, and around 2018 in Türkiye. Recently established populations are likely to spread further in future, and impacts in the invasive range may change over time. New data on many aspects of *P. shantungensis* are being published very regularly. With the current state of knowledge, a more detailed PRA would not add anything to the current assessment and is not recommended. This document has used all accessible information that could reasonably be found to make the assessments. Current knowledge gaps are almost certainly due to the information not being available (or perhaps not accessible).

As with all pest risk analyses, regular horizon scanning to identify new information relevant to the risk assessment for the UK will take place. If any new data are found which might alter the conclusions of this PRA, notably established populations found in areas with cooler summers, then this PRA would require revision.

No	✓				
Yes		PRA area: UK or EPPO		PRA scheme: UK or EPPO	

Given the information assembled within the time scale required, is statutory action considered appropriate / justified?

All parts of the UK have a substantially cooler summer than any part of the current range of *P. shantungensis*. Two of the conclusions of this PRA are that the pest is unable establish in the UK, and is not expected to cause unacceptable economic impacts. Therefore, though transient damage may occur from repeated introductions of the pest, *P. shantungensis* does not meet the criteria to be a quarantine pest.

Yes Statutory action ☐ No Statutory action ☑

Stage 1: Initiation

1. What is the name of the pest?

Pochazia shantungensis (Chou & Lu, 1977) (Insecta, Hemiptera, Ricaniidae).

Synonym: *Ricania shantungensis* Chou & Lu, 1977. This name is still used in some recent publications.

Brown-winged planthopper. The common name brown-winged cicada is often used, but this insect is not a cicada and planthopper is more correct.

Originally described in the genus *Ricania* by Chou and Lu (1977), the authors gave a species description in Chinese and included illustrations of wing characters. Rahman *et al.* (2012) redescribed the species in English under the genus *Pochazia*, providing more detail and describing the male genitalia for the first time. The morphological characters separating the *Ricania* and *Pochazia* are not clear, and neither genus appears to be monophyletic (Stroinski & Bourgoin, 2022). Kobayashi *et al.* (2024) gave a further description of *P. shantungensis*, again in English, and provided characters which allow fifth instar nymphs to be morphologically separated from the closely related *P. sublimata*, as well as further morphological characters of adults, both male and female.

Molecular analysis on "*P. shantungensis*" specimens from South Korea and China have revealed a cryptic species new to science (Lee *et al.*, 2024). *Pochazia chinensis* shows clear separation from *P. shantungensis* based on the portion of mitochondrial genome analysed, and some subtle morphological characters are given to separate adults of the two species (Lee *et al.*, 2024). These morphological characters do not seem to be sufficient for species level identification of the intercepted specimens from Italy (S. Reid, Fera Science Ltd., pers. comm., October 2024). Both *P. shantungensis* and *P. chinensis* have been recorded from parts of China and South Korea, but due to the very recent description of the new species, it is unclear where else *P. chinensis* may occur. Within this PRA, it is acknowledged that some populations referred to as *P. shantungensis* may be *P. chinensis*, or both species may be present in a given location, but based on current information this cannot be determined. Thus, throughout this PRA, all information that refers to *P. shantungensis* may also/instead refer to *P. chinensis*.

Many South Korean authors refer to "*Ricania* sp.", including papers published several years after Rahman *et al.* (2012) clarified the identity of the invasive species in South Korea. Papers using the name *Ricania* sp. are included in this PRA if machine translation of the Korean text (especially background information in the introduction) and the cited references make it clear they are referring to *P. shantungensis*. Park and Jung (2020) and Park and Jung (2021) refer to the species in South Korea as *Ricania sublimata*, but Kobayashi *et al.* (2024) state this is a misidentification of *P. shantungensis*.

2. What initiated this rapid PRA?

Pochazia shantungensis was first reported from the EPPO region in 2018, from Türkiye (Hızal *et al.*, 2019), and France (Bourgoin *et al.*, 2020). In the following years it was also recorded from other parts of Europe, including Italy (Stroiński *et al.*, 2022). It is an economically damaging pest in eastern Asia, and so the spread of this pest into new parts of the world was concerning. The European and Mediterranean Plant Protection Organisation (EPPO) added it to their early warning Alert List in 2021 (EPPO, 2021). This prompted the addition of the pest to the UK plant health risk register. The results of the rapid screening of the risk register (designed to be precautionary) were presented to the UK's Plant Health Risk Group in March 2023 and this concluded *P. shantungensis* potentially met the criteria to be a quarantine pest for Great Britain. Therefore, the conclusion was that statutory action should be taken on findings pending a more detailed assessment to fully evaluate the risk to the UK. A PRA was requested to research the risk from *P. shantungensis* in more detail, including assessing whether it should be added to the plant health legislation as a quarantine pest for Great Britain. Elsewhere in Europe, there have been rapid PRAs by Germany (Schrader, 2021), the Netherlands (Netherlands NPPO, 2023b) and a pest categorisation by the European Food Safety Authority (Bragard *et al.*, 2023). In 2024, the Plant Health and Seeds Inspectorate in England and Wales started to detect *P. shantungensis* on consignments of plants imported from Italy. Due to a large number of infested consignments being destroyed, this PRA became very high priority, in order to fully assess the potential risk of this pest to the UK.

3. What is the PRA area?

The PRA area is the United Kingdom of Great Britain and Northern Ireland.

Stage 2: Risk Assessment

4. What is the pest's status in the plant health legislation, and in the lists of EPPO[1]?

The legislation for Great Britain is the Phytosanitary Conditions Regulation (assimilated regulation (EU) 2019/2072)[2]. The legislation which applies to Northern Ireland is the EU legislation: 2019/2072[3] and 2016/2031. *Pochazia shantungensis* is not listed as a quarantine pest in either set of legislation.

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[1] https://www.eppo.int/ACTIVITIES/quarantine_activities

[2] https://www.legislation.gov.uk/eur/2019/2072 (link to latest consolidated version)

[3] The latest consolidated version can be accessed on the left-hand side of https://eur-lex.europa.eu/eli/reg_impl/2019/2072/oj

EFSA determined through a pest categorisation that *P. shantungensis* met the criteria to be a quarantine pest for the EU (Bragard *et al.*, 2023), but this is a recommendation to the EU Commission and not a legal decision. Likewise, in the UK the risk register screening considered there was enough evidence of the risk of *P. shantungensis* to take statutory action against this pest when detected, pending the full assessment from this PRA.

Pochazia shantungensis was added to the EPPO Alert List in June 2021 (EPPO, 2021) as an early warning to member countries. It is not currently on the lists of pests recommended for regulation (i.e., is not included on the EPPO A2 list).

5. What is the pest's current geographical distribution?

Apparently native to eastern China, there are scattered records of *P. shantungensis* from several provinces in the eastern part of the country. Few data other than occurrence records and morphological descriptions are available from China, with most biological information coming from populations in Zhejiang, just south of Shanghai.

Pochazia shantungensis is an invasive pest in other parts of eastern Asia (Table 1, Fig. 1). The first reports of this species from outside China were from South Korea in 2011, though it had likely been present since at least 2009 (Rahman *et al.*, 2012). Initially tentatively identified as a *Ricanula* sp. (Choe *et al.*, 2011; Choi *et al.*, 2011; Jo *et al.*, 2011), Rahman *et al.* (2012) examined dried specimens, compared them with the holotype, and identified the unknown insect as *P. shantungensis*. At first it was distributed only in the western regions of South Korea, but the pest has now spread across the peninsula and surveys by Kim *et al.* (2022) show numerous records on the east coast as well. It should be noted, for the sake of clarity, not all published South Korean records are shown in Figure 1. In Japan, it is suspected that *P. shantungensis* has been present since 2015, based on internet photos (Kobayashi *et al.*, 2024). The species identity was confirmed in 2024 from detailed morphological examination of specimens from several prefectures, and previous unidentified records from elsewhere in Japan were assigned to *P. shantungensis* (Kobayashi *et al.*, 2024).

In Europe and western Asia (Table 1, Fig. 2), *Pochazia shantungensis* was first detected in Türkiye in November 2018 (Çetín *et al.*, 2019; Hızal *et al.*, 2019) in several provinces around Istanbul.

In France, the first published report was from Cagnes-sur-Mer (Alpes-Maritimes), initially recorded in November 2018 with further findings a year later in November 2019 (Bourgoin *et al.*, 2020). More individuals have been caught in this region in recent years (EPPO, 2025). There have been findings elsewhere in France, in Montpellier (Occitanie) in 2022 (Berthelot *et al.*, 2023). There was a second tentative report from Montpellier in 2023 from the community web identification site iNaturalist, including a rather blurry photo, though identification based on a photograph could not be certain. More specimens were trapped in the same general area in 2023 and elsewhere in the region in 2024 (EPPO, 2025). In Corsica, adults and nymphs were detected in two locations in 2023 (EPPO, 2024) with additional findings in 2024 (EPPO, 2025). The official pest status of *P. shantungensis* in France is present, not widely distributed and under official control (EPPO, 2025).

In Italy, *P. shantungensis* was first recorded in the province of Pistoia in September 2019, with more specimens collected in 2022 from a second location less than 0.5 km away (Stroiński *et al.*, 2022).

The first reports from Russia were of a colony of late instar nymphs found in Sochi in September 2022, which were reared to adult for species confirmation (Zhuravleva *et al.*, 2023). Subsequently there have been four iNaturalist reports in 2024 from the general Sochi region, though the posted photographs are variable in quality.

There have been additional reports of *P. shantungensis* in Europe, but the following records are not thought to be indicative of established populations at the time of writing. There was an isolated finding in a private garden in Germany (Federal State of Baden-Würtenburg) in 2021 on a *Catalpa* plant which had been imported from Italy (Schrader, 2021). The insects from the initial report were killed, and follow up inspections in 2022 and 2023 did not detect the pest. Therefore, *P. shantungensis* was declared eradicated from Germany in 2023 by the National Plant Protection Organisation (NPPO) (EPPO, 2024). There has been a similar isolated finding in July 2023 of nymphs in a private garden in the Netherlands (Hendrik-Ido-Ambacht), potentially linked to recently purchased plants (Netherlands NPPO, 2023a; den Bieman *et al.*, 2024). Adults were reared for species confirmation. Follow up inspections of the affected garden and limited traceback activity was planned (Netherlands NPPO, 2023a). The QuickScan following this finding noted that eradication is difficult due to the wide host range and limited pesticides available for use in private gardens (Netherlands NPPO, 2023b). The NPPO of the Netherlands declared the status of *P. shantungensis* in the Netherlands to be transient, non-actionable (EPPO, 2024). Three adults were found in a nursery in Hungary (Pécs-Hird, Baranya county) in September and October 2024 (Schlitt *et al.*, 2024). The nursery had imported laurel cuttings from Italy about 18 months previously and was also growing plants the nursery had propagated itself. No eggs were found and it is unclear if the species has established in Hungary (Schlitt *et al.*, 2024). There has been a finding of four nymphs in a glasshouse in January 2025 in the Grand-Est region of France (bordering Germany and Switzerland), but no further specimens were found after inspection (EPPO, 2025). Two planthoppers were recorded in Bulgaria in the vicinity of a flower market (Gjonov & Simov, 2025).

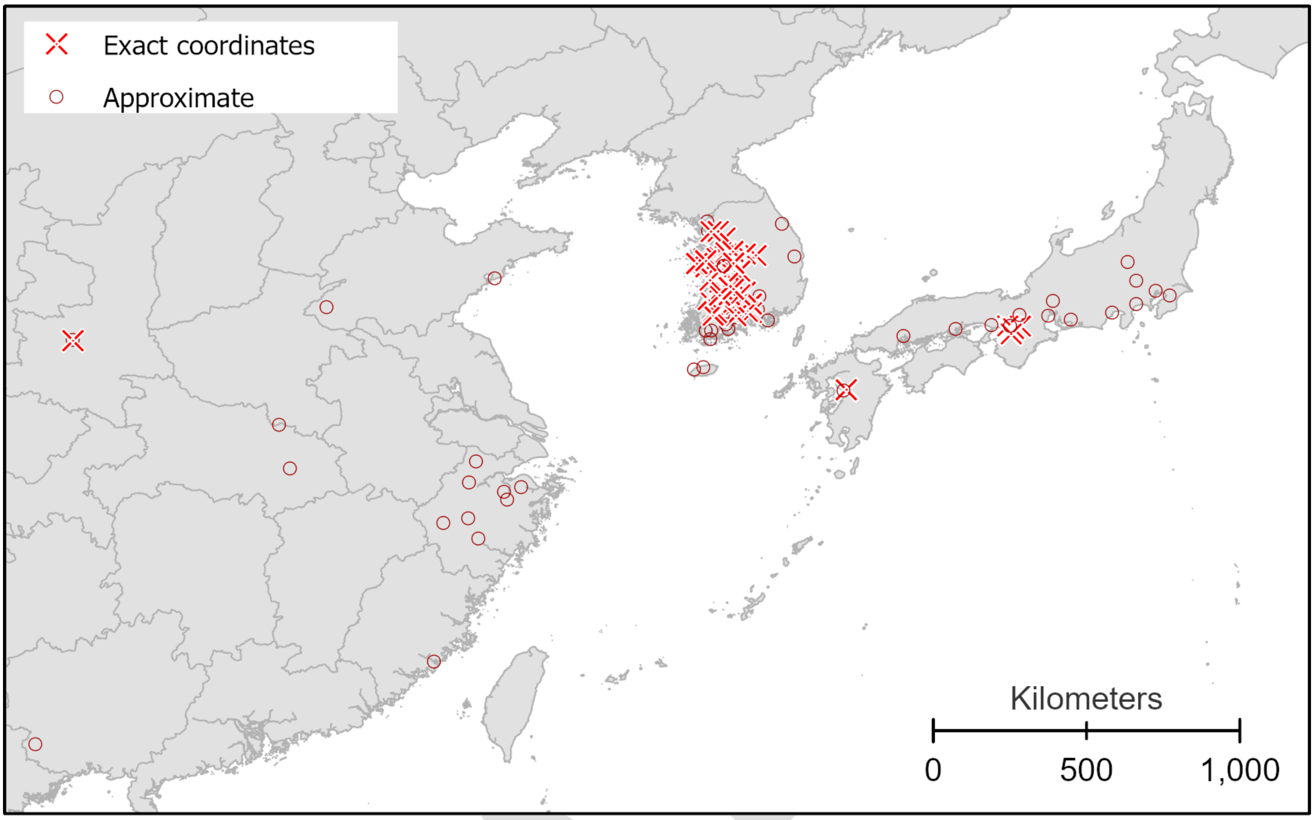

Figure 1. Distribution records of *Pochazia shantungensis* in eastern Asia. The map includes both the presumed native range in China as well as records from South Korea and Japan, where the species has been recently introduced and may still be spreading. Red crosses indicate exact locations from coordinates, brown circles are approximated from location names.

Figure 2. **Distribution records of *Pochazia shantungensis* in Europe and western Asia**. The species has been recently introduced to the marked locations and seems likely to spread further. This map does not include records based only on citizen science reports. Red crosses indicate exact locations from coordinates, brown circles are approximated from location names, black question marks are populations which may not be established.

Table 1: Distribution of established (or apparently established) populations of *Pochazia shantungensis* (potentially some may be *P. chinensis*)

North America:	Not known to be present
Central America:	Not known to be present
South America:	Not known to be present
Europe:	France: Provence-Alpes-Côte d'Azur (Bourgoin *et al.*, 2020), Corsica (EPPO, 2024), Occitanie (Berthelot *et al.*, 2023). Official pest status in France: present, not widely distributed and under official control (EPPO, 2025) Italy: Pistoia (Stroiński *et al.*, 2022) Russian Federation: Sochi: Krasnodar Krai (Zhuravleva *et al.*, 2023) Türkiye: Istanbul, Kocaeli and Yalova (Çetín *et al.*, 2019; Hızal *et al.*, 2023)
Africa:	Not known to be present
Asia:	China: Guangxi (Jiang *et al.*, 2023), Fujian (Lee *et al.*, 2024), Henan (Jiang *et al.*, 2023), Hubei (Lee *et al.*, 2024), Shaanxi (Jiang *et al.*, 2019; Jiang *et al.*, 2023), Shandong (Chou & Lu, 1977; Lee *et al.*, 2024), Zhejiang (Li *et al.*, 2006; Shen *et al.*, 2007; Lee *et al.*, 2024) Japan: Honshu and Kyushu (Kobayashi *et al.*, 2024) South Korea (Rahman *et al.*, 2012; Lee *et al.*, 2024)
Oceania:	Not known to be present

Another source of records which have not usually been included in this PRA are citizen science / internet community identification sources, notably iNaturalist[4] (which contributes verified records to www.gbif.org). The veracity of the posted identifications cannot always be determined. Accurate species identification is not possible from a photograph, especially for records in eastern Asia (for example, see the discussion in Stroinski & Bourgoin, 2022), and so this PRA relies on records from published papers as a primary source. iNaturalist records from countries where *P. shantungensis* is not known to be present, e.g. India, have not been considered here as they require additional verification. However, records from within the current known global distribution are more plausible. In one instance in this PRA, iNaturalist records were used as an indication that *P. shantungensis* is likely to have persisted in a location since the initial published reports of a single finding: Sochi in Russia. Other European iNaturalist sightings have been recorded from Austria, Belgium (where the insect was explicitly associated with imported plants from Italy), Spain and Switzerland. In Italy, there are numerous iNaturalist records from across the north of the country and one from Sicily.

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[4] https://www.inaturalist.org/observations?subview=map&taxon_id=565012 last accessed 3 March 2025

6. Is the pest established or transient, or suspected to be established/transient in the UK/PRA area?

Until 2024, no records of *P. shantungensis* were known from the UK. In May 2024, the Plant Health and Seeds Inspectorate for England and Wales detected nymphs on imported plants from Italy, and specimens were identified using molecular analysis. In the autumn of 2024, large numbers of infested consignments started to be detected during import inspections, all originating from the Pistoia province (Tuscany region) of Italy. In September and early October, interceptions were of nymphs and adults, but by the end of October, eggs laid in twigs and leaf veins of various woody plants started to be detected on imported plants. All interceptions so far have been confirmed as *P. shantungensis* and not *P. chinensis* using molecular methods. Initially, samples of intercepted nymphs (where viable) were reared to adult for detailed morphological analysis as well as molecular identification. The morphological characters for separation of adults of the two species given by Lee *et al.* (2024) do not seem to be sufficient for species level identification of the intercepted specimens (S. Reid, Fera Science Ltd., pers. comm., October 2024). Intercepted adults are often smaller in size than sizes reported in the Korean literature (R. Deady, Fera Science Ltd., pers. comm., February 2025).

As of 4 March 2025, there have been 48 confirmed interceptions of *P. shantungensis* in England and Wales, with an additional 11 findings from a detailed survey of an individual nursery. This is a minimum number of interceptions, as verified species identification takes some time and it is possible that recent interceptions are still waiting to be confirmed.

As of 3 March 2025, two observations of *P. shantungensis* in the UK are available on iNaturalist, both specimens detected in August 2024. One was from Essex and the second in Monmouthshire. Both observations include good photographs, and while these are not sufficient to absolutely confirm the species identify, given the number of interceptions later in the year, the suggested identifications appear very plausible. There have been other apparent findings in the UK of *P. shantungensis* reported on the internet in 2024, but none have been verified through the collection of specimens.

7. What are the pest's natural and experimental host plants; of these, which are of economic and/or environmental importance in the UK/PRA area?

This pest is highly polyphagous with hosts from over 80 different plant families (Bourgoin *et al.*, 2020) recorded so far. However, as both adults and nymphs are highly mobile, it is unclear if every plant *P. shantungensis* is found on would allow the insect to develop over the full lifecycle and thus are true hosts. It seems likely that plants where eggs are laid may be more suitable, as the female has chosen to oviposit in the twigs, but even this is unknown. First instar nymphs hatching onto an unsuitable plant would be able to move onto other plants nearby.

Different hosts are used at different parts of the lifecycle. Nymphs mostly feed on low growing plants, such as herbaceous plants or shrubs (Choi *et al.*, 2017a). In a survey of forest vegetation in South Korea, adults in the pre-oviposition period were commonly found on herbaceous or shrubby plants, especially *Helianthus annuus* (sunflower), *Oenothera biennis* (evening primrose) and *Solanum nigrum* (black nightshade) (Choi *et al.*, 2017a). After the pre-oviposition period was over and egg laying started, adults moved to a wide range of perennial (woody) trees and shrubs. Hatching success the following year varied according to host, with a suggestion that lower success rates in some hosts could be due to the twigs containing eggs drying out overwinter (Choi *et al.*, 2017a). Comparing persimmon and chestnut twigs, more eggs survived in the chestnut, perhaps due to the natural properties of the wood: chestnut twigs have a higher water content compared to persimmons (Baek *et al.*, 2025).

Lengthy host lists are often reported in the literature: Table 2 contains a brief summary compiled from data in four key references. Kobayashi *et al.* (2024) has a list of recorded hosts in Japan and Hızal *et al.* (2023) a list for Türkiye, both with an indication of which life stage was reported on which plant. In South Korea, Kim *et al.* (2015) and Choi *et al.* (2017a) both have detailed tables of hosts, with the Latin names and an indication of how many adults and nymphs were found on each host. Choi *et al.* (2017a) also include data on whether eggs were laid in each species. The information on hosts which follows is highly abstracted, focussing on a small selection of highly favoured plants of particular relevance because the plant species or genus is commonly grown in the UK.

Table 2. Number of recorded hosts of *Pochazia shantungensis* from various countries in the current distribution. Host taxonomy (for example, family attribution) is as reported in each paper, and was not validated.

Country	Total number of host families	Total number of host species	No. of host species with eggs	No. of host species with nymphs	No. of host species with adults	Source
Japan	31	61	44	7	39	Kobayashi *et al.* (2024)
South Korea	60	131	–	–	–	Kim *et al.* (2015)
South Korea	34 (nymphs) 26 (any life stage)[5]	47[5]	17	55	39	Choi *et al.* (2017a)
Türkiye	31	58	29	55	42	Hızal *et al.* (2023)

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[5] Choi *et al.* (2017a) include Table 1 for nymphs and Table 2 for all life stages. In this PRA, total host families are reported separately for each table. Total host species in this PRA are based on authors' Table 2 only.

Eggs have been laid on hosts in Japan which include genera of importance to the UK, though usually the exact Japanese species is not widely grown here. Kobayashi *et al.* (2024) report eggs laid in *Camellia*, *Cornus* (dogwoods), *Ilex* (hollies), *Ligustrum* (privets), *Prunus* (stone fruits)*, Quercus* (oaks)*, Rhododendron* and *Vitis* (grapevines) among many others. In Türkiye favoured plants for egg laying include *Laurus nobilis* (bay laurel), *Ligustrum lucidum* (glossy privet) and *Olea europaea* (olive) (Hızal *et al.*, 2023), all commonly grown as ornamentals in the UK. In a survey in a forest in South Korea, eggs were preferentially laid in *Albizia julibrissin, Amorpha fruticosa, Cornus officinalis*, *Flueggea suffruticosa* (as *Securinega suffruticosa*), *Fraxinus chinensis* subsp. *rhynchophylla*, *Lindera obtusiloba, Robinia pseudoacacia, Rhododendron* spp. and *Zanthoxylum schinifolium* (Choi *et al.*, 2017a).

South Korean data on hosts which had more than 100 nymphs or adults on them, and which are widely grown in the UK, include *Ailanthus altissima* (tree of heaven)*, Euonymus alatus* (winged spindle)*, Paulownia tomentosa* var. *tomentosa* (under the synonym *P. coreana*) (foxglove tree)*,* several *Prunus* spp., several *Quercus* spp. (but not species commonly grown in the UK), *Rosa multiflora* (a rose)*,* several *Salix* spp. (willows) and *Syringa oblata* subsp. *dilatata* (a lilac) (Kim *et al.*, 2015). In a survey of fruit orchards, over 75% of both eggs and adults showed a preference for apple and peach orchards, with much smaller numbers detected on other trees such as jujube, grape, blueberry, pear, persimmon and various *Prunus* (Lee *et al.*, 2023).

The interceptions in England and Wales towards the end of 2024 of eggs in twigs of woody plants from Italy have been on a variety of species and genera, including *Arbutus unedo* (strawberry tree)*, Camellia japonica* (Japanese camellia)*, Elaeagnus* × *submacrophylla* (synonym *E.* × *ebbingei*) (oleaster)*, Euonymus japonicus* (evergreen spindle)*, Ilex*, *Laurus*, *Ligustrum, Magnolia, Photinia* and *Prunus lusitanica* (Portuguese laurel)*.* Identifying the host species associated with the interceptions of nymphs is more problematic. The intercepted consignments often contained multiple hosts in one container with no separation between different plants. The nymphs are very mobile, so it was unclear which plant the nymphs may have originated on as they were free to move between the plants in the consignment, although all findings were made associated with consignments of hardy ornamental nursery stock.

8. Summary of pest biology and/or lifecycle

Two generations per year have been recorded in Zhejiang, China (Li *et al.*, 2006; Shen *et al.*, 2007), Japan (Kobayashi *et al.*, 2024) and Türkiye (Çetín *et al.*, 2019; Hızal *et al.*, 2023). Only one generation has been recorded in South Korea (Choi *et al.*, 2012a; Jo *et al.*, 2016; Choi *et al.*, 2018). Choi *et al.* (2017a) suggest a very small number of early instar nymphs present at the time of adult flight in South Korea may be due to a partial second generation (machine translation of Korean paper), but no further details are available. Figure 3 summarises different lifecycle timings from various locations where the pest is present, though data are from different years and are not directly comparable. No evidence was found that this pest is capable of overwintering in any life stage other than eggs. No evidence was found that eggs will delay hatching by a year if conditions are not favourable.

The overwintering life stage are eggs laid inside twigs (and sometimes leaf veins) of woody plants. In the spring, egg hatching dates are dependent on temperature (Baek *et al.*, 2019b). After hatching, there are five nymphal instars, all highly mobile, before a final moult to adult occurs (Jo *et al.*, 2016). Only four nymphal instars were reported by Choi *et al.* (2012a). In South Korea, adults are most active in the evenings and first part of the night, between about 7–11 pm (Choi *et al.*, 2019; Choi *et al.*, 2020), though a different South Korean study reported that peak flight was considered to be 3–6 pm with almost no flight during the night (Kim *et al.*, 2018). Adults require a relatively long pre-oviposition period, though the reported length varies: Shen *et al.* (2007) say there are at least ten days before mating, and another ten days before egg laying (machine translation of Chinese text); Jo *et al.* (2016) state the total preoviposition period is 3–4 weeks; while Im *et al.* (2011) state this is approximately two months (machine translation of Korean conference abstract). It is unclear how males and females locate one another to mate, either for *P. shantungensis* specifically or in Ricaniidae more generally. Males and females of an Australian ricaniid, *Scolypopa australis*, are known to produce sex-specific vibrational signals, but investigations are ongoing as to whether this is a mate-finding mechanism (Sullivan *et al.*, 2022; MacDougall *et al.*, 2024).

After the maturation period, adult females lay their eggs obliquely in a zig-zag or herringbone pattern of double rows deep inside one-year old woody twigs of a wide variety of plants, covering them with fluffy wax deposits (Baek *et al.*, 2019b; Hızal *et al.*, 2023). Shen *et al.* (2007) report that most eggs are laid between 6 am and 4 pm. Eggs in the stem can be covered with discarded plant fibres in addition to the wax, and eggs can also be laid on the underside of leaves in the mid-rib: depending on the thickness of the stem, eggs can sometimes be present in single rows (R. Deady, pers. comm. January 2025). Eggs are usually laid in the apical (younger) portions of twigs: in chestnut, approximately 80% of eggs were laid in the apical 50 cm of twigs, and almost all were found in the apical 100 cm (Baek *et al.*, 2020). Host species and the condition of the host may also have an effect on the depth eggs are laid in the stem, and in some cases the plant will create a callus around the wound in response, presenting a deformed look to the oviposition site (R. Deady, pers. comm., January 2025). Depending on location (and temperature), eggs laid by the first generation of adults may either hatch the same year into a second generation of nymphs, or overwinter as eggs inside the twigs until the following spring.

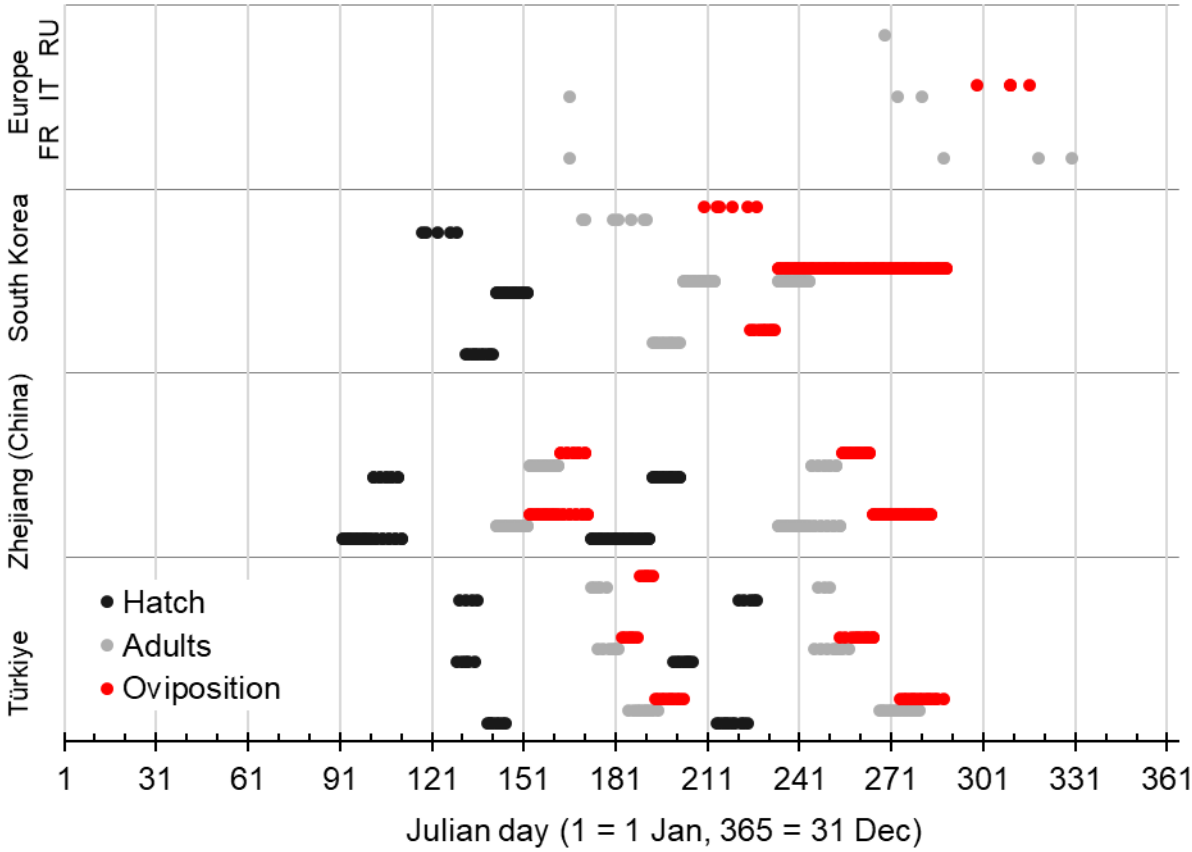

Figure 3. Phenology (lifecycle timings) of *Pochazia shantungensis* from its existing range based on published papers. Data are from different years, reported to different levels of accuracy, and are not directly comparable. Two annual generations have been recorded in Türkiye (Çetín *et al.*, 2019; Hızal *et al.*, 2023) and in Zhejiang, China (Li *et al.*, 2006; Shen *et al.*, 2007). Only one generation per year has been recorded in South Korea (Choi *et al.*, 2012a; Jo *et al.*, 2016; Choi *et al.*, 2018). The number of generations in southern Europe has not yet been determined and data are from individual reports (Stroinski & Bourgoin, 2022; Zhuravleva *et al.*, 2023; interceptions in England and Wales of different life stages on plants from Italy, 2024).

The mean number of eggs in each egg mass laid in the branches of apple and plum twigs in South Korea was 18.7 and 15.3 respectively (Choi *et al.*, 2011). In *Cornus officinalis, Diospyros kaki, Castanea crenata, Eucommia ulmoides* and *Styrax japonica*, the number of eggs per egg mass was higher, between 25 and 31 (Choi *et al.*, 2012a). In Türkiye, the mean number of eggs laid in *Ligustrum lucidum* and *Olea europaea* was 31.9 and 21.8 respectively (Hızal *et al.*, 2023). In China the reported range was between 7 and 65 eggs per mass (Shen *et al.*, 2007) (machine translation of Chinese text). No data could be found on how many egg masses a female may lay in total.

9. What pathways provide opportunities for the pest to enter and transfer to a suitable host and what is the likelihood of entering the UK/PRA area?

Plants for planting

Planting material is suspected to have been the pathway of introduction of *P. shantungensis* to Sochi in Russia (Zhuravleva *et al.*, 2023). Transient populations in Germany (Schrader, 2021), the Netherlands (Netherlands NPPO, 2023a) and potentially Hungary (Schlitt *et al.*, 2024) have all been linked to recently imported plants*.* There have been numerous interceptions of viable nymphs and eggs intercepted in the UK on plants for planting imported from Italy.

Eggs are laid in batches of 15-30 eggs or more (Choi *et al.*, 2011; Hızal *et al.*, 2023). Though not all of these will successfully hatch and develop to adult, and nymphs will show some local dispersal during development, it is possible that sufficient numbers could develop to adult in the same general location and be able to find one another to mate upon maturity. Numbers of nymphs arriving on an individual plant are likely to be lower, but it is possible that individuals may be capable of developing to adult and locating each other if a large number of imported plants were kept in the same location, e.g. a nursery for growing on plants before final retail. Both adults and nymphs are mobile, and highly polyphagous, and so they are likely to be capable of locating suitable plants even if they leave the host they were imported on.

While a number of woody hosts are regulated in similar ways in the plant health legislation for both Great Britain and Northern Ireland, these regulations are unlikely to substantially reduce the likelihood of entry. Some hosts are prohibited, or prohibited pending a PRA, but the pest is highly polyphagous and many hosts do not have specific regulations. The general requirement for deciduous trees and shrubs from outside Europe to be dormant and free from leaves will still allow the movement of eggs inside twigs in overwintering, dormant plants. None of the prohibitions nor the requirement for deciduous plants to be dormant apply to plants originating in the EU.

Entry on the pathway of plants for planting is considered **very likely** with **high confidence**. There have been numerous interceptions of viable eggs and nymphs in the UK, and this is also the pathway suggested as most likely for several incursions of the pest elsewhere in Europe.

Cut flowers or branches

Both nymphs and adults in the pre-oviposition phase will feed on herbaceous plants (Choi *et al.*, 2017a) and so both cut flowers and branches could potentially have nymphs and adults associated with them. However, the disturbance caused by cutting and packing the foliage seems likely to reduce the numbers of these life stages as they are very mobile. Unless the cut material is kept in water, the insects will not be able to feed as turgor pressure will be low. Hemiptera rely on the plant's turgor pressure to push sap into their mouthparts, so for cut stems, insects will have limited success in feeding. Pest interceptions on cut flowers in England and Wales 2021–2024 inclusive show that the only Hemiptera detected were Aleyrodidae, which are sessile throughout much of their lifecycle and cannot move if they are unable to feed (APHA, unpublished data). If the foliage is refrigerated to prolong its life during transport, the lower temperatures may harm *P. shantungensis* nymphs or adults, though this is not known.

Cut branches with eggs laid in the stems are more likely to be a pathway than foliage with mobile life stages. Eggs are laid in thin twigs and occasionally the midrib of leaves, and so could be associated with the commodity. Eggs are laid deep inside the stem and covered with wax and plant fibres: though the oviposition wounds are visible, they may not affect the foliage quality and the branches could still be used for floristry. Eggs do not need to feed during transport, and the branches will be kept humid to prevent them drying out which will also help the eggs to survive. As eggs are the overwintering stage, if low temperatures are used during transport, this is unlikely to affect their viability unless they were almost ready to hatch. Though not all will survive to adult, eggs are laid in batches and so there is a greater chance of multiple insects developing to adult and being able to locate one another, mate and lay the next generation of eggs. Transfer to a living host after arrival in the UK is likely to be the limiting step. Any nymphs which hatch will have to quickly locate a suitable host as they are unlikely to be able to survive for long on the cut foliage. If the cut branch is kept in water (e.g. flower arrangement), they may be able to feed for a time. A floristry arrangement not kept in water, such as a wreath, would not allow the newly hatched insects to feed. If the cut branches are kept indoors nymphs will have difficulty transferring to a growing host outdoors even though they are mobile and can walk and jump.

Cut branches of specified plant species must meet certain requirements (depending on plant species or genus) before they can be imported into either Great Britain or Northern Ireland. However, *P. shantungensis* is highly polyphagous and cut flowers or branches of some hosts are not subject to any specific regulations, needing only a phytosanitary certificate for import.

The pathway of cut flowers and branches is considered **very unlikely** with **medium confidence**. Limited numbers of nymphs or adults likely to be associated with cut flowers or branches. While large number of eggs may be present, newly hatched nymphs could have difficulties transferring to a growing host in order to feed and develop.

Fresh produce (fruit, vegetables, cut herbs)

Pochazia shantungensis is a highly mobile insect. Any nymphs or adults would seem likely to move off the produce during the disturbance of harvesting and packaging. The ricaniid superfamily Fulgoroidea has about 12,500 described species worldwide, but the proportion of intercepted species (54) is lower when compared to many other Hemipteran superfamilies (Liebhold *et al.*, 2024). Cut produce will provide little opportunity for a hemipteran insect to feed, as the plant will not be actively growing and turgor pressure in the harvested plant parts will be low. However, humidity is likely to be reasonably high in these consignments and so the insects are more likely to survive transport as they will lose relatively little moisture. After arrival, nymphs and adults are mobile and could be able to locate growing plants, though nymphs would be able to travel shorter distances than the winged adults. However, produce will often be kept indoors, reducing the chances of the insects being able to find growing hosts in the wider environment.

All types of fresh produce are perishable and therefore rapidly processed or dispersed for retail and quickly consumed or discarded. Nymphs or adults of *P. shantungensis* will need to find a growing host in order to complete development and/or lay eggs. It is considered unlikely that enough mature individuals would be present in a single final location to initiate an invasive population. Regulation of fresh produce is complex, but the movement of many products from the EU into the UK is unregulated and can be carried out without a phytosanitary certificate.

Mainly due to the lack of association of the pest with fresh produce, the limited lifespan of the commodity and the rapid dispersal into smaller amounts, the pathway of fresh produce is considered **very unlikely** with **high confidence**.

Contaminating pest (hitchhiking)

As both nymphs and adults are very mobile, they could move onto a variety of substrates, both plant and non-plant. It is unclear how long an insect would remain on something it could not feed on, or if it would rapidly move off in search of a suitable host. As the insects could be on almost any commodity, the volume of potentially infested goods could be quite high. If the insect was trapped inside a container or similar, it is possible it could survive for a few days while being transported long distances. Nymphs would seem likely to desiccate and die faster than adults, depending how much moisture was available in the environment. Upon arrival, adults would be able to fly and locate a host plant over longer distances than nymphs which are restricted to walking or jumping, but both are mobile and would be able to find plants growing close to their final destination. Unless there was something to attract insects to containers in the exporting country, for example security lights at night or perhaps containers painted a colour attractive to insects, numbers of individuals on any one consignment would be low. Therefore, the greatest risk would likely be from a mated female which would just need to locate a suitable host to lay eggs. If nymphs were the life stage hitchhiking, at least two individuals of opposite sexes would need to develop to adult and locate one another to mate. A study in South Korea detected *P. shantungensis* as a hitchhiker on ships twice in approximately 15 months, though the photos suggest the specimens were dead when found (Kang *et al.*, 2023).

Travel on the outside of a road vehicle seems less likely to contribute to entry to the UK as the insects could easily leave when stopped at intermediate places during travel. Vehicles travelling from Italy or the south of France will need to make rest stops during the journey to the UK, even if just short halts to change drivers. Insects are also likely to be blown off during travel at high speed, unless they are in a sheltered location such as an air vent. Therefore, hitchhiking on the outside of vehicles is considered to be more local spread than long distance entry, and is covered in section 12 on potential spread within the PRA area.

Overall *P. shantungensis* entering the UK as a contaminating pest is considered **unlikely**, with **medium confidence**. It is highly mobile and could be temporarily associated with almost any import. However, limiting factors include survival during transport, low numbers of insects on any given consignment, and the need to transfer to a suitable growing host quickly after arrival.

Plants for planting	Very unlikely ☐	Unlikely ☐	Moderately likely ☐	Likely ☐	Very likely ☑
Confidence	High Confidence ☑	Medium Confidence ☐	Low Confidence ☐		

Cut flowers or branches	Very unlikely ☑	Unlikely ☐	Moderately likely ☐	Likely ☐	Very likely ☐
Confidence	High Confidence ☐	Medium Confidence ☑	Low Confidence ☐		

Fresh produce	Very unlikely ☑	Unlikely ☐	Moderately likely ☐	Likely ☐	Very likely ☐
Confidence	High Confidence ☑	Medium Confidence ☐	Low Confidence ☐		

Contaminating pest	Very unlikely ☐	Unlikely ☑	Moderately likely ☐	Likely ☐	Very likely ☐
Confidence	High Confidence ☐	Medium Confidence ☑	Low Confidence ☐		

Pathways not assessed in detail

- **Wood**
  Eggs are laid inside thin twigs, and not in bark of thicker branches which might be included under the wood pathway. Any other life stage associated with wood would be present as a contaminating pest and are covered under that pathway.

- **Growing media or soil**
  No life stage of this insect is associated with the soil or roots, only above ground plant parts.
- **Natural spread**
  While adults can fly, there is no evidence they are capable of undertaking long distance migrations from the nearest established populations in the south of Europe to the UK. There is also no evidence they are capable of sustained flight for tens of kilometres, i.e. sufficient to cross the English Channel from northern France.

10. If the pest needs a vector, is it present in the UK/PRA area?

No vector is required. This is a free living organism.

11. How likely is the pest to establish outdoors or under protection in the UK/PRA area?

Outdoors

As *P. shantungensis* is highly polyphagous, and is known to feed on plant species and genera widespread in the UK, suitable host availability is unlikely to be a limiting factor.

Important caveat: it must be remembered throughout the rest of this section that *P. shantungensis* is a newly invasive pest in several countries. The pest's distribution is still increasing, and it seems unlikely that *P. shantungensis* is currently limited by temperature or any other climatic factors in its current invasive range. While temperatures in areas where it has successfully established have substantially hotter summers than the UK, these newly invaded locations may not represent areas where the climate suitability is marginal and limiting the pest. Thus, the pest may be capable of expanding its geographic range into areas with different climatic conditions than those in its current distribution. If this occurs and the new areas have climates more similar to the UK, establishment would need to be reconsidered. Data on distribution in China (where it is apparently native and probably is limited in some places by climate) is patchy and does not allow for detailed modelling. While this section of the PRA does come to conclusions about the suitability of the UK for establishment of *P. shantungensis*, new information could substantially change these conclusions, especially if the pest was able to establish in areas with relatively cooler summers compared to locations where the pest is currently found.

As is usual for insects, development rates are dependent on temperature and this was the key parameter used to assess the climatic suitability of the UK for *P. shantungensis*. Threshold temperatures for development are an intrinsic biological feature for a given pest species. Therefore, even though the distribution of *P. shantungensis* is still expanding, thermal requirements are a stable indicator of how suitable an area could be for the pest.

One uncertainty which may become important is that individual populations could be more or less cold-adapted, though no evidence of this has been found when researching this PRA.

This establishment section of the PRA provides summaries of the key data used in the analysis, and the conclusions drawn. Appendix 1 contains more details of the analyses and reasons behind the assumptions made, and discusses why some data were excluded from the analyses or only partially considered. Appendix 1 also contains some additional analyses which support the conclusions reached here, but merely add supporting evidence to points already justified in this section of the PRA.

Most data on **temperature requirements to allow growth and development** are from work in South Korea. A graphical summary is provided in Fig. 4, with full data and sources in Appendix 1 (table A3). The appendix also contains discussion and justification for why particular temperatures were chosen when data conflict (e.g. lower threshold for egg hatching). Experimental protocols vary, for example one study (Kang *et al.*, 2013) had much lower survival at all temperatures compared to the other work. Hosts also differed between studies which may have affected some results. While all experiments on eggs and nymphs used field-collected twigs, the dates of collection would have varied and thus some eggs may have been much closer to hatching when collected.

Overall, the data seem to suggest that temperatures around 10–12°C are too cool to permit any significant development or activity of *P. shantungensis*. Temperatures of 14–16°C allow some development at slow rates, but it is unclear if they are warm enough to enable *P. shantungensis* to complete its lifecycle, and these temperatures seem likely to cause thermal stress. Temperatures of around 20–30°C seem likely to allow the insect to grow and develop successfully and the optimum temperature for development is likely to be at the upper end of this range.

Key temperatures for the development of *P. shantungensis* were analysed from one of the warmest locations in the UK, Kew Gardens in London (data 2014–2023 inclusive). The full analysis is available in Appendix 1, but some key information is repeated here. Total days per year where the minimum temperatures were above the bottom of the range where *P. shantungensis* can develop successfully were low. The count of annual days where the minimum temperature was ≥15°C was 12–37 days. There were only 0–6 days per year with minimum temperatures of ≥18°C. The number of days per year with maximum temperatures that reach or exceed optimum temperatures for *P. shantungensis* were again very low: 1–31 days ≥27°C, and only 0–10 days per year ≥31°C. Monthly averages also demonstrate the UK summers are cooler. Both minimum and maximum mean monthly temperatures are lower in southern UK between at least April and October compared to the current species range (see Appendix 1, Figs. A7 and A8).

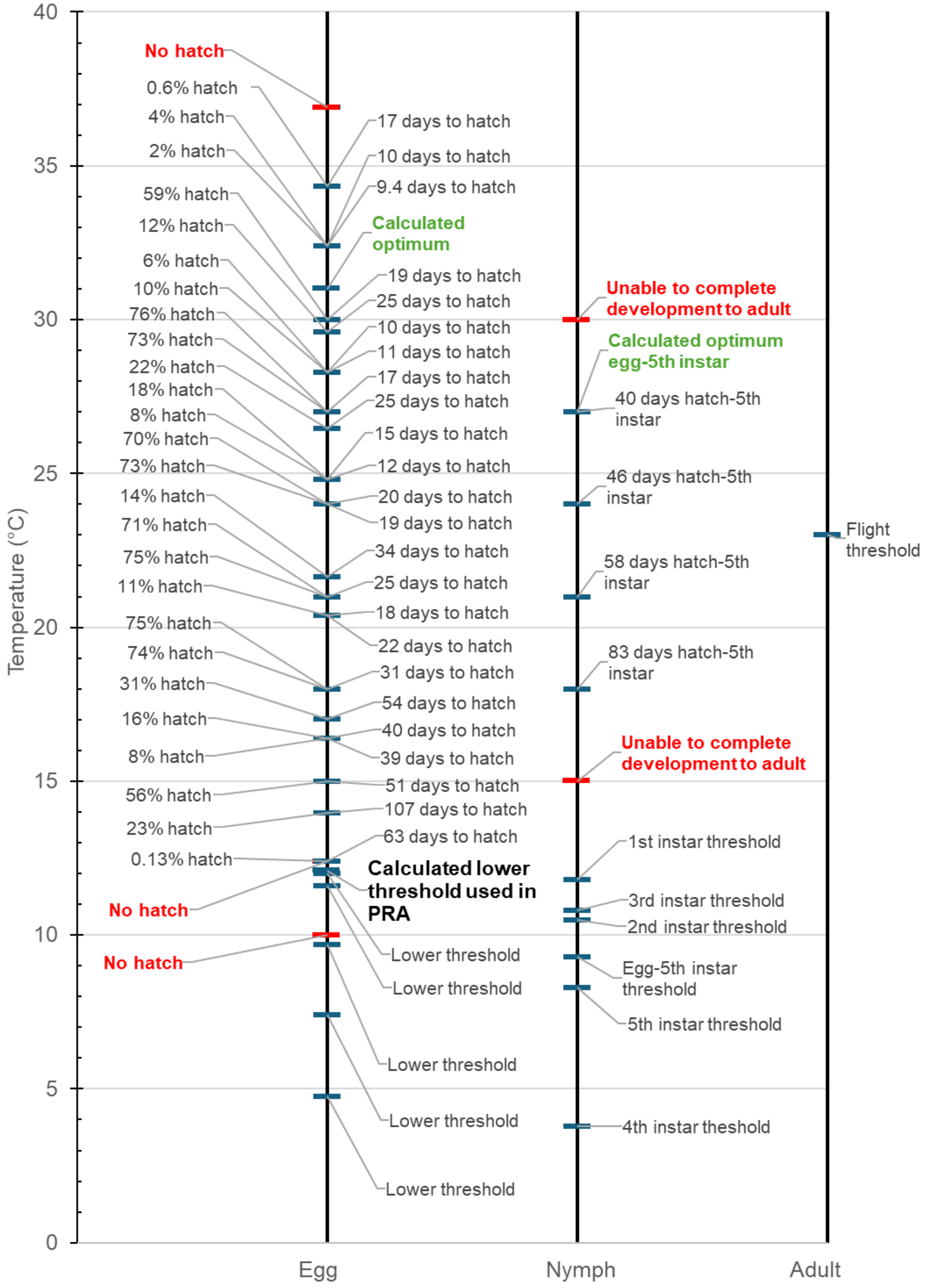

Figure 4. Thresholds and development success reported in literature for *Pochazia shantungensis* eggs, nymphs and adults. Experimental protocols vary and this explains some of the variation, e.g. one source had very low survival at all temperatures compared to other papers. Full data sources for each point are given in Appendix 1 (table A3).

Predictive species distribution models for *P. shantungensis* have been developed in South Korea, though the published results only consider that country and do not attempt to predict potential global distributions. Models developed by Kim *et al.* (2015), when *P. shantungensis* was restricted to the western half of the country, showed high predictive values, but also showed the eastern half of South Korea as having low probability for the pest to occur. Ten years later, though still more commonly recorded on the western side of the peninsula, *P. shantungensis* has been recorded in areas Kim *et al.* (2015)'s models did not predict as suitable. Baek *et al.* (2019a) used CLIMEX's climate matching module to again predict the suitability of South Korea for *P. shantungensis*. All of South Korea had a high CLIMEX climate match index with Zhejiang in China (the only source region used in the analysis), though the eastern areas of South Korea were slightly less similar. Baek *et al.* (2019a) also used MaxEnt models, and the presence probability map showed again that overall, the western parts of South Korea were more likely to have *P. shantungensis* than the east, but some parts of the east coast were more suitable than suggested by the previous model by Kim *et al.* (Baek *et al.*, 2019a). None of the models were considered to be of practical use in predicting the potential distribution in Europe, even if the South Korean parameters were used. The distribution of *P. shantungensis* is still increasing, and MaxEnt models, especially, broadly consider that if a pest has not been recorded in a given location, then that location is not climatically suitable for the pest. There are a lack of distribution records of *P. shantungensis* from the native range of China. It is not known if any of the distribution records are from areas known to be at the climatic limits of the pest. Therefore, at present, predictive modelling using pest presence/absence seems unlikely to provide accurate answers as to which European regions may be most at risk, or whether UK currently provides a suitable climate for *P. shantungensis* to establish.

At least five **egg hatch degree day thresholds** are available in the literature but only one is considered here. See Appendix 1 for details of the other thresholds and why they were not chosen. From laboratory rearing data on eggs in chestnut branches, the lower development threshold was estimated to be 12.1°C and 202 DD were required for egg hatch, though later in the paper DD were quoted as a higher value of 264.3 (Baek *et al.*, 2019b). Comparison of predicted and actual hatching dates of overwintered eggs at three different field sites in 2018 showed that the degree day model predicted the 50% hatch rate within 2-4 days of the actual hatching dates, using lower and upper threshold temperatures of 11.6°C and 36.9°C respectively: it is unclear why a slightly different lower temperature threshold was used. The southern half of the South Korean peninsula was predicted to have 50% hatch by late May, much of the rest of the country by early June, and a small area in the north-east by mid-June or later (Baek *et al.*, 2019b). Using approximations of the lower values of 12°C and 200 DD in the Met Office webtool[6] for the UK, no hatching would have been predicted in May in any part of the UK, except for parts of London in the very warm spring of 2011 (date range 1991-2024 inclusive). After relatively warm springs, hatching could occur before the end of June in England, south-east of an approximate line between the Humber and Severn estuaries. Following cool

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[6] https://www.metoffice.gov.uk/hadobs/biosecurity_uk_hist/ and selecting "user thresholds"

springs, 50% hatching would mostly occur in July (Julian day 182 or later). The rest of the UK could expect hatching even later in the year, and areas such as the Highlands of Scotland may never get sufficiently warm for long enough periods for egg hatch. Comparing these dates with reported hatching dates from the current range (Fig. 3 in the section summary of pest biology), UK eggs would be expected to hatch substantially later than the overwintering egg hatch in any part of the current range. Overwintering eggs would theoretically be hatching in the UK around the time the second generation of eggs are recorded as hatching in Zhejiang, the Chinese insects having already completed their first generation. Figure 5 illustrates this in a different way: using 12°C as a threshold temperature for development, all parts of the current range of *P. shantungensis* (solid coloured lines) begin to accumulate DD significantly before the warmest parts of the UK (dashed greyscale lines), in each of the three most recent years.

Degree day accumulations at selected locations were used to compare the UK with existing locations in the current distribution. It must be noted that neither the threshold temperature nor DD for the whole lifecycle are known, and the values discussed here may not match the actual requirements of the insect. Threshold temperatures of around 12°C for the whole lifecycle were chosen as reasonable: see Appendix 1 for more discussion and reasons for the selection of this value. Hourly data for Camborne in Cornwall suggests, using threshold temperature of 12.1°C, between 368 and 634 DD for the year are possible (Met Office, date range 2014-2023) (data not shown). Kew Gardens in London, one of the warmest locations in the UK, accumulates between 682 and 1,000 DD using 12.1°C and the Met Office hourly data (data not shown). Using 2022-2024 data from weather stations in or near the current range of *P. shantungensis*, virtually all locations accumulate more than 2,000 DD using a threshold temperature of 12°C, including Peretola near Pistoia Italy, Nice in France and Istanbul in Türkiye (Fig. 5). Only Chongju in South Korea accumulated less than this once in the three years analysed, with an annual sum of 1,932 DD in 2022 (BizEE Degree Days, 2024). Using the same data source for UK sites, and the same threshold temperature of 12°C, the warmest parts of the UK accumulate less than 900 DD 2022-2024 inclusive (Fig. 5), and most years less than 800 (BizEE Degree Days, 2024). While it is unclear what the exact threshold temperatures for development and DD requirements are, compared to areas where it has established, the UK has much cooler summers and accumulates less than half the DD at a threshold temperature for development of 12°C. The locations where data was analysed include sites in South Korea, where the pest has only been recorded having one complete generation per year. As the pest appears to develop successfully at 18°C, global maps of DD accumulation using this threshold were prepared (data sourced from Mistry, 2019a; Mistry, 2019b) and are presented in Appendix 1.

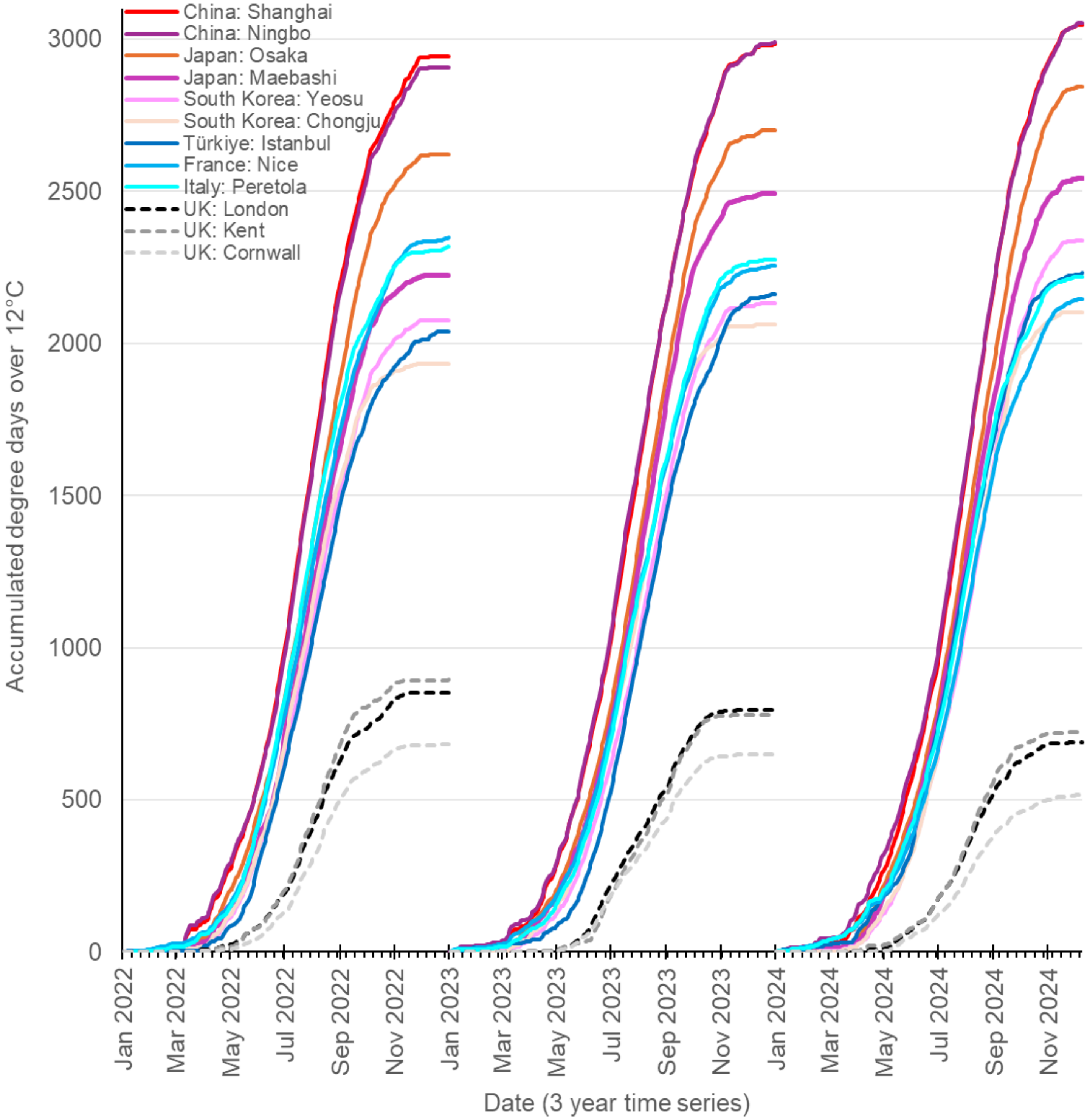

Figure 5. Annual accumulation of degree days above 12°C for selected locations 2022 to 2024. Solid lines indicate degree days based on daily temperature data from locations in China, Japan and Türkiye (2 annual generations of *Pochazia shantungensis*), South Korea (1 annual generation), and locations where it is established in Europe (generations unknown). Grey broken lines indicate three warm locations in the UK. Degree day calculations from https://www.degreedays.net/. Range in Asia: reds and pinks. European range: blues. UK: greyscale dashed lines.

Winter temperatures in areas where the pest is present in South Korea are lower than those commonly experienced in the UK. Over a four year time period, the mean monthly temperatures in January in the Gurye region ranged from -3.8°C in 2011 to 0.8°C in 2014 (Choi *et al.*, 2016) and daily minimum temperatures in Yesan in 2013 were occasionally below -20°C (Kang *et al.*, 2013). Eggs therefore appear to be able to tolerate temperatures substantially below freezing, though the percentage of eggs successfully hatching in spring is greater when winter temperatures are warmer (Choi *et al.*, 2016). The UK has a temperate oceanic climate, and average winter temperatures are substantially warmer than those in South Korea (World Meteorological Organisation, 2024) (see Appendix 1, Figs. A7 and A8). Therefore, the eggs of *P. shantungensis* would seem very likely to be able to survive their overwintering phase in the UK.

Data on **other climatic factors** which may influence establishment of *P. shantungensis* are scarce. Choi *et al.* (2017a) suggest that wind and rain drive nymphs down from the tree canopy into lower growing shrubs and grasses, which may help to explain why nymphs apparently prefer to feed on herbaceous plants and shrubs (machine translation of Korean paper). However, no further research appears to have been carried out on this phenomenon, and it is unclear if high rainfall affects nymph survival.

Climate change is not expected to increase the risks to the UK from *P. shantungensis* in the medium future (up to 2040–2050). Even by 2100, far beyond the lifespan of this PRA, temperatures are expected to increase by around 2.5°C above the warmest year so far (2022) in a median climate change scenario. A temperature increase of 3°C, even in south-east England and London, would still result in DD accumulations lower than those under the current climate and existing pest distribution. Under this warming, it is reasonable to assume there would be an increased chance of some very warm microclimates allowing establishment of small populations. Even in a climate change scenario of rampant fossil fuel usage and warming of 4°C by 2100, only a small part of London might be expected to accumulate similar DD to the current species range. Therefore, the effects of climate change would not be sufficient reason for reviewing this PRA in the next decade. PRA review for other reasons such as continuing geographical spread are likely to be far more important.

In summary, it is likely that eggs will successfully hatch, though in all but the very warmest springs, predicted hatching dates of the first instar nymphs in the UK would be substantially later than hatching of overwintered eggs in any part of the current range. No part of the UK is considered to be warm enough for the nymphs to complete development to mature egg laying adult before winter, though it must be noted the thermal requirements for the full lifecycle are not known. There are no records of overwintering of nymphs in the current range and this assessment considers that eggs are necessary for this pest to survive the winter. Therefore *P. shantungensis* is not likely to be able to complete its lifecycle outdoors in any part of the UK. However, eggs laid by nymphs or adults arriving later in the year are likely to successfully overwinter in the UK as winters here are warmer than in South Korea. It must be noted (again) that the pest’s range is still expanding, indicating it is not yet limited by climate and so the exact climatic limitations of the pest are not known, and this does create some uncertainty in this assessment. Nonetheless, based on data from the current distribution, establishment of the pest outdoors in the UK is considered **unlikely** with **medium confidence**. Despite the large number of assumptions and unknowns, all parts of the pest's current range have very warm summers for several consecutive months. Even in very warm years in the UK, summer temperatures are generally cooler, and heatwaves are typically only 1-2 weeks in duration. In Appendix 1, figure A6 shows that maximum daily temperatures of ≥23°C are only reached for 33–63 days of the year in Kew Gardens (London) between 2014 and 2023, and there are only 1–24 days per year where the daily maximum temperature is ≥27°C. The timing of the pest's lifecycle in its current range suggests it needs long periods of high temperatures to develop to adult, and these conditions do not occur in the UK with its comparatively cool summers. In future, if spread of the pest continues to be only to locations which are climatically similar to the existing distribution, then it may be appropriate to revisit the rating for outdoor establishment. At that point consideration could be given to changing the rating to very unlikely for outdoor establishment in the UK.

Under protection

Pochazia shantungensis has not been recorded as a pest inside glasshouses or other protected cultivation to date. Temperatures will be warmer in these environments, and the pest may be capable of completing its lifecycle. The availability of suitable hosts year-round is likely to be more limiting in these environments. Though nymphs and adults in the pre-oviposition period apparently prefer herbaceous plants and shrubs (Choi *et al.*, 2017a), adults usually lay their eggs inside thin twigs of woody trees and shrubs. While woody shrubs could be propagated inside glasshouses, in a commercial setting they are usually grown-on outdoors unless they are specialised houseplants. Tropical or subtropical glasshouses in botanical collections with mature or semi-mature trees may be most at risk of *P. shantungensis* establishing, as they will have a variety of hosts planted year round, including woody plants. Given the pest can have either one or two generations a year in the current range, the lifecycle may not have a requirement for overwintering if the temperatures remain high all year round.

Another environment which may be at increased risk from *P. shantungensis* in the UK is semi-protected cultivation used to grow cherry trees. The polytunnels are covered around the time the trees are in flower and kept covered until harvest. The roof is solid, but the sides of the tunnels are left open. Temperatures are higher in such environments. Maximum and mean temperatures in full polytunnels are higher than temperatures outside, typically by 4–10°C in daytime, though temperatures typically fall to near ambient at night (various data reviewed by Menzel, 2025). Polytunnels for semi-protected cultivation with open sides would almost certainly have lower temperature increases than these figures. UK cherry crops often have netting on the open sides to reduce attacks by *Drosophila suzukii*, and this would also serve to exclude adult *P. shantungensis*. Increases in UK temperatures of 3°C still provide fewer DD than are found in the current range, and thus even if *P. shantungensis* could get into semi-protected cherry production, temperatures are likely to be marginal or still unsuitable for the pest to complete its lifecycle. Any populations would also be limited in extent, as they could not establish in the wider environment but would be restricted to the polytunnels.

Overall, establishment in protected cultivation is considered **unlikely** with **medium confidence** due to a lack of woody hosts for egg-laying, but specialist glasshouses growing a range of woody hosts would have a higher risk of establishment. Temperatures in semi-protected cultivation used to grow cherries in the UK are likely to still be too low for very high populations of *P. shantungensis* to build up.

Outdoors	Very unlikely ☐	Unlikely ☑	Moderately likely ☐	Likely ☐	Very likely ☐
Confidence	High Confidence ☐	Medium Confidence ☑	Low Confidence ☐		

Under protection	Very unlikely ☐	Unlikely ☑	Moderately likely ☐	Likely ☐	Very likely ☐
Confidence	High Confidence ☐	Medium Confidence ☑	Low Confidence ☐		

12. How quickly could the pest spread in the UK/PRA area?

Natural spread

Adults have wings and can fly. No data could be found on the distances they travel, or whether they are capable of sustained flight or only short hops from plant to plant. Adults were caught in traps at all heights from 0.5–8.9 m, but it is unclear how many were feeding or egg laying high in the trees to start with, and how many flew to this height (Kim *et al.*, 2018). Experiments in South Korea with harmonic radar tags were carried out at 29°C and low wind speeds (Kim *et al.*, 2016b). The insect studied was identified as “recent invasive species” *Ricania* sp., which this PRA considers likely to be *P. shantungensis.* The radar tag reduced the number of *P. shantungensis* that voluntarily started to fly, but around 80% of the untagged control insects made sustained flights of >30 m (Kim *et al.*, 2016b). Baek *et al.* (2024) state that “*P. shantungensis* is a poor flyer” but no further details are provided. A different ricaniid, *Scolypopa australis*, mostly travelled less than 40 m in release-recapture experiments in New Zealand, though a small number of individuals were trapped 70 m from the release point (the most distant trap in the experiment) (Tomkins *et al.*, 2000).

Adults are most likely to be captured in traps (i.e. flying and active) when the night time temperature is 23°C or greater (Choi *et al.*, 2019; Choi *et al.*, 2020). The methods in the papers are a little unclear, but traps were certainly run between the hours 1800 and 2400, and probably over the rest of the night as there are catches recorded “after 2400”. The majority of adults were captured 2000–2100 (Choi *et al.*, 2019). During July and August in South Korea (2015-2017), 29-52 days had minimum temperatures of 23°C (the exact date ranges and hence number of days in the period vary) (Choi *et al.*, 2019). In comparison, daily minimum temperatures for one of the warmest parts of the UK, Kew Gardens in London, were analysed (Appendix 1, Fig. A5). Between 2014 and 2023, no day had a minimum temperature of at least 23°C, and only one day in 2022 had a minimum temperature ≥20°C (Met Office, 2024). Therefore, in the UK, adults seem less likely to fly routinely, though it seems likely they would still jump and walk at lower temperatures.

Limited data on dispersal of nymphs are available. Baek and Lee (2021) considered that samples of *P. shantungensis* nymphs less than 60 m apart in South Korean chestnut fields were not independent. This suggests nymphs may be capable of dispersing tens of meters during their development. Considering a *Ricania* species collected in Philippines (likely to be reasonably closely related to *P. shantungensis*), McDonald *et al.* (2024) demonstrated that the wax "tails" help to stabilise jumping insects while in the air, meaning that almost all nymphs were able to land on their feet. Nymphs whose wax tails had been removed only landed on their feet 35.5% of the time, and rotated far more while in the air compared to nymphs with intact tails (McDonald *et al.*, 2024).

If suitable hosts are available in the immediate surroundings, most insects will not move far. A common dispersal pattern across many taxa is that most individuals travel only short distances, but a small number will move much further. It is unclear if this pattern will apply to *P. shantungensis*, especially as it is so polyphagous and will not need to travel far to find new hosts. Natural spread is considered to be at **moderate pace** but with **low confidence** as so few data are available.

Spread with trade

Most spread within the UK due to trade is likely to be movement of eggs, nymphs or adults on infested plants for planting, similar to the pathways of entry into the UK. No unambiguous evidence has been found for dispersal along roads (linked to insects hitchhiking on or in vehicles) in the current invasive range. Modelling of dispersal in South Korea is unclear. One study found the probability of occurrence in South Korea was greater in transport locations as well as natural areas (Kim *et al.*, 2015). However, Baek *et al.* (2019a), modelling *P. shantungensis* potential distribution and spread, did not find roads and other human-related variables were significant in their work with MaxEnt (which, in addition to the normal bioclimatic variables, included four custom variables: elevation, traffic volume, footprint and landcover). The related flatid bug, *Metcalfa pruinosa* (invasive in Europe) was shown to spread over middle and long distances via road traffic (cited in Lauterer & Malenovsky, 2002). Mainly due to movement on planting material, spread with trade is considered to be **very quickly** with **high confidence**.

Natural Spread	Very slowly	☐	Slowly	☐	Moderate pace	☑	Quickly	☐	Very quickly	☐
Confidence	High Confidence	☐	Medium Confidence	☐	Low Confidence	☑				

With trade	Very slowly ☐	Slowly ☐	Moderate pace ☐	Quickly ☐	Very quickly ☑
Confidence	High Confidence ☑	Medium Confidence ☐	Low Confidence ☐		

13. What is the pest’s economic, environmental and social impact within its existing distribution?

The most severe impacts are due to the damage done by the female laying eggs deep in year-old twigs. The oviposition scar affects both phloem and xylem flow in the twig, and developing fruit may suffer reductions in quality especially as, in South Korea, oviposition occurs in early autumn around the time of fruit harvest (Jo *et al.*, 2011; Cho *et al.*, 2012; Jo *et al.*, 2016). Other damage is due to sap-feeding by nymphs and adults. Similar to many phloem-feeding Hemiptera, high populations can lead to a loss of plant vigour when large volumes of sap are consumed. Secondary impacts are again similar to other Hemiptera and include excretion of honeydew and the resultant growth of sooty moulds (Jo *et al.*, 2011; Jo *et al.*, 2016).

In the native range in China, impacts have been reported from Zhejiang. Shen *et al.* (2007) stated that *P. shantungensis* became a pest due to planting green corridors of preferred hosts in China along roads and other infrastructure (machine translation of Chinese text). Other recorded impacts in Zhejiang have been on assorted fruit trees (Rahman *et al.*, 2012) but no further details were available. No reports of damage elsewhere in China were found. No recent data on impacts in Zhejiang were found either, though this may be due to it being a well-known native pest for which control measures are well-established, and there is no reason to report routine damage.

In South Korea, damage started to occur within apple and chestnut orchards within a few years of the first detection of the species, and a small number of orchards saw “almost all trees” killed (Baek *et al.*, 2024). A lot of papers and conference abstracts are available from this country but many are in Korean and so details and nuances will have been missed in the information which follows. Surveys in Chungbuk province 2021-2022 found on average 25% or fewer fruit orchards surveyed had *P. shantungensis* eggs or adults (Lee *et al.*, 2023). Well over half of the surveyed area had “low” occurrence of adults, and less than 37 ha from a total of 192 ha where the pest was found were classed as “high” or “very high”. Similarly, less than 18 ha of orchards had high or very high degree of infestation with eggs, out of almost 148 ha surveyed (Lee *et al.*, 2023).

Individual *Diospyros kaki* (persimmon) twigs began to show dieback if more than four or five egg masses were laid in each, and if more than ten egg masses were laid, almost 100% of the twigs died (Baek *et al.*, 2024). However, only a small number of samples from the orchards showed very high infestation levels. The conclusion was that if there were >5.5 egg masses in the apical 60 cm of a persimmon branch, control measures should be applied to limit damage (Baek *et al.*, 2024). A study on blueberries found that over half of branches had one egg mass, and only around 14% had 3 or more egg masses (Kim *et al.*, 2016a; Kim *et al.*, 2017b) (machine translation of Korean text).

Oviposition damage on apple twigs has been reported as affecting fruit yields in the year they were laid, but one study suggests this damage may not impact either the fruit quality or branch measurements the subsequent year. Two apple cultivars ‘Hongro’/M.9 and ‘Fugi’/M.9 were studied for longer-term impacts of *P. shantungensis* eggs laid in branches the previous year (Song *et al.*, 2021). The fruit on the two-year-old branches of both cultivars did not show any statistical difference in fruit weight, size, acidity or any other tests of quality, whether or not the branches bearing the apples had been infested the previous autumn. The two-year-old branches were the same diameter at the base whether eggs had been laid in them the previous year or not, and any difference in length was not statistically significant (Song *et al.*, 2021). If branches had died due to high numbers of eggs laid in the first year they would not have been counted in this study, though the loss of branches would have impacted the tree the next growing season. However, the work of Song *et al.* (2021) does suggest that trees are able to heal the damage caused by the oviposition scars in the next growing season as long as the affected twigs survived.

South Korean persimmon orchards had more egg masses laid on terminal twigs “high” in the tree (Baek *et al.*, 2022), though no height range was given and this is assumed to refer to canopy levels relative to each individual tree. Machine translation of Korean text suggests a similar pattern in blueberries: over half of eggs were laid in the upper third of the plant, and less than 20% in the lower part (Kim *et al.*, 2016a; Kim *et al.*, 2017b). However, in chestnuts there was no pattern to the vertical distribution of egg masses within the trees, perhaps because orchard management includes pruning and so younger branches are available at all heights within the tree (Baek *et al.*, 2020).

In other parts of the invasive range, impacts have not apparently been recorded. In Japan, where *P. shantungensis* seems likely to have been present since around 2015, “serious damage has not been confirmed” (Kobayashi *et al.*, 2024) even though high densities of the leafhopper have been recorded in some locations. Adults were collected with light traps, and adults and immatures collected from a variety of plant species in a range of habitats including urban street trees, parks, botanical gardens, around the edges of agricultural fields and natural forest vegetation (Kobayashi *et al.*, 2024). No information about impacts is available from other countries where it has recently established, such as Türkiye or Italy. Often, it can take several years or longer for pest populations to build up to damaging levels, and it is possible that damage may occur in some of these locations in future. In South Korea, it is possible that *P. shantungensis* could have been present at low levels for some years before it was first identified in that country in around 2009. Jo *et al.* (2016) even seem to suggest that it could have been an overlooked or unidentified native species in South Korea, and that changes in crops and the climate led to it becoming damaging.

Impacts in **South Korea** are assessed as **large**, and in the rest of the current range overall as **small**, though sporadic impacts in China do seem to occur. Both assessments are made with **medium confidence***.* The pest has only recently established in many countries, including Japan and parts of Europe, and it is possible that populations are still too low to cause noticeable damage. In future, as populations build up, it is possible that damage may start to be reported in additional regions.

Impacts: South Korea	Very small ☐	Small ☐	Medium ☐	Large ☑	Very large ☐
Impacts: other countries (to date)	Very small ☐	Small ☑	Medium ☐	Large ☐	Very large ☐
Confidence	High Confidence ☐	Medium Confidence ☑	Low Confidence ☐		

14. What is the pest’s potential to cause economic, environmental and social impacts in the UK/PRA area?

All potential impacts outdoors are considered to be **very small** with **high confidence** as the pest is not considered capable of completing its lifecycle and hence establishing in any part of the UK. Most impacts are caused by the adult laying eggs inside branches (Jo *et al.*, 2011; Jo *et al.*, 2016), and the UK is not considered to have long periods of very warm temperatures which would allow overwintering eggs to develop through all nymphal instars and into mature adults capable of laying eggs. Though some impacts could occur from sap feeding, these are unlikely to be more serious than native or already established sap feeding Hemiptera. Even if the pest was able to establish in a localised very warm microclimate (or the assessment on establishment potential is wrong), then adults would be expected to lay eggs much later in the autumn than in South Korea. Most of the impacts in South Korea are due to eggs being laid deep in twigs just as fruit is ripening. The disruption to sap flow from the oviposition wounds reduces the quality of the fruit at harvest. Thus, even if the pest did establish in the UK, and twigs were to be damaged or die back from egg laying, fruit harvests are considered unlikely to be affected. Impacts on an individual tree could be severe if population levels were high, as damage may be aggregated depending on the host. In chestnut orchards in South Korea there was evidence of clumped distribution (Baek & Lee, 2021). In blueberries, distribution across the study field was more even except in the vicinity of preferred hosts (machine translation of Korean conference abstract) (Kim *et al.*, 2017b). Persimmon twigs begin to show dieback if more than five egg masses are laid in each twig, but even in South Korea this level of infestation was not common (Baek *et al.*, 2024). It seems very unlikely that such high densities of oviposition wounds would be common in the UK, even if insects were highly clumped in their distribution.

Even without establishment, some impacts may occur from repeated introductions of late instar nymphs or adults. These insects would be able to feed and perhaps lay eggs, which could hatch the following year. However, the nymphs from the overwintering eggs would not be able to develop to adult and therefore these would be transient populations, not capable of establishing. Given a population could not establish, only a small amount of localised damage would be expected for a short time. It is possible that a transient population could have already occurred in the UK: eggs were found in the winter of 2024 in the twigs of plants which had been imported over a year earlier, in autumn 2023 (APHA/Fera internal data, unpublished). Eggs were not obviously dead, and there was no evidence of hatching (S. Reid & R. Deady, Fera Science Ltd., pers. comm. February 2025). While the circumstances cannot be known with certainty, one scenario was that the plants imported in 2023 were not infested. New imports of plants could have arrived in the affected nursery during summer/autumn 2024, infested with *P. shantungensis* nymphs or adult(s). These insect(s) could then have developed to mature adult(s) and laid the eggs found in the 2023 plant stems.

If a population were able to establish in a glasshouse with woody plants, for example a visitor attraction with a tropical glasshouse, or a nursery growing on heated houseplants, some local damage might occur if the pest were able to enter the glasshouse. However, relatively few sites would be affected and the pest would have difficulty spreading to new locations. In a production nursery, eradication from protected cultivation would theoretically be possible. Glasshouses with large well established plants would face considerably more challenges. However, unless population levels of *P. shantungensis* were very high, levels of damage to young twigs of ornamental plants may be tolerable from a cosmetic viewpoint.

Overall, impacts in the UK are all expected to be **very small** with **high confidence**. The pest is considered unlikely to establish, and so any damage would be transient and almost certainly localised. Even if *P. shantungensis* were able to establish in an exceptionally warm microclimate, the population is likely to be at the extreme edge of its thermal tolerance. The insects would be under significant stress and very unlikely to be capable of building up to damaging levels. If the pest were to establish in a heated glasshouse growing woody plants, again impacts would be localised as the pest would have difficulty moving to another heated glasshouse growing suitable woody plants.

Economic Impacts	Very small ☑	Small ☐	Medium ☐	Large ☐	Very large ☐
Confidence	High Confidence ☑	Medium Confidence ☐	Low Confidence ☐		
Environ - mental Impacts	Very small ☑	Small ☐	Medium ☐	Large ☐	Very large ☐
Confidence	High Confidence ☑	Medium Confidence ☐	Low Confidence ☐		
Social Impacts	Very small ☑	Small ☐	Medium ☐	Large ☐	Very large ☐
Confidence	High Confidence ☑	Medium Confidence ☐	Low Confidence ☐		

15. What is the pest’s potential as a vector of plant pathogens?

No records of *P. shantungensis* as a vector of plant pathogens have been found. As a phloem-feeding hemipteran bug, it may be capable of transmitting some viruses or other pathogens, but this has not been determined.

16. What is the area endangered by the pest?

No part of the UK is considered to be warm enough for the pest to establish and cause economically important losses, therefore no part of the country is considered to be endangered by *P. shantungensis*.

Stage 3: Pest Risk Management

17. What are the risk management options for the UK/PRA area?

Exclusion

Exclusion refers to the application of phytosanitary measures to prevent entry or establishment of the pest. Preventing entry would be difficult. The host range is very wide, and even the long lists of recorded hosts are unlikely to represent the true range of plants that could be used by this insect. Egg masses can be detected at inspection, but they are somewhat cryptic as the eggs are laid deep in the stems and covered in wax and plant debris. While the wax is visible, it may not be recognised as an egg mass. Nymphs and adults are very mobile, and some may escape detection if they move away from the disturbance of an inspector moving the plant material. As the pest is present in parts of the EU, including the Tuscany region in Italy which grows a large number of ornamental plants for export, large volumes of material are traded to all parts of the UK. Any specific measures would need to include a wide range of plant genera and species and, as already noted, *P. shantungensis* seems likely to be able to use more plants than those currently recorded as hosts.

Listing *P. shantungensis* as a quarantine pest for Great Britain is unlikely to be technically justified based on the information presented in this PRA. The pest is considered unlikely to establish (even considering all the caveats listed in the establishment outdoors section). It is also considered unlikely to cause unacceptable economic, environmental or social impacts in any part of the UK.

Control options

Jo *et al.* (2011), Cho *et al.* (2012), Kim *et al.* (2016a) and others note that any control needs to be applied not only to the crop to be protected, but to the surrounding plants as well. If only the crop is treated, adults will simply move back onto the crops from surrounding plants (machine translations of Korean conference abstracts). Given the number of potential hosts and that both nymphs and adults are mobile insects, eradication or containment of any outbreaks in the wider environment would be very challenging. Efforts to eradicate even a small population would probably be far more damaging than the expected impacts of *P. shantungensis*. Eradication in an enclosed environment such as a heated glasshouse would theoretically be more achievable, but would still be very challenging especially in settings such as botanical collections with established woody trees.

Most of the information which follows is from experiments in South Korea, both in the field and laboratory. *Pochazia shantungensis* has been established in this country for over 15 years, and is causing damage. Therefore, there has been a lot of research into control options and other ways to limit population levels. While reading this section, it must be noted that chemical approvals differ markedly between countries and change over time. Many of the products discussed here will not be approved for use in any part of the UK, for example, the machine oil treatments. Even if there is existing approval for a particular product in the UK, it may not extend to use on trees, especially in an urban setting or in the wider environment. The register for plant protection products with current approvals for use in Great Britain or Northern Ireland, and the plants on which they may be used, can be searched here: https://secure.pesticides.gov.uk/pestreg/ProdSearch.asp

Chemical insecticides used to successfully control *P. shantungensis* in the early 2000s in China are mentioned by Li *et al.* (2006) and Shen *et al.* (2007). Choi *et al.* (2018) found that formulations of dinotefuran, chlorpyrifos (both 1,000 dilution) and acetamiprid (2,000 dilution) all showed 100% mortality one day after treatment, while deltamethrin (1,000 dilution) showed 100% nymph and 70% adult mortality. Five systemic chemicals were tested on sunflowers and blueberries for their toxicity to *P. shantungensis*. Acetamiprid, dinotefuran, imidacloprid and thiamethoxam all showed at least 90% control of pre-oviposition adults in sunflowers, with etofenprox providing over 80% control (Choi *et al.*, 2017b). The number of adults attracted to treated two-year-old blueberry plants compared to untreated controls did not show large reductions (and most were not statistically significant), but significantly fewer egg masses were laid for the four most effective chemicals. The blueberry plants treated with etofenprox did not show a decline in egg masses compared to the untreated control (Choi *et al.*, 2017b). Experiments on caged nymphs in Türkiye on *Ligustrum vulgare* (privet) suggest the greatest control was achieved with acetamiprid and deltamethrin (up to 100% mortality 11 days after treatment), with sulphur less effective (Çetin *et al.*, 2024).

Over 100 pesticides have been registered for use against *P. shantungensis* in South Korea, though all are targeted against the newly hatched nymphs, need to be applied when the trees are flowering, but are toxic to honeybees (Baek *et al.*, 2024).

Plant based insecticides would still need to have approval for use in the UK. These options have been researched in South Korea, due to the wish to use control in autumn when adults are laying eggs. As this coincides with harvesting of fruit for consumption, chemical controls are not a preferred option. This seems to be an area of active research in South Korea, with a lot of different extracts and compounds tested in a variety of experimental protocols.

Two extracts appear to show control across several different studies, at least in the laboratory. Matrine (extract from *Sophoroa* plants) showed the highest mortality (up to 100%) of the chemicals tested against *P. shantungensis*, at all three dilution levels studied (500, 1,000 and 2,000), both in the laboratory and field (Jo *et al.*, 2016). Similar results were reported for dilutions of 500, 750 and 1,000, though mortality of second and third instar nymphs was higher than adults (Choi *et al.*, 2012a). Rotenone (extract from *Derris* plants) also caused significant mortality (up to 40%) of *P. shantungensis* at dilutions of 500 and 1,000, but not at 2,000 dilution (Jo *et al.*, 2016). At 1,000 times dilution, rotenone was more effective against adults than second and third instar nymphs (Choi *et al.*, 2012a). Rotenone and matrine provided the greatest control of a range of actives tested by Cho *et al.* (2012), machine translation of Korean conference abstract.

The evidence for the efficacy of neem (extract from *Azadirachta indica*) is more mixed. At 1,000 times dilution, neem showed mortality of adults and nymphs roughly comparable to matrine and rotenone according to Choi *et al.* (2012a) and Choi *et al.* (2018). However, Jo *et al.* (2016) and Cho *et al.* (2012) found that neem was less effective. In Türkiye, azadirachtin provided some control, but it was less effective than the chemical options tested (Çetin *et al.*, 2024).

Many other extracts and combinations of extracts have been tested, but the data on their efficacy are more difficult to interpret, or data are only from one paper. Laboratory experiments on 4–5th instar nymphs and adults were undertaken by Choi *et al.* (2018). The active ingredients tested included various combinations of *Sophora* (both root and seed oil), neem, garlic oil, citronella oil and castor oil. Most compounds tested showed at least 50% mortality five days after treatment, used alone or in combination, and some killed over 90% of the insects tested (Choi *et al.*, 2018). Toosandonine, oxymathrin, eugenol, veratrine and emodin were all tested at different dilutions but all were less effective than rotenone and matrine (Cho *et al.*, 2012; Jo *et al.*, 2016). Spellings are given as per the papers cited but it is possible that some names have been misspelt, notably toosendanin and oxymatrine. Methylcinnamate extracted from *Alpinia galanga* showed 36% mortality at 100 times dilution (Park *et al.*, 2019) (abstract only, full text Korean hwp filetype could not be opened or converted). *Syzygium aromaticum* (clove) oils (reported under the synonym *Eugenia caryophyllata*) and several eugenol compounds were tested against *P. shantungensis* in laboratory experiments (Lee *et al.*, 2016). All of the tested chemicals showed toxicity to both nymphs and adults, with isoeugenol being the most potent; eugenol and methyl eugenol were demonstrated to be the active insecticidal components of the clove oil (Lee *et al.*, 2016). *Valeriana fauriei* oils showed 100% mortality of both adults and nymphs 48 hours after exposure in laboratory trials (Lee *et al.*, 2018), though the authors note that *P. shantungensis* was difficult to keep alive and even the distilled water control had over 23% mortality of adults after 48 hours (machine translation of Korean paper). Extracts from five different plant species were tested against *P. shantungensis* nymphs and adults in the laboratory, and 72 hours after exposure *Thymus vulgaris* (thyme) showed the greatest efficacy (lowest concentration to achieve 50 or 90% mortality after 72 hours) (Park *et al.*, 2017). The active compounds in the thyme extracts were shown to be carvacrol and thymol. In a very similar experiment testing five different plant extracts, *Tagetes erecta* (African marigold) oils required the lowest concentration of the tested extracts to achieve 50% mortality (Jeon *et al.*, 2016).

Repellents. The line between plant extracts as insecticides and repellents is not always that clear, as different concentrations of the same extract could produce control (toxicity) and repellent effects. Both plant extracts and whole plants have been investigated for repellent qualities in South Korea.

Twenty-three essential oils from eleven different plant families were tested on adults in Y shaped olfactometers (Ryu *et al.*, 2016). Peppermint oil (*Mentha* × *piperita*) had over 70% repellent effect at the highest dose tested in the laboratory. This effect continued in the field: sticky traps with peppermint oil caught significantly fewer *P. shantungensis*, but the effectiveness decreased over time (and the experiment only ran for seven days). The number of egg masses laid in apple tree branches treated with peppermint oil was lower compared to untreated controls, though the difference was not statistically significant (Ryu *et al.*, 2016). Lemongrass essential oil (*Cymbopogon citratus*) also showed repellence to *P. shantungensis* in the olfactometer, but it was less effective than peppermint (Ryu *et al.*, 2016). Methylcinnamate from *Alpinia galanga* showed 40% repellent effects at both 100 and 250 times dilution (Park *et al.*, 2019) (abstract only, full text Korean in hwp filetype).

In terms of whole plant repellents, *Lilium longiflorum* was less preferred than “blueberry” (assumed to be a *Vaccinium* species) in field experiments, though extracts of the plant were not repellent in laboratory studies unless extracted with methanol (Jo *et al.*, 2016).

Before any repellents could be used in the UK, authorisation by Chemical Regulations Division (CRD) would be required, both in Great Britain and Northern Ireland.

Attractants. All research into attractants appears to be based on providing preferred host plants to attract insects away from a vulnerable crop. *Clerodendrum trichotomum* was more attractive than “blueberry” (assumed to be a *Vaccinium* species) in field experiments, even if the *C. trichotomum* plants were sprayed with a chemical insecticide (Jo *et al.*, 2016). This could also be demonstrated in laboratory experiments, as *C. trichotomum* extracts attracted *P. shantungensis*.

During the pre-oviposition period, sunflowers were far more attractive than blueberry plants in an experimental set up using potted plants in the field, with over 90% of adults attracted to the sunflowers (Choi *et al.*, 2017b). However, once the adults were mature and ready to lay eggs, this pattern reversed, with over 85% of adults attracted to the woody blueberry plants rather than the herbaceous sunflowers. It was suggested that over the longer term, sunflowers treated with insecticides may be a useful strategy to reduce the population density of *P. shantungensis*, and hence damage to fruit crops (Choi *et al.*, 2017b) (machine translation of Korean paper).

Traps. Testing light traps, the most effective light colours of the six tested were daylight, black and red, with yellow and green the least effective (Choi *et al.*, 2019; Choi *et al.*, 2020). The authors suggested the trapping regime which caught most insects was to run the traps between 7 and 11 pm, when the night time temperature is 23°C or greater. An earlier version of the trap was run with different colours of lights during day and night (Choi *et al.*, 2018), machine translation of Korean paper. Yellow sticky traps in South Korean blueberry orchards attracted adult *P. shantungensis*, and significantly reduced the number of egg masses per plant compared to control plots (Kim *et al.*, 2016a).

Pheromones. It does not seem to be known whether *P. shantungensis* uses pheromones at all, but https://pherobase.com/database/invasive-family/family-Ricaniidae.php states that pheromones are not available for any species in the six ricaniid genera it includes (last accessed 30 January 2025). As far as can be determined, none of the control methods used or in development in South Korea against *P. shantungensis* use pheromones.

Biocontrol. Before any non-native biocontrol agent can be used in the UK, risk assessments need to be conducted. Approvals for release of biocontrol agents are a devolved matter, with each of the four countries within the UK considering any proposed release through their own processes.

No commercial biocontrol options for *P. shantungensis* are known. *Verticillium lecanii* strain bb-1 1 was tested on nymphs in Türkiye, but provided only limited control (Çetin *et al.*, 2024). Experiments in South Korea were carried out by Choi *et al.* (2018), but using machine translation it was not possible to determine exactly what organisms were used, or if the tests were with live organisms or extracts of some description.

Candidate biocontrol organisms which have been identified as reasonably specific to *P. shantungensis* in other countries are unlikely to have pre-existing approval for release in any part of the UK. In South Korea and China, a species of egg parasitoid wasp, *Phanuromyia ricaniae*, has been identified from the eggs of *P. shantungensis*, though it has also been isolated from a different (unidentified) ricaniid egg, suggesting it is not species-specific (Nam *et al.*, 2020). *Telenomus* sp. is another egg parasitoid that has been identified in South Korea, with egg parasitism rates of over 40% in some years and locations, though eggs in other regions showed no evidence of parasitoids (Choi *et al.*, 2018). Parasitism rates between 37% and 66% were reported in South Korea, though the hymenopteran parasitoid responsible still requires full identification (Kim *et al.*, 2016c), machine translation of Korean conference abstract. Kim *et al.* (2018) gives detailed information about the South Korean parasitoid, including some details of the genetic analysis which suggest the closest match is to *Telonomus*, but that no barcode for the parasitoid species exists in the NCBI database (machine translation of Korean text).

Pruning. As eggs are usually laid in year-old twigs, removal of young growth in the winter would serve to reduce populations of the insect. Depending on plant species, this may be when routine pruning already occurs, though in other species winter pruning is not ideal as it may affect the growth of the plant in the spring. Shen *et al.* (2007) recommend pruning with burning or deep burial of the twigs to help control, as well as recommending consideration of which plant species are grown (machine translation of Chinese text). Even if pruned twigs are just left, with no further treatment of the removed material, this may still reduce populations. If twigs with egg masses are cut from the plant, very few eggs hatch, presumably because the cut twigs dry out and the eggs also desiccate (Kim *et al.*, 2017a; Kim *et al.*, 2018). This is supported by the data showing a small number of eggs hatched from twigs pruned in March, whereas no eggs hatched from twigs pruned in December (Kim *et al.*, 2017a; Kim *et al.*, 2018).

Machine oil at various dilutions has been painted or sprayed on egg masses to kill the eggs and/or prevent nymphs emerging (Choi *et al.*, 2018; Song *et al.*, 2021). Machine oil has also been tested for its ability to kill nymphs and adults (Choi *et al.*, 2018). Dilutions of 20 times were more effective (lower percentage of eggs hatched) compared to dilutions of 50 times (Song *et al.*, 2021).

18. References

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Appendix 1

Climate analysis details and supplementary information

Summary of key degree day information used in this PRA

Laboratory studies showed that no eggs hatched from chestnut twigs at 12.4°C, but at 16.4°C nymphs emerged and the threshold temperature for development was calculated as 12.1°C (Baek *et al.*, 2019b), though other papers report much lower thresholds (see Appendix 1 for details). In persimmon twigs, one egg out of 793 did hatch at 12.4°C (Baek *et al.*, 2025). Choi *et al.* (2016) reported that over 70% of eggs hatched between 18 and 27°C, and at 15°C over half the eggs hatched. Optimum temperatures for egg hatch were determined by Baek *et al.* (2019b) to be 31.0°C. In a separate study, no hatching of overwintered eggs occurred at 10°C, while eggs kept at 14°C had 23.1% emergence success, and took a very long time (107.1 days) for the first instar nymph to develop to second instar (Kang *et al.*, 2013). In comparison, eggs kept at 21.6°C hatched in around 34 days, and at 29.6°C took 25 days, though emergence was only 13.8 and 11.9% respectively (Kang *et al.*, 2013). An abstract of conference proceedings in Korean, using machine translation, suggests that nymphs were not able to complete development to adult at 15°C (Im *et al.*, 2011). For egg-fifth instar nymph, the overall lower development threshold was considered to be 9.3°C with 693.3 accumulated degree days (DD), though different life stages had very different threshold thresholds ranging from 3.8°C (fourth instar nymph) to 11.8°C (first instar) (Choi *et al.*, 2016). The optimum temperature for development egg-fifth instar was estimated as 27°C (Choi *et al.*, 2016). More adults were found in sunny areas in study sites in South Korea, and the number of eggs laid was higher in sunny locations than in shaded locations, which suggests that the insects actively choose warmer locations (Choi *et al.*, 2017a). Adults are most likely to be captured in traps (i.e. flying and active) when the overnight temperature is ≥23°C (Choi *et al.*, 2019; Choi *et al.*, 2020).

Degree days required for egg hatching in spring

Experimental rearing of eggs at different temperatures to determine threshold temperatures and accumulated degree days (DD) required for hatching have been studied in South Korea. All eggs used appear to have been field collected over the winter and spring.

Choi *et al.* (2012b) reared eggs at constant temperatures between 15 and 30°C, at 3°C intervals. They calculated the lower threshold for development as 4.75°C, requiring 429.3 DD, using a linear model. These data were from a Korean conference abstract, and no further details are available.

Kang *et al.* (2013) reared eggs at constant temperatures of 10–34°C, at approximately 4°C intervals. No hatching occurred at 10°C, and emergence rates were very low at 34.3°C.

Median periods to hatch were the longest at 14°C at over 100 days, and decreased to less than 30 days at temperatures of 26°C and over. Though Kang *et al.* (2013) did not calculate lower developmental threshold temperatures or DD, Baek *et al.* (2019b) used their rearing data to suggest values of 9.7°C and 434.8 respectively though it is not known what model was fitted to the data.

Choi *et al.* (2016) again reared eggs at 3°C intervals at constant temperatures 15–30°C. Over 400 eggs were kept at each experimental temperature. Eggs hatched in the shortest time at 27°C, and took longest at 15°C. Both extremes (15 and 30°C) showed lower hatching rates of less than 60%, compared to the four temperatures 18–27°C, where hatching rates were over 70%. The calculated lower threshold temperature for egg development was 7.4°C, and required 330.2 DD, calculated using a linear model.

Baek *et al.* (2019b) noted the previous studies had quite different values and suggesting re-estimation of egg hatching thresholds was required. In the laboratory, eggs collected on chestnut branches were reared at constant temperatures. Temperatures used were in the range 12–36°C at intervals of approximately 4°C, and over 400 eggs were tested at each temperature. No individuals survived at either 12.4 or 36.9°C. Both linear and non-linear models were fitted and the estimated lower development threshold was 12.1°C with 202 DD. Baek *et al.* (2019b) also used field studies to validate their model. Eggs on chestnut trees in the field were covered in mesh bags so emerging nymphs could be collected and counted. Accumulated degree days over a threshold temperature of 11.6°C after 1 January were calculated from met stations within 20 km of the experimental site. It should be noted that the mesh bags could have changed the temperatures experienced by the eggs, likely increasing the temperature compared to twigs not covered in bags. Comparison of predicted and actual hatching dates at three different field sites used 264.3 DD to predict 50% hatching. Thus, two different thresholds were actually provided: 12.1°C and 202 DD for the lab rearing experiments, and 11.6°C and 264.3 DD for validated 50% field hatching dates. However, in their table 3, they report 12.1°C and 264.3 DD, an apparent mixture of both datasets (Baek *et al.*, 2019b).

The most recent work was by Baek *et al.* (2025) on persimmons (contrasting with the previous study on chestnuts). This paper was published after the modelling in this PRA was finished, but is reported here for completeness. The experimental set up was almost identical to the studies on chestnuts by Baek *et al.* (2019b), other than the twigs with overwintering eggs were collected from persimmon trees. At 12.4°C, only one nymph hatched out of 793 eggs. Nymphs hatched at temperatures between 16.4 and 32.4°C, with survivorship highest at 20.4°C. No individuals survived at 36.9°C. The lower threshold temperature was calculated as 12.0°C, requiring 159.9 DD using a linear model. The authors note that, while the development rate of *P. shantungensis* was slower in chestnuts compared to persimmons, more eggs survived in the chestnut, perhaps due to the higher water content in chestnut twigs compared to persimmons (Baek *et al.*, 2025).

Baek *et al.* (2019b) and Baek *et al.* (2025) used their models to predict hatching rates and compared them with field observations of actual hatch dates from three sites. Their own work on chestnuts had a difference of 2-4 days between predicted and actual values (probably using 11.6°C and 264.3 DD). Their calculations using data from Kang *et al.* (2013) showed a difference of 10–13 days. Choi *et al.* (2016)'s model showed 10–16 days' difference between predicted and actual values according to Baek *et al.* (2019b), and Choi *et al.* (2012b) showed the least agreement, with differences of 15–22 days. In the recent work on persimmons, again there was good agreement between predicted and actual hatching dates, with a maximum of 5 days' divergence in the sites studied (Baek *et al.*, 2025).

This PRA made similar attempts to compare predicted and actual hatching dates for the different thresholds, although a lot of approximations were used and the results presented are only indicative. Phenology data was sourced from studies in China, South Korea and Turkey (Li *et al.*, 2006; Shen *et al.*, 2007; Choi *et al.*, 2012a; Jo *et al.*, 2016; Hızal *et al.*, 2023). Daily maximum and minimum data for sites close to the phenology locations was sourced from Weather Underground (note: not official met data) for years mentioned in the phenology papers, though the choice of station was restricted by availability of historical data. The DD for each met station were calculated using the method of Baker (1980) for each threshold at the given date of emergence, and compared with the predicted DD from each author (fig. A1). The two locations from China required fewest DD, perhaps because the eggs had undergone some development in the autumn before overwintering. As these locations are systematically different from the other locations used, the Chinese emergence dates were given less weight when assessing actual and predicted egg hatch. Though the comparisons are very approximate, they do suggest that DD using thresholds of 4.75 and 9.7°C (Choi *et al.*, 2012b; Kang *et al.*, 2013) do not match the observed data particularly well. There is probably the best agreement in this approximate comparison using the laboratory values of 12.1°C and 202 DD from the most recent work examined in detail (Baek *et al.*, 2019b).

Degree days for rest of lifecycle

Various Korean authors have mentioned in passing that it has not proved possible to rear *P. shantungensis* through its complete lifecycle in the laboratory. This may help to explain why there are no egg to egg or even egg to adult thermal thresholds available. Choi *et al.* (2016) reared field collected eggs at constant temperatures 18–30°C, at 3°C intervals and collected data up to fifth instar nymph. Over 400 eggs were kept at each experimental temperature and it is assumed that results were based on all survivors at each stage. Developmental periods for each life stage egg-fifth instar nymph were recorded. The overall lower development temperature egg-fifth instar was calculated using linear regression as 9.3°C, but this masks a lot of variation in the values measured for each instar. First instars had the highest lower threshold temperature, at 11.8°C. Second and third instars were quite similar, at 10.5 and 10.8°C respectively. Fourth instar nymphs had a much lower calculated temperature than any other life stage, at 3.8°C. Fifth instars required minimum temperatures of 8.3. In terms of development rate, development was slowest at 18°C (as would be expected), and the time spent in each instar decreased as the rearing temperature increased. At 30°C, nymphs did not survive to the end of the fourth instar (Choi *et al.*, 2016).

The threshold temperature for the full life cycle of *P. shantungensis* is not known, nor the number of DD required for a full generation (either including or excluding the pre-oviposition period). Using the at least partially validated egg hatching threshold of Baek *et al.* (2019b) as a starting point, and considering that development seems to be markedly slow at 14–15°C, a threshold temperature of around 12°C would seem to fit the reported biology of the pest. Though a lower temperature threshold was suggested by Choi *et al.* (2016), their predicted data for egg hatch discussed in the previous section did not have a particularly good match to observed data. Given the very wide variation in threshold temperatures for the different nymphal instars, it was considered that the suggested threshold temperature of 9.3°C would require further validation.

Using methods outlined under the egg hatch section, this PRA attempted to calculate approximations of DD using data from met stations located near the sites of phenology reports, using data from the same years. Threshold temperatures from the literature between 7.4 and 12.1°C were considered, and a higher threshold of 14°C was added. The dates were calculated for the complete egg-egg lifecycle, i.e. egg laying right through to the next generation of adults observed laying eggs again. Eggs which overwintered had autumn DD added to spring and summer values for the next year, and overwintered eggs were considered separately to eggs from the second generation (Fig. A2). These should only be viewed as an indication, and certainly should not be used to give DD estimates for the whole life cycle. Nonetheless, the analysis does seem to suggest that *P. shantungensis* requires very substantial degree day accumulations (i.e., warm or hot temperatures for long periods) in order to complete its development.

While closely related insects can have very different thermal requirements, thresholds for other insects are briefly discussed here. *Pochazia guttifera* is found in southern Asia, including southern China, India, Myanmar, the Philippines, Sri Lanka and Vietnam[7]. Experiments on temperatures required for *P. guttifera* overwintering eggs to hatch suggest that the threshold temperature is 11.58°C, with 526.32 DD above this threshold required (Jin *et al.*, 2020). Eggs kept at 16°C showed a much slower development than eggs kept at temperatures of 19°C or more, and less than 30% hatch rate (Jin *et al.*, 2020). These responses to temperatures in these ranges appear to be similar to the responses of *P. shantungensis*. Though in a different family, *Metcalfa pruinosa* (Flatidae) is a species invasive in parts of Europe as well as South Korea (Strauss, 2010; Kim *et al.*, 2022). The CLIMEX model developed for *M. pruinosa* suggests a threshold temperature of 13°C and 500 DD for one generation, these values based on locations where it is known to have established populations (Strauss, 2010). The NAPPFAST insect development database described by Nietschke *et al.* (2007) has only 60/512 insects where the egg development threshold temperature is ≥12°C, and only 17 Hemiptera. Of these 17, the whitefly *Aleurocanthus woglumi* was deregulated in Great Britain after EU exit. The pentatomid *Graphosoma lineatum* has a decision for no statutory action recorded on the UK plant health risk register. Selected other insects with egg threshold temperatures ≥12°C which

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[7] Species name search on https://flow.hemiptera-databases.org/flow/ (accessed 4 March 2025)

have been screened for their risk to the UK include the crambid moths *Diaphania indica* and *D. nitidalis* and the agromyzid fly *Liriomyza chinensis*, all of which have no statutory action recorded on the risk register.

Degree days over threshold temperature of 18°C

Though the threshold temperatures for *P. shantungensis* are taken to be around 12°C in this PRA, the insect appears to develop very slowly below 15–16°C. Data from Choi *et al.* (2016) suggest that development rate starts to increase linearly with temperature around 18°C. Global maps (0.25° × 0.25° resolution) of annual cooling DD at 18°C were analysed as this appears to be a temperature at which the insect is not under a great deal of thermal stress (data from time period 1970–2018) (Mistry, 2019a; Mistry, 2019b). Degree days were calculated using the average of the daily minimum and maximum temperatures. The results are shown in figures A3 (Europe) and A4 (Asia).

The UK accumulates very few DD over a threshold of 18°C according to Mistry (2019a): interrogating the map shows <7 DD in the warmest square in south-east England. In contrast, areas in France where the pest is present have 211–555 DD; Pistoia in Italy has 330; Türkiye has at least 370 DD and Sochi in Russia 153. All locations in China where *P. shantungensis* has been recorded have >700 DD. Locations in South Korea where *P. shantungensis* have been recorded all appear to have >150 DD. In Japan, the pest has been recorded from locations with at least 200 DD.

Individual years can be warmer in the UK: using the pest development webtool from the UK Met Office[8] (1991–2024, 1 km resolution) and a threshold temperature of 18°C, the warmest grid cell in London has over 350 DD in the two warmest years (2018 and 2022), and even in the coolest year (1993), almost 150 DD are reached in a small number of grid cells. However, this dataset is UK-specific and cannot be compared with areas where *P. shantungensis* is currently present. Additionally, the Met Office web tool calculation of DD follows the methods outlined in Baker (1980). This calculation differs from Mistry (2019b), who subtract the threshold temperature from the daily average temperature, as long as the difference is positive.

Temperatures recorded in central London

Temperature data (2014-2023 inclusive) from one of the warmest locations in the UK, Kew Gardens in London, were studied (Met Office, 2024). The number of days per year where the daily minimum or maximum temperatures reached some of the important temperatures for *P. shantungensis* development were counted. These statistics only give a partial picture, as for many days, temperatures will exceed a given threshold, even if the minimum temperature for the day doesn’t meet this threshold. Likewise, if the maximum temperature exceeds a threshold, it does not necessarily follow that the whole day was warmer than that threshold. Degree day calculations, which do take account of varying

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[8] https://hadleyserver.metoffice.gov.uk/biosecurity_uk_hist/ and choosing “user thresholds”

temperatures across the day, are discussed elsewhere. The temperature thresholds chosen and the reasons for each are listed in Table A1. Between 2014 and 2023, at Kew Gardens, very few days per year had a minimum temperatures of at least 15°C, with annual totals between 12 and 37 days (Fig. A5). There were only 0–6 days per year with minimum temperatures of ≥18°C. Obviously, a larger number of days had maximum temperatures over these thresholds: 171–211 days per year reached at least 15°C and 115–158 days ≥18°C. Only a small number of days per year had maximum temperatures that reach or exceed optimum temperatures for *P. shantungensis*: 1–31 days reached at least 27°C, and only 0–10 days per year were ≥31°C (Fig. A6).

Mean monthly temperatures

Data from the World Meteorological Organisation (2024) were used to compare mean monthly temperatures from locations near to where *P. shantungensis* has been recorded, both in the native and invasive ranges. Data were also downloaded for three of the warmest sites in the UK. The mean monthly maximum temperatures (Fig. A7) show that from April until about October or November, the UK is cooler than any country in the existing distribution. The mean monthly minimum temperatures (Fig. A8) show that the UK is cooler from about April to September. Locations in South Korea and near Sochi in Russia are cooler than UK locations in winter, as mentioned elsewhere in this PRA. It must be noted that the data are from different time periods depending on country (see Table A2 for full details). Türkiye in particular should not be directly compared with other countries.

Appendix figures

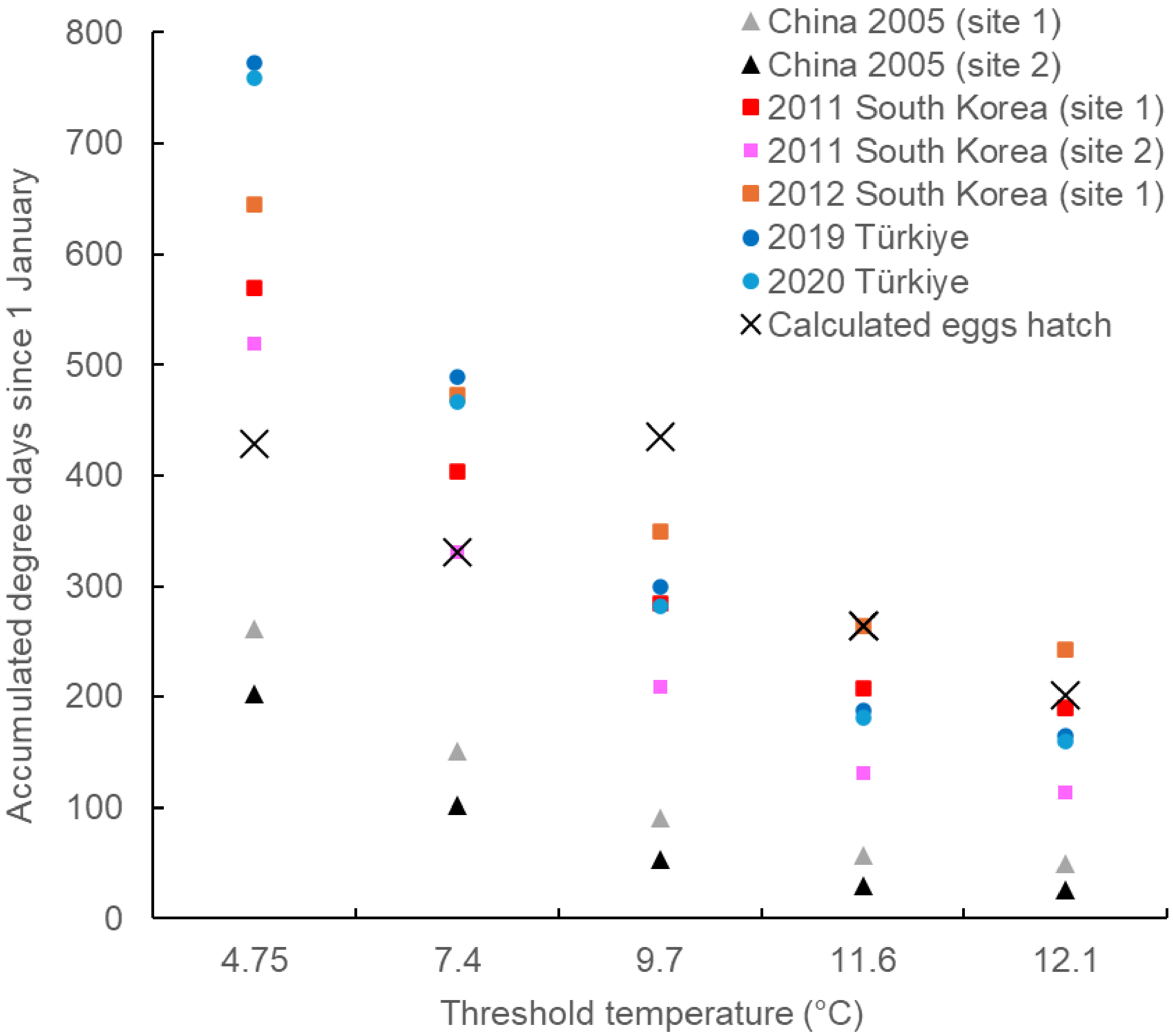

Figure A1. Comparison of theoretical degree day egg hatch thresholds for *Pochazia shantungensis* with approximations of the accumulated degree days based on meteorological station data and published phenology. Theoretical data from laboratory studies for egg hatch in *Pochazia shantungensis* were plotted (black crosses). These data were compared with degree days calculated from nearby meteorological stations between 1 January and the published date of egg hatch (coloured shapes). Phenology data was sourced from studies in China, South Korea and Turkey. Daily data for sites close to the phenology locations was sourced from Weather Underground for years mentioned in the phenology papers. See text for detailed reference sources.

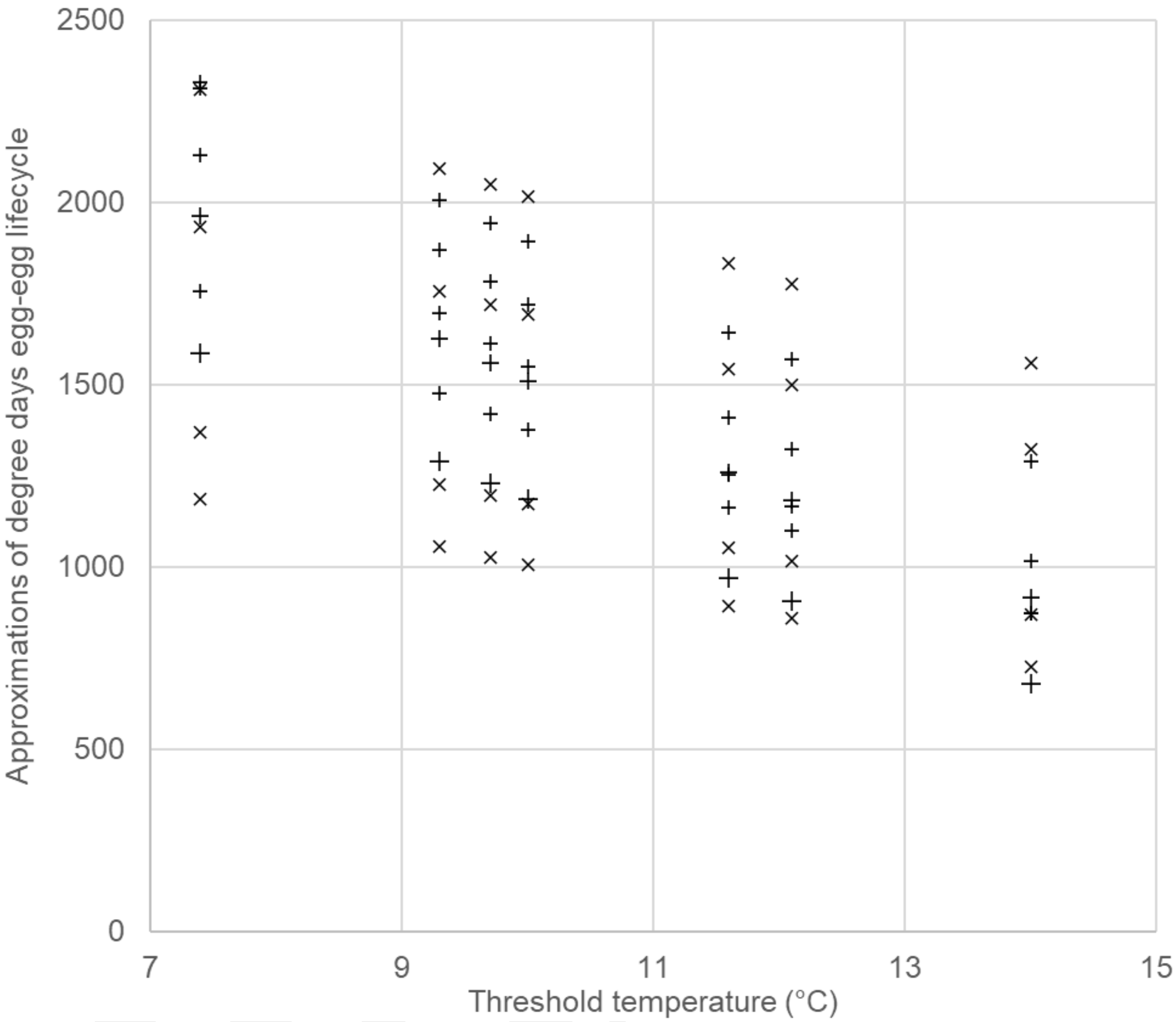

Figure A2. Approximations of the accumulated degree days for the egg-egg lifecycle of *Pochazia shantungensis* based on meteorological station data and published phenology. Degree days for each threshold were calculated from met stations near sites where phenology has been recorded, using historical data from the same years as the observed lifecycle. The graph presents the range of accumulated degree days, separating data for overwintering eggs (+) and the second generation (×). Phenology data was sourced from studies in China, South Korea and Turkey. Daily data for sites close to the phenology locations was sourced from Weather Underground (note: not official met data) See text for detailed reference sources.

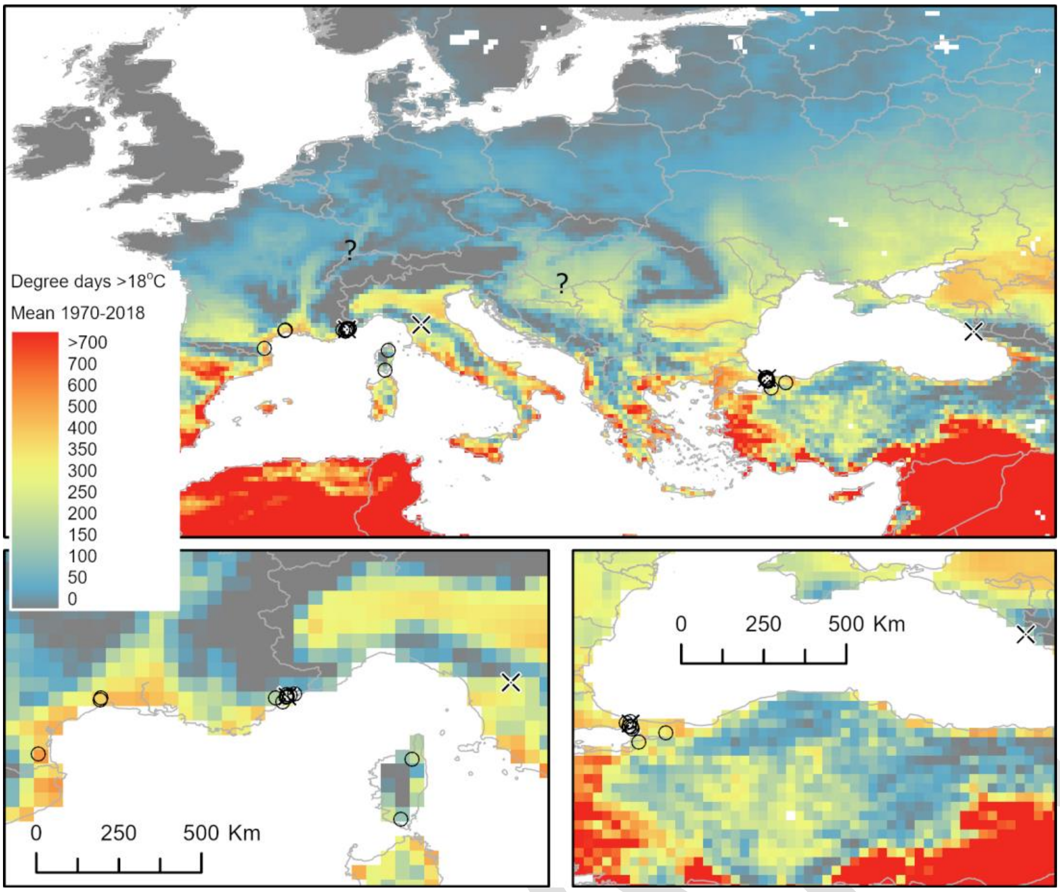

Figure A3. Degree day accumulation over a threshold of 18°C in Europe using data from Mistry (2019a). Top: Europe overview; bottom left: southern France and northern Italy; bottom right: Türkiye and western Russia. Distribution records of *Pochazia shantungensis* have been included for comparison: crosses are exact coordinates; circles are less precise (e.g. location names); question marks are populations which may not be established.

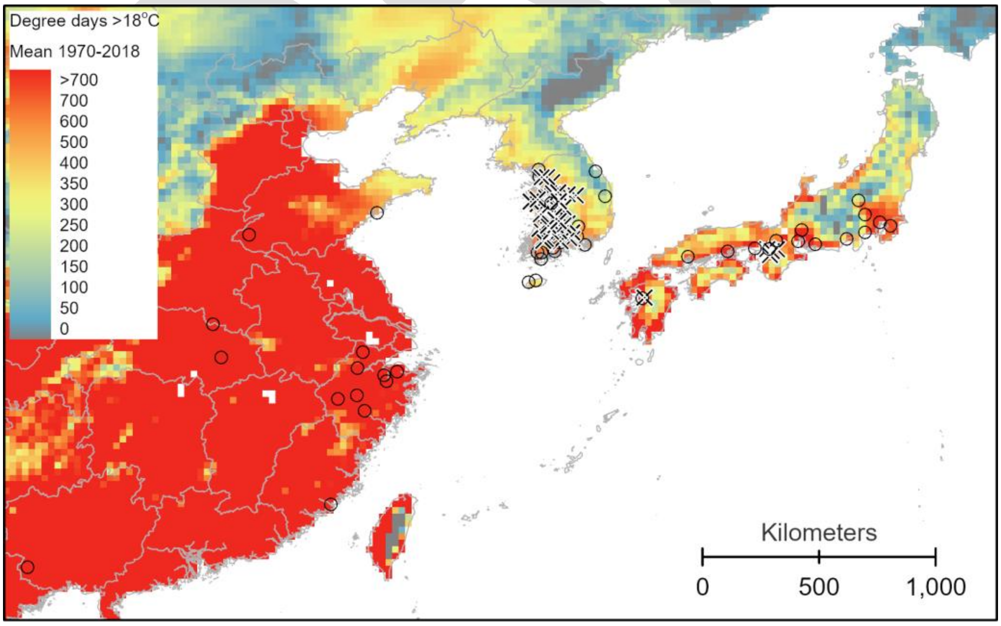

Figure A4. Degree day accumulation over a threshold of 18°C in eastern Asia using data from Mistry (2019a). Distribution records of *Pochazia shantungensis* have been included for comparison: crosses are exact coordinates; circles are less precise (e.g. location names).

Table A1. Key temperatures for *Pochazia shantungensis* development from the literature.

Temperature	Importance to *P. shantungensis* lifecycle	Source(s)
31°C	Optimal temperature for egg hatching	Baek *et al.* (2019b)
27°C	Optimal temperature for nymphal development	Choi *et al.* (2016)
23°C	Adult flight (night time temperatures)	Choi *et al.* (2019); Choi *et al.* (2020)
20°C	Growth and development likely to be successful	No specific source
18°C	Lower end of range for nymphs to develop reasonably quickly	Choi *et al.* (2016)
15°C	Development of eggs and nymphs is very slow and full lifecycle may not be possible	Kang *et al.* (2013); Im *et al.* (2011)

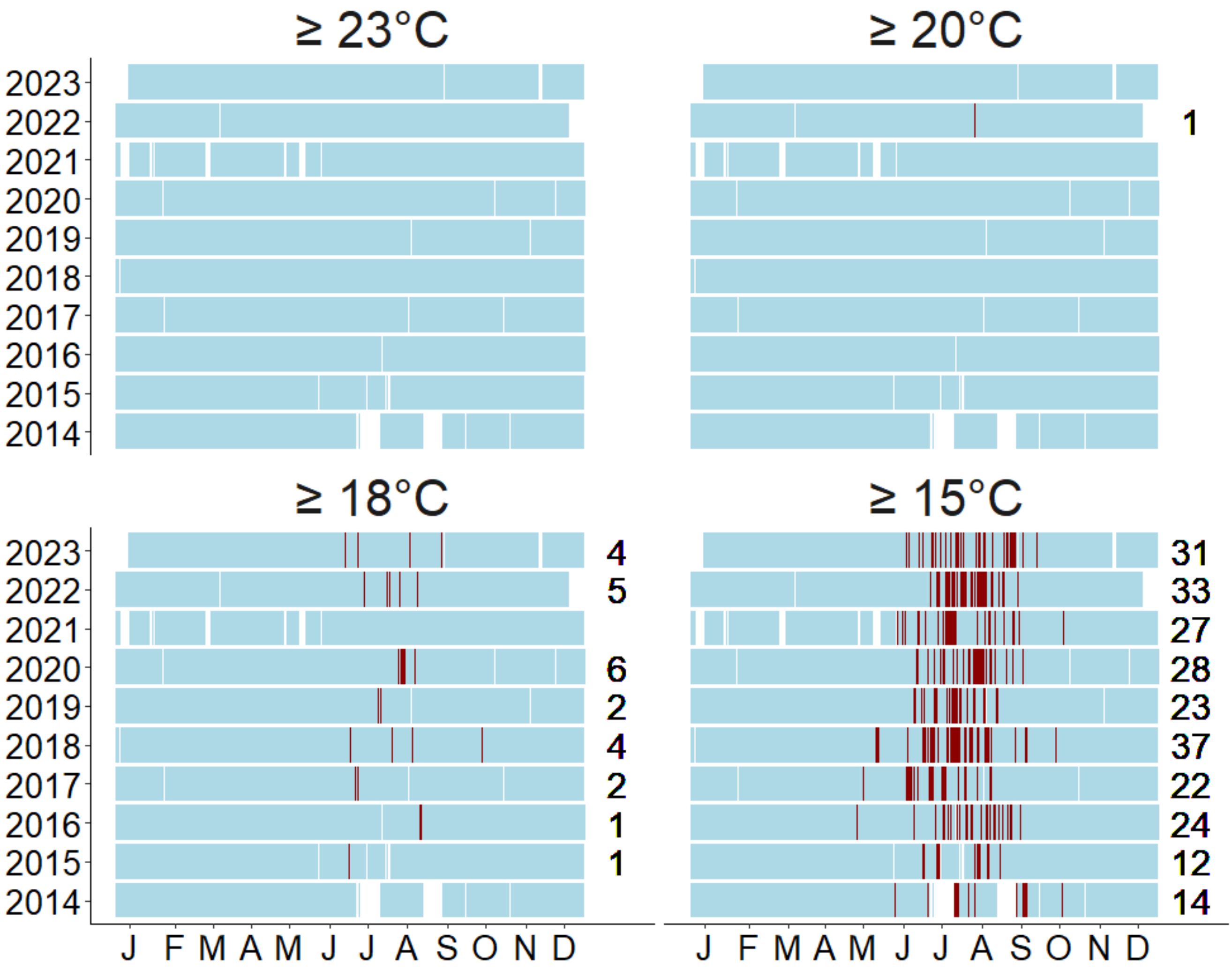

Figure A5. Annual days in Kew Gardens (London) (2014-2023) where the daily minimum temperature was greater than or equal to temperatures of relevance to the lifecycle or activity of *Pochazia shantungensis* (table A1). Blue: days where the temperature did not reach the threshold; dark red: reached or exceeded threshold; white: data missing. The numbers on the right give the total days for that year. Source: MIDAS: UK hourly weather observation data (Met Office, 2024).

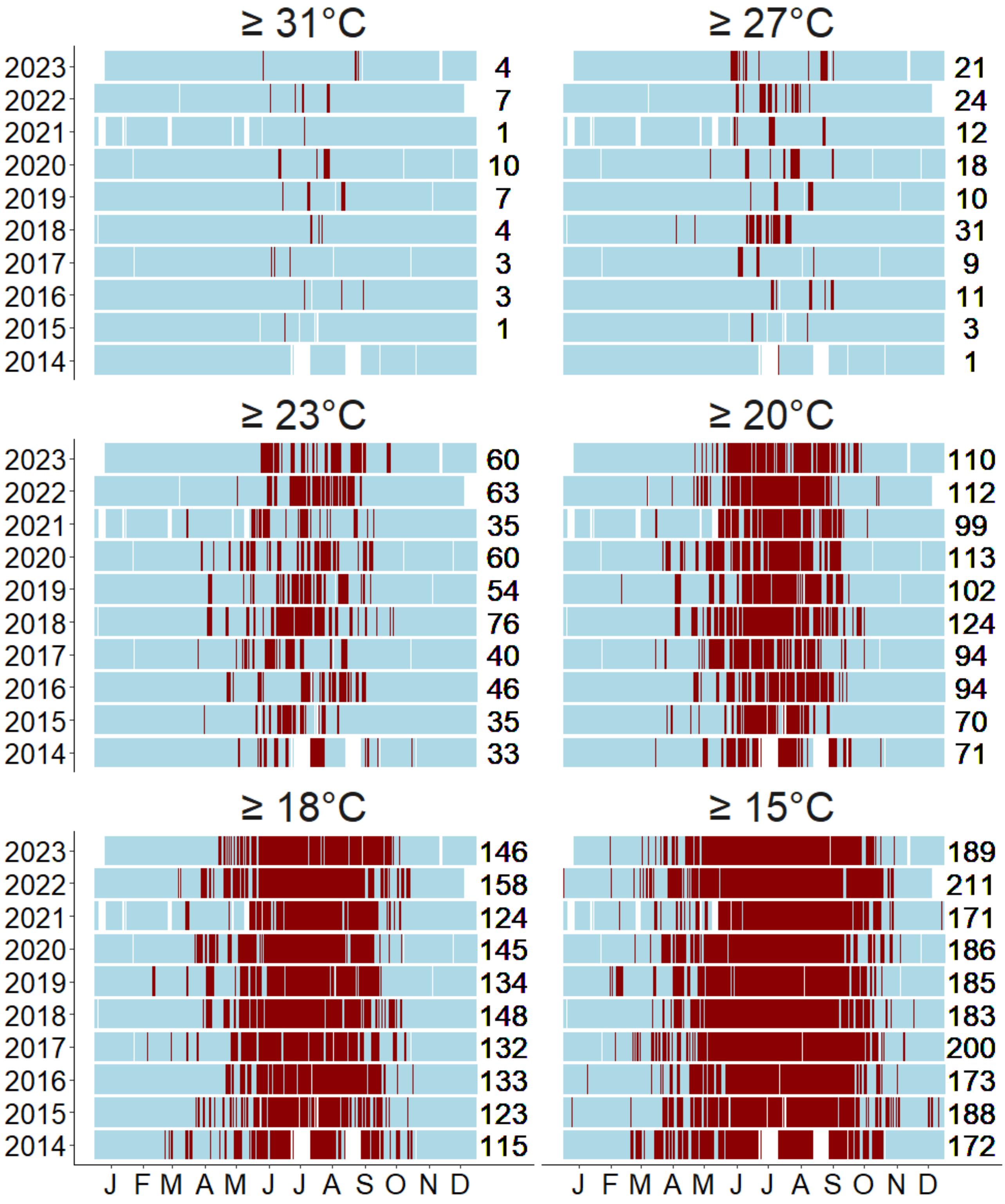

Figure A6. Annual days in Kew Gardens (London) (2014-2023) where the daily maximum temperature was greater than or equal to temperatures of relevance to the lifecycle or activity of *Pochazia shantungensis* (table A1). Blue: days where the temperature did not reach the threshold; dark red: reached or exceeded threshold; white: data missing. The numbers on the right give the total days for that year. Source: MIDAS: UK hourly weather observation data (Met Office, 2024).

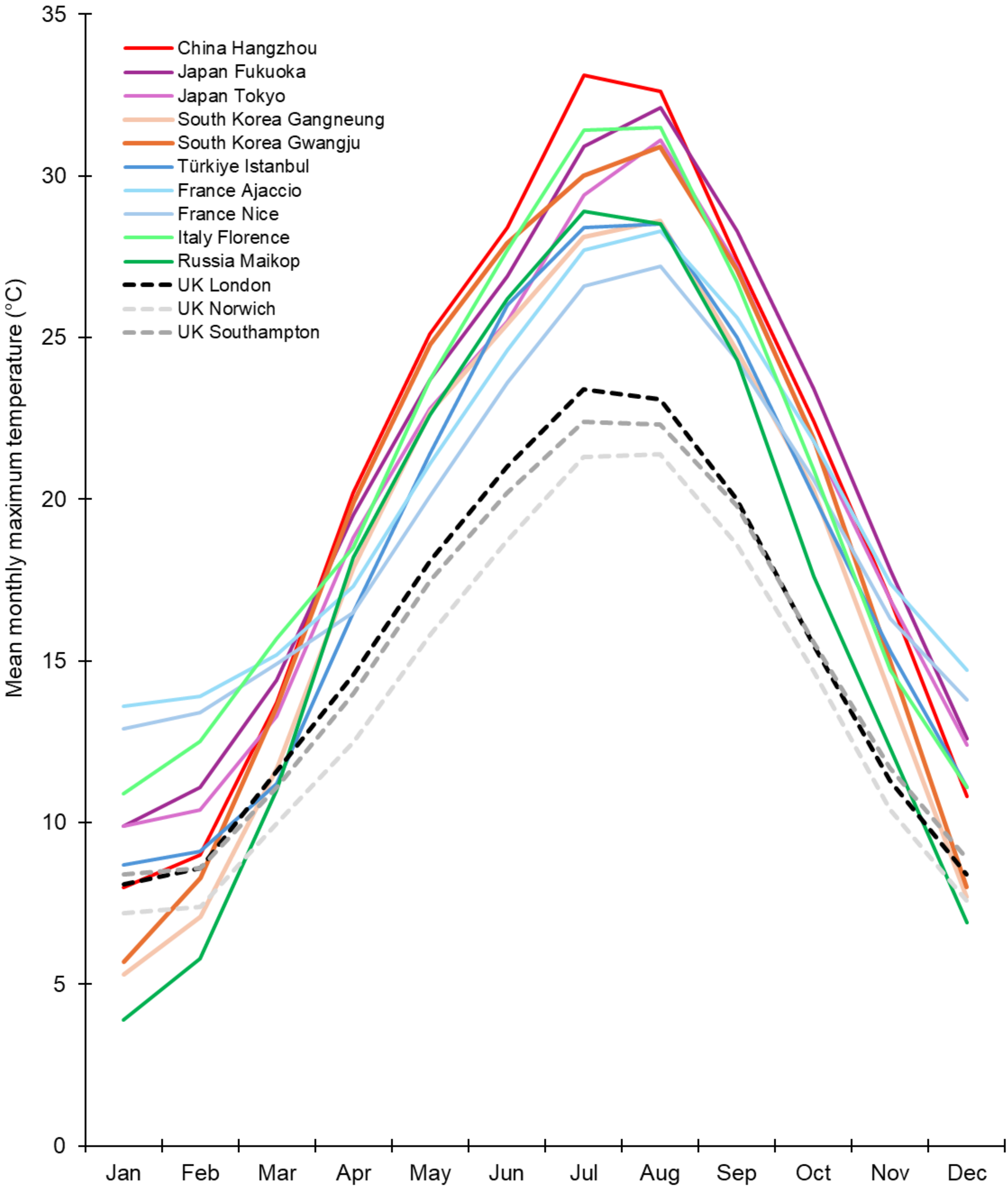

Figure A7. Mean monthly maximum temperatures in the current range of *Pochazia shantungensis* compared to three warm locations in the UK. Reds are Asia, blues and greens Europe and the UK are greyscale dashed lines. Data source: World Meteorological Organisation (2024)

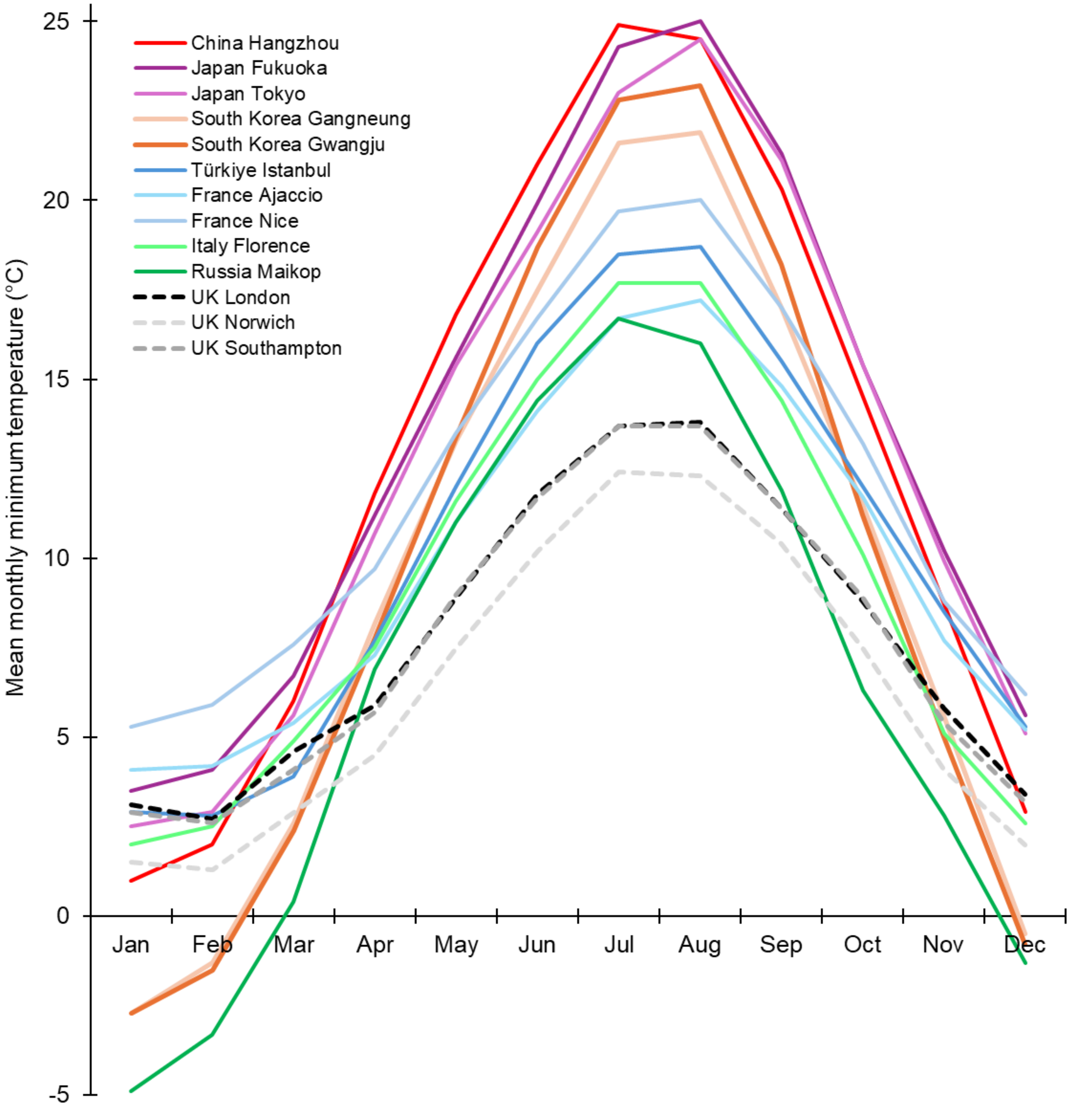

Figure A8. Mean monthly minimum temperatures in the current range of *Pochazia shantungensis* compared to three warm locations in the UK. Reds are Asia, blues and greens Europe and the UK are greyscale dashed lines. Data source: World Meteorological Organisation (2024)

Meteorological daily data sources (table A2)

World Meteorological Organisation

https://worldweather.wmo.int/en/home.html

Data in this site are provided by national meteorological organisations of each country concerned and therefore are official data. Data are averaged over different time periods depending on the contributing organisation, and so care needs to be taken when comparing data from different countries. The averaging period for each country is noted in Table A2, but it should be noted that Türkiye has a very different period (1929-2000) compared to other countries which use relatively recent 30-year time spans.

Monthly data were sourced for locations near where *P. shantungensis* is known to be present: China (Hangzhou), France (Nice and Ajaccio in southern Corsica), Italy (Florence), Japan (Tokyo and Fukuoka), Russia (Maikop), South Korea (Gwangju in the south east and Gangneung in the north west) and Türkiye (Istanbul). These were compared with three sites in southern UK: London, Norwich and Southampton.

UK Met Office

Met Office (2024) hourly MIDAS data were used for UK locations, using the stations Camborne (Cornwall) and Kew Gardens (London), the latter one of the warmest locations in the UK. These are official data for the UK.

Weather underground

https://www.wunderground.com/history

Daily maximum/minimum temperature data were sourced from the monthly historical data feature available in Weather Underground (2024), the years downloaded for each site matching the year(s) the phenology studies were carried out. Note, Weather Underground is a collection of personal weather stations. It is not an official source of data, and the accuracy of each weather station is not known. Maximum and minimum temperatures were reported to the nearest °C. Hourly data are available, but for a year’s worth of data, it was not realistic to obtain these week by week. In some cases (across several locations), minimum temperatures of 0 were replaced if apparently anomalous. Approximated replacement values used back calculations from the reported average temperature for the day. For example, Shanghai Hongqiao International Airport data for 24 June 2002 reported max, average, min temperatures (°C) as 29, 23.4, 0; the 0 was replaced with 17.8 before calculation of DD (all other reported minimum temperatures for the month were ≥19°C).

Degree days were then calculated using the method of Baker (1980) from the daily maximum and minimum temperatures for a variety of threshold temperatures.

BizEE cooling degree days

https://www.degreedays.net/

This website is designed for building engineers, for the purposes of identifying how much energy for heating or cooling a building might need to keep the interior at a comfortable temperature at a given location. They note that their expertise is in these buildings and energy saving calculations, and not in growing degree days for plants. BizEE Degree Days (2024) allow download of DD from a wide range of meteorological stations, calculating the DD from multiple daily readings for a variety of user-selected thresholds. A lot of background computation appears to go into the calculations, including verifying data, estimating missing values, and such like. It is unclear where the raw data for each station is obtained. The downloadable DD results give daily values for the chosen threshold and include data on which values (if any) required estimation. The station selection options also give some indication of data quality before the calculations are made. Cooling degree days with a threshold temperature of 12°C (i.e. temperatures greater than the selected threshold) for the most recent 36 months were downloaded for selected locations. For the sake of equal comparison across the world, three sites from the UK were also used.

Appendix tables

Table A2. Locations, time periods and sources of temperature data used in the detailed climate analyses for *Pochazia shantungensis*. Details of which source was used for each analysis is given in the relevant text. Some stations were just used to cross check that data from the same area gave similar results, and only one of the locations was chosen for the final analysis.

Year(s) used	Country	Location	Source	Station code	Data type	Phenology location (source)
Not stated	China	Hangzhou	World Meteorological Organisation (2024)	Hangzhou	Monthly mean max and min	N/A – long-term climate average
2022-2024	China	Ningbo (lishe)	BizEE Degree Days (2024)	ZSNB	Daily cooling degree days (12°C)	Yuyao (Shen *et al.*, 2007)
2022-2024	China	Shanghai Hongqiao	BizEE Degree Days (2024)	ZSSS	Daily cooling degree days (12°C)	Shengzhou (Li *et al.*, 2006) and Yuyao (Shen *et al.*, 2007)
2002, 2003, 2005	China	Shanghai Hongqiao International Airport	Weather Underground (2024)	ISHANG68	Daily max and min (°C)	Shengzhou (Li *et al.*, 2006) and Yuyao (Shen *et al.*, 2007)
2005	China	Shanghai Pudong International Airport	Weather Underground (2024)	ZSPD	Daily max and min (°C)	Shengzhou (Li *et al.*, 2006) and Yuyao (Shen *et al.*, 2007)
1971-2000	France	Ajaccio	World Meteorological Organisation (2024)	Ajaccio	Monthly mean max and min	N/A – long-term climate average
2022-2024	France	Nice	BizEE Degree Days (2024)	LFMN	Daily cooling degree days (12°C)	Cagnes-sur-Mer (Bourgoin *et al.*, 2020)
1971-2000	France	Nice	World Meteorological Organisation (2024)	Nice	Monthly mean max and min	N/A – long-term climate average
2022	France	Nice-Côte d'Azur Airport Station	Weather Underground (2024)	LFMN	Daily max and min (°C)	Cagnes-sur-Mer (Bourgoin *et al.*, 2020)
2022-2024	Italy	Firenze (Peretola)	BizEE Degree Days (2024)	LIRQ	Daily cooling degree days (12°C)	Pistoia (Stroiński *et al.*, 2022)
1971-2000	Italy	Florence	World Meteorological Organisation (2024)	Florence	Monthly mean max and min	N/A – long-term climate average
2024	Italy	Peretola Airport Station	Weather Underground (2024)	ISESTOFI22	Daily max and min (°C)	Pistoia (Stroiński *et al.*, 2022)

Year(s) used	Country	Location	Source	Station code	Data type	Phenology location (source)
1981-2010	Japan	Fukuoka	World Meteorological Organisation (2024)	Fukuoka	Monthly mean max and min	N/A – long-term climate average
2022-2024	Japan	Maebashi	BizEE Degree Days (2024)	47624	Daily cooling degree days (12°C)	Gunma (cited in Kobayashi *et al.*, 2024)
2022-2024	Japan	Osaka	BizEE Degree Days (2024)	47772	Daily cooling degree days (12°C)	Osaka (Kobayashi *et al.*, 2024)
1981-2010	Japan	Tokyo	World Meteorological Organisation (2024)	Tokyo	Monthly mean max and min	N/A – long-term climate average
Not stated	Russia	Maikop	World Meteorological Organisation (2024)	Maikop	Monthly mean max and min	N/A – long-term climate average
2011, 2012	South Korea	Cheongju International Airport	Weather Underground (2024)	ICHEON24	Daily max and min (°C)	Gongju (Jo *et al.*, 2016)
2022-2024	South Korea	Chongju Ab	BizEE Degree Days (2024)	RKTU	Daily cooling degree days (12°C)	Gongju (Jo *et al.*, 2016)
1991-2020	South Korea	Gangneung	World Meteorological Organisation (2024)	Gangneung	Monthly mean max and min	N/A – long-term climate average
1991-2020	South Korea	Gwangju	World Meteorological Organisation (2024)	Gwangju	Monthly mean max and min	N/A – long-term climate average
2022-2024	South Korea	Muan International Airport	BizEE Degree Days (2024)	RKJB	Daily cooling degree days (12°C)	Kurye, Jeonnam (Choi *et al.*, 2012a)
2022-2024	South Korea	Suncheon	BizEE Degree Days (2024)	47174	Daily cooling degree days (12°C)	Kurye, Jeonnam (Choi *et al.*, 2012a)
2022-2024	South Korea	Yeosu	BizEE Degree Days (2024)	47168	Daily cooling degree days (12°C)	Kurye, Jeonnam (Choi *et al.*, 2012a)
2011	South Korea	Yeosu Airport Station	Weather Underground (2024)	RKJY	Daily max and min (°C)	Kurye, Jeonnam (Choi *et al.*, 2012a)
1929-2000	Türkiye	Istanbul	World Meteorological Organisation (2024)	Istanbul	Monthly mean max and min	N/A – long-term climate average
2022-2024	Türkiye	Istanbul (Ataturk)	BizEE Degree Days (2024)	LTBA	Daily cooling degree days (12°C)	Kadıköy and Sarıyer (Hızal *et al.*, 2023)

Year(s) used	**Country**	**Location**	**Source**	**Station code**	**Data type**	**Phenology location (source)**
2022-2024	Türkiye	Istanbul (Sabiha Gokcen)	BizEE Degree Days (2024)	LTFJ	Daily cooling degree days (12°C)	Kadıköy and Sarıyer (Hızal *et al.*, 2023)
2019, 2020	Türkiye	Istanbul Atatürk Airport	Weather Underground (2024)	IBAHEL4	Daily max and min (°C)	Kadıköy and Sarıyer (Hızal *et al.*, 2023)
2014-2023	UK	Cambourne (Cornwall)	Met Office (2024)	01395	Hourly temperature (°C)	N/A
2022-2024	UK	Culdrose (Cornwall)	BizEE Degree Days (2024)	EGDR	Daily cooling degree days (12°C)	N/A
2014-2023	UK	Kew Gardens (London)	Met Office (2024)	00723	Hourly temperature (°C)	N/A
2022-2024	UK	London	BizEE Degree Days (2024)	EGRB	Daily cooling degree days (12°C)	N/A
1981-2010	UK	London	World Meteorological Organisation (2024)	London	Monthly mean max and min	N/A – long-term climate average
2022-2024	UK	Manston (Kent)	BizEE Degree Days (2024)	EGMH	Daily cooling degree days (12°C)	N/A
2022-2024	UK	Manston (Kent)	BizEE Degree Days (2024)	EGUM	Daily cooling degree days (12°C)	N/A
1981-2010	UK	Norwich	World Meteorological Organisation (2024)	Norwich	Monthly mean max and min	N/A – long-term climate average
1981-2010	UK	Southampton	World Meteorological Organisation (2024)	Southampton	Monthly mean max and min	N/A – long-term climate average

Table A3. Thresholds and development success reported in literature for *Pochazia shantungensis* eggs, nymphs and adults. Detailed source data for figure 4 in the main PRA. Experimental protocols vary and this explains some of the variation.

Life stage	Temperature (°C)	Description	Source
Adult	23	Flight threshold	Choi *et al.* (2019)
Egg	4.75	Lower threshold	Choi *et al.* (2012b)
Egg	7.4	Lower threshold	Choi *et al.* (2016)
Egg	9.7	Lower threshold	Kang *et al.* (2013)
Egg	10	No hatch	Kang *et al.* (2013)
Egg	11.6	Lower threshold from field work	Baek *et al.* (2019b)
Egg	12	Lower threshold	Baek *et al.* (2025)
Egg	12.1	Calculated lower threshold from lab experiments	Baek *et al.* (2019b)
Egg	12.4	No hatch	Baek *et al.* (2019b)
Egg	12.4	0.13% hatch	Baek *et al.* (2025)
Egg	12.4	63 days to hatch	Baek *et al.* (2025)
Egg	13.97	23% hatch	Kang *et al.* (2013)
Egg	13.97	107 days to hatch	Kang *et al.* (2013)
Egg	15	51 days to hatch	Choi *et al.* (2012b)
Egg	15	56% hatch	Choi *et al.* (2012b)
Egg	15	56.2% hatch	Choi *et al.* (2016)
Egg	15	51 days to hatch	Choi *et al.* (2016)
Egg	16.4	39 days to hatch	Baek *et al.* (2019b)
Egg	16.4	16% hatch	Baek *et al.* (2019b)
Egg	16.4	40 days to hatch	Baek *et al.* (2025)
Egg	16.4	8% hatch	Baek *et al.* (2025)
Egg	17.03	54 days to hatch	Kang *et al.* (2013)
Egg	17.03	31% hatch	Kang *et al.* (2013)
Egg	18	31 days to hatch	Choi *et al.* (2012b)
Egg	18	74% hatch	Choi *et al.* (2012b)
Egg	18	75% hatch	Choi *et al.* (2016)
Egg	18	31 days to hatch	Choi *et al.* (2016)

Life stage	Temperature (°C)	Description	Source
Egg	20.4	22 days to hatch	Baek *et al.* (2019b)
Egg	20.4	11% hatch	Baek *et al.* (2019b)
Egg	20.4	18 days to hatch	Baek *et al.* (2025)
Egg	20.4	11% hatch	Baek *et al.* (2025)
Egg	21	25 days to hatch	Choi *et al.* (2012b)
Egg	21	75% hatch	Choi *et al.* (2012b)
Egg	21	71% hatch	Choi *et al.* (2016)
Egg	21	25 days to hatch	Choi *et al.* (2016)
Egg	21.64	34 days to hatch	Kang *et al.* (2013)
Egg	21.64	14% hatch	Kang *et al.* (2013)
Egg	24	20 days to hatch	Choi *et al.* (2012b)
Egg	24	70% hatch	Choi *et al.* (2012b)
Egg	24	73% hatch	Choi *et al.* (2016)
Egg	24	19 days to hatch	Choi *et al.* (2016)
Egg	24.8	15 days to hatch	Baek *et al.* (2019b)
Egg	24.8	18% hatch	Baek *et al.* (2019b)
Egg	24.8	12 days to hatch	Baek *et al.* (2025)
Egg	24.8	8% hatch	Baek *et al.* (2025)
Egg	26.46	25 days to hatch	Kang *et al.* (2013)
Egg	26.46	22% hatch	Kang *et al.* (2013)
Egg	27	17 days to hatch	Choi *et al.* (2012b)
Egg	27	73% hatch	Choi *et al.* (2012b)
Egg	27	76% hatch	Choi *et al.* (2016)
Egg	27	17 days to hatch	Choi *et al.* (2016)
Egg	28.3	11 days to hatch	Baek *et al.* (2019b)
Egg	28.3	10% hatch	Baek *et al.* (2019b)
Egg	28.3	10 days to hatch	Baek *et al.* (2025)
Egg	28.3	6% hatch	Baek *et al.* (2025)
Egg	29.61	25 days to hatch	Kang *et al.* (2013)
Egg	29.61	12% hatch	Kang *et al.* (2013)

Life stage	Temperature (°C)	Description	Source
Egg	30	19 days to hatch	Choi *et al.* (2012b)
Egg	30	59% hatch	Choi *et al.* (2012b)
Egg	30	59% hatch	Choi *et al.* (2016)
Egg	30	19 days to hatch	Choi *et al.* (2016)
Egg	31	Calculated optimum	Baek *et al.* (2019b)
Egg	32.4	10 days to hatch	Baek *et al.* (2019b)
Egg	32.4	2% hatch	Baek *et al.* (2019b)
Egg	32.4	9.4 days to hatch	Baek *et al.* (2025)
Egg	32.4	4% hatch	Baek *et al.* (2025)
Egg	34.34	17 days to hatch	Kang *et al.* (2013)
Egg	34.34	0.6% hatch	Kang *et al.* (2013)
Egg	36.9	No hatch	Baek *et al.* (2019b)
Egg	36.9	No hatch	Baek *et al.* (2025)
Nymph	3.8	4th instar threshold	Choi *et al.* (2016)
Nymph	8.3	5th instar threshold	Choi *et al.* (2016)
Nymph	9.3	Egg-5th instar threshold	Choi *et al.* (2016)
Nymph	10.5	2nd instar threshold	Choi *et al.* (2016)
Nymph	10.8	3rd instar threshold	Choi *et al.* (2016)
Nymph	11.8	1st instar threshold	Choi *et al.* (2016)
Nymph	15	Unable to complete development to adult	Im *et al.* (2011)
Nymph	18	83 days hatch-5th instar	Choi *et al.* (2016)
Nymph	21	58 days hatch-5th instar	Choi *et al.* (2016)
Nymph	24	46 days hatch-5th instar	Choi *et al.* (2016)
Nymph	27	Calculated optimum egg-5th instar	Choi *et al.* (2016)
Nymph	27	40 days hatch-5th instar	Choi *et al.* (2016)
Nymph	30	Unable to complete development to adult	Choi *et al.* (2016)

This publication is available via the UK Plant Health Information portal https://planthealthportal.defra.gov.uk/

This PRA has been undertaken following IPPC International Standards for Phytosanitary Measures (ISPMs 2 and 11) and it provides technical evidence relating to the risk assessment and risk management of this pest.

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

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

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

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