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Pest categorisation of *Hoplolaimus galeatus*

EFSA Panel on Plant Health (PLH),
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, Emilio Stefani, Hans-Hermann Thulke, Wopke Van der Werf, Antonio Vicent Civera, Jonathan Yuen, Lucia Zappalà, Quirico Migheli, Irene Vloutoglou, Andrea Maiorano, Marco Pautasso and Philippe Lucien Reignault

Abstract

The EFSA Panel on Plant Health performed a pest categorisation of *Hoplolaimus galeatus* (Nematoda: Hoplolaimidae) for the EU. *H. galeatus* belongs to the order Rhabditida, subfamily Hoplolaiminae. This nematode is not reported from the EU and is not included in the EU Commission Implementing Regulation 2019/2072. It is widely distributed in the USA and is also reported from South America, Africa, Asia and Australia. The identity of *H. galeatus* is clearly defined and methods for its identification are available. *H. galeatus* is polyphagous and natural hosts include barley, wheat, rye, red and white clover, alfalfa, cabbage, pine, spruce, oak, apple, grapevine, as well as various ornamental plants and turf grasses. These hosts are grown over vast areas of the EU. The climate of the EU is suitable for the establishment of *H. galeatus*. Pathways of entry are host plants for planting except seeds, but also soil as a contaminant. Soil import to the EU is prohibited and special requirements apply to import of machinery for agricultural/forestry purposes from third countries. Impact of the nematode is best known for North American plant species. The nematode has been reported to damage cotton, maize, soybean, pine, oak and turfgrass. Many of the hosts represent a considerable economic and environmental value to the EU. Therefore, the Panel concludes that *H. galeatus* satisfies all the criteria that are within the remit of EFSA to assess for it to be regarded as a potential Union quarantine pest.

Keywords: pest risk, plant health, plant pest, plants for planting, polyphagous, quarantine, soil

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Correspondence: plants@efsa.europa.eu

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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

Hoplolaimus galeatus is one of a number of pests listed in Annex 1C to 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

The pest categorisation was initiated following the commodity risk assessment of *Malus domestica* and *Prunus persica* and *P. dulcis* plants from Türkiye (EFSA PLH Panel, 2022, 2023).

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), EFSA consults the NPPOs of the relevant MSs. As H. galeatus is not reported in the EU, information on the official pest status for *H. galeatus* was not requested from NPPOs, with the exception of Spain given a doubtful record in the Fauna Europaea (see Section 3.2.2).

2.1.2. Literature search

A literature search on *Hoplolaimus galeatus* 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. 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), 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 *H. galeatus* 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 *H. galeatus*, 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 clearly defined based on both morphology and molecular sequences.

Hoplolaimus galeatus belongs to the order Rhabditida, family Hoplolaimidae, subfamily Hoplolaiminae. The genus *Hoplolaimus* currently contains 35 species (Handoo and Golden, 1992; Marais et al., 2020). Molecular sequences are available for the identification of this species.

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

[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 (Griessinger and Roy, 2015; EPPO, 2019)

3.1.2. Biology of the pest

Hoplolaimus galeatus is a free-living plant parasitic nematode with sexual reproduction (Table 2). The life cycle consists of egg, four juvenile and adult stages (either females or males). The pest is a root parasite and lives mostly as an endoparasite. This nematode has many host plants among trees, agricultural, horticultural crops and grasses (Appendix A). The nematode is widespread in the USA, where damage is reported primarily on woody and gramineous plants.

Table 2: Important features of the life-history strategy of *Hoplolaimus galeatus*

Life stage	Phenology and relation to host	Other relevant information
Egg	Eggs are laid in soil and/or in the root tissue.	–
Juveniles	There are four juvenile stages (J). The first stage J1 moults in the egg. The J2 stage hatches from the egg. The stages J2–J4 can attack the root from the outside or infect the root tissue.	The juveniles move freely in the soil water films and in the root tissue.
Adult	The adults occur in soil and roots. The feeding occurs primarily in the root cortex. The pest is mostly endoparasitic but on some hosts (e.g. sycamore), it feeds as semi-endoparasite with the anterior body embedded in the root.	The pest has one or more generations per year. Highest populations may occur during summer and autumn, but the population may also fluctuate throughout the season with no distinct peaks. The reproduction is sexual. The pest moves only short distances in a year. Longer dispersal is possible only by movement of soil, water and plants. In experimental conditions, a multiplication factor of 4 was recorded after 9 months on sycamore (*Platanus occidentalis*) (Churchill and Ruehle, 1971), and 3.5–5 on maize over 7 months (Rhoades, 1987), and 1.5–5.2 on loblolly pine (*Pinus taeda*) over 6 months (Ruehle and Sasser, 1962).

3.1.3. Host range/species affected

Hoplolaimus galeatus parasitises a wide variety of hosts (Appendix A). Many trees, crops and grasses are subject to damage (Crow and Brammer, 2015). Main hosts (based on the severity of symptoms and the relevance for EU agriculture/forestry) include pines, cotton and species in the Poaceae family.

Among agricultural and horticultural hosts are *Hordeum vulgare* (Goodey et al., 1965), *Triticum aestivum* (Sharma, 2001), Secale cereale (Ahmed and Chen, 1980), *Trifolium pratense*, *Trifolium repens*, *Medicago sativa* (Goodey et al., 1965), *Oryza sativa* (Sharma, 2001), *Pimpinella anisum* (Kepenekci, 2003), *Gossypium hirsutum* (Goodey et al., 1965), *Malus* spp. (EFSA PLH Panel, 2022), *Zea mays* (Rhoades, 1987) and *Vitis vinicola* (Sher, 1963; Ibrahim et al., 2010, 2023).

The pest also attacks forest trees and ornamentals grown in Europe such as *Quercus palustris, Quercus rubra* (Viggars and Tarjan, 1949; Ruehle, 1967), *Chamaecyparis* (Goodey et al., 1965), *Picea abies* (Ruehle, 1967), *Picea glauca* (Goodey et al., 1965), *Pinus sylvestris*, *Pinus nigra*, *Pinus mugo* (Ruehle, 1967) and *Pinus clausa* (Ruehle, 1969). Hosts also include grasses in some common genera such as *Agropyron* (Krupinsky et al., 1983; Sun et al., 1997), *Agrostis* (Settle et al., 2006, 2007), *Cynodon* (Bae et al., 2008), *Dactylis* (Goodey et al., 1965), *Digitaria* (Goodey et al., 1965), *Elymus* (Krupinsky et al., 1983), *Festuca* and *Lolium* (Goodey et al., 1965).

3.1.4. Intraspecific diversity

There is little information on the intraspecific and geographical diversity of *H. galeatus*, except for a study showing that intraspecific and geographical diversity is small in southern USA (Holguin et al., 2015). Sexual reproduction may result in intraspecific diversity.

3.1.5. Detection and identification of the pest

Are detection and identification methods available for the pest?
Yes, both morphological and molecular methods are available for its identification.

H. galeatus can be distinguished on morphological characters, i.e. morphology of head (number of head annules and number of incisures on the basal head annule), stylet, pharyngeal glands, lateral field, posterior intestine and position of phasmids (Handoo and Golden, 1992). Regarding morphology, there may be an uncertainty in the distinction of *H. galeatus* from the closely related *H. stephanus* and *H. smokyensis* because of the need for skilled diagnosticians and advanced light microscopy techniques (Ma et al., 2019).

The whole genome of this species has been documented and molecular sequences are available for its identification (Bae et al., 2008; Ma et al., 2011; Holguin et al., 2015; https://www.ncbi.nlm.nih.gov/nuccore). In a comparative study of *Hoplolaimus* spp., Ma et al. (2011) deposited 11 sequences of *H. galeatus* in the Genbank, with accession numbers HQ678701-08 (actin), HQ678725-28 (ITS) and HQ678709 and HQ678709-12 (LSUD). In total, Genbank contains 88 annotations for *H. galeatus* including whole genome sequencing data (https://www.ncbi.nlm.nih.gov/nuccore).

3.2. Pest distribution

3.2.1. Pest distribution outside the EU

The current geographical distribution of *H. galeatus* is shown in Figure 1. A complete list of the countries and states/provinces from where *H. galeatus* has been reported is included in Appendix B. The records are based on literature, Nemaplex and the CABI Invasive Species Compendium; accessed in May 2023.

H. galeatus is widespread in the USA, where it is reported from 22 of the 50 states (Alabama, Arkansas, California, North Carolina, South Carolina, Colorado, Florida, Georgia, Illinois, Indiana, Iowa, Kansas, Louisiana, Maryland, Minnesota, Mississippi, Missouri, Pennsylvania, Tennessee, Texas, Virginia and Wisconsin). The pest is also present in South America (Argentina, Brazil, Paraguay and Peru), Africa (Egypt, Tanzania) and Asia (Bangladesh, India, Indonesia (Sumatra), Pakistan and Turkiye). The nematode was also reported in Australia (New South Wales and Western Australia) (Nambiar et al., 2008) (Figure 1 and Appendix B).

There is uncertainty on the geographical distribution outside the EU, because older literature data could not consider current morphological identification methods.

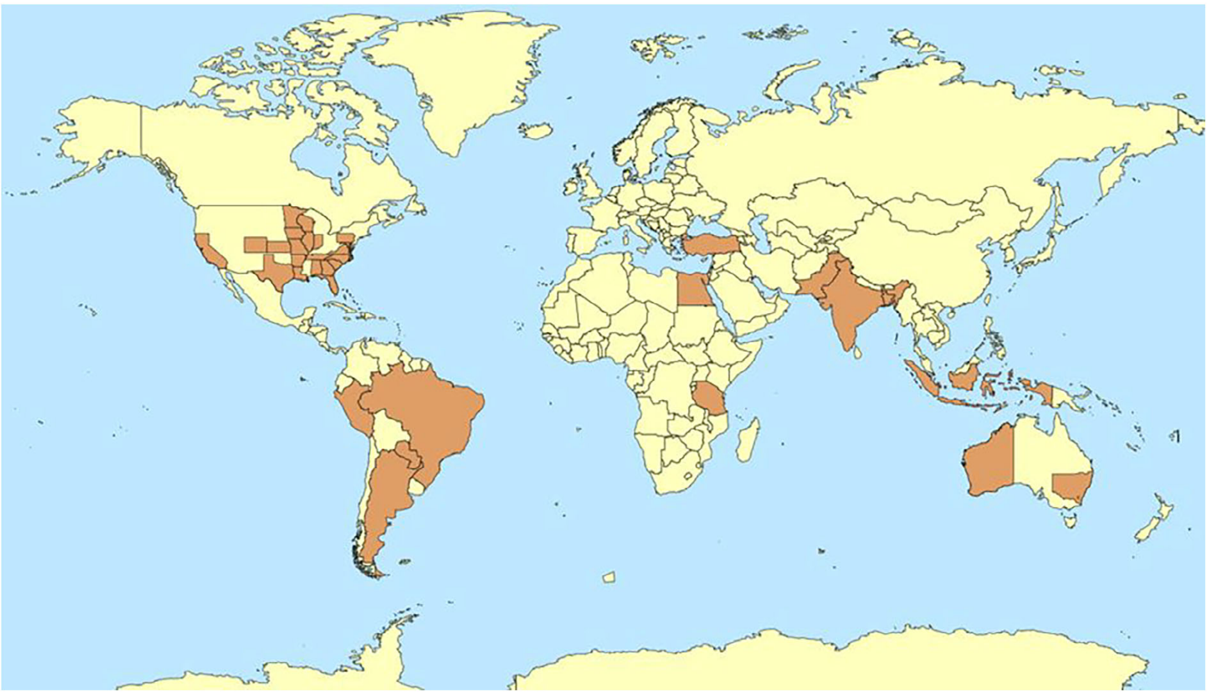

Figure 1: Global distribution of *Hoplolaimus galeatus* (Source: CABI (2021), Nemaplex (Ferris, 2023) and other literature (see Appendix B)

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**. *Hoplolaimus galeatus* is not known to be present in the EU.

Hoplolaimus galeatus is not known to be present in the EU. Fauna Europaea (https://fauna-eu.org/cdm_dataportal/taxon/30abcc32-67cf-4b06-ac6e-1392119a5bde) reports the presence of *H. galeatus* in mainland Spain. However, in Talavera and Navas (2002), this was not confirmed at the species level but only at the genus level.

The Spanish NPPO confirmed in June 2023 that the Fauna Europaea record is not reliable, given the lack of location and publication supporting it. The pest status is considered by the NPPO as 'Absent, no pest record' rather than 'Absent, invalid record'.

3.3. Regulatory status

3.3.1. Commission implementing regulation 2019/2072

Hoplolaimus galeatus 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

A list of main hosts included in Annex VI of Commission Implementing Regulation (EU) 2019/2072 is provided in Table 3. Hosts of the genera *Acer, Castanea, Diospyros, Ligustrum*, *Malus*, *Prunus, Quercus, Taxus* are included in the Commission Implementing Regulation (EU) 2018/2019 on high-risk plants.

Table 3: List of plants, plant products and other objects that are *Hoplolaimus galeatus* 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
8.	Plants for planting of [...]., *Malus* Mill., *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 [...] *Malus* Mill., *Prunus* L. [...] and their hybrids, [...]	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	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

		ex 0602 90 70 ex 0602 90 91 ex 0602 90 99	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 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
14.	Plants for planting of the family Poaceae, other than plants of ornamental perennial grasses of the subfamilies Bambusoideae and Panicoideae and of the genera *Buchloe*, *Bouteloua* Lag., *Calamagrostis*, *Cortaderia* Stapf., *Glyceria* R. Br., *Hakonechloa* Mak. ex Honda, *Hystrix*, *Molinia*, *Phalaris* L., *Shibataea*, *Spartina* Schreb., *Stipa* L. and *Uniola* L., other than seeds	ex 0602 90 50 ex 0602 90 91 ex 0602 90 99	Third countries other than Albania, Algeria, Andorra, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Canary Islands, Egypt, Faeroe Islands, Georgia, Iceland, Israel, Jordan, Lebanon, Libya, Liechtenstein, Moldova, Monaco, Montenegro, Morocco, 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 and the United Kingdom
19.	Soil as such consisting in part of solid organic substances	ex 2530 90 00 ex 3824 99 93	Third countries other than Switzerland
20.	Growing medium as such, other than soil, consisting in whole or in part of solid organic substances, other than that composed entirely of peat or fibre of *Cocos nucifera* L., previously not used for growing of plants or for any agricultural purposes	ex 2530 10 00 ex 2530 90 00 ex 2703 00 00 ex 3101 00 00 ex 3824 99 93	Third countries other than Switzerland

3.4. Entry, establishment and spread in the EU

3.4.1. Entry

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

Yes, the pathways are plants for planting, except seeds, and soil as a contaminant.

The main pathways of entry are plants for planting, except seeds, but including turf rolls, as well as soil as a contaminant (Table 4).

Table 4: Potential pathways for *Hoplolaimus galeatus* 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]
Soil as a contaminant	All	Soil as such is not allowed to be imported from third countries, other than Switzerland (Annex VI, 19).
Growing media attached to or associated with host and non-host plants	All	There are several requirements for growing media (Annex VII 1).
Host plants for planting, other than seed	All	See Table 3 for prohibited host plants for planting.
Machinery and vehicles which have been operated for agricultural purposes in infested areas		Official statement that machinery and vehicles are cleaned and free from soil and plant debris (Annex VII 2).

Untreated field soil from third countries (other than Switzerland) including soil attached to plants is prohibited to be imported into the EU (Annex VI, 19).

Notifications of interceptions of harmful organisms began to be compiled in Europhyt in May 1994 and in TRACES in May 2020. There are no records of interceptions of *H. galeatus* in EUROPHYT and Traces databases, as of June 2023. California intercepted the pest multiple times on plants with soil from Florida (Scheck, 2022).

3.4.2. Establishment

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

Yes, the pest can become established in the EU, as hosts are widely distributed and climatic conditions are suitable.

3.4.2.1. EU distribution of main host plants

Hosts of *H. galeatus* are commonly cultivated throughout the risk assessment area (Table 5).

Table 5: Harvested area of *Hoplolaimus galeatus* main hosts in EU, 2016–2020 (1,000 ha). Source EUROSTAT (accessed 30/05/2023)

Crop	CN Code	2016	2017	2018	2019	2020
Barley	C1300	11,179.59	10,862.69	11,144.80	11,138.94	11,016.58
Cotton	I1150	301.35	326.12	345.64	361.78	344.35
Wheat & spelt	C1100	25,210.30	24,138.62	23,751.66	24,212.28	22,768.45
Green maize	G3000	6,061.45	5,985.90	6,134.91	6,210.36	6,325.30
Peppers	V3600	59.95	59.50	58.92	59.60	57.41
Apples	F1110	505.66	504.61	506.27	491.08	484.63
Peaches	F1210	156.39	154.06	150.80	144.78	137.07
Oranges	T1000	278.67	272.42	273.64	271.97	275.39
Rice	C2000	448.74	440.68	417.37	419.09	427.55
Soya	I1130	831.18	962.39	955.40	907.91	942.50

H. galeatus is well known as a pest of forest trees in USA (Ruehle, 1967). This nematode has been reported to impair establishment of *Pinus taeda* and *P. eliottii* in plantations in southern USA (Ruehle and Sasser, 1962).

Three *Pinus* species common in the EU (*P. sylvestris, P. nigra* and *P. mugo*) are hosts of *H. galeatus* (Section 3.1.3). Figure 2 shows the relative probability of the presence of the genus *Pinus* in Europe.

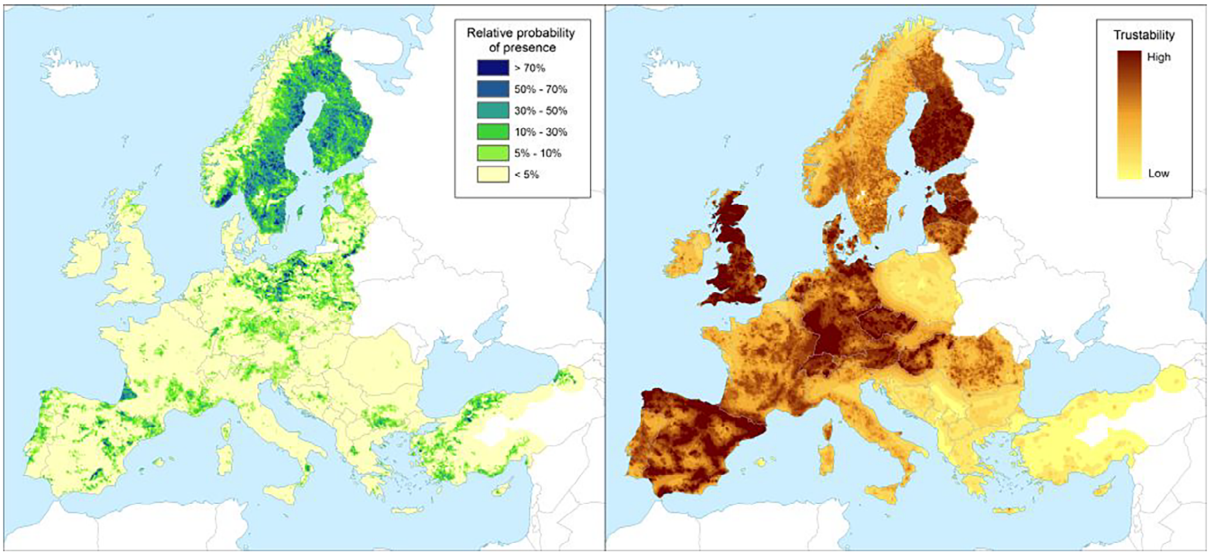

Figure 2: Left panel: Relative probability of presence (RPP) of the genus *Pinus* in Europe, mapped at 100 km^2 resolution. The underlying data are from European-wide forest monitoring data sets and from national forestry inventories based on standard observation plots measuring in the order of hundreds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

3.4.2.2. Climatic conditions affecting establishment

A Köppen–Geiger comparison (Figure 3) shows that most of the EU is likely to be suitable for pest establishment, because the range of climates in EU includes climates in countries where *H. galeatus* is reported.

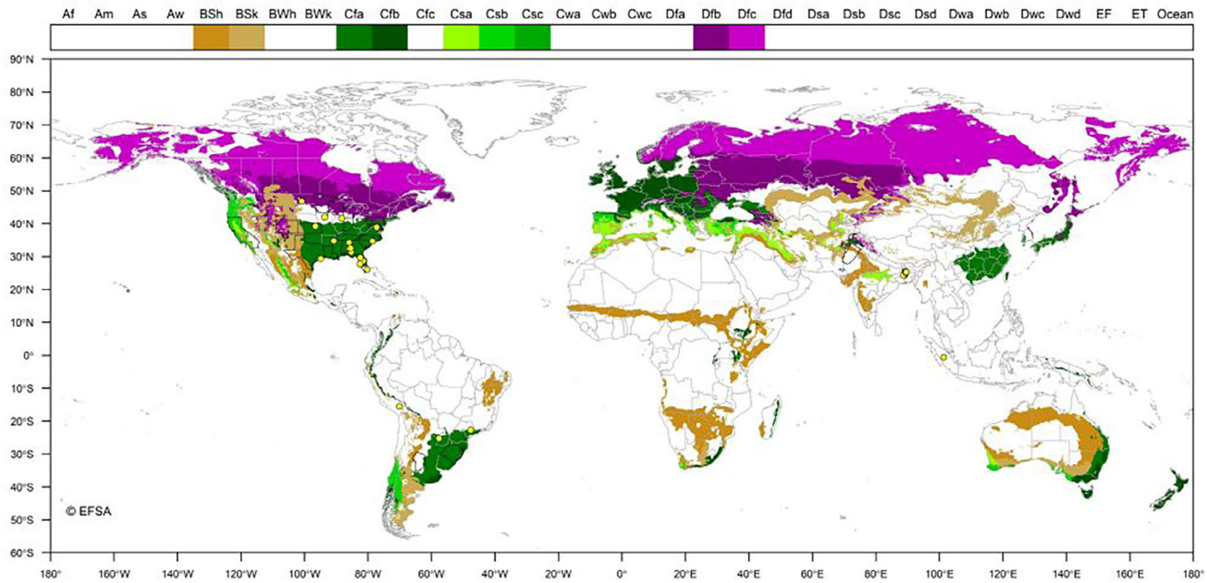

Figure 3: Distribution of nine Köppen–Geiger climate types, i.e. BSh, BSk, Cfa, Cfb, Csa, Csb, Csc, Dfb and Dfc that occur in the EU and in countries where *Hoplolaimus galeatus* has been reported. The legend shows the list of Köppen–Geiger climates. Yellow dots indicate point locations where *H. galeatus* was reported (Appendix B)

3.4.3. Spread

Describe how the pest would be able to spread within the EU territory following establishment? Following its establishment, *H. galeatus* could potentially spread within the EU by natural and human-assisted means. *Comment on plants for planting as a mechanism of spread*. Plants for planting are the main means of spread of this pest.

The pest can easily spread with plants for planting due to the internal root infection. This may especially concern ornamental trees, which may not readily show clear symptoms due to their large size. Additional possible means of spread include natural ones (run-off water, flooding, landslides) and human-assisted ones including tubers, corms, roots, movement of soil, soil adherent to non-host plants, machinery, footware and packaging.

3.5. Impacts

Would the pests' introduction have an economic or environmental impact on the EU territory? **Yes**, the pest introduction would have an economic and environmental impact in the EU.

Hoplolaimus galeatus has been reported to have a high impact on several host plants. In turf, the nematode infection results in patches of chlorotic plants. The patches enlarge over time with wilting plants showing dark necrotic roots lacking normal development of lateral roots (Crow and Brammer, 2015).

In North Carolina, severe damage was reported in cotton, *Gossypium hirsutum*, in connection with field infestation of *H. galeatus*. Infected plants were severely stunted, chlorotic and defoliated. The pest lived both as an ectoparasite and endoparasite. Nematodes infecting the roots caused considerable damage in the cortex because of their migration through the tissue. The vascular and phloem tissue was preferred resulting in severe damage, including abnormal cell divisions of phloem parenchyma, and occasional formation of tyloses in xylem vessels (Krusberg and Sasser, 1956). The pest is also reported to damage wheat (Sharma, 2001).

In pine (*Pinus eliottii* and *P. taeda*), trees infected by *H. galeatus* became chlorotic, wilted and stunted with few lateral roots (Ruehle and Sasser, 1962). In roots of both pine species, the damage was concentrated to the cortex and caused by the migration of the nematodes (Ruehle, 1962, 1973). Oak (*Quercus palustris* and *Q. rubra*) trees showed hypersensitivity to drought and had chlorotic and necrotic leaves, as well as growth fissures on stems. Root systems had few fibrous roots (Viggars and Tarjan, 1949).

Plants which could potentially be affected in the EU include: barley, wheat, rye, red and white clover, alfalfa, beans, cabbage, pine, spruce, oak, apple, grapevine, as well as various ornamental plants and turf (Appendix A). Well-documented cases of impact relate to oak (Viggars and Tarjan, 1949), cotton (Krusberg and Sasser, 1956), pine (Ruehle, 1962; Ruehle and Sasser, 1962), sycamore (Churchill and Ruehle, 1971; Ruehle, 1971) and turf (Crow and Brammer, 2015).

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**. Although not specifically targeted against *H. galeatus*, existing phytosanitary measures (see Sections 3.3.2 and 3.4.1) mitigate the likelihood of the pest entry into the EU territory on certain host plants. Potential additional measures are also available to further mitigate the risk of entry, establishment, spread and impacts of the pest in the EU (see Section 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	• Plants come from country officially free from pest. • Plants originate in a pest-free area. • Plants come from a pest free 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. Plants originate in a place of production with complete physical isolation. Turf is composed by typical host plants of *H. galeatus*, so in areas with turf production, it is essential to keep it isolated from production sites.	Entry (reduce contamination/infestation)/spread
Managed growing conditions	Plants grown in pots at least 50 cm above ground targets nematodes.	Entry (reduce contamination/infestation)/spread
Crop rotation, associations and density, weed/volunteer control	Crop rotation, associations and density, weed/volunteer control are used to prevent problems related to pests and are usually applied in various combinations to make the habitat less favourable for pests. The measures deal with (1) allocation of crops to field (over time and space) (multi-crop, diversity cropping) and (2) to control weeds and volunteers as hosts of pests/vectors. Pre-cropping of Bahia grass (*Paspalum notatum*) and drilling it in before peanuts was reported effective for the control of *H. galeatus* (Norden et al., 1977). This was also the case for cotton (*Gossypium hirsutum*) as reported by Rodriguez-Kabana et al. (1993).	Entry/establishment/impact
Use of resistant and tolerant plant species/varieties	Resistant plants are used to restrict the growth and development of a specified pest and/or the damage they cause when compared to susceptible plant varieties under similar environmental conditions and pest pressure. • It is important to distinguish resistant from tolerant species/varieties. Resistant plants for this pest are very few.	Entry/establishment/impact
Chemical treatments on crops including reproductive material	*H. galeatus* is difficult to control with chemicals. In the past, fumigation with D-D was reported effective in reducing the rate of field infection (Ruehle and Sasser, 1962). This chemical is outdated and probably not available on the market. Root dips in pesticides were also reported effectful. On infected Bermuda grass, root dips for 30 min in Fenamiphos (ethyl 4-(methylthio)-m-tolyl isopropyl-phosphoramidate) (Bay 68138) was reported to control *H. galeatus* (Johnson, 1970). Fenamiphos is not approved in the EU. There is no information on the effect of other alternative nematicides on *H. galeatus*. Dipping roots in hot water (hot water treatment) could reduce the	Entry/establishment/impact

Control measure/Risk reduction option (Blue underline = Zenodo doc, Blue = WIP)	RRO summary	Risk element targeted (entry/establishment/spread/impact)
	abundance of the pest, but there are no protocols available for hot water treatment regarding *H. galeatus*.	
Chemical treatments on consignments or during processing	Use of chemical compounds that may be applied to plants or to plant products after harvest, during process or packaging operations and storage. 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
Cleaning and disinfection of facilities, tools and machinery	The physical and chemical cleaning and disinfection of facilities, tools, machinery, transport means, facilities and other accessories (e.g. boxes, pots, pallets, palox, supports, hand tools). The measures addressed in this information sheet are washing, sweeping and fumigation. Clean facilities of production and clean equipment would be helpful in preventing infestation of commodities.	Entry/spread
Limits on soil	• Plants and other pathway agents (e.g. used farm machinery) should be free from soil or growing medium; • Use of clean growing medium is important. The growing medium should be free from soil and organic matter and should not have been used for growing plants or agricultural purposes. The growing medium can be composed entirely of peat or fibre. Alternatively, the medium should have been fumigated or heat treated to be free of pests. The medium may also have been subjected to an effective systems approach to ensure pest freedom. • Consignments or lots of root vegetables, bulbs, corms and rhizomes should not contain more than 1% by net weight of soil (see Section 3.4.1). This is to some degree helpful, but in respect to *H. galeatus* nematodes may still be in the roots.	Entry/spread
Soil treatment	The control of soil organisms by chemical and physical methods listed below: (a) Fumigation; (b) heating; (c) solarisation (for seasonal crops); (d) flooding; (e) soil suppression; (f) augmentative biological control; (g) biofumigation fumigation, steaming, solarisation, flooding, adding organic material to soil would all be effective against the pest. In early studies, fumigation reduced the impact of *H. galeatus* in field plots of loblolly pine, *Pinus taeda* (Ruehle and Sasser, 1962), but the chemicals used are not allowed in the EU. *H. galeatus* may be controlled by addition of carbon material and keeping flooded conditions. Population densities of *H. galeatus* in turf plots with *Poa annua* and *Agrostis palustris* were reduced by 97% by adding molasses to soil and keeping high water contents (Browning et al., 1999). Addition of organic material also alleviated disease expression on *Quercus rubra* and *Q. palustris* (Viggars and Tarjan, 1949).	Entry/establishment/impact

Control measure/Risk reduction option (Blue underline = Zenodo doc, Blue = WIP)	RRO summary	Risk element targeted (entry/establishment/spread/impact)
Use of non-contaminated water	Chemical and physical treatment of water to eliminate waterborne microorganisms. The measures addressed in this information sheet are: chemical treatments (e.g. chlorine, chlorine dioxide, ozone); physical treatments (e.g. membrane filters, ultraviolet radiation, heat); ecological treatments (e.g. slow sand filtration). Clean water would be helpful in reducing infection of consignments.	Entry/spread
Waste management	Waste (plants and soil) should be collected and kept in a place isolated from the production area. Deep burial, composting and incineration are effective methods.	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. The measures addressed in this information sheet are autoclaving; steam; hot water; hot air; cold treatment. Heat treatment (autoclaving, steaming of soil and growing media) and hot water dips of plant roots would be helpful in reducing infestations of consignments.	Entry/spread
Post-entry quarantine and other restrictions of movement in the importing country	This information sheet covers post-entry quarantine 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. This is helpful because symptoms may not be present at the time of importation.	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	Inspection is defined 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 (ISPM 5). The effectiveness of sampling and subsequent inspection to detect pests may be enhanced by including trapping and luring techniques. • Growing season inspections conducted and no pests or symptoms detected on shoots or roots; • Plants for export are inspected prior to export, and no pest found or symptoms detected on the root system.	Establishment/spread

Supporting measure (Blue underline = Zenodo doc, Blue = WIP)	Summary	Risk element targeted (entry/establishment/ 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. Testing of growing media would be important.	Entry/establishment
Sampling	According to ISPM 31, 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. Important to sample symptomatic plants if detected.	Entry/spread
Phytosanitary certificate and plant passport	An official paper document or its official electronic equivalent, consistent with the model certificates of the IPPC, attesting that a consignment meets phytosanitary import requirements (ISPM 5) a) export certificate (import) b) plant passport (EU internal trade)	Entry, establishment, 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, establishment, 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
Delimitation of Buffer zones	ISPM 5 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' (ISPM 5). 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 is a good means to guarantee that plants originate from a pest-free area or a pest-free place of production.	Spread

3.6.1.3. Biological or technical factors limiting the effectiveness of measures

- Plants may be asymptomatic, and symptoms may develop gradually so frequent inspections are needed to detect infested plants.
- Laboratory testing without root incubation may fail in detecting early infections.
- Unskillful microscopy may not detect the pest.
- Failure in waste management within premises may increase infestation with the pest.
- Too little surveillance of the pest will increase the risk of infection.
- Failure in fulfilment of the requirements stated in the phytosanitary certificates and shortcomings in traceability would put the product at risk from pest infestation.
- Root washings that are frequently used against nematodes are ineffective against *H. galeatus* because it is an endoparasite.

3.7. Uncertainty

There are no key uncertainties potentially affecting the conclusions.

4. Conclusions

Hoplolaimus galeatus has not been reported from the EU. It can potentially damage a wide range of plants used in agriculture, horticulture, forestry, as well as ornamental plants including turf. The climatic conditions of vast areas of EU are suitable for establishment, and many potential host plants are grown over wide areas.

H. galeatus therefore meets the criteria that are within the remit of EFSA to assess for this species 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)	Yes, the identity of *H. galeatus* is clearly defined.	None
Absence/presence of the pest in the EU (Section 3.2)	The pest is not known to be present in the EU.	None
Pest potential for entry, establishment and spread in the EU (Section 3.4)	Yes, with plants for planting and movement of soil.	None
Potential for consequences in the EU (Section 3.5)	Yes, due to the presence of many host plants and a suitable climate.	None
Available measures (Section 3.6)	Measures are available to prevent pest entry, establishment, spread and impact.	None
Conclusion (Section 4)	All criteria assessed by EFSA above for consideration as a potential quarantine pest were met.	
Aspects of assessment to focus on/ scenarios to address in future if appropriate:	Surveys to clarify the distribution of the pest worldwide would be beneficial.	

References

Abedin N, Ara N, Ali MS and Khalequzzaman M, 2011. Nematode diversity in banana rhizosphere from northern districts of Bangladesh. Journal of Bio-Science, 19, 65–75.

Adams JR, Rodriguez-Kabana R and King PS, 1979. The non-target effects of pentachloronitrobenzene on plant parasitic and free-living nematodes. Nematropica, 9, 110–122.

Ahmed M and Chen TA, 1980. Effect of certain environmental factors and host plants on reproduction of *Hoplolaimus galeatus*. Plant Disease, 64, 479–480.

Alby T, Ferris JM and Ferris VR, 1983. Dispersion and distribution of *Pratylenchus scribneri* and *Hoplolaimus galeatus* in soybean fields. Journal of Nematology, 15, 418–426.

Allen JB, Bond JP and Schmidt ME, 2005. Incidence of *Meloidogyne incognita* and development of resistant soybean germplasm in Illinois. Plant Health Progress, 6, 1–10.

Bae CH, Szalanski AL and Robbins RT, 2008. Molecular analysis of the lance nematode, *Hoplolaimus* spp., using the first internal transcribed spacer and the D1-D3 expansion segments of 28S Ribosomal DNA. Journal of Nematology, 40, 201–209.

Bossard M, Feranec J and Otahel J, 2000. CORINE land cover technical guide - Addendum 2000. Tech. Rep. 40, European Environment Agency. Available online: https://www.eea.europa.eu/ds_resolveuid/032TFUPGVR

Browning M, Dawson C, Alm SR, McElderry CF and Amador JA, 1999. Effect of carbon amendment and soil moisture on *Tylenchorhynchus* spp. and *Hoplolaimus galeatus*. Journal of Nematology, 31, 445.

Büttner G, Kosztra B, Maucha G and Pataki R, 2012. Implementation and achievements of CLC2006. Technical Report. European Environment Agency. Available online: http://www.eea.europa.eu/ds_resolveuid/GQ4JECM8TB

CABI, 2021. *Hoplolaimus galeatus*. CABI Compendium https://doi.org/10.1079/cabicompendium.27520

Churchill RC and Ruehle JL, 1971. Occurrence, parasitism, and pathogenicity of nematodes associated with sycamore (*Platanus occidentalis* L.). Journal of Nematology, 3, 189–196.

Ciancio A, Farfan VV, Torres EC and Grasso G, 1998. Observations on a *Pasteuria* isolate parasitic on *Hoplolaimus galeatus* in Peru. Journal of Nematology, 30, 206–210.

Crow WT and Brammer AS, 2015. Lance Nematode, *Hoplolaimus galeatus* (Cobb, 1913) Thorne, 1935 (Nematoda: Secernentea: Tylenchida: Tylenchoidea: Hoplolaimidae). University of Florida IFAS Extension. Available online: https://entnemdept.ufl.edu/creatures/nematode/lance_nematode.htm [Accessed June 2023].

Cuarezma-Terán JA, Trevathan LE and Bost SC, 1984. Nematodes associated with *Sorghum* in Mississippi. Plant Disease, 68, 1083–1085.

da Luz WC, 1982. Nematoides fitoparasitas associados com trigo no Rio Grande do Sul. Pesquisa Agropecuária Brasileira, 17, 215–217.

de Rigo D, 2012. Semantic Array Programming for environmental modelling: application of the Mastrave library. In: R Seppelt, AA Voinov, S Lange and 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. Available online: http://scholarsarchive.byu.edu/iemssconference/2012/Stream-B/69

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

de Rigo D, Caudullo G, Houston Durrant T and 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 and A Mauri (eds). European Atlas of Forest Tree Species. Publ. Off. EU, Luxembourg. e01aa69+. Available online: https://w3id.org/mtv/FISE-Comm/v01/e01aa69

de Rigo D, Caudullo G, San-Miguel-Ayanz J and Barredo JI, 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

Donald PA, Holguin CM and Agudelo PA, 2013. First report of lance nematode (*Hoplolaimus magnistylus*) on corn, soybean, and cotton in Tennessee. Plant Disease, 97, 1389.

Doucet ME, 1980. Description of 2 new *Peltamigratus* species and of a *Hoplolaimus galeatus* population from Cordoba province, Argentina. Nematologica, 26, 34–46.

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 JA, MacLeod A, Navajas Navarro M, Niere B, Parnell S, Potting R, Rafoss T, Rossi V, Urek G, Van Bruggen A, Van Der Werf W, West J, Winter S, Hart A, Schans J, Schrader G, Suffert M, Kertesz V, Kozelska S, Mannino MR, Mosbach-Schulz O, Pautasso M, Stancanelli G, Tramontini S, Vos S and Gilioli G, 2018. Guidance on quantitative pest risk assessment. EFSA Journal 2018;16(8):5350, 86 pp. https://doi.org/10.2903/j.efsa.2018.5350

EFSA PLH Panel (EFSA Panel on Plant Health), Bragard C, Baptista P, Chatzivassiliou E, Gonthier P, Jaques Miret JA, Justesen Af, MacLeod A, Magnusson CS, Milonas P, Navas-Cortes JA, Parnell S, Potting R, Reignault PL, Stefani E, Thulke H-H, Van der Werf W, Civera AV, Zappala L, Lucchi A, G omez P, Urek G, Bernardo U, Bubici G, Carluccio AV, Chiumenti M, Di Serio F, Fanelli E, Gardi C, Marzachı C, Mosbach-Schulz O and Yuen J, 2022. Scientific Opinion on the commodity risk assessment of *Malus domestica* plants from Turkey. EFSA Journal 2022;20(5):7301, 185 pp. https://doi.org/10.2903/j.efsa.2022.730

EFSA PLH Panel (EFSA Panel on Plant Health), Bragard C, Baptista P, Chatzivassiliou E, Gonthier P, Jaques Miret JA, Justesen AF, MacLeod A, Magnusson CS, Milonas P, Navas-Cortes JA, Parnell S, Potting R, Reignault PL, Stefani E, Thulke H-H, Van der Werf W, Vicent Civera A, Zappalà L, Lucchi A, Gómez P, Urek G, Bernardo U, Bubici G, Carluccio AV, Chiumenti M, Di Serio F, Fanelli E, Kaczmarek A, Marzachì C, Mosbach-Schulz O and Yuen J, 2023.

Scientific Opinion on the commodity risk assessment of *Prunus persica* and *P. dulcis* plants from Türkiye. EFSA Journal 2023;21(1):7735, 212 pp. https://doi.org/10.2903/j.efsa.2023.7735

EFSA Scientific Committee, Hardy A, Benford D, Halldorsson T, Jeger MJ, Knutsen HK, More S, Naegeli H, Noteborn H, Ockleford C, Ricci A, Rychen G, Schlatter JR, Silano V, Solecki R, Turck D, Benfenati E, Chaudhry QM, Craig P, Frampton G, Greiner M, Hart A, Hogstrand C, Lambre C, Luttik R, Makowski D, Siani A, Wahlstroem H, Aguilera J, Dorne J-L, Fernandez Dumont A, Hempen M, Valtue~na Martınez S, Martino L, Smeraldi C, Terron A, Georgiadis N and Younes M, 2017. Scientific Opinion on the guidance on the use of the weight of evidence approach in scientific assessments. EFSA Journal 2017;15(8):4971, 69 pp. https://doi.org/10.2903/j.efsa.2017.4971

Eisenback JD, 2018. Plant parasitic nematodes of Virginia and West Virginia. In: SA Subbotin and JJ Chitasmbar (eds). Plant Parasitic Nematodes in Sustainable Agriculture of North America. Springer. pp. 277–304. Available online: https://link.springer.com/chapter/10.1007/978-3-319-99588-5_11

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

EPPO (European and Mediterranean Plant Protection Organization), online. EPPO Global Database. Available online: https://gd.eppo.int [Accessed June 2023].

EUFGIS (European Information System on Forest Genetic Resources), online. EUFGIS database. Available online: http://portal.eufgis.org

FAO (Food and Agriculture Organization of the United Nations), 2013. ISPM (International Standards for Phytosanitary Measures) 11—Pest risk analysis for quarantine pests. FAO, Rome, 36 pp. Available online: 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), 2022. International Standards for Phytosanitary Measures. ISPM 5 Glossary of phytosanitary terms. FAO, Rome. Available online: https://www.fao.org/3/mc891e/mc891e.pdf

Ferris H, 2023. Nemaplex (The Nematode-Plant Expert Information System). Available online: http://nemaplex.ucdavis.edu/ [Accessed: May 2023].

Goodey JB, Franklin MT and Hooper DJ, 1965. T. Goodey's: The Nematode Parasites of Plants Catalogued Under Their Hosts. Third edn. Commonwealth Agricultural Bureaux, Farnham Royal, Bucks, England. 140 p.

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

Handoo Z and Golden AM, 1992. A key and diagnostic compendium to the species of the genus *Hoplolaimus* Daday, 1905 (Nematoda: Hoplolaimidae). Journal of Nematology, 24, 45–53.

Haroon S and Smart GC, 1984. Effects of eight species of nematodes on Pangola and Transvala digitgrasses. Nematologica, 30, 241–243.

Henn RA and Dunn RA, 1989. Reproduction of *Hoplolaimus galeatus* and growth of seven St. Augustinegrass (*Stenotaphrum secundatum*) cultivars. Nematropica, 19, 81–87.

Hiederer R, Houston Durrant T, Granke O, Lambotte M, Lorenz M, Mignon B and 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 and 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

Hixson AC, Crow WT, McSorley R and Trenholm LE, 2004. Host status of 'SeaIsle 1' seashore paspalum (*Paspalum vaginatum*) to *Belonolaimus longicaudatus* and *Hoplolaimus galeatus*. Journal of Nematology, 36, 493–498.

Holguin CM, Baeza JA, Mueller JD and Agudelo P, 2015. High genetic diversity and geographic subdivision of three lance nematode species (*Hoplolaimus* spp.) in the United States. Ecology and Evolution, 5, 2929–2944.

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

Houston Durrant T, San-Miguel-Ayanz J, Schulte E and 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

Ibrahim IK, Mokbel AA and Handoo ZA, 2010. Current status of phytoparasitic nematodes and their host plants in Egypt. Nematropica, 40, 239–262.

Ibrahim IK, Kantor M and Handoo ZA, 2023. Current status of genera and species of phytoparasitic nematodes in Egypt. Nematropica, in press. Available online: https://journals.flvc.org/nematropica/article/view/134242 [Accessed June 2023].

INRAE, 2020. INRAe, Biogeco, EvolTree. GD^2 database. Available online: http://gd2.pierroton.inra.fr [Accessed June 2023].

Johnson AW, 1970. Control of the Lance Nematode, *Hoplolaimus galeatus*, on 'Tifdwarf' Bermudagrass by Chemical Dips. Journal of Nematology, 2, 179–181.

Kepenekci I, 2003. Preliminary list of Tylenchida (Nematoda) associated with anise (*Pimpinella anisum* L.) in Turkey. Pakistan Journal of Nematology, 21, 37–40.

Krupinsky JM, Barker RE and Donald PA, 1983. Frequency of plant-parasitic nematodes associated with blue grama and Western wheatgrass in the Western Dakotas. Plant Disease, 67, 399–401.
Krusberg LR and Sasser JN, 1956. Host-parasite relationships of the lance nematode in cotton roots. Phytopathology, 46, 505–510.
Ma X, Agudelo P, Mueller JD and Knap HT, 2011. Molecular characterization and phylogenetic analysis of *Hoplolaimus stephanus*. Journal of Nematology, 43, 25–34.
Ma X, Robbins RT, Bernard EC, Holguin CM and Agudelo P, 2019. Morphological and molecular characterisation of *Hoplolaimus smokyensis* n. sp. (Nematoda: Hoplolaimidae), a lance nematode from Great Smoky Mountains National Park, USA. Nematology, 21, 923–935.
Ma X, Agudelo P, Richards VP and Baeza JA, 2022. Genome survey sequencing of the phyto-parasitic nematode *Hoplolaimus galeatus*. PeerJ, 10, e12749.
MacGowan JB and Dunn RA, 1989. *Hoplolaimus galeatus*: lance nematode on St. Augustinegrass from Florida. Florida Department of Agriculture, Division of Plant Industry. Nematology Circular (161).
Marais M, van den Berg E, Fourie H and Rashidifard M, 2020. Morphological and molecular characterization of *Hoplolaimus pararobustus* (Schuurmans Stekhoven and Teunissen, 1938) Sher 1963 with its first report on *Zea mays* roots in Namibia. Journal of Nematology, 52, 1–12.
Mashela P, McSorley R, Duncan LW and Dunn RA, 1991. Correlation of *Belonolaimus longicaudatus*, *Hoplolaimus galeatus*, and soil texture with yield of Alyceclover (*Alysicarpus* spp.). Nematropica, 21, 177–184.
Mashela P, McSorley R and Duncan LW, 1992. Damage potential and reproduction of *Belonolaimus longicaudatus* and *Hoplolaimus galeatus* on Alyceclover. Journal of Nematology, 24, 438–441.
Nambiar L, Quader M and Nobbs JM, 2008. First record of *Hoplolaimus galeatus* in Australia. Australasian Plant Disease Notes, 3, 145–146.
Nguyen TH, Bui QD and Trinh PQ, 2015. Description of *Hoplolaimus bachlongviensis* sp. n. (Nematoda: Hoplolaimidae) from banana soil in Vietnam. Biodiversity Data Journal, 3, e6523.
Norden AJ, Perry VG, Martin FG and NeSmith J, 1977. Effect of age of bahiagrass sod on succeeding peanut crops. Peanut Science, 4, 71–74.
Norton DC and Edwards J, 1988. Age structure and community diversity of nematodes associated with maize in Iowa sandy soils. Journal of Nematology, 20, 340.
Pokharel R, 2011. Importance of Plant Parasitic Nematodes in Colorado. Fact Sheet No. 2.952. Crops ColoradoState University, Western Colorado Research Center. 5/2011.
Rhoades HL, 1981. Effect of nematicides on yield of pepper in *Belonolaimus longicaudatus* infested soil. Nematropica, 11, 121–127.
Rhoades HL, 1987. Effects of *Hoplolaimus galeatus* on ten vegetable crops in Florida. Nematropica, 17, 213–218.
Riffle JW, 1972. Effect of certain nematodes on the growth of *Pinus edulis* and *Juniperus monosperma* seedlings. Journal of Nematology, 4, 91–94.
Rodriguez-Kabana R and Ingram EG, 1978. Susceptibility of pigeon peas to plant parasitic nematodes in Alabama. Nematropica, 8, 32–34.
Rodriguez-Kabana R and Thurlow DL, 1980. Effect of *Hoplolaimus galeatus* and other nematodes on yield of selected soybean cultivars. Nematropica, 10, 130–138.
Rodriguez-Kabana R, Robertson DG and Bannon J, 1993. Bahiagrass-cotton rotations and the management of *Meloidogyne incognita* and *Hoplolaimus galeatus*. Nematropica, 23, 141–147.
Ruehle JL, 1962. Histopathological studies on pine roots infected with lance and pine cystoid nematodes. Phytopathology, 52, 68–71.
Ruehle JL, 1967. Distribution of Plant-Parasitic Nematodes Associated with Forest Trees of the World. U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station, Ashville, North Carolina. 155 pp.
Ruehle JL, 1969. Nematodes parasitic on forest trees II. Reproduction of endoparasites on pines. Nematologica, 15, 76–90.
Ruehle JL, 1971. Nematodes parasitic on forest trees: III. reproduction on selected hardwoods. Journal of Nematology, 3, 170–173.
Ruehle JL, 1973. Nematodes and forest trees—types of damage to tree roots. Annual Review of Phytopathology, 11, 99–118.
Ruehle JL and Sasser JN, 1962. The role of plant-parasitic nematodes in stunting pines in southern plantations. Phytopathology, 52, 56–68.
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 and A Mauri (eds). European Atlas of Forest Tree Species. Publ. Off. EU, Luxembourg. e012228+. Available online: https://w3id.org/mtv/FISE-Comm/v01/e012228
San-Miguel-Ayanz J, de Rigo D, Caudullo G, Houston Durrant T and Mauri A, 2016. European Atlas of Forest Tree Species. Publication Office of the European Union, Luxembourg ISBN: 978-92-79-36740-3. Available online: https://w3id.org/mtv/FISE-Comm/v01
Sayers EW, Cavanaugh M, Clark K, Ostell J, Pruitt KD and Karsch-Mizrachi I, 2020. Genbank. Nucleic Acids Research, 48(Database issue), D84–D86. https://doi.org/10.1093/nar/gkz956

Scheck HJ, 2022. California Pest Rating Proposal for *Hoplolaimus galeatus* (Cobb, 1913) Filipjev & Schuurmans Stekh - Lance nematode. California Department of Food and Agriculture, 7 pp. Available online: https://blogs.cdfa.ca.gov/Section3162/wp-content/uploads/2022/04/Hoplolaimus-galeatus_ADA_PRP.pdf [Accessed June 2023].

Settle DM, Todd TC, Fry JD and Tisserat NA, 2005. Influence of soil temperature on host suitability of eight turfgrass species to the lance nematode (*Hoplolaimus galeatus*). International Turfgrass Society Research Journal, 10, 265–272.

Settle DM, Fry JD, Todd TC and Tisserat NA, 2006. Population dynamics of the lance nematode (*Hoplolaimus galeatus*) in creeping bentgrass. Plant Disease, 90, 44–50.

Settle DM, Fry JD, Milliken GA, Tisserat NA and Todd TC, 2007. Quantifying the effects of lance nematode parasitism in creeping bentgrass. Plant Disease, 91, 1170–1179.

Sharma SB, 2001. Plant parasitic nematodes in rice-wheat based cropping systems in South Asia. Journal of Crop Production, 4, 227–247.

Sher SA, 1963. Revision of the Hoplolaiminae (Nematoda) II. *Hoplolaimus* Daday, 1905 and *Aorolaimus* n. gen. Nematologica, 9, 267–295.

Sun H, Schmidt RE and Eisenback JD, 1997. The effect of seaweed concentrate on the growth of nematode-infected bent grown under low soil moisture. International Turfgrass Society Research Journal, 8, 1336–1342.

Talavera M and Navas A, 2002. Incidence of plant-parasitic nematodes in natural and semi-natural mountain grassland and the host status of some common grass species. Nematology, 4, 541–552.

Tedford EC and Jaffee BA, 1995. In vitro parasitism of *Rotylenchus robustus* by isolates of *Hirsutella rhossiliensis*. Journal of Nematology, 27, 486.

Toy SJ and Newfield MJ, 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, 123–133.

Viggars RM and Tarjan AC, 1949. A new root disease of pin oaks possibly caused by the nematode *Hoplolaimus coronatus*. Plant Disease Report, 33, 132–133.

Walters SA, Bond JP, Babadoost M, Edwards DI and Handoo ZA, 2004. Plant-parasitic nematodes associated with horseradish in Illinois. Nematropica, 191–198.

Zeng Y, Ye W, Martin SB, Martin M and Tredway L, 2012a. Diversity and occurrence of plant-parasitic nematodes associated with golf course turfgrasses in North and South Carolina, USA. Journal of Nematology, 44, 337–347.

Zeng Y, Ye W, Tredway L, Martin S and Martin M, 2012b. Taxonomy and morphology of plant-parasitic nematodes associated with turfgrasses in North and South Carolina, USA. Zootaxa, 3452, 1–46.

Abbreviations

CABI	Centre for Agriculture and Bioscience International
EPPO	European and Mediterranean Plant Protection Organization
EUFGIS	European Information System on Forest Genetic Resources
FAO	Food and Agriculture Organization
IPPC	International Plant Protection Convention
ISPM	International Standards for Phytosanitary Measures
MS	Member State
Nemaplex	The Nematode-Plant Expert Information System
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, 2022).
Control (of a pest)	Suppression, containment or eradication of a pest population (FAO, 2022).
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, 2022).
Eradication (of a pest)	Application of phytosanitary measures to eliminate a pest from an area (FAO, 2022).
Establishment (of a pest)	Perpetuation, for the foreseeable future, of a pest within an area after entry (FAO, 2022).

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 and 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, 2022).
Pathway	Any means that allows the entry or spread of a pest (FAO, 2022).
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, 2022).
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, 2022).
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, 2022)

Appendix A – *Hoplolaimus galeatus* host plants/species affected

Source: CABI Crop Protection Compendium (CABI, 2021), Nemaplex (Ferris, 2023) and other literature.

Host status	Host name	Plant family	Common name	Reference
Cultivated hosts	*Acer negundo*	Sapindaceae	Box elder	Ruehle (1967)
	Acer palmatum	Sapindaceae	Japanese marple	Ruehle (1967)
	Acer rubrum	Sapindaceae	Red marple	Ruehle (1967)
	Agropyron smithii	Poaceae	Western Wheatgrass	Krupinsky et al. (1983)
	Agrostis canina	Poaceae	Velvet bentgrass	Settle et al. (2007)
	Agrostis palustris	Poaceae	Creeping bentgrass	Settle et al. (2007)
	Agrostis stolonifera	Poaceae	Creeping bentgrass	Zeng et al. (2012a)
	Alysicarpus ovalifolius	Fabaceae	Alyce clover	Mashela et al. (1991)
	Alysicarpus vaginalis	Fabaceae	Alyce clover	Mashela et al. (1992)
	Amaryllis	Amaryllidaceae	Amaryllis	Sher (1963)
	Andromeda sp	Ericaceae	Bog Rosemary	Goodey et al. (1965)
	Antirrhinum sp	Scrophulariaceae	Snapdragon	Goodey et al. (1965)
	Arachis hypogaea	Fabaceae	Peanut	EFSA PLH Panel (2022)
	Armoracia rusticana	Brassicaceae	Horseradish	Walters et al. (2004)
	Bambusa	Poaceae	Bamboo	CABI (2021)
	Betula populifolia	Betulaceae	Grey birch	Ruehle (1967)
	Borrichia frutescens	Asteraceae	Sea-oxeye	CABI (2021)
	Brassica oleracea	Brassicaceae	Cabbage	Ahmed and Chen (1980); EFSA PLH Panel (2022)
	Buxus sempervirens	Buxaceae	Boxwood	EFSA PLH Panel (2022)
	Capsicum annuum	Solanaceae	Pepper	Rhoades (1981)
	Castanea mollissima	Fagaceae	Chinese chesnut	Ruehle (1967)
	Cedrus libani	Pinaceae	Libanese cedar	Ruehle (1967)
	Chamaecyparis	Cupressaceae	Chamaecyparis	Goodey et al. (1965)
	Citrus sinensis	Rutaceae	Sweet orange	Goodey et al. (1965)
	Cornus florida	Cornaceae	Flowering dogwood	Ruehle (1967)
	Cynodon dactylon	Poaceae	Bermuda grass	Bae et al. (2008)
	Dactylis glomerata	Poaceae	Cock's foot	Goodey et al. (1965)
	Dianthus caryophyllus	Caryophyllaceae	Carnation	EFSA PLH Panel (2022)
	Digitaria decumbens	Poaceae	Pangola grass	Haroon and Smart (1984)
	Digitaria sanguinalis	Poaceae	Large Crabgrass	Goodey et al. (1965)
	Diospyros kaki	Ebenaceae	Persimmon	CABI (2021)
	Elymus wawawaiensis	Poaceae	Snake River Wheatgrass	Krupinsky et al. (1983)
	Eremochloa ophiuroides	Poaceae	Centipede grass	Goodey et al. (1965)
	Festuca elatior	Poaceae	Tall fescue	Goodey et al. (1965)
	Franklinia alatamha	Theaceae	Franklin tree	Ruehle (1967)
	Ginkgo biloba	Ginkgoaceae	Gingko	Ruehle (1967)
	Glycine max	Fabaceae	Soyabean	Rodriguez-Kabana and Thurlow (1980)
	Gossypium hirsutum	Malvaceae	Cotton	Goodey et al. (1965)
	Hibiscus syriacus	Malvaceae	Rose mallow	Ruehle (1967)
	Hordeum vulgare	Poaceae	Barley	Goodey et al. (1965)
	Ilex crenata	Aquifoliaceae	Japanese holly	Goodey et al. (1965)
	Ipomoea batatas	Convolvulaceae	Sweet potato	EFSA PLH Panel (2022)

Host status	Host name	Plant family	Common name	Reference
	Larix leptplepis	Pinaceae	Japanese larch	Ruehle (1967)
	Lespedeza cuneata	Fabaceae	Chinese Lespedeza	Goodey et al. (1965)
	Lespedeza stipulacea	Fabaceae	Korean Lespedeza	Goodey et al. (1965)
	Ligustrum ovalifolium	Oleaceae	Garden privet	Ruehle (1967)
	Liquidambar styraciflua	Altingiaceae	American sweetgum	Ruehle (1967)
	Lolium multiflorum	Poaceae	Italian ryegrass	Goodey et al. (1965)
	Malus domestica	Rosaceae	Apple	Pokharel (2011); Crow and Brammer (2015)
	Medicago sativa	Poaceae	Alfalfa	Goodey et al. (1965)
	Morus alba	Moraceae	White mulberry	Ruehle (1967)
	Musa	Mucaceae	Banana	EFSA PLH Panel (2022)
	Opuntia	Cactaceae	Pear cactus	Sher (1963)
	Oryza sativa	Poaceae	Rice	Sharma (2001)
	Paspalum vaginatum	Poaceae	Water fingergrass	Hixson et al. (2004)
	Phaseolus vulgaris	Fabaceae	Common bean	Ahmed and Chen (1980)
	Picea abies	Pinaceae	Norway spruce	Ruehle (1967)
	Picea glauca	Pinaceae	White spruce	Goodey et al. (1965)
	Picea pungens	Pinaceae	Blue spruce	Ruehle (1967)
	Pimpinella anisum	Apiaceae	Anise	Kepenekci (2003)
	Pinus elliottii	Pinaceae	Slash pine	Ruehle (1969)
	Pinus mugo	Pinaceae	Mountain pine	Ruehle (1967)
	Pinus nigra	Pinaceae	Austrian pine	Ruehle (1967)
	Pinus sylvestris	Pinaceae	Scots pine	Ruehle (1967)
	Pinus taeda	Pinaceae	Loblolly pine	Ruehle (1969)
	Pisum sativum	Fabaceae	Pea	EFSA PLH Panel (2022)
	Platanus occidentalis	Platanaceae	American sycamore	Ruehle (1969)
	Poa annua	Poaceae	Annual meadowgrass	Browning et al. (1999)
	Prunus americana	Rocaceae	American plum	Ruehle (1967)
	Prunus dulcis	Rosaceae	Peach	Eisenback (2018); Ferris (2023)
	Prunus persica	Rocaceae	Peach	EFSA PLH Panel (2022)
	Prunus serotina	Rocaceae	Black cherry	Ruehle (1967)
	Prunus virginiana	Rocaceae	Chokecherry	Ruehle (1967)
	Pseudotsuga menziesii	Pinaceae	Douglas-fir	Ruehle (1967)
	Quercus falcata	Fagaceae	Southern red oak	Ruehle (1967)
	Quercus palustris	Fagaceae	Pin oak	Viggars and Tarjan (1949); Ruehle (1967)
	Quercus rubra	Fagaceae	Red oak	Viggars and Tarjan (1949)
	Quercus velutina	Fagaceae	Black oak	Ruehle (1967)
	Rhododendron catawbiense	Ericaceae	Catawba rhododendron	Ruehle (1967)
	Rhododendron maximum	Ericaceae	Great laurel	Ruehle (1967)
	Saccharum officinarum	Poaceae	Sugarcane	Goodey et al. (1965)
	Sansevieria trifasciata	Agavaceae	Mother-in-law's tongue	CABI (2021)
	Secale cereale	Poaceae	Rye	Ahmed and Chen (1980)
	Solanum lycopericum	Solanaceae	Tomato	Ahmed and Chen (1980)

Host status	Host name	Plant family	Common name	Reference
	Sorghum bicolor	Poaceae	Sudan grass	Cuarezma-Terán et al. (1984)
	Stenotaphrum secundatum	Poaceae	Buffalo grass	Henn and Dunn (1989)
	Taxus bacata	Taxaceae	European yew	Ruehle (1967)
	Taxus cuspidata	Taxaceae	Japanese yew	Ruehle (1967)
	Trifolium pratense	Fabaceae	Red clover	Goodey et al. (1965)
	Trifolium repens	Fabaceae	White clover	Goodey et al. (1965)
	Triticum aestivum	Poaceae	Wheat	Sharma (2001)
	Vicia	Fabaceae	Bean	EFSA PLH Panel (2022)
	Vitis vinifera	Vitaceae	Grapevine	Ibrahim et al. (2010, 2023)
	Zea mays	Poaceae	Maize	Rhoades (1987)
	Zoysia	Poaceae	–	Goodey et al. (1965)
Artificial/ experimental host	*Pinus clausa*	Pinaceae	–	Ruehle (1969)
	Pinus cubensis	Pinaceae	–	Goodey et al. (1965)
	Pinus echinata	Pinaceae	Shortleaf pine	Ruehle (1969)
	Pinus edulis	Pinaceae	Nut pine	Riffle (1972)
	Pinus palustris	Pinaceae	Long-leaf pine	Ruehle (1969)
	Pinus ponderosa	Pinaceae	Ponderosa pine	Riffle (1972)
	Pinus rigida	Pinaceae	Pitch pine	Ruehle (1967)
	Pinus serotina	Pinaceae	Pine	Ruehle (1969)
	Pinus strobus	Pinaceae	White pine	Ruehle (1969)
	Pinus virginiana	Pinaceae	Virginia pine	Ruehle (1969)
	Populus heterophylla	Salicaceae	Cottonwood	Churchill and Ruehle (1971)
	Vaccinium spp.	Oxycoccus	Cranberry	EFSA PLH Panel (2022)
Wild weed hosts				

Appendix B – Distribution of *Hoplolaimus galeatus*

Distribution records based on CABI Crop Protection Compendium (CABI, 2021), Nemaplex (Ferris, 2023) and other literature.

Region	Country	Subnational (e.g. State)	Reference
North America	USA		Allen et al. (2005); Zeng et al. (2012b)
		Alabama	Rodriguez-Kabana and Ingram (1978)
		Arkansas	Donald et al. (2013)
		California	Ma et al. (2022)
		Colorado	Ma et al. (2022)
		Florida	CABI (2021)
		Georgia	Ruehle and Sasser (1962)
		Illinois	Allen et al. (2005)
		Iowa	Norton and Edwards (1988)
		Indiana	Alby et al. (1983)
		Kansas	Settle et al. (2006)
		Louisiana	Ma et al. (2022)
		Maryland	Settle et al. (2005)
		Minnesota	Ma et al. (2022)
		Missouri	CABI (2021)
		North Carolina	Zeng et al. (2012a)
		Pennsylvania	Tedford and Jaffee (1995)
		South Carolina	Zeng et al. (2012a)
		Tennessee	Donald et al. (2013)
		Texas	Ma et al. (2022)
		Virginia	Adams et al. (1979)
		Wisconsin	Ma et al. (2022)
South America	Argentina		Doucet (1980)
	Brazil		da Luz (1982)
	Paraguay		Nguyen et al. (2015)
	Peru		Ciancio et al. (1998)
Africa	Tanzania		Ma et al. (2022)
	Egypt		Ibrahim et al. (2010, 2023)
Asia	Bangladesh		Abedin et al. (2011)
	India		MacGowan and Dunn (1989)
	Indonesia	Sumatra	Ma et al. (2022)
	Pakistan		CABI (2021)
	Turkiye		Kepenekci (2003)
Oceania	Australia	New South Wales	Nambiar et al. (2008)
		Western Australia	Nambiar et al. (2008)

Appendix C – EU and member state cultivation/harvested/production area of *Hoplolaimus galeatus* hosts (in 1,000 ha)

Source: Eurostat, accessed on 30/05/2023.

Barley	2016	2017	2018	2019	2020
EU	11,179.59	10,862.69	11,144.80	11,138.94	11,016.58
Belgium	55.43	45.29	42.16	46.76	43.98
Bulgaria	159.83	128.37	103.57	112.03	130.76
Czechia	325.73	327.71	324.72	319.58	331.91
Denmark	706.90	665.40	795.30	583.20	653.20
Germany	1,605.00	1,566.10	1,662.00	1,708.80	1,667.30
Estonia	135.40	102.49	138.49	123.38	130.73
Ireland	189.21	180.19	185.21	179.36	193.18
Greece	132.80	133.38	129.19	132.57	136.97
Spain	2,563.20	2,597.53	2,569.46	2,693.51	2,749.04
France	1,917.55	1,904.86	1,767.97	1,944.19	1,972.27
Croatia	56.48	53.95	50.99	53.66	66.33
Italy	249.37	250.53	262.48	261.41	263.43
Cyprus	14.54	10.95	12.80	11.58	12.52
Latvia	94.40	70.30	118.30	86.80	84.40
Lithuania	172.54	141.65	225.91	174.77	164.87
Luxembourg	6.90	6.59	6.00	6.06	6.00
Hungary	313.09	268.08	244.17	247.37	261.38
Netherlands	34.43	29.72	35.97	33.39	38.38
Austria	140.43	138.90	139.27	137.24	134.80
Poland	915.30	953.78	975.74	975.29	676.30
Portugal	20.62	23.20	20.53	21.94	19.02
Romania	481.61	455.46	423.50	448.89	441.98
Slovenia	19.18	20.37	20.99	21.14	22.21
Slovakia	114.85	120.33	124.16	126.37	130.86
Finland	435.90	358.30	405.10	397.90	392.10
Sweden	318.92	309.28	360.81	291.76	292.66

Cotton	2016	2017	2018	2019	2020
EU	301.35	326.12	345.64	361.78	344.35
Bulgaria	4.49	4.81	3.16	3.46	3.28
Greece	236.04	258.33	277.36	292.17	279.50
Spain	60.81	62.98	65.12	66.15	61.57

Wheat and spelt	2016	2017	2018	2019	2020
EU	25,210.30	24,138.62	23,751.66	24,212.28	22,768.45
Belgium	215.72	197.59	195.69	203.76	194.66
Bulgaria	1,192.59	1,144.52	1,212.01	1,198.68	1,200.18
Czechia	839.71	832.06	819.69	839.45	798.58
Denmark	583.00	586.60	425.80	573.40	502.60
Germany	3,201.70	3,202.60	3,036.30	3,118.10	2,835.50
Estonia	164.50	169.75	154.58	166.98	168.04
Ireland	67.92	67.05	57.98	63.48	46.99
Greece	537.59	415.95	404.49	350.49	355.88

Wheat and spelt	2016	2017	2018	2019	2020
Spain	2,256.85	2,062.71	2,063.68	1,920.09	1,914.66
France	5,542.25	5,332.08	5,234.09	5,244.25	4,512.42
Croatia	171.40	118.38	138.46	143.15	147.84
Italy	1,912.42	1,806.57	1,821.73	1,754.64	1,711.22
Cyprus	8.39	8.68	10.20	10.59	12.97
Latvia	479.10	446.80	417.20	492.70	498.20
Lithuania	880.53	811.95	772.89	895.76	893.51
Luxembourg	13.81	14.11	12.87	13.36	11.93
Hungary	1,044.31	966.40	1,026.15	1,015.64	936.62
Netherlands	127.33	115.92	111.66	120.55	108.91
Austria	317.76	297.28	294.29	278.34	279.02
Poland	2,364.08	2,391.85	2,417.23	2,511.33	2,391.00
Portugal	38.20	29.02	27.03	28.53	30.14
Romania	2,137.73	2,052.92	2,116.15	2,168.37	2,155.25
Slovenia	31.46	28.02	27.82	26.73	27.29
Slovakia	417.71	373.67	403.37	406.82	387.08
Finland	215.10	194.28	177.80	197.60	198.80
Sweden	449.15	471.87	372.50	469.49	449.17

Green maize	2016	2017	2018	2019	2020
EU	6,061.45	5,985.90	6,134.91	6,210.36	6,325.30
Belgium	168.74	171.28	179.74	175.30	181.54
Bulgaria	31.10	29.93	27.24	27.50	30.44
Czechia	234.40	223.21	224.11	232.39	226.16
Denmark	182.40	166.70	179.60	186.40	188.70
Germany	2,137.60	2,095.90	2,195.90	2,222.70	2,299.70
Estonia	7.96	9.18	10.55	13.71	13.60
Ireland	10.92	11.88	17.76	16.62	14.77
Greece	118.69	125.55	129.64	128.07	103.19
Spain	106.24	107.36	107.34	116.46	115.12
France	1,423.73	1,406.01	1,415.73	1,438.25	1,418.89
Croatia	30.98	28.29	25.35	25.41	30.11
Italy	325.04	342.10	355.33	367.42	379.07
Cyprus	0.20	0.17	0.12	0.14	0.13
Latvia	25.90	22.10	25.50	23.80	22.80
Lithuania	26.59	24.34	28.25	32.94	29.92
Luxembourg	14.94	15.19	15.88	15.78	16.87
Hungary	76.41	69.05	66.40	66.30	62.04
Malta	0.00	0.00	0.00	0.00	0.00
Netherlands	203.81	203.51	203.22	186.23	194.65
Austria	84.64	82.19	83.35	85.68	86.86
Poland	597.00	596.01	601.58	599.86	674.31
Portugal	80.26	78.43	74.33	71.94	71.27
Romania	51.42	50.10	47.76	51.81	47.24
Slovenia	28.69	29.19	29.82	30.15	30.63
Slovakia	78.05	81.44	73.11	75.10	67.58
Finland	0.00	0.00	0.00	0.00	0.00
Sweden	15.74	16.80	17.29	20.39	19.72

Peppers	2016	2017	2018	2019	2020
EU	59.95	59.50	58.92	59.60	57.41
Belgium	0.10	0.10	0.09	0.10	0.10
Bulgaria	3.66	3.35	2.95	3.22	2.72
Czechia	0.00	0.00	0.42	0.27	0.29
Germany	0.08	0.09	0.11	0.11	0.11
Greece	3.77	4.03	3.84	3.39	3.45
Spain	19.62	20.50	20.58	21.43	21.75
France	0.84	0.96	0.95	0.94	1.16
Croatia	1.35	1.02	1.02	0.56	0.68
Italy	11.04	10.32	10.52	10.28	10.01
Cyprus	0.04	0.03	0.04	0.03	0.04
Hungary	2.79	2.57	1.91	1.85	1.57
Netherlands	1.32	1.32	1.31	1.50	1.53
Austria	0.17	0.18	0.16	0.16	0.16
Poland	3.78	3.63	3.71	3.70	2.90
Portugal	0.97	1.21	0.93	0.85	1.28
Romania	9.93	9.71	9.96	10.78	9.26
Slovenia	0.17	0.16	0.16	0.20	0.22
Slovakia	0.32	0.31	0.27	0.22	0.17
Finland	0.01	0.01	0.01	0.01	0.01

Apples	2016	2017	2018	2019	2020
EU	505.66	504.61	506.27	491.08	484.63
Belgium	6.49	6.16	5.99	5.79	5.48
Bulgaria	4.11	3.97	3.98	4.14	3.56
Czechia	7.49	7.35	7.25	7.32	7.19
Denmark	1.35	1.28	1.42	1.39	1.38
Germany	31.74	33.98	33.98	33.98	33.98
Estonia	0.51	0.48	0.60	0.57	0.62
Ireland	0.70	0.70	0.71	0.71	0.71
Greece	10.04	9.60	10.35	9.82	14.38
Spain	30.87	30.55	29.93	29.64	29.49
France	49.65	50.31	50.54	50.37	50.15
Croatia	5.89	4.84	4.73	4.95	4.36
Italy	56.16	57.26	57.44	55.00	54.91
Cyprus	0.53	0.37	0.37	0.37	0.41
Latvia	2.40	3.30	3.20	3.44	3.50
Lithuania	9.70	9.82	10.13	10.18	10.50
Luxembourg	0.26	0.27	0.27	0.27	0.08
Hungary	32.49	32.17	31.84	30.97	25.97
Netherlands	7.30	7.00	6.60	6.42	6.20
Austria	6.67	6.67	6.74	6.59	6.43
Poland	164.76	162.53	166.15	155.62	152.60
Portugal	14.16	13.85	13.61	14.31	14.31
Romania	55.53	55.60	53.94	52.74	52.34
Slovenia	2.42	2.36	2.33	2.27	2.16
Slovakia	2.31	2.18	2.14	2.06	1.80
Finland	0.62	0.63	0.63	0.65	0.67
Sweden	1.54	1.40	1.41	1.52	1.44

Peaches	**2016**	**2017**	**2018**	**2019**	**2020**
EU	156.39	154.06	150.80	144.78	137.07
Bulgaria	3.66	3.73	3.40	3.02	2.70
Czechia	0.39	0.37	0.38	0.34	0.34
Germany	0.00	0.11	0.11	0.11	0.11
Greece	33.47	33.68	34.76	33.61	32.94
Spain	52.88	52.14	49.87	47.94	44.42
France	4.83	4.80	4.69	4.65	4.75
Croatia	0.79	0.71	0.64	0.68	0.61
Italy	47.03	45.49	44.42	41.93	41.04
Cyprus	0.24	0.21	0.21	0.22	0.23
Hungary	5.42	5.34	4.93	4.79	3.89
Austria	0.16	0.16	0.18	0.18	0.18
Poland	2.23	2.13	2.12	2.15	0.80
Portugal	2.94	2.97	2.84	2.87	2.88
Romania	1.68	1.62	1.64	1.72	1.62
Slovenia	0.30	0.28	0.26	0.25	0.25
Slovakia	0.37	0.32	0.36	0.35	0.31

Oranges	**2016**	**2017**	**2018**	**2019**	**2020**
EU	278.67	272.42	273.64	271.97	275.39
Greece	31.71	29.60	31.60	30.32	30.60
Spain	142.17	140.51	139.63	140.31	141.13
France	1.03	1.00	1.00	1.05	0.98
Croatia	0.03	0.02	0.03	0.05	0.04
Italy	85.59	83.22	82.80	81.85	84.16
Cyprus	1.30	1.09	1.12	1.26	1.27
Portugal	16.84	16.98	17.47	17.13	17.22

Rice	**2016**	**2017**	**2018**	**2019**	**2020**
EU	448.74	440.68	417.37	419.09	427.55
Bulgaria	11.99	10.43	11.00	11.82	12.35
Greece	35.14	30.95	30.35	29.86	36.09
Spain	109.27	107.60	105.01	103.37	102.06
France	16.71	16.72	13.28	15.10	14.81
Italy	234.13	234.13	217.19	220.03	227.32
Hungary	2.91	2.77	2.93	2.65	2.99
Portugal	29.15	28.94	29.35	28.83	25.94
Romania	9.44	9.13	8.25	7.43	6.00

Soya	**2016**	**2017**	**2018**	**2019**	**2020**
EU	831.18	962.39	955.40	907.91	942.50
Bulgaria	14.16	11.53	2.32	3.86	4.51
Czechia	10.61	15.34	15.23	12.24	14.15
Germany	15.80	19.10	24.10	28.90	33.80
Greece	1.55	1.46	0.61	1.03	0.99
Spain	1.00	1.69	1.48	1.57	1.45
France	136.52	141.83	153.85	163.80	186.72
Croatia	78.61	85.13	77.09	78.33	86.19

Soya	2016	2017	2018	2019	2020
Italy	288.06	322.42	326.59	273.33	256.13
Lithuania	1.85	2.47	1.92	1.82	2.07
Luxembourg	0.00	0.00	0.00	0.00	0.01
Hungary	61.03	75.67	62.12	58.23	58.67
Netherlands	0.00	0.00	0.54	0.48	0.00
Austria	49.79	64.47	67.62	69.21	68.50
Poland	7.60	9.33	5.45	7.92	7.71
Romania	127.27	165.14	169.42	158.15	168.90
Slovenia	2.47	2.91	1.76	1.43	1.64
Slovakia	34.87	43.90	45.30	47.60	51.07

Appendix D – Methodological notes on Figure 2

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 multiscale 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 geodatabases that provide presence/absence data for tree species and genera (de Rigo et al., 2014, 2016, 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). 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, http://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 approximately 375,000 sample points with a spatial resolution of 1km^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 and 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 geodatabase that provides information on tree species composition in over 3,200 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 from EUFGIS (online).

Georeferenced Data on Genetic Diversity (GD^2) is a smaller geodatabase as well. It provides information about 63 species that are of interest for genetic conservation. It counts 6,254 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 (INRAE, 2020).

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

[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.

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 multiscale 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 multiscale aggregation of the entire arrays of kernels and data sets 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 the 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.