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SCIENTIFIC OPINION

Pest categorisation of *Garella musculana*

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Abstract

The European Commission requested the EFSA Panel on Plant Health to conduct a pest categorisation of *Garella musculana* (Erschov) (Lepidoptera: Nolidae), following a commodity risk assessment of *Juglans regia* plants for planting from Türkiye, in which *G. musculana* was identified as a pest of possible concern to the European Union (EU). Commonly known as the Asian walnut moth, this pest is native to Central Asia and develops on shoots, buds and fruits of *Juglans* species such as the English walnut, *J. regia* and the black walnut, *J. nigra*. Other reported host plants, such as *Prunus dulcis* and *Populus* spp., still require confirmation. The pest was first recorded in the EU (Bulgaria) in 2016 and was then reported in Romania in 2018 and Italy in 2021. This moth completes from one to four generations per year depending on environmental conditions (from valley to mountain forests and orchards up to an altitude of 2100 m). Eggs are laid in groups of 2–3 on young nuts or on buds of 1-year-old shoots. Neonate larvae usually enter the young nut through the peduncle. After fully exploiting one nut, the larva continues feeding in another one. Development takes 25–40 days. Larvae of the autumn generation do not enter the nuts, and so feed only in the pericarp. Larvae also often feed inside 1-year-old shoots or leaf axils. Larvae develop within the host but exit to pupate under loose bark or in deep cracks of bark. The pest overwinters at the larval or pupal stages. Plants for planting, cut branches and infested nuts provide pathways for entry. Climatic conditions and availability of host plants in southern and central EU MSs have allowed this species to establish and spread in Bulgaria, Romania and Italy. Adults can fly and the pest could spread naturally within the EU. Impact on *Juglans* spp. cultivated for fruit, timber and ornamental purposes is anticipated. Phytosanitary measures are available to reduce the likelihood of entry and further spread of *G. musculana*. This species meets the criteria that are within the remit of EFSA to assess for this species to be regarded as a potential Union quarantine pest.

KEYWORDS

Asian walnut moth, *Erschoviella musculana*, Lepidoptera, Nolidae, plant pest, quarantine

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1 | INTRODUCTION

1.1 | Background and Terms of Reference as provided by the requestor

1.1.1 | Background

The new Plant Health Regulation (EU) 2016/2031, on the protective measures against pests of plants, is applying from 14 December 2019. Conditions are laid down in this legislation in order for pests to qualify for listing as Union quarantine pests, protected zone quarantine pests or Union regulated non-quarantine pests. The lists of the EU regulated pests together with the associated import or internal movement requirements of commodities are included in Commission Implementing Regulation (EU) 2019/2072. Additionally, as stipulated in the Commission Implementing Regulation 2018/2019, certain commodities are provisionally prohibited to enter in the EU (high risk plants, HRP). EFSA is performing the risk assessment of the dossiers submitted by exporting to the EU countries of the HRP commodities, as stipulated in Commission Implementing Regulation 2018/2018. Furthermore, EFSA has evaluated a number of requests from exporting to the EU countries for derogations from specific EU import requirements.

In line with the principles of the new plant health law, the European Commission with the Member States are discussing monthly the reports of the interceptions and the outbreaks of pests notified by the Member States. Notifications of an imminent danger from pests that may fulfil the conditions for inclusion in the list of the Union quarantine pest are included. Furthermore, EFSA has been performing horizon scanning of media and literature.

As a follow-up of the above-mentioned activities (reporting of interceptions and outbreaks, HRP, derogation requests and horizon scanning), a number of pests of concern have been identified. EFSA is requested to provide scientific opinions for these pests, in view of their potential inclusion by the risk manager in the lists of Commission Implementing Regulation (EU) 2019/2072 and the inclusion of specific import requirements for relevant host commodities, when deemed necessary by the risk manager.

1.1.2 | Terms of Reference

EFSA is requested, pursuant to Article 29(1) of Regulation (EC) No 178/2002, to provide scientific opinions in the field of plant health.

EFSA is requested to deliver 53 pest categorisations for the pests listed in Annex 1A, 1B, 1D and 1E (for more details see mandate M-2021-00027 on the Open.EFSA portal). Additionally, EFSA is requested to perform pest categorisations for the pests so far not regulated in the EU, identified as pests potentially associated with a commodity in the commodity risk assessments of the HRP dossiers (Annex 1C; for more details see mandate M-2021-00027 on the Open.EFSA portal). Such pest categorisations are needed in the case where there are not available risk assessments for the EU.

When the pests of Annex 1A are qualifying as potential Union quarantine pests, EFSA should proceed to phase 2 risk assessment. The opinions should address entry pathways, spread, establishment, impact and include a risk reduction options analysis.

Additionally, EFSA is requested to develop further the quantitative methodology currently followed for risk assessment, in order to have the possibility to deliver an express risk assessment methodology. Such methodological development should take into account the EFSA Plant Health Panel Guidance on quantitative pest risk assessment and the experience obtained during its implementation for the Union candidate priority pests and for the likelihood of pest freedom at entry for the commodity risk assessment of High Risk Plants.

1.2 | Interpretation of the Terms of Reference

Garella musculana is one of a number of pests relevant to Annex 1C of the Terms of Reference (ToR) to be subject to pest categorisation to determine whether it fulfils the criteria of a potential Union quarantine pest for the area of the EU excluding Ceuta, Melilla and the outermost regions of Member States referred to in Article 355(1) of the Treaty on the Functioning of the European Union (TFEU), other than Madeira and the Azores, and so inform EU decision-making as to its appropriateness for potential inclusion in the lists of pests of Commission Implementing Regulation (EU) 2019/ 2072. If a pest fulfils the criteria to be potentially listed as a Union quarantine pest, risk reduction options will be identified.

1.3 | Additional information

This pest categorisation was initiated following the commodity risk assessment of *Juglans regia* plants for planting from Türkiye performed by EFSA (EFSA PLH Panel, 2021), in which *G. musculana* was identified as a relevant non-regulated EU pest which could potentially enter the EU on *J. regia* plants.

2 | DATA AND METHODOLOGIES

2.1 | Data

2.1.1 | Information on pest status from NPPOs

In the context of the current mandate, EFSA is preparing pest categorisations for new/emerging pests that are not yet regulated in the EU. When official pest status is not available in the European and Mediterranean Plant Protection Organization (EPPO) Global Database (EPPO, online-a), EFSA consults the NPPO of any relevant MS. To obtain information on the official pest status for *G. musculana*, EFSA contacted the NPPO of Romania in January 2024.

2.1.2 | Literature search

A literature search on *G. musculana* was conducted at the beginning of the categorisation in the ISI Web of Science bibliographic database, using the scientific name of the pest as search term (Appendix A). Papers relevant for the pest categorisation were reviewed, and further references and information were obtained from experts, as well as from citations within the references and grey literature.

2.1.3 | Database search

Pest information, on host(s) and distribution, was retrieved from the European and Mediterranean Plant Protection Organization (EPPO) Global Database (EPPO, online-a), the CABI databases and scientific literature databases as referred above in Section 2.1.1.

Data about the import of commodity types that could potentially provide a pathway for the pest to enter the EU and about the area of hosts grown in the EU were obtained from EUROSTAT (Statistical Office of the European Communities).

The Europhyt and TRACES databases were consulted for pest-specific notifications on interceptions and outbreaks. Europhyt is a web-based network run by the Directorate General for Health and Food Safety (DG SANTÉ) of the European Commission as a subproject of PHYSAN (Phyto-Sanitary Controls) specifically concerned with plant health information. TRACES is the European Commission's multilingual online platform for sanitary and phytosanitary certification required for the importation of animals, animal products, food and feed of non-animal origin and plants into the European Union, and the intra-EU trade and EU exports of animals and certain animal products. Up until May 2020, the Europhyt database managed notifications of interceptions of plants or plant products that do not comply with EU legislation, as well as notifications of plant pests detected in the territory of the Member States and the phytosanitary measures taken to eradicate or avoid their spread. The recording of interceptions switched from Europhyt to TRACES in May 2020.

GenBank was searched to determine whether it contained any nucleotide sequences for *G. musculana* which could be used as reference material for molecular diagnosis. GenBank® (www.ncbi.nlm.nih.gov/genbank/) is a comprehensive publicly available database that as of August 2019 (release version 227) contained over 6.25 trillion base pairs from over 1.6 billion nucleotide sequences for 450,000 formally described species (Sayers et al., 2020).

2.2 | Methodologies

The Panel performed the pest categorisation for *G. musculana*, following guiding principles and steps presented in the EFSA guidance on quantitative pest risk assessment (EFSA PLH Panel, 2018), the EFSA guidance on the use of the weight of evidence approach in scientific assessments (EFSA Scientific Committee, 2017) and the International Standards for Phytosanitary Measures No. 11 (FAO, 2013).

The criteria to be considered when categorising a pest as a potential Union quarantine pest (QP) is given in Regulation (EU) 2016/2031 Article 3 and Annex I, Section 1 of the Regulation. Table 1 presents the Regulation (EU) 2016/2031 pest categorisation criteria on which the Panel bases its conclusions. In judging whether a criterion is met the Panel uses its best professional judgement (EFSA Scientific Committee, 2017) by integrating a range of evidence from a variety of sources (as presented above in Section 2.1) to reach an informed conclusion as to whether or not a criterion is satisfied.

The Panel's conclusions are formulated respecting its remit and particularly with regard to the principle of separation between risk assessment and risk management (EFSA founding regulation (EU) No 178/2002); therefore, instead of determining whether the pest is likely to have an unacceptable impact, deemed to be a risk management decision, the Panel will present a summary of the observed impacts in the areas where the pest occurs, and make a judgement about potential likely impacts in the EU. While the Panel may quote impacts reported from areas where the pest occurs in monetary terms, the Panel will seek to express potential EU impacts in terms of yield and quality losses and not in monetary terms, in agreement with the EFSA guidance on quantitative pest risk assessment (EFSA PLH Panel, 2018). Article 3 (d) of Regulation (EU) 2016/2031 refers to unacceptable social impact as a criterion for quarantine pest status. Assessing social impact is outside the remit of the Panel.

TABLE 1 Pest categorisation criteria under evaluation, as derived from Regulation (EU) 2016/2031 on protective measures against pests of plants (the number of the relevant sections of the pest categorisation is shown in brackets in the first column).

Criterion of pest categorisation	Criterion in regulation (EU) 2016/2031 regarding union quarantine pest (article 3)
Identity of the pest (Section 3.1)	Is the identity of the pest clearly defined, or has it been shown to produce consistent symptoms and to be transmissible?
Absence/presence of the pest in the EU territory (Section 3.2)	Is the pest present in the EU territory? If present, is the pest in a limited part of the EU or is it scarce, irregular, isolated or present infrequently? If so, the pest is considered to be not widely distributed
Pest potential for entry, establishment and spread in the EU territory (Section 3.4)	Is the pest able to enter into, become established in, and spread within, the EU territory? If yes, briefly list the pathways for entry and spread
Potential for consequences in the EU territory (Section 3.5)	Would the pests' introduction have an economic or environmental impact on the EU territory?
Available measures (Section 3.6)	Are there measures available to prevent pest entry, establishment, spread or impacts?
Conclusion of pest categorisation (Section 4)	A statement as to whether (1) all criteria assessed by EFSA above for consideration as a potential quarantine pest were met and (2) if not, which one(s) were not met

3 | PEST CATEGORISATION

3.1 | Identity and biology of the pest

3.1.1 | Identity and taxonomy

Is the identity of the pest clearly defined, or has it been shown to produce consistent symptoms and/or to be transmissible?

Yes, the identity of the pest is established and *Garella musculana* (Erschov) is the accepted name.

Garella musculana (Erschov) is an insect within the order Lepidoptera, family Nolidae and is commonly known as the Asian walnut moth (EPPO, online-a). This moth was originally described as *Erschoviella musculana* by Erschov in 1874 but later transferred to the genus *Garella* by Fibiger et al. (2009).

The EPPO code[1] (EPPO, 2019; Griessinger & Roy, 2015) for this species is ERSHMU (EPPO, online-a).

3.1.2 | Biology of the pest

G. musculana has four life stages (egg, four larval instars, pupa and adult) and completes from 1 to 4 generations per year depending on climatic conditions (Bostancı et al., 2019). In Central Asia, in valleys and on southern slopes at altitudes of 1100–1300 m, the flight peak of the first generation usually occurs from the beginning of April until the end of May. The flight peak of the second generation occurs in June–July and that of the third generation in August. At higher altitudes (1700–1900 m), the pest completes only two generations per year. In this case, the first-generation adults fly in May and the second at the beginning of August. Above 1900 m, the pest completes only one generation per year and the adults fly from the end of May until June (EPPO, online-f). Four generations have been observed at sea level in Bartın, Türkiye (Bostancı et al., 2019). Adults feed on nectar and live for about 21 days. The female lays 30–120 eggs, usually in groups of 2–3 on either young nuts (often at the contact point between two nuts) or buds of 1-year-old shoots of walnut (Khan et al., 2023). Neonate larvae usually enter the young nut through the peduncle. The entrance hole, usually at the base of the peduncle, is small and filled with excrement (easily seen from outside). After fully exploiting one nut, the larva moves to another one. Infested nuts usually contain one larva, but it is possible to find nuts with two, and even three, larvae (EPPO, online-a; Gull et al., 2019).

Larvae of *G. musculana* are known to feed also in young 1-year-old shoots and in leaf axils especially during years of low fruit production. On *J. nigra*, young larvae enter the shoots and bore tunnels up to 6 cm long (2 cm in leaf axil); after

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[1]An EPPO code, formerly known as a Bayer code, is a unique identifier linked to the name of a plant or plant pest important in agriculture and plant protection. Codes are based on genus and species names. However, if a scientific name is changed, the EPPO code remains the same. This provides a harmonised system to facilitate the management of plant and pest names in computerised databases, as well as data exchange between IT systems (EPPO, 2019; Griessinger & Roy, 2015).

15 days of feeding, the shoots are emptied and die (Bostancı et al., 2019). The larvae of the last generation in late summer–autumn are unable to enter the lignified nuts and therefore can feed only in the pericarp (EPPO, online-f). At the end of larval development, which takes 25–40 days, mature larvae leave the fruit, through a round emergence hole, to pupate on tree stem and branches. The pupal stage usually lasts 10 days and overwintering occurs as mature larva or pupa inside a cocoon (EPPO, online-f) (Degtyareva, 1964; Dzhaparov, 1990; Makhnovskii, 1955, 1970; Vassiliev, 1912). Pupation usually occurs in deep cracks in the bark or under loose bark in the butt part of the trunk up to several meters above the soil. It is possible sometimes to find large aggregations of cocoons (up to 170) in some refuges (usually under loose bark) (Khan et al., 2023). Larvae of the first two generations may also pupate in the grass or on branches (EPPO, online-f). In field observations conducted in Türkiye on the effects of host phenology, temperature and humidity, the larvae preferred to feed into young shoots and fruits pericarp of the host plants between beginning of fruiting and harvest causing premature dropping and the larval activity was observed from July (mean temperature 22°C, mean relative humidity 74%) to October (mean temperature 15°C, mean relative humidity 90%). The damage rate of *G. musculana* was seen to be more correlated with the temperature than the relative humidity (Yoğurtçu & Kaçar, 2022). In Iran, the minimum and maximum temperature recorded was 3–27°C (15°C) and minimum and maximum humidity was 32%–96% (64%) during the whole duration of the life cycle (Khan et al., 2023).

The biology of the pest is summarised in Table 2.

TABLE 2 Important features of the life-history strategy of *Garella musculana*.

Life stage	Phenology and relation to host	Other relevant information
Egg	Each female lays 30–120 eggs, usually in groups of 2–3 on either young nuts (often at the contact point between two nuts) or buds of 1-year-old shoots of walnut	
Larva	Neonate larvae enter the young nut digging a small entrance hole at the base of the peduncle, which is filled with excrement (easily seen from outside)	Larval development takes 25–40 days
Pupa	Mature larvae leave the fruit, making a round emergence hole, to pupate on tree stem and branches	The pupal stage usually lasts 10 days and occurs inside cocoons, isolated or in groups in bark cracks or under loose bark
Adult	Adults feed on nectar and live for 21 days	No data on the distance covered in flight by *G. musculana* adults is available; however, potential for natural spread is rather limited

3.1.3 | Host range/species affected

The larvae of *G. musculana* feed on wild and cultivated *Juglans regia* and *J. nigra* (EPPO, online-c; Bostancı et al., 2019). *Carya illinoinensis*, *Populus* spp. and *Prunus dulcis* have also been reported as hosts (EPPO, online-c; Esonbaev et al., 2020; Robinson et al., 2010) although EPPO (online-c) considers the last two as doubtful, and Zanolli et al. (2023) state that they still need to be confirmed as hosts (Appendix B).

3.1.4 | Intraspecific diversity

No intraspecific diversity has been reported for this species.

3.1.5 | Detection and identification of the pest

Are detection and identification methods available for the pest?

Yes, the pest has been clearly described and morphological and molecular identification is possible. Light and baited traps can be used to collect *G. musculana* adults.

Detection

Infested plants can be detected based on visual symptoms (see below). Additionally, on young trees, trapping corrugated cardboard bands can be used to catch fourth-instar larvae as they move to the bark to pupate (Yoğurtçu & Kaçar, 2022). The pupae, inside white cocoons, could be found under the bark. Fallen fruit and pruning plant residues should be inspected for pest presence (EPPO, online_f). Aggregations of pupae are easy to detect under loose bark and in other refuges.

Plant damage might not be obvious in early infestation. Light and sugar baited traps combined with yellow and red plastic cards with insecticides can be set to collect *G. musculana* adults, also helping to identify their flight period (Yoğurtçu & Kaçar, 2022).

Symptoms

Damaged fruits (Figure 1E) are usually easily recognised by brown excrement accumulated at the entry hole of the larva in the fruit or in the shoot (Bozkurt et al., 2018). If fruit damage is detected, it may be confused with damage of the codling moth, *Cydia pomonella* L. (Lepidoptera: Tortricidae), and on shoots with damage of the leopard moth, *Zeuzera pyrina* (L.) (Lepidoptera: Cossidae). Damaged shoots (Figure 1D) often show yellowing and wilting (EPPO, online-f).

Identification

The identification of *G. musculana* requires microscopic examination of slide-mounted adult genitalia and verification of the presence of key morphological characteristics. Detailed morphological descriptions, illustrations and keys of adult *G. musculana* and other species can be found in Fibiger et al. (2009).

Molecular techniques based on the nucleotide sequences of the mitochondrial cytochrome c oxidase subunits I (COI) genes have been developed for species identification. GenBank contains COI gene nucleotide sequences for *G. musculana* (https://www.ncbi.nlm.nih.gov/nuccore/?term=garella+musculana).

Description

The eggs of *G. musculana* are yellowish grey to reddish-grey, spherical, 0.5 mm in diameter, strongly flattened from below and slightly flattened from the top. The neonate larva, 2–3 mm long, is cream-white to yellowish white with a dark-brown head; the fully grown larva before pupation is 15–20 mm long, light greenish-cream to greenish-brown or reddish-brown. The body is covered by a few light brownish-cream hairs, short on the head and rather long on the dorsal and lateral sides of the body, based on small dark-brown round scutella. The anal plate is dark brown. The head is brown and bright, 3–4 mm in diameter (Figure 1A). The pupa is 11–12 mm long and 3.5–3.6 mm wide; light brownish-ochre with a wide, darker brown to black-brown longitudinal stripe running along the dorsal side. The top of the abdomen is rounded. The pupa is in a snow-white dense cocoon (Figure 1B), which is 12–14 mm long and 4.5–5.2 mm wide (in the middle), narrowed at both ends. The adult (Figure 1C) wingspan is 18–23 mm. The length of the body is 8–9 mm. The fore wings are grey with transverse brown, white and black bands and lines. The wing fringe is grey with black points. The hind wings are grey. The thorax is grey or brownish grey with dark transverse stripe. The antennae are thin, light to dark brown. The underside of wings and of the body is light grey (EPPO, online-f).
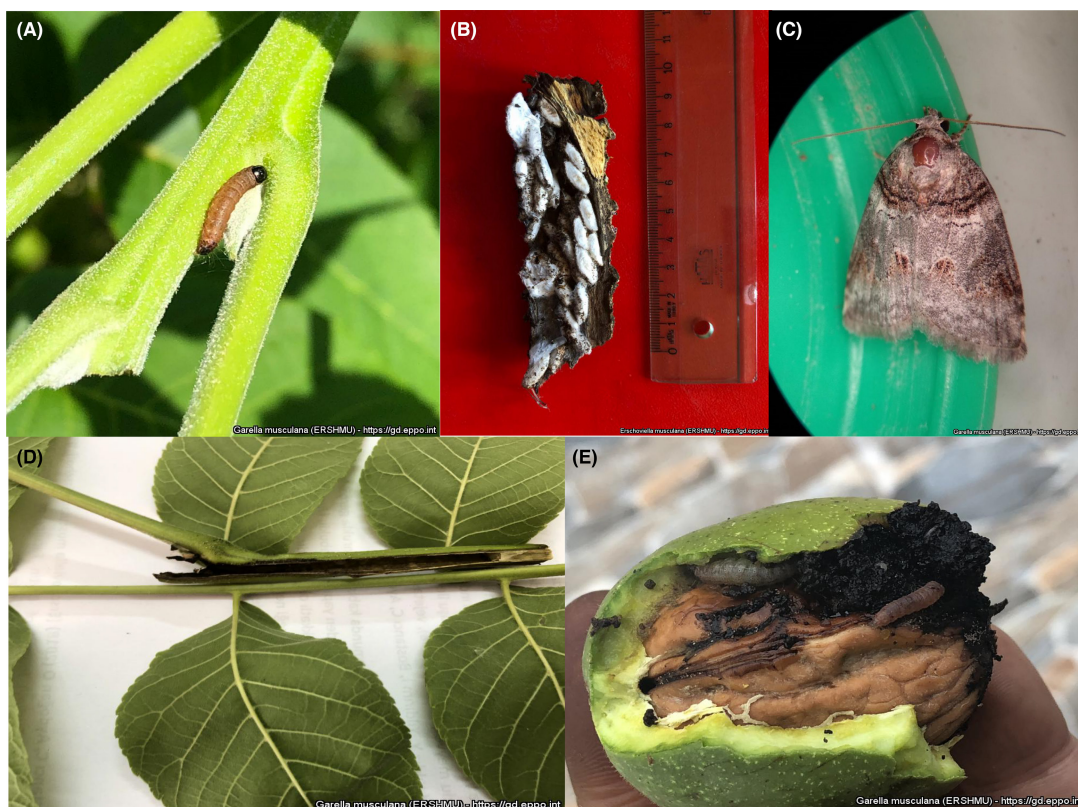

FIGURE 1 Life stages and damage of *Garella musculana*: larva (A); cocoons containing pupae (B); adult (C); larval galleries in shoot of *Juglans nigra* (D); larvae and damage on a walnut (E). Courtesy of Cengiz Bostancı ((EPPO (online-a) and Bugwood.org (online)).

3.2 | Pest distribution

3.2.1 | Pest distribution outside the EU

G. musculana is native to Central Asia and the north of Iran, and it is present in Afghanistan, India, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan (EPPO, online-b; Fibiger et al., 2009; Khan et al., 2011, 2023; Figure 2). Reports from China and Pakistan (Fibiger et al., 2009) are unconfirmed and could be misidentifications of its eastern sister taxon *Garella ruficirra* (Hampson, 1905) (Lepidoptera: Nolidae). Since 2008, *G. musculana* has been also reported in Eastern Europe, in Sevastopol (Crimea), and its current distribution includes Türkiye, Bulgaria, Romania, Russia and Italy (EPPO, online-b; Bostancı et al., 2021; Fibiger et al., 2009; Scaccini et al., 2023; Sviridov, 2008; Yoğurtçu & Kaçar, 2018).
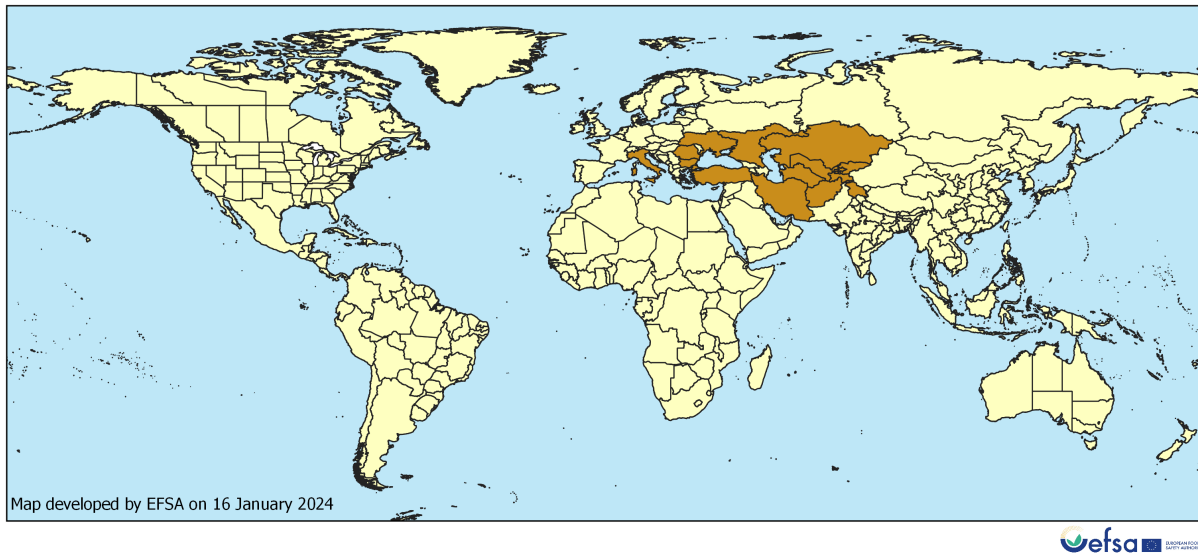
FIGURE 2 Global distribution of *Garella musculana* (Source: literature; for details, see Appendix C).

3.2.2 | Pest distribution in the EU

> *Is the pest present in the EU territory? If present, is the pest in a limited part of the EU or is it scarce, irregular, isolated or present infrequently? If so, the pest is considered to be not widely distributed*.
>
> **Yes.** *G. musculana* has a restricted distribution in Romania, Bulgaria and Italy, and is currently spreading in North-East Italy.

G. musculana was reported in Bulgaria in 2016 (Beaumont, 2018), and in Romania between 2018 and 2020, specifically in Albesti and Arsa (localities close to each other), both on saplings and 50-year-old walnut trees (Bostancı et al., 2021), and it was reported in 2021 in NE Italy (Veneto region), where adults were initially found in a light lamp (Scaccini et al., 2023) and the species is now expanding in Veneto region and in Emilia Romagna (Zanolli et al., 2023). The Italian NPPO declared in January 2022 the pest status as transient, actionable, under surveillance; the Bulgarian NPPO declared in November 2019 the pest only present in some parts of the Member State, in particular in the Varna province (municipality of Aksakovo) (EPPO, online-d).

3.3 | Regulatory status

3.3.1 | Commission implementing regulation 2019/2072

G. musculana is not listed in Annex II of Commission Implementing Regulation (EU) 2019/2072, an implementing act of Regulation (EU) 2016/2031. However, as mentioned in the Commission Implementing Regulation (EU) 2022/490, temporary phytosanitary measures concerning *G. musculana* are in place regarding plants for planting of *J. regia* meeting specific

criteria originating in Türkiye. The Regulation (EU) 2022/490 recognises that *G. musculana* could be added to Annex II of Regulation (EU) 2019/2072 if the necessary conditions are fulfilled after a complete risk assessment has been carried out.

3.3.2 | Hosts or species affected that are prohibited from entering the union from third countries

According to the Commission Implementing Regulation (EU) 2019/2072, Annex VI, introduction of several *G. musculana* hosts in the Union from certain third countries is prohibited (Table 3).

Plants for planting of *Juglans*, which are hosts of *G. musculana*, and of *Prunus* and *Populus*, which are doubtful hosts (Appendix B) are considered high-risk plants for the EU and their import is prohibited pending risk assessment (EU 2018/2019). However, *Juglans* other than up to 2-year-old plants for planting of *Juglans regia* L. which are bare-rooted, free of leaves and with a maximum diameter of 2 cm at the base of the stem, originating in Türkiye are exempt from being regarded as high-risk plants ((EU) 2022/490).

TABLE 3 List of plants, plant products and other objects that are *Garella musculana* hosts whose introduction into the Union from certain third countries is prohibited (Source: Commission Implementing Regulation (EU) 2019/2072, Annex VI).

List of plants, plant products and other objects whose introduction into the union from certain third countries is prohibited			
	Description	**CN code**	**Third country, group of third countries or specific area of third country**
3.	Plants of *Populus* L., with leaves, other than fruit and seeds	ex 0602 10 90 ex 0602 20 20 ex 0602 20 80 ex 0602 90 41 ex 0602 90 45 ex 0602 90 46 ex 0602 90 48 ex 0602 90 50 ex 0602 90 70 ex 0602 90 99 ex 0604 20 90 ex 1404 90 00	Canada, Mexico, United States
7.	Isolated bark of *Populus* L.	ex 1404 90 00 ex 4401 40 90	The Americas
8.	Plants for planting of […] *Prunus* L., […] other than dormant plants free from leaves, flowers and fruits	ex 0602 10 90 ex 0602 20 20 ex 0602 20 80 ex 0602 40 00 ex 0602 90 41 ex 0602 90 45 ex 0602 90 46 ex 0602 90 47 ex 0602 90 48 ex 0602 90 50 ex 0602 90 70 ex 0602 90 91 ex 0602 90 99	Third countries other than Albania, Andorra, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Canary Islands, Faeroe Islands, Georgia, Iceland, Liechtenstein, Moldova, Monaco, Montenegro, North Macedonia, Norway, Russia only the following parts: Central Federal District (Tsentralny federalny okrug), Northwestern Federal District (Severo- Zapadny federalny okrug), Southern Federal District (Yuzhny federalny okrug), North Caucasian Federal District (Severo-Kavkazsky federalny okrug) and Volga Federal District (Privolzhsky federalny okrug), San Marino, Serbia, Switzerland, Türkiye, Ukraine and the United Kingdom
9.	Plants for planting of […] *Prunus* L. […] other than seeds	ex 0602 10 90 ex 0602 20 20 ex 0602 90 30 ex 0602 90 41 ex 0602 90 45 ex 0602 90 46 ex 0602 90 48 ex 0602 90 50 ex 0602 90 70 ex 0602 90 91 ex 0602 90 99	Third countries other than Albania, Algeria, Andorra, Armenia, Australia, Azerbaijan, Belarus, Bosnia and Herzegovina, Canada, Canary Islands, Egypt, Faeroe Islands, Georgia, Iceland, Israel, Jordan, Lebanon, Libya, Liechtenstein, Moldova, Monaco, Montenegro, Morocco, New Zealand, North Macedonia, Norway, Russia only the following parts: Central Federal District (Tsentralny federalny okrug), Northwestern Federal District (Severo Zapadny federalny okrug), Southern Federal District (Yuzhny federalny okrug), North Caucasian Federal District (Severo- Kavkazsky federalny okrug) and Volga Federal District (Privolzhsky federalny okrug), San Marino, Serbia, Switzerland, Syria, Tunisia, Türkiye, Ukraine, the United Kingdom (1) and United States other than Hawaii

3.4 | Entry, establishment and spread in the EU

3.4.1 | Entry

Is the pest able to enter into the EU territory? If yes, identify and list the pathways.

Yes. *G. musculana* has already entered the EU territory. Possible pathways of (re)entry are plants for planting (except seeds, bulbs, and tubers), cut branches, fruits (nuts), and wood with bark or isolated bark.

Comment on plants for planting as a pathway.

Plants for planting provide one of the main pathways for *G. musculana* to (re)enter the EU (Table 4).

Although no specific data is available on Asian walnut adult moths, potential for natural spread is rather limited (EPPO, online-e). Other life stages can easily be transported through human activities (EPPO, online-f). Plants for planting and wood with bark are the main potential pathways for entry of *G. musculana* (Table 4). Annual imports of *G. musculana* hosts from countries where the pest is known to occur are provided in Table 5.

TABLE 4 Potential pathways for *Garella musculana* into the EU.

Pathways (e.g. host/intended use/source)	Life stage	Relevant mitigations [e.g. prohibitions (Annex VI), special requirements (Annex VII) or phytosanitary certificates (Annex XI) within implementing regulation 2019/2072
Plants for planting	Eggs and larvae	EU 2018/2019 (High-risk plants prohibition i.e. *Juglans* L., *Populus* L. and *Prunus* L. Annex VI) However, for *Juglans regia* originating in Türkiye, the pathway exists which requires specific phytosanitary measures for their introduction into the EU [Commission Implementing Regulation (EU) 2022/490]
Cut branches	Eggs and larvae	Introduction of foliage, branches and other parts of plants of *Juglans* L requires phytosanitary certification from Russia and Ukraine where the pest is present (Annex XI, Part A Section 3)
Fruits (nuts)	Eggs and larvae	–
Wood with bark or isolated bark	Pupae	Isolated bark and wood of *Juglans* permitted from USA, where the pest is not reported, with special conditions (Annex VII, section 84); Wood, isolated bark and objects made of bark of *Juglans ailantifolia*, *J. mandshurica* permitted from… China … with conditions (Annex VII, sections 87 and 89)

TABLE 5 EU annual imports of wood and fresh or dried almonds, pecans and walnuts in shell from countries where *Garella musculana* is present, 2018–2022 (Tonnes) Source: Eurostat accessed on 6 December 2023.

Commodity	HS code	2018	2019	2020	2021	2022
***Populus* spp. wood in the rough**[a]	4403 97 00	305,182.10	225,129.08	248,010.27	155,670.93	28,632.18
Wood in the rough[b]	4403 99	12,306.89	179.58	123.23	17.61	1.92
Walnuts	0802 31 00	677.10	319.27	522.86	203.99	713.88
Almonds	0802 11	142.87	177.85	162.94	296.98	201.85
Pecans	0802 99	32.89	0.71	18.37	0.02	0.04

[a]Poplar and aspen '*Populus* spp.' in the rough, whether or not stripped of bark or sapwood, or roughly squared […].

[b]Wood in the rough whether or not stripped of bark or sapwood, or roughly squared.

Excl. rough-cut wood for walking sticks, umbrellas, tool shafts and the like; wood cut into boards or beams, etc.; *wood treated with paint, stains, creosote or other preservatives, coniferous and tropical wood, oak, beech, birch, poplar, aspen and eucalyptus*.

Notifications of interceptions of harmful organisms began to be compiled in Europhyt in May 1994 and in TRACES in May 2020. As at 06/12/2023, there were no records of interception of *G. musculana* in the Europhyt and TRACES databases.

3.4.2 | Establishment

Is the pest able to become established in the EU territory?

Yes, *G. musculana* has established in the EU (Bulgaria, Romania and Italy). Biotic factors (host availability) and abiotic factors (climate suitability) suggest that other parts of the EU would also be suitable for establishment.

Based on climate matching, large parts of the EU correspond to climate types that occur in countries where *G. musculana* occurs.

Climatic mapping is the principal method for identifying areas that could provide suitable conditions for the establishment of a pest taking key abiotic factors into account (Baker, 2002). Availability of hosts is considered in Section 3.4.2.1. Climatic factors are considered in Section 3.4.2.2.

### 3.4.2.1 | *EU distribution of main host plants*

All the species reported as *G. musculana* hosts, namely *Juglans* spp., *Populus* spp. and *Prunus dulcis,* are present or are grown widely across the EU (Tables 6, 7; Figure 3).

TABLE 6 Harvested area of walnuts (code: F4100) in the EU, 2018–2022 (1000 ha). Source Eurostat (accessed 6/12/2023).

Walnuts	2018	2019	2020	2021	2022
EU	80.60	87.62	99.21	97.00	102.05
France	22.17	25.88	27.18	26.85	26.90
Greece	15.27	14.82	20.27	16.58	16.71
Spain	11.00	11.44	12.29	12.78	12.71
Croatia	6.70	7.21	8.11	8.42	8.91
Bulgaria	6.18	6.36	7.10	8.07	8.33
Hungary	5.40	6.00	6.40	6.44	7.82
Portugal	3.85	5.37	5.40	5.61	5.49
Italy	4.50	4.67	4.93	5.39	5.44
Poland	2.31	2.27	3.00	2.70	3.40
Romania	1.59	1.62	1.91	2.40	2.83
Slovakia	0.36	0.63	1.17	0.00	1.19
Germany	0.29	0.29	0.29	0.29	0.73
Slovenia	0.38	0.44	0.48	0.52	0.56
Lithuania	0.00	0.00	0.00	0.27	0.30
Cyprus	0.18	0.21	0.22	0.22	0.22
Austria	0.17	0.17	0.18	0.19	0.19
Belgium	0.08	0.10	0.10	0.14	0.16
Czechia	0.17	0.13	0.16	0.13	0.14
Luxembourg	0.01	0.01	0.01	0.01	0.01

TABLE 7 Harvested area of almonds (code: F4300]) in the EU, 2018–2022 (1000 ha). Source Eurostat (accessed 6/12/2023).

Almonds	2018	2019	2020	2021	2022
EU	773.88	809.56	853.83	881.06	905.43
Spain	657.77	687.23	718.54	744.47	761.66
Portugal	38.68	49.35	52.34	58.40	63.88
Italy	57.99	52.04	52.65	53.72	53.89
Greece	14.14	15.13	23.71	17.66	18.40
Cyprus	2.31	2.71	2.38	2.12	2.40
France	1.22	1.18	2.11	2.21	2.21
Bulgaria	1.09	1.01	0.93	1.28	1.51
Croatia	0.42	0.62	0.81	0.81	1.04
Hungary	0.26	0.31	0.35	0.39	0.42
Slovenia	0.01	0.00	0.01	0.01	0.02
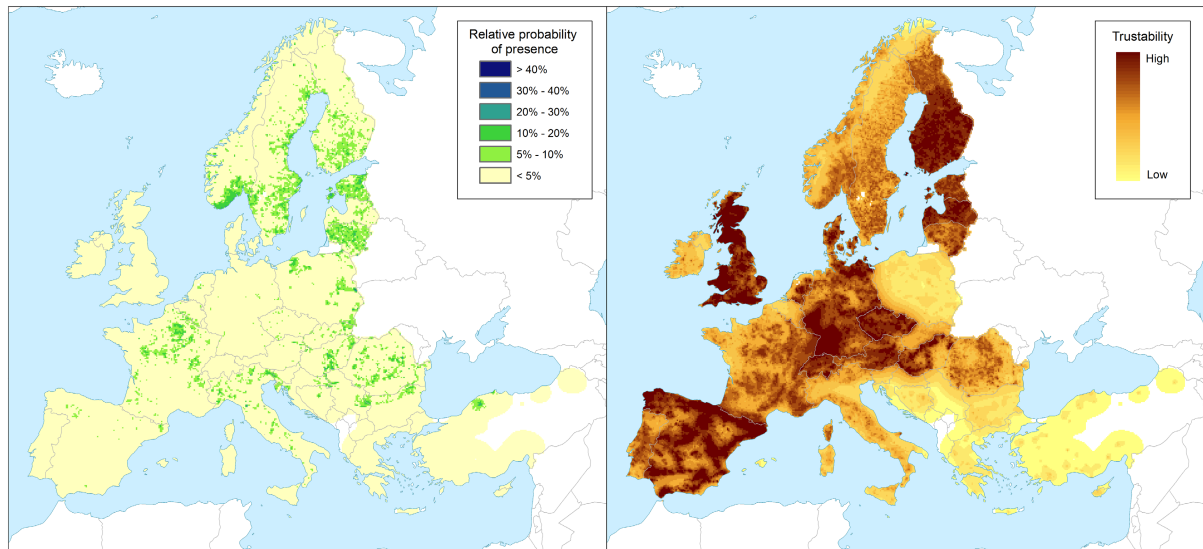
FIGURE 3 Left panel: Relative probability of the presence (RPP) of the genus *Populus* in Europe, mapped at 100 km² resolution. The underlying data are from European-wide forest monitoring data sets and from national forestry inventories based on standard observation plots measuring in the order of hundreds m². RPP represents the probability of finding at least one individual of the taxon in a standard plot placed randomly within the grid cell. For details, see Appendix D (courtesy of JRC, 2017). Right panel: Trustability of RPP. This metric expresses the strength of the underlying information in each grid cell and varies according to the spatial variability in forestry inventories. The colour scale of the trustability map is obtained by plotting the cumulative probabilities (0–1) of the underlying index (for details on methodology, see Appendix D).

3.4.2.2 | Climatic conditions affecting establishment

G. musculana is native to Central Asia, it invaded Crimea (Ukraine) and nowadays it is present in Bulgaria, Romania, Russia and Türkiye; it was recently reported as spreading in northeastern Italy (EPPO, online-a; Zanolli et al., 2023). Figure 4 shows the world distribution of Köppen–Geiger climate types (Kottek et al., 2006) that occur in the EU and which occur in countries where *G. musculana* has been reported. Several EU countries may provide suitable climatic conditions for the establishment of *G. musculana*, as well as host presence (Tables 6, 7).
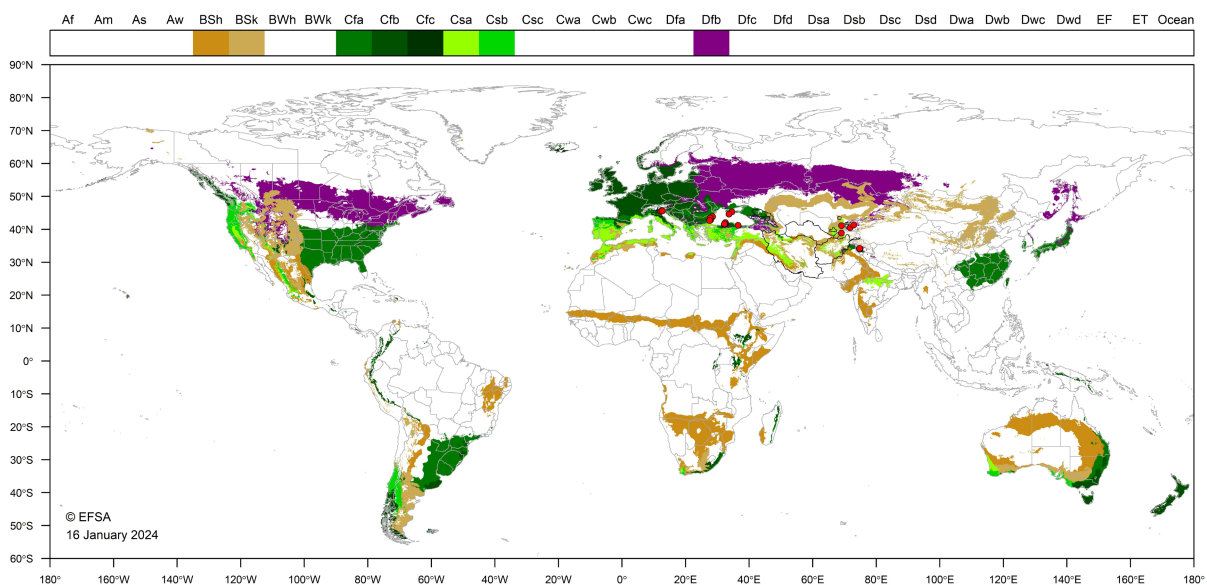
FIGURE 4 World distribution of Köppen–Geiger climate types that occur in the EU and which occur in countries where *Garella musculana* has been reported.

3.4.3 | Spread

> *Describe how the pest would be able to spread within the EU territory following establishment?*
>
> *G. musculana* can spread naturally by flight or be transported in wood with bark (as pupae), in green husk fruit (as eggs or larvae) and in plants for planting, including green grafting buds (as eggs or larvae).
>
> *Comment on plants for planting as a mechanism of spread.*
>
> Plants for planting provide one of the main spread mechanisms for *G. musculana* over long distances.

The introduction of *G. musculana* in all its development stages may occur through plants for planting, cut branches, fruits (nuts), wood with bark (EFSA PLH Panel, 2021) and isolated bark; Yıldız et al. (2018) considered wood with bark at high risk for transport between countries. Adults can fly only over short distances (EPPO, online-f). During the growing season, eggs and larvae can be transported in green husk fruits, potted seedlings, cut branches, plants for planting and grafts. Pupae can spread throughout the year by transporting trunks and logs of walnut with bark (EFSA PLH Panel, 2021). While damaged fruits are considered at low risk as they are less likely to be traded, cut branches and plants for planting, especially green saplings for planting, are at higher risk because they possibly carry eggs and living larvae (EPPO, online-e; Bostancı et al., 2019, 2021).

3.5 | Impacts

> *Would the pests' introduction have an economic or environmental impact on the EU territory?*
>
> **Yes,** *G. musculana* established in the EU, and an economic impact could be anticipated.

G. musculana is a major pest of walnuts, causing the loss of young walnut fruits. One caterpillar may destroy several fruits. When the larva feeds on the fruit husk, the fruit is deformed. It can reduce fruit yields by 70%–80%. This leads directly to economic damage in commercial walnut orchards (Bostancı et al., 2019; Bozkurt et al., 2018; EFSA PLH Panel, 2021; Yıldız et al., 2018; Yoğurtçu & Kaçar, 2022). When fruit set is low, the larvae feed in young shoots causing them to weaken, especially in young trees (EPPO, online-f). *G. musculana* caused 11%–60% of shoots and fruit damage in Türkiye (Yoğurtçu & Kaçar, 2022). Pest damage causing walnut tree mortality can indirectly cause soil erosion in the mountains because natural regeneration is compromised (EPPO, online-e).

In Bulgaria, in the province of Burgas (municipality of Kableshkovo) in a plot of 2.3 ha of *J. regia*, about 20% of trees showed symptoms, mainly on the young shoots (EPPO, online-b).

3.6 | Available measures and their limitations

> *Are there measures available to prevent pest entry, establishment, spread or impacts such that the risk becomes mitigated?*
>
> **Yes**. The existing phytosanitary measures identified in Section 3.3.2 mitigate the likelihood of entry of *G. musculana* on plants for planting of *J. regia* meeting specific criteria originating in Türkiye.

3.6.1 | Identification of potential additional measures

Phytosanitary measures (prohibitions) are currently applied to some host plants for planting (see Section 3.3.2).
Additional potential risk reduction options and supporting measures are shown in Sections 3.6.1.1 and 3.6.1.2.

3.6.1.1 | *Additional potential risk reduction options*

Potential additional control measures are listed in Table 8.

TABLE 8 Selected control measures (a full list is available in EFSA PLH Panel, 2018) for pest entry/establishment/spread/impact in relation to currently unregulated hosts and pathways. Control measures are measures that have a direct effect on pest abundance.

Control measure/risk reduction option (blue underline = Zenodo doc, blue = WIP)	RRO summary	Risk element targeted (entry/ establishment/ spread/impact)
Require pest freedom	Commodities of host plants exported to the EU should be produced in an officially recognised pest-free country, area, place of production and production site	Entry/Spread
Growing plants in isolation	Description of possible exclusion conditions that could be implemented to isolate the crop from pests and if applicable relevant vectors. E.g. a dedicated structure such as glass or plastic greenhouses	Entry/Spread
Managed growing conditions	The management possibilities of this harmful insect are very limited. Young shoots should be checked by the growers for the presence of new galleries. The fallen fruit and pupal cocoons should be collected and destroyed (Degtyareva, 1964; Dzhaparov, 1990; Makhnovskii, 1970)	Entry/Spread
Roguing and pruning	Roguing is defined as the removal of infested plants and/or uninfested host plants in a delimited area, whereas pruning is defined as the removal of infested plant parts only without affecting the viability of the plant Roguing/pruning is unlikely to remove the plants/plant parts recently colonised by the larvae. Therefore, the measure will not be fully effective	Entry/Spread/Impact
Biological control and behavioural manipulation	Pest control such as: (a) Biological control Studies were carried out with applications of bacterial (*Bacillus thuringiensis*) or fungal pathogen (*Beauveria bassiana*) preparations against the larvae. Natural enemies can play an important role in reducing the population of *G. musculana*; parasitoids recovered belong to the families Ichneumonidae, Braconidae, Pteromalidae, Torymidae, Trichogrammatidae, (Hymenoptera), while predators to the families Formicidae (Hymenoptera), Carabidae (Coleoptera) and Raphidiidae (Neuroptera). The most common of these beneficials are *Trichogramma* sp. and *Pimpla instigator* (Bozkurt et al., 2018) (b) Mass trapping Trapping bands should be used against the larvae in young trees (Bozkurt et al., 2018) Light and sugar baited traps combined with yellow and red plastic cards with insecticides can be set to collect *G. musculana* adults, also helping to identify their flight period (Yoğurtçu & Kaçar, 2022)	Impact
Chemical treatments on crops including reproductive material	Although the pest has concealed habits and some chemicals might not be effective (Bozkurt et al., 2018), insecticides and microbial preparations can target the adults, or newly hatched larvae in their effort to enter the plant tissues and provide a degree of control.	Entry/Establishment/ Spread/Impact
Chemical treatments on consignments or during processing	Chemical compounds may be applied to plants, during process or packaging operations and storage, though no information was found on the chemical treatment of host plant commodities The treatments addressed in this information sheet are: a. fumigation; b. spraying/dipping pesticides; c. surface disinfectants; d. process additives; e. protective compounds	Entry/ Spread
Physical treatments on consignments or during processing	This risk mitigation measure includes irradiation/ionisation; mechanical cleaning (brushing, washing); sorting and grading, and removal of plant parts (e.g. debarking wood) Corrugated cardboard strips can be wrapped around trunks or thick branches to trap and destroy *G. musculana* pupae to control its density (Yoğurtçu & Kaçar, 2022)	Entry/Spread
Waste management	The destruction of fallen walnut fruits may give good results in managing *G. musculana* (EPPO, online-f)	Establishment/Spread
Heat and cold treatments	Controlled temperature treatments aimed to kill or inactivate pests without causing any unacceptable prejudice to the treated material itself	Entry/Spread
Conditions of transport	Specific requirements for mode and timing of transport of commodities to prevent escape of the pest and/or contamination. a. physical protection of consignment b. timing of transport/trade	Entry/Spread
Controlled atmosphere	Treatment of plants by storage in a modified atmosphere (including modified humidity, O_2, CO_2, temperature, pressure)	Entry/Spread (via commodity)
Post-entry quarantine and other restrictions of movement in the importing country	This risk mitigation measure covers post-entry quarantine (PEQ) of relevant commodities; temporal, spatial and end-use restrictions in the importing country for import of relevant commodities; Prohibition of import of relevant commodities into the domestic country 'Relevant commodities' are plants, plant parts and other materials that may carry pests, either as infection, infestation or contamination	Establishment/Spread

3.6.1.2 | *Additional supporting measures*

Potential additional supporting measures are listed in Table 9.

TABLE 9 Selected supporting measures (a full list is available in EFSA PLH Panel, 2018) in relation to currently unregulated hosts and pathways. Supporting measures are organisational measures or procedures supporting the choice of appropriate risk reduction options that do not directly affect pest abundance.

Supporting measure (blue underline = Zenodo doc, blue = WIP)	Summary	Risk element targeted (entry/ establishment/ spread/impact)
Inspection and trapping	ISPM 5 (FAO, 2023) defines inspection as the official visual examination of plants, plant products or other regulated articles to determine if pests are present or to determine compliance with phytosanitary regulations The effectiveness of sampling and subsequent inspection to detect pests may be enhanced by including trapping and luring techniques	Entry/Spread/Impact
Laboratory testing	Examination, other than visual, to determine if pests are present using official diagnostic protocols. Diagnostic protocols describe the minimum requirements for reliable diagnosis of regulated pests	Entry/Spread
Sampling	According to ISPM 31 (FAO, 2008), it is usually not feasible to inspect entire consignments, so phytosanitary inspection is performed mainly on samples obtained from a consignment. It is noted that the sampling concepts presented in this standard may also apply to other phytosanitary procedures, notably selection of units for testing For inspection, testing and/or surveillance purposes the sample may be taken according to a statistically based or a non-statistical sampling methodology	Entry
Phytosanitary certificate and plant passport	According to ISPM 5 (FAO, 2023), a phytosanitary certificate and a plant passport are official paper documents or their official electronic equivalents, consistent with the model certificates of the IPPC, attesting that a consignment meets phytosanitary import requirements: (a) export certificate (import) (b) plant passport (EU internal trade)	Entry/Spread
Certified and approved premises	Mandatory/voluntary certification/approval of premises is a process including a set of procedures and of actions implemented by producers, conditioners and traders contributing to ensure the phytosanitary compliance of consignments. It can be a part of a larger system maintained by the NPPO in order to guarantee the fulfilment of plant health requirements of plants and plant products intended for trade. Key property of certified or approved premises is the traceability of activities and tasks (and their components) inherent the pursued phytosanitary objective. Traceability aims to provide access to all trustful pieces of information that may help to prove the compliance of consignments with phytosanitary requirements of importing countries	Entry/Spread
Certification of reproductive material (voluntary/ official)	Plants come from within an approved propagation scheme and are certified pest free (level of infestation) following testing; Used to mitigate against pests that are included in a certification scheme	Entry/Spread
Delimitation of Buffer zones	ISPM 5 (FAO, 2023) defines a buffer zone as 'an area surrounding or adjacent to an area officially delimited for phytosanitary purposes in order to minimise the probability of spread of the target pest into or out of the delimited area, and subject to phytosanitary or other control measures, if appropriate'. The objectives for delimiting a buffer zone can be to prevent spread from the outbreak area and to maintain a pest-free production place (PFPP), site (PFPS) or area (PFA)	Spread
Surveillance	Surveillance to guarantee that plants and produce originate from a pest-free area could be an option	Spread

3.6.1.3 | *Biological or technical factors limiting the effectiveness of measures*

– Pupation occurs under the bark;
– Larvae usually feed and develop inside nuts and/or 1-year-old shoots.

3.7 | Uncertainty

No key uncertainties of the assessment have been identified.

4 | CONCLUSIONS

G. musculana satisfies all the criteria that are within the remit of EFSA to assess for it to be regarded as a potential Union quarantine pest (Table 10).

TABLE 10 The Panel's conclusions on the pest categorisation criteria defined in Regulation (EU) 2016/2031 on protective measures against pests of plants (the number of the relevant sections of the pest categorisation is shown in brackets in the first column).

Criterion of pest categorisation	Panel's conclusions against criterion in regulation (EU) 2016/2031 regarding union quarantine pest	Key uncertainties
Identity of the pest (Section 3.1)	The identity of *G. musculana* is established. Taxonomic keys based on morphology of adults exist. There are also molecular techniques for species identification	None
Absence/presence of the pest in the EU (Section 3.2)	Yes, *G. musculana* is present in the EU, in Romania, Bulgaria and Italy, with restricted distribution	None
Pest potential for entry, establishment and spread in the EU (Section 3.4)	*G. musculana* is able to further enter, become established and spread within the EU territory. The main pathway are plants for planting and wood with bark	None
Potential for consequences in the EU (Section 3.5)	The introduction of the pest could cause yield losses and death of the walnut trees.	None
Available measures (Section 3.6)	There are measures available to prevent entry, establishment and spread of *G. musculana* in the EU. Risk reduction options include inspections, chemical and physical treatments on consignments of fresh plant material from infested countries and the production of plants for import in the EU in pest-free areas	None
Conclusion (Section 4)	*G. musculana* satisfies all the criteria that are within the remit of EFSA to assess for it to be regarded as a potential Union quarantine pest	None
Aspects of assessment to focus on/scenarios to address in future if appropriate	More studies on impact and biology, particularly on natural enemies would be beneficial	

ABBREVIATIONS

EPPO   European and Mediterranean Plant Protection Organisation
FAO   Food and Agriculture Organisation
IPPC   International Plant Protection Convention
ISPM   International Standards for Phytosanitary Measures
MS   Member State
PLH   EFSA Panel on Plant Health
PZ   Protected Zone
TFEU   Treaty on the Functioning of the European Union
ToR   Terms of Reference

GLOSSARY

Containment (of a pest)	Application of phytosanitary measures in and around an infested area to prevent spread of a pest (FAO, 2023).
Control (of a pest)	Suppression, containment or eradication of a pest population (FAO, 2023).
Entry (of a pest)	Movement of a pest into an area where it is not yet present, or present but not widely distributed and being officially controlled (FAO, 2023).
Eradication (of a pest)	Application of phytosanitary measures to eliminate a pest from an area (FAO, 2023).
Establishment (of a pest)	Perpetuation, for the foreseeable future, of a pest within an area after entry (FAO, 2023).
Greenhouse	A walk-in, static, closed place of crop production with a usually translucent outer shell, which allows controlled exchange of material and energy with the surroundings and prevents release of plant protection products (PPPs) into the environment.
Hitchhiker	An organism sheltering or transported accidentally via inanimate pathways including with machinery, shipping containers and vehicles; such organisms are also known as contaminating pests or stowaways (Toy & Newfield, 2010).

Impact (of a pest)	The impact of the pest on the crop output and quality and on the environment in the occupied spatial units.
Introduction (of a pest)	The entry of a pest resulting in its establishment (FAO, 2023).
Pathway	Any means that allows the entry or spread of a pest (FAO, 2023).
Phytosanitary measures	Any legislation, regulation or official procedure having the purpose to prevent the introduction or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests (FAO, 2023).
Quarantine pest	A pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled (FAO, 2023).
Risk reduction option (RRO)	A measure acting on pest introduction and/or pest spread and/or the magnitude of the biological impact of the pest should the pest be present. A RRO may become a phytosanitary measure, action or procedure according to the decision of the risk manager.
Spread (of a pest)	Expansion of the geographical distribution of a pest within an area (FAO, 2023).

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CONFLICT OF INTEREST

If you wish to access the declaration of interests of any expert contributing to an EFSA scientific assessment, please contact interestmanagement@efsa.europa.eu.

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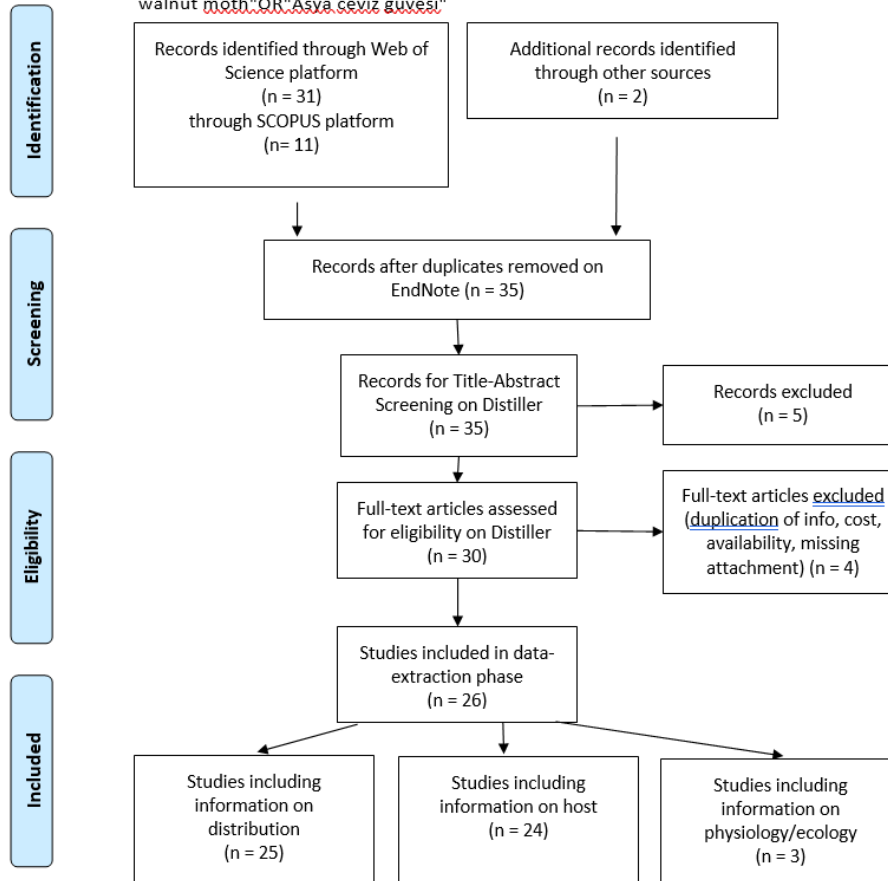
APPENDIX A

Literature search methodology

PRISMA 2009 Flow Diagram

Name of the Pest: *Garella musculana*
Date of the search: 27/10/2023
Approved Literature Search String: "Garella musculana"OR"Erschoviella musculana"OR"Nycteola musculana"OR"Sarrothripa musculana"OR"G. musculana"OR"E. musculana"OR"N. musculana"OR"S. musculana"OR"Asian walnut moth"OR"Asya ceviz güvesi"

Identification

| Records identified through Web of Science platform (n = 31) through SCOPUS platform (n= 11) | Additional records identified through other sources (n = 2) |

Screening

Records after duplicates removed on EndNote (n = 35)

Records for Title-Abstract Screening on Distiller (n = 35) → Records excluded (n = 5)

Eligibility

Full-text articles assessed for eligibility on Distiller (n = 30) → Full-text articles excluded (duplication of info, cost, availability, missing attachment) (n = 4)

Studies included in data-extraction phase (n = 26)

Included

| Studies including information on distribution (n = 25) | Studies including information on host (n = 24) | Studies including information on physiology/ecology (n = 3) |

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). *Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS* Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit www.prisma-statement.org.

APPENDIX B

Garella musculana host plants/species affected

Host name	Plant family	Common name	Reference
Carya illinoinensis	Juglandaceae	Pecan	EPPO (online-c)
Juglans nigra	Juglandaceae	American walnut	EPPO (online-c), Bostancı et al. (2019)
Juglans regia	Juglandaceae	Common walnut	EPPO (online-c), Scaccini et al. (2023)
Populus	Salicaceae	–	EPPO (online-c), Scaccini et al. (2023)
Prunus dulcis	Rosaceae	Almond	EPPO (online-c), Esonbaev et al. (2020)

APPENDIX C

Distribution of *Garella musculana*

Distribution records based on EPPO Global Database (EPPO, online-a) and literature.

Region	Country	Sub-national (e.g. state)	Status
Asia	Afghanistan		Present, no details
	India		Present, restricted distribution
	India	Jammu & Kashmir	Present, no details
	Iran		Present, no details
	Kazakhstan		Present, restricted distribution
	Kyrgyzstan		Present, no details
	Tajikistan		Present, no details
	Turkmenistan		Present, no details
	Uzbekistan		Present, no details
EU (27)	Bulgaria		Present, restricted distribution
	Italy		Present, restricted distribution
	Romania		Present, no details
Other Europe	Russia		Present, restricted distribution
	Russia	Southern Russia	Present, no details
	Türkiye		Present, restricted distribution
	Ukraine		Present, no details

APPENDIX D

Methodological notes on Figure 3

The relative probability of presence (RPP) reported here and in the European Atlas of Forest Tree Species (de Rigo et al., 2016; San-Miguel-Ayanz et al., 2016) is the probability of a species, and sometimes a genus, occurring in a given spatial unit (de Rigo et al., 2017). The maps of RPP are produced by spatial multi-scale frequency analysis (C-SMFA) (de Rigo et al., 2014, 2016) of species presence data reported in geolocated plots by different forest inventories.

Geolocated plot databases

The RPP models rely on five geo-databases that provide presence/absence data for tree species and genera (de Rigo et al., 2014; de Rigo et al., 2016; de Rigo et al., 2017). The databases report observations made inside geo-localised sample plots positioned in a forested area, but do not provide information about the plot size or consistent quantitative information about the recorded species beyond presence/absence.

The harmonisation of these data sets was performed as activity within the research project at the origin of the European Atlas of Forest Tree Species (de Rigo et al., 2016; San-Miguel-Ayanz, 2016; San-Miguel-Ayanz et al., 2016). All data sets were harmonised to an INSPIRE compliant geospatial grid, with a spatial resolution of 1 km^2 pixel size, using the ETRS89 Lambert Azimuthal Equal-Area as geospatial projection (EPSG: 3035, https://spatialreference.org/ref/epsg/etrs89-etrs-laea/).

European National Forestry Inventories database

This data set derived from National Forest Inventory data and provides information on the presence/absence of forest tree species in ~375,000 sample points with a spatial resolution of 1 km^2/pixel, covering 21 European countries (de Rigo et al., 2014, 2016).

Forest Focus/Monitoring data set

This project is a Community scheme for harmonised long-term monitoring of air pollution effects in European forest ecosystems, normed by EC Regulation No 2152/2003.[2] Under this scheme, the monitoring is carried out by participating countries on the basis of a systematic network of observation points (Level I) and a network of observation plots for intensive and continuous monitoring (Level II). For managing the data, the JRC implemented a Forest Focus Monitoring Database System, from which the data used in this project were taken (Hiederer et al., 2007; Houston Durrant & Hiederer, 2009). The complete Forest Focus data set covers 30 European Countries with more than 8600 sample points.

BioSoil data set

This data set was produced by one of a number of demonstration studies initiated in response to the 'Forest Focus' Regulation (EC) No 2152/2003 mentioned above. The aim of the BioSoil project was to provide harmonised soil and forest biodiversity data. It comprised two modules: a Soil Module (Hiederer et al., 2011) and a Biodiversity Module (Houston Durrant et al., 2011). The data set used in the C-SMFA RPP model came from the Biodiversity module, in which plant species from both the tree layer and the ground vegetation layer was recorded for more than 3300 sample points in 19 European Countries.

European Information System on Forest Genetic Resources

(EUFGIS) is a smaller geo-database that provides information on tree species composition in over 3200 forest plots in 34 European countries. The plots are part of a network of forest stands managed for the genetic conservation of one or more target tree species. Hence, the plots represent the natural environment to which the target tree species are adapted (EUFGIS, online).

Georeferenced Data on Genetic Diversity

(GD^2) is a smaller geo-database as well. It provides information about a 63 species that are of interest for genetic conservation. It counts 6254 forest plots that are located in stands of natural populations that are traditionally analysed in genetic surveys. While this database covers fewer species than the others, it does covers 66 countries in Europe, North Africa and the Middle East, making it the data set with the largest geographic extent (INRA, online).

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[2]Regulation (EC) No 2152/2003 of the European Parliament and of the Council of 17 November 2003 concerning monitoring of forests and environmental interactions in the Community (Forest Focus). Official Journal of the European Union 46 (L 324), 1-8.

Modelling methodology

For modelling, the data were harmonised in order to have the same spatial resolution (1 km^2) and filtered to a study area that comprises 36 countries in the European continent. The density of field observations varies greatly throughout the study area and large areas are poorly covered by the plot databases. A low density of field plots is particularly problematic in heterogenous landscapes, such as mountainous regions and areas with many different land use and cover types, where a plot in one location is not representative of many nearby locations (de Rigo et al., 2014). To account for the spatial variation in plot density, the model used here (C-SMFA) considers multiple spatial scales when estimating RPP.

C-SMFA preforms spatial frequency analysis of the geolocated plot data to create preliminary RPP maps (de Rigo et al., 2014). For each 1-km^2 grid cell, it estimates kernel densities over a range of kernel sizes to estimate the probability that a given species is present in that cell. The entire array of multi-scale spatial kernels is aggregated with adaptive weights based on the local pattern of data density. Thus, in areas where plot data are scarce or inconsistent, the method tends to put weight on larger kernels. Wherever denser local data are available, they are privileged ensuring a more detailed local RPP estimation. Therefore, a smooth multi-scale aggregation of the entire arrays of kernels and datasets is applied instead of selecting a local 'best preforming' one and discarding the remaining information. This array-based processing and the entire data harmonisation procedure are made possible thanks to the semantic modularisation which define Semantic Array Programming modelling paradigm (de Rigo, 2012).

The probability to find a single species in a 1-km^2 grid cell cannot be higher than the probability of presence of all the broadleaved (or coniferous) species combined, because all sample plots are localised inside forested areas. Thus, to improve the accuracy of the maps, the preliminary RPP values were constrained to not exceed the local forest-type cover fraction (de Rigo et al., 2014). The latter was estimated from the 'Broadleaved forest', 'Coniferous forest' and 'Mixed forest' classes of the Corine Land Cover (CLC) maps (Bossard et al., 2000; Büttner et al., 2012), with 'Mixed forest' cover assumed to be equally split between broadleaved and coniferous.

The robustness of RPP maps depends strongly on sample plot density, as areas with few field observations are mapped with greater uncertainty. This uncertainty is shown qualitatively in maps of 'RPP trustability'. RPP trustability is computed on the basis of aggregated equivalent number of sample plots in each grid cell (equivalent local density of plot data). The trustability map scale is relative, ranging from 0 to 1, as it is based on the quantiles of the local plot density map obtained using all field observations for the species. Thus, trustability maps may vary among species based on the number of databases that report it (de Rigo et al., 2014, 2016).

The RPP and relative trustability range from 0 to 1 and are mapped at 1 km spatial. To improve visualisation, these maps can be aggregated to coarser scales (i.e. 10 × 10 pixels or 25 × 25 pixels, respectively, summarising the information for aggregated spatial cells of 100 and 625 km^2) by averaging the values in larger grid cells.