Adopted: 23 May 2024

DOI: 10.2903/j.efsa.2024.8831

SCIENTIFIC OPINION

efsa JOURNAL

Pest categorisation of *Monema flavescens*

EFSA Panel on Plant Health (PLH) | Claude Bragard | Paula Baptista | Elisavet Chatzivassiliou | Francesco Di Serio | Paolo Gonthier | Josep Anton Jaques Miret | Annemarie Fejer Justesen | Christer Sven Magnusson | Panagiotis Milonas | Juan A. Navas-Cortes | Stephen Parnell | Roel Potting | Philippe Lucien Reignault | Emilio Stefani | Hans-Hermann Thulke | Wopke Van der Werf | Antonio Vicent Civera | Jonathan Yuen | Lucia Zappalà | Jean-Claude Grégoire | Chris Malumphy | Alex Gobbi | Dejana Golic | Virag Kertesz | Oresteia Sfyra | Alan MacLeod

Correspondence: plants@efsa.europa.eu

Abstract

The EFSA Panel on Plant Health performed a pest categorisation of *Monema flavescens* (Lepidoptera, Limacodidae), following the commodity risk assessment of *Acer palmatum* plants grafted on *A. davidii* from China, in which *M. flavescens* was identified as a pest of possible concern to the European Union. This species can be identified by morphological taxonomic keys and by barcoding. The adults of the overwintering generation emerge from late June to late August. The eggs are laid in groups on the underside of the host-plant leaves, on which the larvae feed throughout their six to eight larval instars. Pupation occurs in ovoid cocoons at the junction between twigs and branches, or on the trunk. Overwintering occurs as fully grown larvae or prepupae in their cocoon. There are one or two generations per year. *M. flavescens* is polyphagous and feeds on broadleaves; it has been reported on 51 plant species belonging to 24 families. It mainly occurs in Asia (Bhutan, China, the Democratic People's Republic of Korea, Japan, Nepal, the Republic of Korea), Russia (Eastern Siberia) and Taiwan. It is also present in the USA (Massachusetts). The pest's flight capacities are unknown. The main pathway for entry and spread is plants for planting with cocoons attached. This is partially closed by prohibition of some hosts. In several EU member states climatic conditions are conducive for establishment and many host plants are widespread. Introduction of *M. flavescens* may result in defoliations influencing tree health and forest diversity. The caterpillars also have urticating spines affecting human health. Phytosanitary measures are available to reduce the likelihood of entry, establishment and spread, and there is a definite potential for classical biological control. Recognising that natural enemies prevent *M. flavescens* being regarded as a pest in Asia, there is uncertainty regarding the magnitude of potential impact in EU depending on the influence of natural enemies. All criteria assessed by EFSA for consideration as a potential quarantine pest are met.

KEYWORDS

Cnidocampa flavescens, pest risk, plant health, plant pest, quarantine

CONTENTS

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

Monema flavescens 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 (QP) 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 QP, risk reduction options will be identified.

1.3 | Additional information

This pest categorisation was initiated following the commodity risk assessment of *Acer palmatum* plants grafted on *A. davidii* from China (EFSA PLH Panel, 2022) in which *M. flavescens* was identified as a relevant non-regulated EU pest which could potentially enter the EU on *Acer* spp. plants.

A large amount of the information in this categorisation has been published in the above commodity risk assessment (EFSA PLH Panel, 2022). This information, when relevant, has been largely reproduced here, with modifications when deemed useful, and additional information from a literature search since 2022.

2 | DATA AND METHODOLOGIES

2.1 | Data

2.1.1 | Literature search

A literature search on *M. flavescens* 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.

2.1.2 | Database search

Pest information, on host(s) and distribution, was retrieved from the CABI Crop Protection Compendium (CABI, online) 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 *Monema flavescens* 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 *M. flavescens*, 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 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. Whilst 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 QP 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 pest is known as *Monema flavescens* Walker. However, the synonym *Cnidocampa flavescens* Dyar, is still regularly used, even in recent literature causing some confusion.

M. flavescens Walker, 1855 is an insect of the family Limacodidae, order Lepidoptera. It is commonly known as the oriental moth (EFSA PLH Panel, 2022; Pan et al., 2013).

Several synonyms exist: *Cnidocampa flavescens, Cnidocampa johanibergmani, Knidocampa flavescens, Miresa flavescens, Monema flavescens* var. *nigrans*, *Monema melli*, *Monema nigrans* (Dyar, 1909; EFSA PLH Panel, 2022; Pan et al., 2013).

The synonym, *Cnidocampa flavescens* Dyar, 1905, is still frequently found in the literature, including publications dating around one century from that description (e.g. Tang ZhiXiang, 2001; Lammers & Stigter, 2004; Huang et al., 2010; Yuan et al., 2015; Peng et al., 2017), which is a cause of confusion.

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

3.1.2 | Biology of the pest

This section has largely drawn from EFSA PLH Panel (2022).

M. flavescens develops through four life stages: egg, larva, pupa and adult (Collins, 1933; Dyar, 1909) (Figures 1, 2A,B). During the summer, recently emerged females use a sex pheromone to attract males for mating (Shibasaki et al., 2013; Yang, 2022; Yang et al., 2016). Mated females lay between 500 and 1000 eggs on the underside of the leaves (Clausen, 1978; Collins, 1933). The eggs are laid in masses (Clausen, 1978). They hatch in about 1 week. The larvae live through 6 to 8 instars. Young larvae feed on small patches of green tissue from the underside of the leaf. Instead, the older larvae consume the entire leaf except for the main veins (Collins, 1933). After some time, the fully grown larva stops feeding and moves from the leaf to the bark of the tree, usually to axils of twigs and branches, where it forms its cocoon (Collins, 1933). Cocoons can be found also on trunks (Furukawa et al., 2017). Pupation occurs in the spring, and adults emerge from the cocoons during summer (Collins, 1933). Adults are active at night and fly only short distances (Dowden, 1946).

Depending on environmental conditions, there are between one (e.g. in USA) and two (e.g. in Japan) generations per year (Collins, 1933; Yamada, 1992). The overwintering stage is either fully grown larva or prepupal stage in cocoons located in axils of twigs and branches (Clausen, 1978). In USA, the adults appear during late June and July. Cocoons are

[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).

formed between early August and early October. The larvae within the cocoons transform to pupae in May (Collins, 1933; Dowden, 1946). In Japan, the first generation-adults appear in June and the second generation in mid to late August (Yamada, 1992).

Table 2 summarises key features of the life history of *M. flavescens*.

TABLE 2 Important features of the life history strategy of *Monema flavescens*.

Life stage	Phenology and relation to host	Other relevant information
Egg	Oviposition in summer, on the underside of the leaves. 500/1000 eggs/female, laid in groups	
Larva/Nymph	6–8 larval instars Young larvae graze the underside of the leaves, older larvae skeletonize the leaves	Overwintering as either fully grown larva or prepupal stage in cocoons
Pupa	In cocoons	Cocoons located on branches or trunks
Adult	Japan (two generations/year): first generation-adults appear in June, second generation in mid-August USA (one generation/year): adults appear in late June and July	

3.1.3 | Host range/species affected

According to EFSA PLH Panel (2022), host plants of *M. flavescens* are *Acer* spp., *A. palmatum, A. platanoides, A. pseudoplatanus, Betula lenta, B. nigra, Castanea* spp., *C. crenata, C. sativa, Celtis* spp., *Citrus reticulata, Diospyros* spp., *D. malabarica, Gleditsia triacanthos, Hicoria* spp., *Juglans* spp., *J. regia, Malus* spp., *Platanus* spp., *Populus* spp., *Prunus* spp., *Pyrus* spp., *Quercus* spp., *Q. acutissima*, *Q. serrata*, *Q. variabilis, Rhamnus* spp., *Salix* spp., *S. chaenomeloides*, *Ulmus* spp., *Zelkova* sp., *Z. serrata* and *Ziziphus* sp. (CABI, online; Collins, 1933; EUROPHYT, online; Lammers & Stigter, 2004; Robinson et al., online).

The moth was reported to attack blueberry plants *(Vaccinium* spp.) in South Korea (Choi et al., 2018), *Ziziphus jujuba* in China (Tang ZhiXiang, 2001), *Diospyros kaki* (Togashi & Ishikawa, 1994) and *Salix subfragilis* in Japan (Yamada, 1992).

According to Furukawa et al. (2017) in Japan, the overwintering cocoons were found on additional plant species such as *Acer buergerianum, Alnus hirsuta* var. *sibirica, Cerasus* x *yedoensis, C. spachiana* var. *spachiana, Cercis chinensis, Cornus kousa*, *Diospyros kaki, Eriobotrya japonica, Hamamelis japonica, Lagerstroemia indica, Photinia glabra, Styrax japonica* and *Ulmus parvifolia*.

A full list of host plants is provided in Appendix B.

3.1.4 | Intraspecific diversity

Pan et al. (2013) described one subspecies based on morphological characters, *Monema flavescens rubriceps* (Matsumura).

Japanese and Chinese populations of *M. flavescens* differ in their responses to sex pheromone blends (see Section 3.1.5 below).

3.1.5 | Detection and identification of the pest

Are detection and identification methods available for the pest?

Yes, the pest can be detected directly or remotely by its symptoms and adults can be captured using pheromone traps. Identification keys are available.

Detection

Visual detection. The fully grown larvae and cocoons have very distinctive features (see below). The damage of the mature larvae is also conspicuous: only the main veins remain from the otherwise fully consumed leaves. The cocoons are usually located on the axils of twigs and branches and can be found also on the trunks.

Remote sensing. In the Republic of Korea, the cocoons have been successfully detected during specifically designed winter aerial surveys of Zelkova trees using a drone equipped with a camera sensitive to visible light, 3–5 m above the canopy, with an accuracy and precision higher to that of conventional ground surveys (Park et al., 2021).

Pheromones. An attractive blend of female sex pheromones has been identified in Japan (Shibasaki et al., 2013). It proved inactive in China, but another, locally active blend was successfully tested (Yang, 2022; Yang et al., 2016). It is unknown whether these pheromones are commercially available.

Identification

Morphological identification. Pan et al. (2013) provide an identification key for the species of the genus *Monema*, and Dyar (1909) describes very precisely all stages of *M. flavescens*. The eggs are oval, flattened, transparent and their size is about 1.8 × 1.2 mm. The first instar larva is semi-transparent/white and approximately the same length as the eggs. With each moult, the larva takes on a greater variety of colours (Collins, 1933). Details on each larval instar can be found in Dyar (1909). The fully grown larva has spiny horns and a very striking appearance, with yellow, blue, green, and purple markings (Collins, 1933). Its length is about 18–24 mm (Dyar, 1909). The cocoon is greyish brown with white markings, smooth, hard and oval, resembling a small bird's egg (Collins, 1933). According to Furukawa et al. (2017), there are two types of cocoons: bold striped (entirely covered with black and white stripes) and non-bold striped (entirely or partly covered with nonbold stripes, or entirely brownish). The adult is light yellow (thorax and inner portion of the wings above) and light reddish brown (other portions of the body and wings) (Collins, 1933). Wing expanse is 35–39 mm in adult females and 30–32 mm in adult males (Pan et al., 2013).

Molecular identification. The complete mitochondrial genome of *M. flavescens* has been sequenced by Liu et al. (2016) and Peng et al. (2017).

FIGURE 1 Larva of *Monema flavescens* (Size: 18–24 mm. Source: Pan et al. (2013). CC BY 3.0, https://commons.wikimedia.org/w/index.php?curid=26502833).

FIGURE 2 (A) *Monema flavescens* cocoon intercepted in the UK on *Acer palmatum* imported from China and (B) the adult that emerged (Image courtesy of Fera).

3.2 | Pest distribution

3.2.1 | Pest distribution outside the EU

M. flavescens mainly occurs in Asia: Bhutan (Peng et al., 2017); China (Yang et al., 2016; Zhao and Chen, 1992); the Democratic People's Republic of Korea (Kawada, 1930); Japan (Asahina et al., 1954; Dowden, 1946; Peng et al., 2017; Shibasaki et al., 2013; Togashi & Ishikawa, 1994; Yamada, 1992; Yang et al., 2016); Nepal (Peng et al., 2017); the Republic of Korea (Peng et al., 2017); Russia (Eastern Siberia) (Yang et al., 2016); Taiwan (Kawada, 1930).

In the United States, the species is restricted to Massachusetts (Dowden, 1946) (Figure 3, Appendix C). The distribution of the pest appears stable since the early 1900s. The fact that there is no recent record of occurrence raises uncertainty as to the presence of *M. flavescens* in the country.

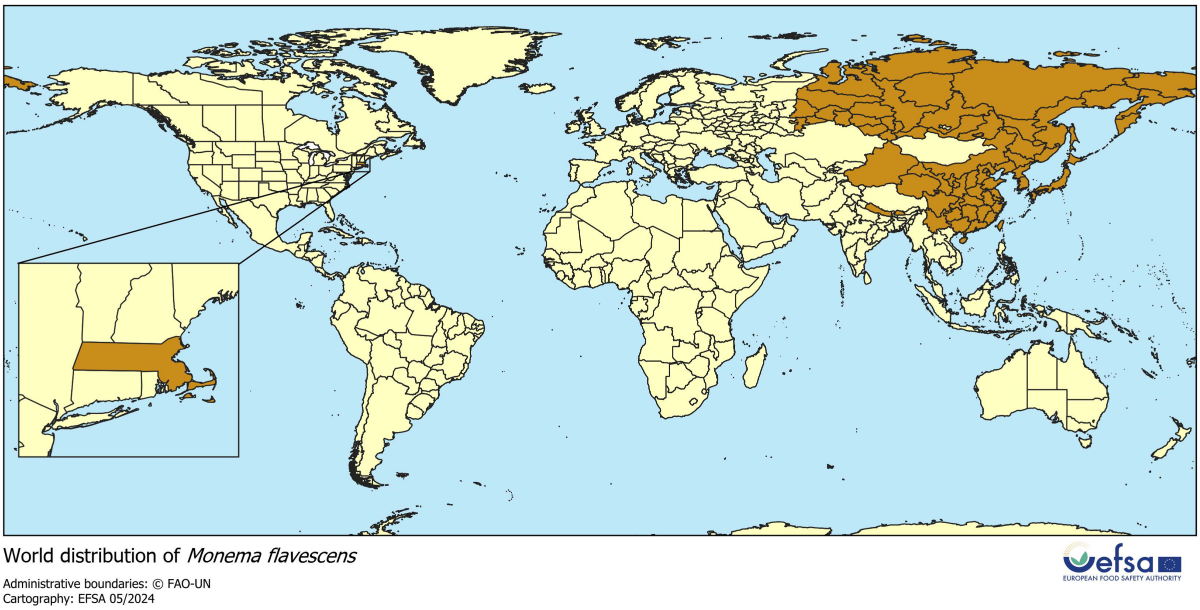


FIGURE 3 Global distribution of *Monema flavescens* (Source: literature; for details see Appendix C).

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.

No, the pest is absent from the EU territory.

3.3 | Regulatory status

3.3.1 | Commission Implementing Regulation 2019/2072

M. flavescens is not listed in Annex II of Commission Implementing Regulation (EU) 2019/2072, an implementing act of Regulation (EU) 2016/2031, or in any emergency plant health legislation.

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 *M. flavescens* hosts in the Union from certain third countries is prohibited (Table 3). However, plants for planting of *Cydonia* Mill., *Malus* Mill., *Prunus* L. and *Pyrus* L. and their hybrids, and […] other than seeds (i.e. item 9.), are permitted from United States where *M. flavescens* is present.

TABLE 3 List of plants, plant products and other objects that are *Monema flavescens* 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**
2.	Plants of *Castanea* Mill. and *Quercus* 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	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
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	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
8.	Plants for planting of […] *Cydonia* Mill., *Malus* Mill., *Prunus* L., *Pyrus* L. and […] 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 *Cydonia* Mill., *Malus* Mill., *Prunus* L. and *Pyrus* L. and their hybrids, and […] 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
11.	Plants of *Citrus* L., […] and their hybrids, other than fruits and seeds	ex 0602 10 90 ex 0602 20 20 0602 20 30 ex 0602 20 80 ex 0602 90 45 ex 0602 90 46 ex 0602 90 47 ex 0602 90 50 ex 0602 90 70 ex 0602 90 91 ex 0602 90 99 ex 0604 20 90 ex 1404 90 00	All third countries

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.

Comment on plants for planting as a pathway.

Yes, the pest is able to enter the EU on plants for planting and cut branches. It has been intercepted as cocoons on plants for planting.

The main pathway for entry is plants for planting with cocoons attached.

Potential entry pathways are listed in Table 4.

TABLE 4 Potential pathways for *Monema flavescens* 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	Cocoons on branches and trunks eggs	Plants for planting that are hosts of *M. flavescens* and are prohibited from being imported from third countries are listed in Table 3 (Regulation 2019/2072, Annex VI)
Cut branches	Cocoons on branches eggs	Introduction of foliage, branches and other parts of plants of various hosts without flowers or flower buds, being goods of a kind suitable for bouquets or for ornamental purposes, fresh) from third countries require a phytosanitary certificate (Regulation 2019/2072, Annex XI, Part A)

Acer L., *Alnus* L., *Castanea* Mill., *Diospyros* L., *Juglans* L., *Malus* Mill., *Populus* L., *Prunus* L, *Quercus* L., *Salix* L., and *Ulmus* L., host plants of *M. flavescens*, are included in the list of high-risk plants (EU 2018/2019) whose introduction is prohibited until a third country-specific full risk assessment has been carried out.

Notifications of interceptions of harmful organisms began to be compiled in Europhyt in May 1994 and in TRACES in May 2020. As at 19.3.2024, there were no records of interception of *M. flavescens* in the Europhyt and TRACES databases.

Lammers and Stigter (2004) report that 'the [Dutch] Plant Protection Service intercepted *M. flavescens* reported as *Cnidocampa flavescens* “several times” in consignments of *Acer* and *Zelkova* plants originating from Asian countries'. *M. flavescens* was also intercepted once on *Ziziphus* sp. plants originating from China to Canada (Lammers & Stigter, 2004, citing others). The pest has also been intercepted as cocoons on *Acer palmatum* in the UK (DEFRA, unpublished).

3.4.2 | Establishment

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

Yes, following entry on plants for planting, *M. flavescens* could become established in the EU as the hosts are available and the climate in most of the EU is suitable.

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*

The main hosts of the pest cultivated in the EU between 2018 and 2022 are shown in Table 5. *M. flavescens* can attack 51 species belonging to 24 families. Among others, apples, cherries, plums, peaches, pears are important crops in the EU. *M. flavences* also attacks plants of *Acer* spp. which are present in the EU (Figure 4).

TABLE 5 Crop area of *Monema flavescens* main hosts in the EU in 10,000 ha (Eurostat accessed on 8 April 2024).

Crop	Code	2018	2019	2020	2021	2022
Apples	F1110	506.27	491.08	489.19	492.56	477.98
Cherries	F1240	175.49	176.30	178.61	175.71	175.31
Plums	F1250	153.43	154.51	160.38	157.68	156.63
Chestnuts	F4400	132.72	142.55	145.36	141.15	144.17
Peaches	F1210	150.80	144.78	138.31	133.06	129.37
Pears	F1120	113.54	110.66	108.29	106.96	103.09
Raspberries	F3200	41.37	41.10	29.03	30.50	31.92

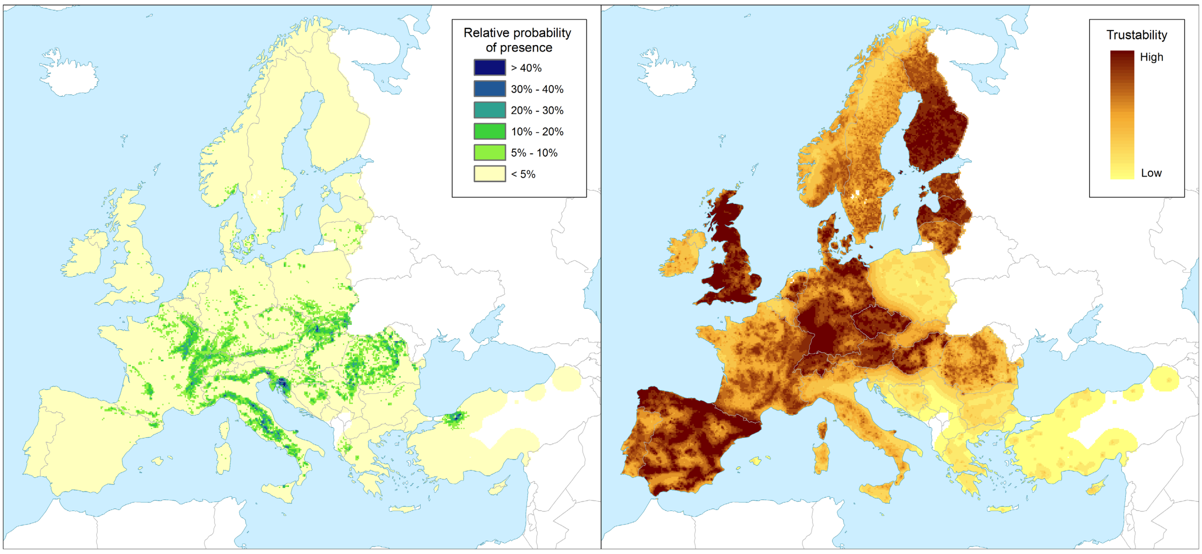


FIGURE 4 Left panel: Relative probability of the presence (RPP) of the genus *Acer* in Europe, mapped at 100 km^2 resolution. The underlying data are from European-wide forest monitoring data sets and from national forestry inventories based on standard observation plots measuring in the order of hundreds m^2. 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 C (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*

The climate in the current area of distribution of the pest is well represented in the EU, especially the Köppen-Geiger climatic zones Cfa, Cfb and Dfb, and to a lesser extent Bsh and Bsk (Kottek et al., 2006). Collectively these zones are represented in 66.5% of EU 27 five arcmin grid cells (MacLeod & Korycinska, 2019) (Figure 5).

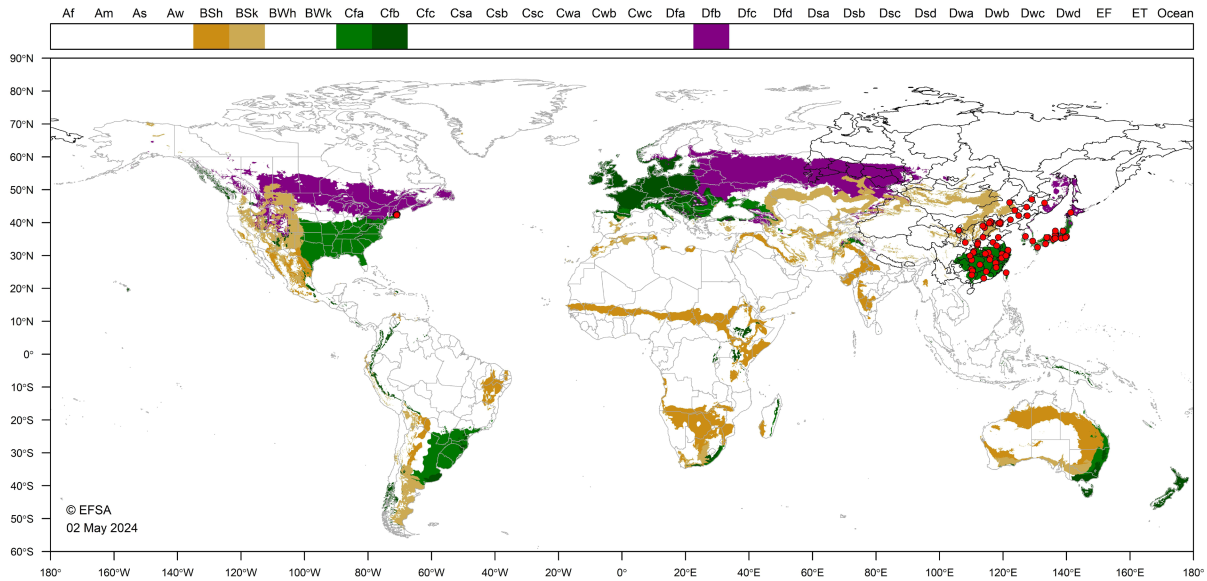


FIGURE 5 World distribution of five Köppen–Geiger climate types that occur in the EU and which occur in countries where *Monema flavescens* has been reported.

3.4.3 | Spread

Describe how the pest would be able to spread within the EU territory following establishment?

Comment on plants for planting as a mechanism of spread.

Yes, the pest could spread within the EU territory following establishment, either by flight or with plants for planting. The main pathway for spread is plants for planting with cocoons attached.

The moth, following introduction to the USA, spread only 25–30 miles during the first 40 years (Dowden, 1946). Intriguingly, to date, it still appears confined to Massachusetts.

3.5 | Impacts

Would the pests' introduction have an economic or environmental impact on the EU territory?

Yes, impact could be expected if contrary to what occurs in native areas and in the US, where native or introduced parasitoids successfully control the pest, native or introduced natural enemies would not exert the same control.

The moth was reported to attack blueberry plants *(Vaccinium* spp.) in South Korea (Choi et al., 2018), *Ziziphus jujuba* in China (Tang ZhiXiang, 2001), *Diospyros kaki* (Togashi & Ishikawa, 1994) and *Salix subfragilis* in Japan (Yamada, 1992). According to EFSA PLH Panel (2022), *M. flavescens* causes damage to its hosts occasionally. In Japan the moth causes defoliation of host trees only rarely, because it is controlled by its parasitoid *Praestochrysis* (= *Chrysis*) *shanghaiensis*. In Russia, it is sometimes a pest in gardens and nurseries (Lammers & Stigter, 2004). In the early 20th century in the USA, the moth caused tree defoliation, including *Prunus, Pyrus* and *Acer platanoides* (Collins, 1933; Dowden, 1946). Since 1946, there is no record of a serious damage caused by *M. flavescens* in Massachusetts. An introduced and established parasitoid from Japan, *Chaetexorista javana* Brauer & Bergenstamm (Diptera, Tachinidae) may have an impact on the population density of the moth in the USA (Dowden, 1946; Lammers & Stigter, 2004).

Recognising that natural enemies prevent *M. flavescens* being regarded as a pest in Asia, there is uncertainty regarding the magnitude of potential impact in EU depending on the influence of natural enemies present in the EU, and the possibility to introduce specific natural enemies from the area of origin.

The larvae of *M. flavescens* have urticating spines that cause serious irritation and inflammation in human skin (Collins, 1933; Dowden, 1946; Lammers & Stigter, 2004).

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, see Sections 3.3.2, 3.4.1 and 3.6.1.

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 6.

TABLE 6 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	• Plant or plant product comes from country officially free from pest, • Pest free area, • Pest free place of production (e.g. place of production and its immediate vicinity is free from pest over an appropriate time period, e.g. since the beginning of the last complete cycle of vegetation, or past 2 or 3 cycles). • Pest free production site	Entry/Spread
Growing plants in isolation	This measure covers 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. • Place of production is insect proof • Originate in a place of production with complete physical isolation	Entry (reduce contamination/infestation)/Spread
Managed growing conditions	• Plants collected directly from natural habitats, have been grown, held and trained for at least 2 consecutive years prior to dispatch in officially registered nurseries, which are subject to an officially supervised control regime	Entry (reduce contamination/infestation)/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. • Plants which have shown symptoms giving rise to the suspicion of contamination by the pests have been rogued out at that place and the plants have undergone appropriate treatment to rid them of specified pests	Entry/Spread/Impact
Biological control and behavioural manipulation	Classical biological control Two family-specific natural enemies are known: the fly *Chaetexorista javana* (Tachinidae) and the wasp *Chrysis shanghaiensis* Smith (Chrysididae). Both were introduced in the USA (Massachusets) in the early 1900s, following the entry and establishment of the pest, and *C. javana* established. *C. javana* rapidly achieved high levels of parasitisation (ca 50%) and is considered a major reason why the pest never spread beyond Massachusetts (Clausen, 1978; Dowden, 1946, 1962)	Entry/Establishment/Spread/Impact
Chemical treatments on crops including reproductive material	A mixture of Avermectin 5% and Cypermethrin SRP 8% is used in nurseries against larvae of *M. flavescens* in June, July and August (EFSA PLH Panel, 2022)	Entry/Establishment/Spread/Impact
Physical treatments on consignments or during processing	This measure covers the following categories of physical treatments: irradiation/ionisation; mechanical cleaning (brushing, washing); sorting and grading, and; removal of plant parts (e.g. debarking wood). The following treatments are not addressed under this measure: heat and cold treatment; roguing and pruning. • Mechanical removal of cocoons is possible	Entry/Spread
Waste management	• Treatment of the waste (deep burial, composting, incineration, chipping, production of bio-energy, etc.) in authorised facilities and official restriction on the movement of waste	Establishment/Spread

TABLE 6 (Continued)

Control measure/risk reduction option (blue underline = Zenodo doc, blue = WIP)	RRO summary	Risk element targeted (entry/establishment/spread/impact)
Heat and cold treatments	Controlled temperature treatments aimed to kill or inactivate pests without causing any unacceptable prejudice to the treated material itself. The measures covered here are autoclaving, steam, hot water, hot air, and cold treatment. • Thermal treatments appear difficult. Prepupae suffer little mortality at temperatures as low as −31° (Clausen, 1978).	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. Insect-proof physical protection of consignment b. Timing of transport/trade, restricted to periods when all cocoons have hatched (late summer to early autumn)	Entry
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	Post-entry quarantine for 1 year	Entry/Establishment/Spread

3.6.1.2 | *Additional supporting measures*

Potential additional supporting measures are listed in Table 7.

TABLE 7 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	Establishment/Spread
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/Spread
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

(Continues)

TABLE 7 (Continued)

Supporting measure (blue underline = Zenodo doc, blue = WIP)	Summary	Risk element targeted (entry/establishment/spread/impact)
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*

The effectiveness of biocontrol in the EU would be delayed if natural enemies from outside the EU had to be introduced. Recognising the time taken to identify appropriate natural enemies, pre-emptive biocontrol (to select, screen and potentially pre-approve natural enemies prior to a pest establishing) could be implemented as part of a contingency plan.

3.7 | Uncertainty

No key uncertainties have been identified.

4 | CONCLUSIONS

Monema flavescens 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 8).

TABLE 8 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 the pest is clearly defined	None
Absence/presence of the pest in the EU (Section 3.2)	The pest is absent from the EU territory	None
Pest potential for entry, establishment and spread in the EU (Section 3.4)	The pest is able to enter, establish and spread in the EU territory. Its main pathway is plants for planting	None
Potential for consequences in the EU (Section 3.5)	Impact could be expected if contrary to what occurs in native areas and in the US, where native or introduced parasitoids successfully control the pest, native or introduced natural enemies would not exert the same control	None
Available measures (Section 3.6)	Measures exist to prevent pest entry, establishment, spread or impacts	None
Conclusion (Section 4)	All criteria assessed by EFSA above for consideration as a potential quarantine pest are met	
Aspects of assessment to focus on/scenarios to address in future if appropriate:	Focused impact studies could clarify the present uncertainty	

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).

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

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.

REQUESTOR

European Commission

QUESTION NUMBER

EFSA-Q-2023-00344

COPYRIGHT FOR NON-EFSA CONTENT

PANEL MEMBERS

Claude Bragard, Paula Baptista, Elisavet Chatzivassiliou, Francesco Di Serio, Paolo Gonthier, Josep Anton Jaques Miret, Annemarie Fejer Justesen, Alan MacLeod, Christer Sven Magnusson, Panagiotis Milonas, Juan A. Navas-Cortes, Stephen Parnell, Roel Potting, Philippe L. Reignault, Emilio Stefani, Hans-Hermann Thulke, Wopke Van der Werf, Antonio Vicent Civera, Jonathan Yuen, and Lucia Zappalà.

MAP DISCLAIMER

The designations employed and the presentation of material on any maps included in this scientific output do not imply the expression of any opinion whatsoever on the part of the European Food Safety Authority concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

REFERENCES

Asahina, E., Aoki, K., & Shinozaki, J. (1954). The freezing process of frost-hardy caterpillars. *Bulletin of Entomological Research*, *45*(2), 329–339.

Baker, R. H. A. (2002). Predicting the limits to the potential distribution of alien crop pests. In G. J. Hallman & C. P. Schwalbe (Eds.), *Invasive arthropods in agriculture: Problems and solutions* (pp. 207–241). Science Publishers Inc.

Bossard, M., Feranec, J., & Otahel, J. (2000). *CORINE land cover technical guide - addendum 2000*. Technical Report 40. European Environment Agency. https://www.eea.europa.eu/ds_resolveuid/032TFUPGVR

Büttner, G., Kosztra, B., Maucha, G., & Pataki, R. (2012). *Implementation and achievements of CLC2006*. Technical report. European Environment Agency. https://www.eea.europa.eu/ds_resolveuid/GQ4JECM8TB

CABI (Centre for Agriculture and Bioscience International). (online). CABI. Crop Protection Compendium. https://www.cabi.org/cpc/

Cai, P., Bai, L. J., Xiang, R. L., & Zhang, L. (2005). The biological characteristics of the leading pests of loquat and their control. *South China Fruits*, *2*, 38–41.

Choi, S. H., Jeong, M. G., & Lee, D. W. (2018). Insecticidal activity of plant extracts against lepidopteran insect pests (*Latoia hilarata, Monema flavescens* and *Euproctis similis*) in blueberry. *The Korean Journal of Pesticide Science*, *22*, 255–260. https://doi.org/10.7585/kjps.2018.22.4.255

Clausen, C. P. (1978). Limacodidae. Oriental moth (*Cnidocampa flavescens* (Walker)). In: Introduced parasites and predators of arthropod pests and weeds: A world review. *Agriculture Handbook*, *480*, 193–194.

Collins, C. W. 1933. The oriental moth (*Cnidocampa* [*Monema*] *flavescens* walk.) and its control, Circular. United States Department of Agriculture, 8 pp.

de Rigo, D. (2012). Semantic Array programming for environmental modelling: Application of the Mastrave library. In R. Seppelt, A. A. Voinov, S. Lange, & D. Bankamp (Eds.), *International environmental modelling and software society (iEMSs) 2012 international congress on environmental modelling and software - managing Resources of a limited planet: Pathways and visions under uncertainty, sixth biennial meeting* (pp. 1167–1176). Brigham Young University, BYU ScholarsArchive. https://scholarsarchive.byu.edu/iemssconference/2012/Stream-B/69

de Rigo, D., Caudullo, G., Busetto, L., & San-Miguel-Ayanz, J. (2014). Supporting EFSA assessment of the EU environmental suitability for exotic forestry pests: Final report. *EFSA Supporting Publications*, *11*(3), EN-434+. https://doi.org/10.2903/sp.efsa.2014.EN-434

de Rigo, D., Caudullo, G., Houston Durrant, T., & San-Miguel-Ayanz, J. (2016). The European atlas of Forest tree species: Modelling, data and information on forest tree species. In J. San-Miguel-Ayanz, D. de Rigo, G. Caudullo, T. Houston Durrant, & A. Mauri (Eds.), *European atlas of Forest tree species. Publ. Off* (e01aa69+). EU. https://w3id.org/mtv/FISE-Comm/v01/e01aa69

de Rigo, D., Caudullo, G., San-Miguel-Ayanz, J., & Barredo, J. I. (2017). Robust modelling of the impacts of climate change on the habitat suitability of forest tree species. Publication Office of the European Union, 58 pp. ISBN: 978–92–79-66704-6. https://doi.org/10.2760/296501

DEFRA (Department for Environment Food & Rural Affairs). (Unpublished). UK.

Dowden, P. B. (1946). Parasitization of the oriental moth (*Cnidocampa flavescens* (walk.)) by *Chaetexorista javana* B. And B. *Annals of the Entomological Society of America*, *39*(2), 225–241. https://doi.org/10.1093/aesa/39.2.225

Dowden, P. B. (1962). Parasites and predators of forest insects liberated in the United States through 1960 (No. 226). Agriculture handbook. No. 226. US Department of Agriculture, Forest Service. 70 pp.

Dyar, H. G. (1909). New species of American lepidoptera. *Proceedings of the Entomological Society of Washington*, *11*, 19–29.

EFSA PLH Panel (EFSA Panel on Plant Health), Bragard, C., Baptista, P., Chatzivassiliou, E., Di Serio, F., Jaques Miret, J. A., Justesen, A. F., MacLeod, A., Magnusson, C. S., Milonas, P., Navas-Cortes, J. A., Parnell, S., Potting, R., Reignault, P. L., Stefani, E., Thulke, H.-H., Van der Werf, W., Vicent Civera, A., Yuen, J., … Gonthier, P. (2022). Scientific opinion on the commodity risk assessment of *Acer palmatum* plants grafted on *Acer davidii* from China. *EFSA Journal*, *20*(5), 7298. https://doi.org/10.2903/j.efsa.2022.7298

EFSA PLH Panel (EFSA Panel on Plant Health), Jeger, M., Bragard, C., Caffier, D., Candresse, T., Chatzivassiliou, E., Dehnen-Schmutz, K., Gregoire, J.-C., Jaques Miret, J. A., MacLeod, A., Navajas Navarro, M., Niere, B., Parnell, S., Potting, R., Rafoss, T., Rossi, V., Urek, G., Van Bruggen, A., Van Der Werf, W., … Gilioli, G. (2018). Guidance on quantitative pest risk assessment. *EFSA Journal*, *16*(8), 5350. https://doi.org/10.2903/j.efsa.2018.5350

EFSA Scientific Committee, Hardy, A., Benford, D., Halldorsson, T., Jeger, M. J., Knutsen, H. K., More, S., Naegeli, H., Noteborn, H., Ockleford, C., Ricci, A., Rychen, G., Schlatter, J. R., Silano, V., Solecki, R., Turck, D., Benfenati, E., Chaudhry, Q. M., Craig, P., … Younes, M. (2017). Scientific opinion on the guidance on the use of the weight of evidence approach in scientific assessments. *EFSA Journal*, *15*(8), 4971. https://doi.org/10.2903/j.efsa.2017.4971

EPPO (European and Mediterranean Plant Protection Organization). (2019). EPPO codes. https://www.eppo.int/RESOURCES/eppo_databases/eppo_codes

EPPO (European and Mediterranean Plant Protection Organization). (online). EPPO Global Database. https://gd.eppo.int

EUFGIS (European Information System on Forest Genetic Resources). (online). EUFGIS Database. https://portal.eufgis.org

EUROPHYT. (online). European Union Notification System for Plant Health Interceptions - EUROPHYT. https://ec.europa.eu/food/plant/plant_health_biosecurity/europhyt/index_en.htm

FAO (Food and Agriculture Organization of the United Nations). (2008). ISPM (International Standards for Phytosanitary Measures) No 31. Methodologies for sampling of consignments. FAO, Rome, 19 pp. https://www.ippc.int/static/media/files/publication/en/2016/11/ISPM_31_2008_Sampling_of_consignments_EN.pdf

FAO (Food and Agriculture Organization of the United Nations). (2013). ISPM (International Standards for Phytosanitary Measures) No 11. Pest risk analysis for quarantine pests. FAO, Rome, 36 pp. https://www.ippc.int/sites/default/files/documents/20140512/ispm_11_2013_en_2014-04-30_201405121523-494.65%20KB.pdf

FAO (Food and Agriculture Organization of the United Nations). (2023). ISPM (International Standards for Phytosanitary Measures) No 5. Glossary of phytosanitary terms. FAO, Rome, 40 pp. https://assets.ippc.int/static/media/files/publication/en/2023/07/ISPM_05_2023_En_Glossary_PostCPM-17_2023-07-12_Fixed.pdf

Fu, J., Fu, C., Yan, X., Yu, S., & Han, X. (2009). Preliminary report of pests and diseases on raspberry in Liaoning province. *Journal of Jilin Agricultural University*, *31*(5), 661–665.

Furukawa, M., Nakanishi, K., Honma, A., Takakura, K. I., Matsuyama, K., Hidaka, N., Sawada, H., & Nishida, T. (2021). Differential performance of contrasting defensive traits of cocoons of two moth species against bird predation. *Entomological Science*, *24*, 261–269.

Furukawa, M., Nakanishi, K., & Nishida, T. (2017). Relationships between environmental factors and cocoon color morphs of a slug moth, *Monema flavescens* in the field. *Japanese Journal of Environmental Entomology and Zoology*, *27*, 133–139.

Griessinger, D., & Roy, A.-S. (2015). EPPO codes: a brief description. https://www.eppo.int/media/uploaded_images/RESOURCES/eppo_databases/A4_EPPO_Codes_2018.pdf

Hiederer, R., Houston Durrant, T., Granke, O., Lambotte, M., Lorenz, M., Mignon, B., & Mues, V. (2007). *Forest focus monitoring database system - validation methodology. Vol. EUR 23020 EN of EUR – Scientific and Technical Research*. Office for Official Publications of the European Communities. https://doi.org/10.2788/51364

Hiederer, R., Houston Durrant, T., & Micheli, E. (2011). *Evaluation of BioSoil demonstration project - soil data analysis. Vol. 24729 of EUR - scientific and technical research*. Publications Office of the European Union. https://doi.org/10.2788/56105

Hong, Y. (2015). Control efficiency analysis of plant source pesticides on *Castanopsis fissarehd* leaf eating pest. *Journal of Southwest Forestry University*, 35, 71–76.

Houston Durrant, T., & Hiederer, R. (2009). Applying quality assurance procedures to environmental monitoring data: A case study. *Journal of Environmental Monitoring*, *11*(4), 774–781. https://doi.org/10.1039/b818274b

Houston Durrant, T., San-Miguel-Ayanz, J., Schulte, E., & Suarez Meyer, A. (2011). Evaluation of BioSoil demonstration project: Forest biodiversity - analysis of biodiversity module. Vol. 24777 of EUR – Scientific and Technical Research. Publications Office of the European Union. https://doi.org/10.2788/84823

Huang, W., Siemann, E., Wheeler, G. S., Zou, J., Carrillo, J., & Ding, J. (2010). Resource allocation to defence and growth are driven by different responses to generalist and specialist herbivory in an invasive plant. *Journal of Ecology*, *98*, 1157–1167.

INRA. (online). INRA, Biogeco, EvolTree. GD² database. http://gd2.pierroton.inra.fr

Ju, R. T., Wang, F., Li, Y. Z., & Wu, S. Y. (2007). Niche and interspecies competition of four Limacodidae species on green belt plants in Shanghai. *Chinese Journal of Ecology*, 26(04), 523–527.

Kawada, A. (1930). A List of Cochlidionid [Limacodid] Moths in Japan, with Descriptions of two new Genera and six new Species. *Journal of the Imperial Agricultural Experimental Station*, 1(3), 231–262.

Kottek, M., Grieser, J., Beck, C., Rudolf, B., & Rubel, F. (2006). World map of the Köppen_Geiger climate classification updated. *Meteorologische Zeitschrift*, *15*, 259–263. https://doi.org/10.1127/0941-2948/2006/0130

Lammers, J. W., & Stigter, H. (2004). Report of a Pest Risk Analysis - *Cnidocampa flavescens*. Netherlands Food and Consumer Product Safety Authority, Plant Protection Service, The Netherlands. 18 pp. https://english.nvwa.nl/documents/plant/plant-health/pest-risk-analysis/documents/pest-risk-analysis-cnidocampa-flavescens

Liu, Q. N., Xin, Z. Z., Bian, D. D., Chai, X. Y., Zhou, C. L., & Tang, B. P. (2016). The first complete mitochondrial genome for the subfamily Limacodidae and implications for the higher phylogeny of lepidoptera. *Scientific Reports*, *6*(1), 35878. https://doi.org/10.1038/srep35878

MacLeod, A., & Korycinska, A. (2019). Detailing Köppen-Geiger climate zones at a country and regional level: A resource for pest risk analysis. *EPPO Bulletin*, *49*(1), 73–82.

Mevzos, N. (1935). Coehlidiidae (Limacodidae) injurious to fruit trees.

Nagano, E. (1916). Life-history of some Japanese lepidoptera containing new genera and species. B*ull. Nawa Entom. Laboratory*, 1–27.

Pan, Z., Zhu, C., & Wu, C. (2013). A review of the genus *Monema* Walker in China (lepidoptera, Limacodidae). *ZooKeys*, *306*, 23. https://doi.org/10.3897/zookeys.306.5216

Park, Y. L., Cho, J. R., Lee, G. S., & Seo, B. Y. (2021). Detection of *Monema flavescens* (lepidoptera: Limacodidae) cocoons using small unmanned aircraft system. *Journal of Economic Entomology*, *114*(5), 1927–1933. https://doi.org/10.1093/jee/toab060

Peng, S., Zhang, Y., Zhang, X., Li, Y., Huang, Z., Zhang, Y., Zhang, X., Ding, J., Geng, X., & Li, J. (2017). Complete mitochondrial genome of *Cnidocampa flavescens* (Lepidoptera: Limacodidae*)*. *Mitochondrial DNA Part B Resources*, *2*, 534–535. https://doi.org/10.1080/23802359.2017.1365651

Piel, O., & Covillard, P. (1933). Contribution à l'étude de Monema flavescens Wkr. et de ses parasites. [Contribution towards the study of Monema flavescens Wkr. and its parasites]. Musée Heude, Notes d'entomologie chinoise.

Robinson, G. S., Ackery, P. R., Kitching, I. J., Beccaloni, G. W., & Hernandez, L. M. (online). HOSTS – a database of the world's Lepidopteran hostplants. Natural History Museum, London. https://www.nhm.ac.uk/ourscience/data/hostplants/search/index.dsml

San-Miguel-Ayanz, J. (2016). The European Union Forest strategy and the Forest information system for Europe. In J. San-Miguel-Ayanz, D. de Rigo, G. Caudullo, T. Houston Durrant, & A. Mauri (Eds.), *European atlas of Forest tree species. Publ. Off* (e012228+). EU. https://w3id.org/mtv/FISE-Comm/v01/e012228

San-Miguel-Ayanz, J., de Rigo, D., Caudullo, G., Houston Durrant, T., & Mauri, A. (Eds.). (2016). *European atlas of Forest tree species*. Publication Office of the European Union, . ISBN: 978–92–79-36740-3. https://w3id.org/mtv/FISE-Comm/v01

Sayers, E. W., Cavanaugh, M., Clark, K., Ostell, J., Pruitt, K. D., & Karsch-Mizrachi, I. (2020). Genbank. *Nucleic Acids Research*, *48*(Database issue), D84–D86. https://doi.org/10.1093/nar/gkz956

Shibasaki, H., Yamamoto, M., Yan, Q., Naka, H., Suzuki, T., & Ando, T. (2013). Identification of the sex pheromone secreted by a nettle moth, *Monema flavescens*, using gas chromatography/Fourier transform infrared spectroscopy. *Journal of Chemical Ecology*, *39*, 350–357.

Song WenJun, S. W. (2000). Studies on the introduction of *Populus deltoides* to the coastal beaches in northern Zhejiang Province.

Sugiharti, M., Ono, C., Ito, T., Asano, S. I., Sahara, K., Pujiastuti, Y., & Bando, H. (2011). Isolation of the Thosea asigna virus (TaV) from the epizootic Setothosea asigna larvae collected in South Sumatra and a study on its pathogenicity to Limacodidae larvae in Japan. *Journal of Insect Biotechnology and Sericology*, 79(3), 3_117–3_124.

Tang ZhiXiang, T. Z. (2001). Occurrence and control of *Cnidocampa flavescens* in *Zizyphus jejuba*. *Journal of Zhejiang Forestry and Technology*, *21*, 46–47.

Togashi, I., & Ishikawa, T. (1994). Parasites reared from cocoons of *Monema flavescens* Walker and *Latola sinica* (Moore) (lepidoptera: Limacodidae) in Ishikawa prefecture. *Transactions of the Shikoku Entomological Society*, *20*, 321–325.

Togashi, I., & Ishikawa, T. (1995). Is *Eurytoma monemae* RUSCHKA (Hymenoptera: Eurytomidae) an effective parasitoid for control of *Monema flavescens* WALKER or Parasa sinica (MOORE)(lepidoptera: Limacodidae)? *Applied Entomology and Zoology*, *30*(3), 493–494.

Toy, S. J., & Newfield, M. J. (2010). The accidental introduction of invasive animals as hitchhikers through inanimate pathways: A New Zealand perspective. *Revue Scientifique et Technique (International Office of Epizootics)*, *29*(1), 123–133.

Yamada, Y. (1992). Spatio-temporal analysis of the population dynamics of the oriental moth, *Monema flavescens* (lepidoptera: Limacodidae). *Researches on Population Ecology*, *34*, 109–130. https://doi.org/10.1007/BF02513525

Yang, C. Y. (2022). Current status and future directions of pheromone research on orchard pests in Korea. *Korean Journal of Applied Entomology*, *61*(1), 51–62.

Yang, P., Guo, R. H., Sun, B. J., Liu, E., & Tao, Y. L. (2007). Four insect pests damaging Acanthopanax sessiliflorus and their control. *Entomological Knowledge*, *44*(4), 577–578.

Yang, S., Liu, H., Zheng, H., Yang, M., Ren, Y., & Zhang, J. (2016). Attraction of *Monema flavescens* males to synthetic blends of sex pheromones. *Bulletin of Insectology*, *69*, 193–198.

Yoshida, T., & Matsumoto, R. (2015). A revision of the genus *Chlorocryptus* Cameron (Hymenoptera, Ichneumonidae), with the first record of the genus from Japan. *Deutsche Entomologische Zeitschrift*, *62*(1), 81–99.

Yu, K., Zou, Y. D., Bi, S. D., Zhao, P., Zhao, X. J., Dang, F. H., & Yu, X. B. (2010). Relationship between five major phytophaga pests and their natural predatory enemies in pomegranate field. *Zhongguo Shengtai Nongye Xuebao/Chinese Journal of Eco-Agriculture*, *18*, 1317–1323.

Yuan, H., Wei, Y., Sun, C., Ding, Y., Qi, X., Liu, J., & Ye, H. (2015). Main pest species and their population dynamics of blueberry in Changchun District. *Journal of Jilin Agricultural University*, 37(2), 160–165.

Zhao, B. G., & Chen, J. J. (1992). Genetic variation among five common species of Limacocidae in the Nanjing area.

How to cite this article: EFSA PLH Panel (EFSA Panel on Plant Health), Bragard, C., Baptista, P., Chatzivassiliou, E., Di Serio, F., Gonthier, P., Jaques Miret, J. A., Justesen, A. F., Magnusson, C. S., Milonas, P., Navas-Cortes, J. A., Parnell, S., Potting, R., Reignault, P. L., Stefani, E., Thulke, H.-H., Van der Werf, W., Vicent Civera, A., Yuen, J., … MacLeod, A. (2024). Pest categorisation of *Monema flavescens*. *EFSA Journal*, *22*(7), e8831. https://doi.org/10.2903/j.efsa.2024.8831

APPENDIX A

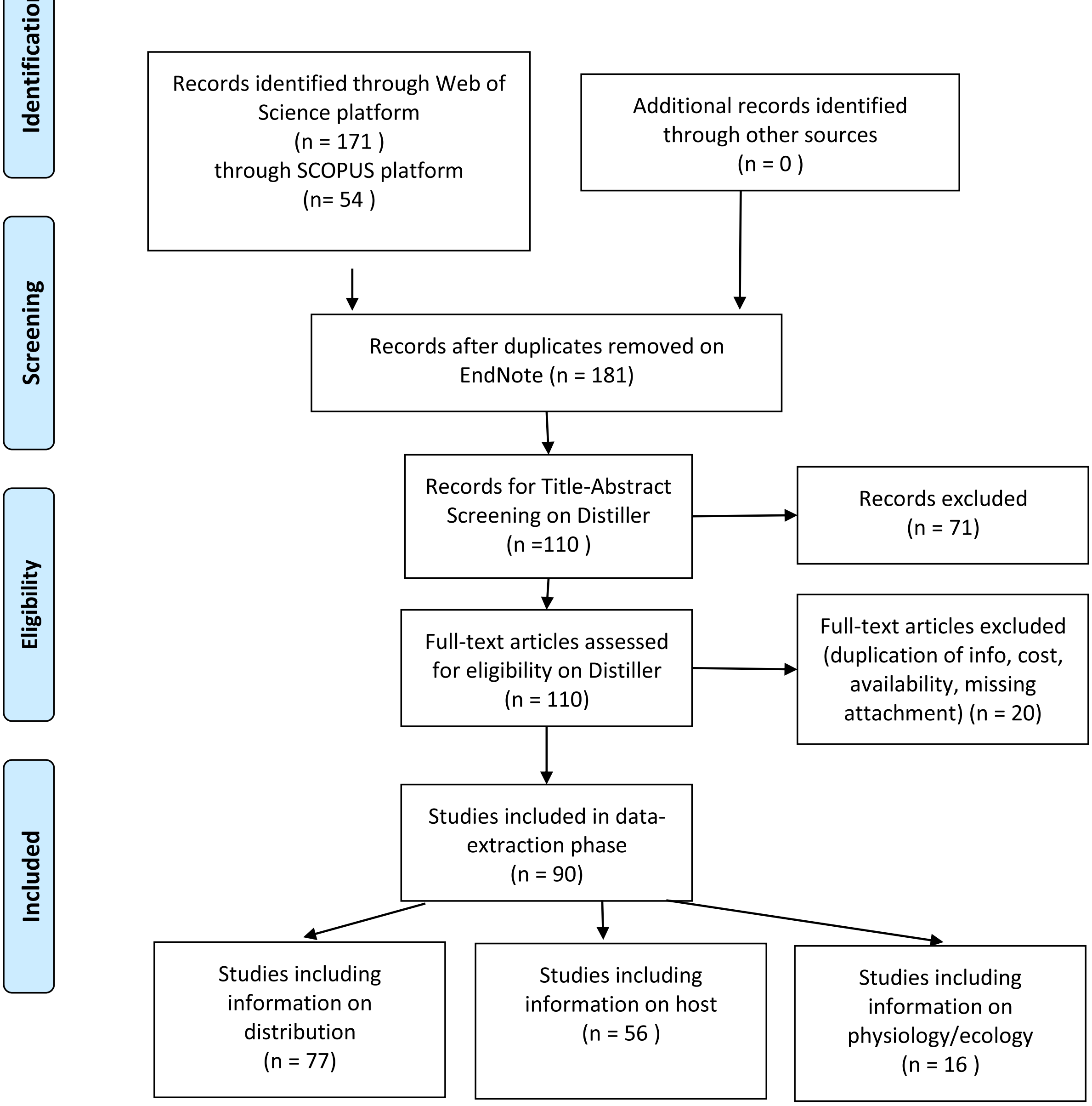
Literature search methodology

PRISMA 2009 Flow Diagram

Name of the Pest: Monema Flavescens

Date of the search: 15.11.2023

Approved Literature Search String: ("Monema flavescens"OR"Cnidocampa flavescens"OR"Knidocampa flavescens"OR"Miresa flavescens"OR"Cnidocampa flavescens"OR"Miresa flavescens"OR"Cnidocampa johani-bergmani"OR"Cnidocampa johanibergmani"OR"Monema melli"OR"Monema nigrans"OR"oriental moth"OR"brown slug moth"OR"cochlide cnidocampe"OR"Spinner-Arten, Assel-"OR"Iraga"OR"Asselspinner")



From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). *P*referred *R*eporting *I*tems for *S*ystematic Reviews and *M*eta-*A*nalyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

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

APPENDIX B

Monema flavescens host plants

Source: CABI CPC (CABI, online) and literature as indicated.

Host status	Host name	Plant family	Common name	Reference[A]
Cultivated hosts				
	Acanthopanax sessiliflorus	Araliaceae	–	Yang et al. (2007)
	Acer palmatum	Aceraceae	Japanese maple	Furukawa et al. (2021)
	Acer platanoides	Aceraceae	Norway maple	Dowden (1946)
	Acer pseudoplatanus	Aceraceae	Sycamore maple	Collins (1933)
	Alnus japonica	Betulaceae	Japanese alder	Nagano (1916)
	Ampelopsis	Vitaceae	–	Piel and Covillard (1933)
	Aphananthe aspera	Cannabaceae	Scabrous aphananthe	Nagano (1916)
	Artemisia argyi	Asteraceae	–	Ju et al. (2007)
	Betula lenta	Betulaceae	Cherry birch	Collins (1933)
	Castanea sativa	Fagaceae	Chestnut	CABI (online)
	Castanopsis fissa	Fagaceae	Breaking fruit evergreen chinkapin	Hong (2015)
	Celtis occidentalis	Cannabaceae	Western hackberry	Collins (1933)
	Celtis sinensis	Cannabaceae	Japanese hackberry	Nagano (1916)
	Citrus x junos	Rutaceae	Yuzu	Park et al. (2021)
	Cydonia japonica	Rosaceae	Japanese flowering quince	Piel and Covillard (1933)
	Diospyros kaki	Ebenaceae	Persimmon	Togashi and Ishikawa (1995)
	Eriobotrya japonica	Rosaceae	Japanese medlar	Cai et al. (2005)
	Gleditsia triacanthos	Fabaceae	Honey locust	Collins (1933)
	Juglans regia	Juglandaceae	Walnut	Yang et al. (2016)
	Kelreuteria bipinnata	Sapindaceae	Chinese flame tree	Piel and Covillard (1933)
	Lagerstroemia indica	Lythraceae	Cannonball	Yang et al. (2016)
	Malus domestica	Rosaceae	Apple	Yang et al. (2016)
	Melia azedarach	Meliaceae	Bead tree	Piel and Covillard (1933)
	Morus alba	Moraceae	Mulberry	Park et al. (2021)
	Mytilaria laosensis	Hamamelidaceae	–	Ju et al. (2007)
	Platanus acerifolia	Platanaceae	London plane	Ju et al. (2007)
	Populus deltoides	Salicaceae	American black poplar	Song (2000)
	Prunus avium	Rosaceae	Cherry	Collins (1933)
	Prunus domestica	Rosaceae	European plum	Sugiharti et al. (2011)
	Prunus mume	Rosaceae	Japanese apricot	Shibasaki et al. (2013)
	Prunus persica	Rosaceae	Peach	Yang et al. (2016)
	Prunus x yedoensis	Rosaceae	Japanese flowering cherry	Furukawa et al. (2021)
	Pterocarya stenoptera	Juglandaceae	Chinese wingnut	Piel and Covillard (1933)
	Punica granatum	Lythraceae	Pomegranate	Yu et al. (2010)
	Pyrus communis	Rosaceae	Pear	Collins (1933)
	Pyrus pyrifolia	Rosaceae	Chinese pear	Nagano (1916)
	Quercus serrata	Fagaceae	Gland-bearing oak	Furukawa et al. (2021)
	Rhamnus cathartica	Rhamnaceae	Buckthorn	Collins (1933)
	Rhamnus davurica	Rhamnaceae	Dahurian buckthorn	Ju et al. (2007)
	Ribes nigrum	Grossulariaceae	Black currant	Mevzos (1935)
	Rubus idaeus	Rosaceae	Raspberry	Fu et al. (2009)
	Salix babylonica	Salicaceae	Chinese willow	Yang et al. (2016)
	Salix chaenomeloides	Salicaceae	Giant pussy willow	Yamada (1992)
	Salix subfragilis	Salicaceae	–	Yamada (1992)

(Continues)

(Continued)

Host status	Host name	Plant family	Common name	Reference[A]
	Sapium sebiferum	Euphorbiaceae	Chinese tallow tree	Ju et al. (2007)
	Sophora japonica	Fabaceae	Japanese pagoda tree	Piel and Covillard (1933)
	Triadica sebifera	Euphorbiaceae	Chinese tallow	Huang et al. (2010)
	Ulmus	Ulmaceae	Elms	CABI (online)
	Ziziphus jujuba	Rhamnaceae	Chinese date	Yang et al. (2016)
	Zelkova serrata	Ulmaceae	Japanese zelkova	Park et al. (2021)
Wild weed hosts	*Alternanthera philoxeroides*	Amaranthaceae	Alligator weed	Ju et al. (2007)

APPENDIX C

Distribution of *Monema flavescens*

Distribution records based on literature.

Region	Country	Sub-national (e.g. state)	Status	References
Asia				
	Bhutan		Present, no details	Peng et al. (2017)
	China		Present, no details	
		Anhui	Present, no details	Yang et al. (2016)
		Beijing	Present, no details	Yang et al. (2016)
		Chongming Island	Present, no details	Yang et al. (2016)
		Chongqing Shi	Present, no details	Yang et al. (2016)
		Fujian	Present, no details	Yang et al. (2016)
		Gansu	Present, no details	Yang et al. (2016)
		Guangdong	Present, no details	Yang et al. (2016)
		Guangxi	Present, no details	Yang et al. (2016)
		Guizhou	Present, no details	Yang et al. (2016)
		Hainan	Present, no details	Yang et al. (2016)
		Hebei	Present, no details	Yang et al. (2016)
		Heilongjiang	Present, no details	Yang et al. (2016)
		Henan	Present, no details	Yang et al. (2016)
		Hubei	Present, no details	Yang et al. (2016)
		Hunan	Present, no details	Yang et al. (2016)
		Inner Mongolia	Present, no details	Yang et al. (2016)
		Jiangsu	Present, no details	Yang et al. (2016)
		Jiangxi	Present, no details	Yang et al. (2016)
		Jilin	Present, no details	Yang et al. (2016)
		Liaoning	Present, no details	Yang et al. (2016)
		Luanxian	Present, no details	Yang et al. (2016)
		Nanjing	Present, no details	Zhao and Chen (1992)
		Nei Mongol Zizhiqu	Present, no details	Yang et al. (2016)
		Ningxia Huizu Zizhiqu	Present, no details	Yang et al. (2016)
		Qinghai	Present, no details	Yang et al. (2016)
		Shaanxi	Present, no details	Yang et al. (2016)
		Shandong	Present, no details	Yang et al. (2016)
		Shanghai	Present, no details	Yang et al. (2016)
		Shanxi	Present, no details	Yang et al. (2016)
		Sichuan	Present, no details	Yang et al. (2016)
		Tianjin Shi	Present, no details	Yang et al. (2016)
		Xinjiang Uygur Zizhiqu	Present, no details	Yang et al. (2016)
		Yunnan	Present, no details	Yang et al. (2016)
		Zhejiang	Present, no details	Yang et al. (2016)
	Democratic People's Republic of Korea		Present, no details	Kawada (1930)
	Japan		Present, no details	Yang et al. (2016)
		Gifu	Present, no details	Shibasaki et al. (2013)
		Hikone	Present, no details	Furukawa et al. (2021)
		Hokkaido	Present, no details	Nagano (1916)
		Honshu	Present, no details	Nagano (1916)
		Isikawa	Present, no details	Togashi and Ishikawa (1994)
		Kanagawa	Present, no details	Dowden (1946)
		Kyoto	Present, no details	Yamada (1992)

(Continues)

(Continued)

Region	Country	Sub-national (e.g. state)	Status	References
		Kyushu	Present, no details	Nagano (1916)
		Nagasaki	Present, no details	Yoshida and Matsumoto (2015)
		Nonoitimati (Nonoichi-machi)	Present, no details	Togashi and Ishikawa (1995)
		Sapporo	Present, no details	Asahina et al. (1954)
		Shikoku	Present, no details	Nagano (1916)
		Tottori	Present, no details	Shibasaki et al. (2013)
	Nepal		Present, no details	Peng et al. (2017)
	Republic of Korea		Present, no details	Peng et al. (2017)
	Russia	Eastern Siberia	Present, no details	Yang et al. (2016)
	Taiwan		Present, no details	Kawada (1930)
United States		Massachusetts	Present, no details	Dowden (1946)

APPENDIX D

Methodological notes on Figure 4

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.

D.1 | 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 datasets 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 datasets 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, http://spatialreference.org/ref/epsg/etrs89-etrs-laea/).

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

D.2 | 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

[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.

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; de Rigo et al., 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.