SCIENTIFIC OPINION

efsa JOURNAL

ADOPTED: 30 March 2023

doi: 10.2903/j.efsa.2023.8004

# Pest risk assessment of *Elasmopalpus lignosellus* for the European Union

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, Philippe Lucien Reignault, Emilio Stefani, Hans-Hermann Thulke,
Antonio Vicent Civera, Jonathan Yuen, Lucia Zappalà, Richard Mally, Ewelina Czwienczek,
Andrea Maiorano, Olaf Mosbach-Schulz, Marco Pautasso, Giuseppe Stancanelli,
Sara Tramontini and Wopke Van der Werf

## Abstract

Following a request from the European Commission, the EFSA Panel on Plant Health performed a quantitative pest risk assessment of *Elasmopalpus lignosellus* (Lepidoptera: Pyralidae), the lesser cornstalk borer, for the EU. The assessment considered entry, establishment, spread and impact. Two scenarios for establishment were considered: (i) under current climatic conditions and (ii) under a future climate based on an ensemble of climate change scenarios. Impact assessment focused on cereal and legume host species. *E. lignosellus* is not known to occur outside of the Americas although it has been intercepted in the EU on fresh asparagus spears for consumption. Based on the size of the trade and evidence of interceptions, the importation of asparagus from Peru was identified as the most important pathway for entry. Using stochastic pathway modelling with parameter values based on Eurostat data and expert knowledge elicitation (EKE), the Panel estimated the median number of infested asparagus spears entering the EU annually to be approximately 8,600 (90% certainty range (CR) approximately 1,300–58,500). Each infested spear is likely to contain only one larva. Conditions are most suitable for establishment in the southern EU, especially around the Mediterranean basin. Under current climatic conditions, around 16% of spears enter regions of the EU suitable for establishment; this rises to 24% in the climate change scenario considered (2040–2059). However, due to estimated small likelihoods of adults emerging and escaping from discarded waste, finding a mate and the subsequent progeny surviving to initiate a founder population, the median number of populations expected to establish was estimated to be 0.0001 per year (90% CR 0.000005–0.002). Were *E. lignosellus* to establish, the median rate of natural spread was estimated to be 7.4 km/year (90% CR 0.6–18.2 km/year), after an initial lag period of 18.5 years (90% CR 3.3–43.8 years) following the establishment of a founder population. Estimated median yield losses in crops of cereals and legumes were estimated to be 0.95% (CR 0.2–2.8%), assuming farmers would adapt control measures such as are in place for other seedling pests. The Panel did not consider a scenario with additional risk reduction options because no feasible options at field level could be identified while export inspections aiming for zero contamination of the commodity are already in place in the exporting country – Peru.

**Keywords:** @risk, climate change, expert knowledge elicitation (EKE), lesser cornstalk borer, quantitative PRA, pathway model

**Requestor:** European Commission

**Question number:** EFSA-Q-2021-00751

**Correspondence:** plants@efsa.europa.eu

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

**Acknowledgements:** The EFSA Plant Health Panel wishes to thank EFSA trainees: Dr Júlia López Mercadal for her substantial contribution to the Scientific opinion namely: development of the methodology used, data collection, data extraction, meta-analysis, data harmonisation, translations from Spanish language, supporting the drafting of the different section and meetings organisation; Eugenio Rossi for his substantial contributions to the climate suitability analysis, in particular to the design and development of methodology, literature search, data extraction, model simulations, map development and drafting of the climate suitability section of this opinion. The EFSA Plant Health Panel wishes to thank the following for the support provided to this scientific output: Irene Pilar Munoz Guajardo from the EFSA library for providing an easy access to the crucial references; ISA Expert: Pamela Menegazzi (Neurobiology and Genetics Biocenter, University of Würzburgam Hubland, Germany), for the first draft of the Expert Knowledge Elicitation evidence dossier for the Spread and Impact session. The EFSA wishes to thank two Hearing Experts: Prof. Paulo Viana (EMBRAPA, Brazil) and Dr Alma Solis (USDA, Smithsonian Institution, USA) for their profound knowledge in the topic of *E. lignosellus* and pyralids.

**Suggested citation:** EFSA PLH Panel (EFSA Panel on Plant Health), Bragard C, Baptista P, Chatzivassiliou E, Di Serio F, 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, Vicent Civera A, Yuen J, Zappalà L, Mally R, Czwienczek E, Maiorano A, Mosbach-Schulz O, Pautasso M, Stancanelli G, Tramontini S and Van der Werf W, 2023. Scientific Opinion on the pest risk assessment of *Elasmopalpus lignosellus* for the European Union. EFSA Journal 2023;21(5):8004, 91 pp. https://doi.org/10.2903/j.efsa.2023.8004

**ISSN:** 1831-4732

The EFSA Journal is a publication of the European Food Safety Authority, a European agency funded by the European Union.

## Summary

The EFSA Panel on Plant Health performed a quantitative pest risk assessment of *Elasmopalpus lignosellus* (Lepidoptera: Pyralidae), the lesser cornstalk borer, for the EU. The quantitative assessment focused on pathways and likelihood of entry, climatic conditions allowing establishment, the distribution of imported material within the EU after entry, the likelihood of establishment, the rate of spread following a lag period and potential impacts to crops. *E. lignosellus* is a pest of sugarcane (*Saccharum officinarum*) and corn (*Zea mays*) in South and Central America and the Southern USA. It is also a pest of asparagus (*Asparagus officinalis*) in Western South America, and on peanuts (*Arachis hypogaea*) in the Southern USA. Besides these hosts, the insect also feeds on other crops, especially on plants in the families Poaceae such as wheat (*Triticum* spp.), sorghum (*Sorghum* spp.) and oat (*Avena sativa*), and Fabaceae like pea (*Pisum sativum*), beans (*Phaseolus* spp.) and soybean (*Glycine max*), as well as on tree seedlings.

*E. lignosellus* is a polyphagous pest, with its larvae boring into the stems or feeding on the roots of their hosts. Due to its wide range of host plants, a variety of potential pathways for entry into the EU were considered. *E. lignosellus* is not known to occur outside of the Americas although it has been intercepted in the EU on asparagus spears for consumption. The large majority of asparagus is imported from Peru, a country with the advantage of year-round production of that crop, and all interceptions of *E. lignosellus* in Europe have been made in asparagus imported from Peru. Based on the size and frequency of imports, and with evidence of interceptions in Europe, the importation of fresh asparagus from Peru for consumption was identified as the most likely pathway for entry. As the species is a stem borer, imported fruits of host plants (e.g. corn cobs, wheat and sorghum grain, peas) bear no risk of infestation with *E. lignosellus* larvae. Although the larvae of *E. lignosellus* are known to also feed on peanut kernels, post-harvesting procedures prevent the import of infested fruits. As eggs are predominantly deposited in the soil around host plants, and pupation takes place in the soil, only the larvae are expected to be found in the entry pathway.

Using stochastic pathway modelling with parameter values based on Eurostat data and expert knowledge elicitation, the Panel estimated that the median number of infested asparagus spears entering the EU annually is approximately 8,600 (90% certainty range (CR) approximately 1,300–58,500). This is a small proportion of the total number of spears that are imported from Peru, which is in the order of hundreds of millions each year (median estimate approximately 815 million; 90% CR 665–877 million).

To identify which regions of the EU exhibit a climate suitable for establishment of *E. lignosellus*, a literature search was conducted to compile data on environmental factors affecting life cycle parameters (development rate, survival, reproduction) as well as to assemble all known location records of the insect worldwide, i.e. in the Americas, where it is endemic. These data were used to model the potential for establishment, using the CLIMEX modelling framework. The occurrence records were mapped on Köppen–Geiger climate maps to identify the climates of the regions inhabited by *E. lignosellus* in the Americas that also occur in Europe. Two scenarios for establishment were considered: (i) under current climatic conditions and (ii) under a future climate (2040–2059) based on an ensemble of climate change scenarios. Climate matching and CLIMEX modelling indicate that conditions are most suitable for establishment of *E. lignosellus* in parts of the southern EU at and near the coast of the Mediterranean Sea. Under current climatic conditions, around 16% of the imported asparagus spears enter these southern regions of the EU that are suitable for establishment.

The Panel thus estimated that annually, approximately 200–9,600 infested spears (90% CR; median estimate approximately 1,400) enter these EU regions climatically suitable for establishment. The region suitable for the insect's establishment is greater in the climate change scenario than with current climate, when 24% of imported asparagus would be expected to enter this extended range. This translates into an estimate of approximately 300–14,100 infested spears each year (90% CR; median 2,100) entering regions favouring establishment in the climate change scenario. The Panel estimated that the probability of a larva successfully developing within a discarded asparagus spear into an adult is 0.12–4.2% (90% CR; median estimate 1.2%). As each infested asparagus spear is likely to contain only a single larva, the establishment of a founder population is thus strongly limited by the likelihood of a male and female emerging at the same time and in spatial proximity in order to locate each other and mate.

Due to the small likelihoods of larvae developing to adulthood from discarded asparagus, then mating and the progeny surviving, the number of newly established founder populations developing under current climate conditions was estimated to be 0.00013 per year (90% CR 0.000005–0.002). In

the climate change scenario, the Panel estimates the number of newly established founder populations to range from 0.000007 to 0.003 each year (90% CR; median 0.0002). Thus, despite being a polyphagous species with a preference for Poaceae and Fabaceae, with both plant families being well represented in the European Mediterranean flora, the Panel does not expect new founder populations within the time horizon of 5 years of this assessment. The expected waiting time until a new founder population with current climate is in the Panel's estimation 500–200,000 years, while with climate change (2040–2059), this waiting time would be 330–143,000 years, which periods are both beyond the time frame of the assessment and beyond the time frame of the climate change projection.

A newly established founder population of *E. lignosellus* is expected to remain local for a number of years, as the lag period following the establishment of a founder population and before sustained spread was estimated to be 18.5 years (90% CR 3.3–43.8 years). Adults of *E. lignosellus* are not considered to be strong flyers, and were the species to establish, the median rate of natural spread was estimated to be 7.4 km/year (90% CR 0.6–18.2 km/year). This estimate is based on consideration of the natural spread of the organism and local, mostly on-farm, practices associated with production, but does not consider movement in intra-EU trade.

The assessment of the potential impact of *E. lignosellus* on European crops focused on species of Poaceae (esp. cereals, corn) and Fabaceae (legumes). In a scenario where *E. lignosellus* has spread across all suitable climatic EU regions and is managed by farmers as part of the general pest fauna, i.e. without specific phytosanitary measures targeted at this species, the median losses in yield were estimated to be 0.95% (CR 0.2–2.8%).

To conclude, *E. lignosellus* has the potential to establish in the EU, via its polyphagous stem-boring larvae entering via imported asparagus and in that case to cause damage to agricultural crops and the flora in general. However, due to the relatively low proportion of infested asparagus among the spears imported to the EU and the estimated low survival rate of larvae in discarded asparagus, the likelihood of two adult moths of the opposite sex finding each other and successfully mating to produce a founder population was estimated once in about 7,500 years (90% CR 500–200,000 years).

## Table of contents

# 1. Introduction

## 1.1. Background and terms of reference as provided by the requestor

### 1.1.1. Background

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

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

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

### 1.1.2. Terms of Reference (ToR)

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 50 pest categorisations for the pests listed in Annex 1A, 1B and 1D. 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). 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.

ANNEX 1 List of pests.

**A)**

1. *Amyelois transitella*.
2. *Citripestis sagittiferella*.
3. *Colletotrichum fructicola*.
4. *Elasmopalpus lignosellus*.
5. *Phlyctinus callosus*.
6. *Resseliella citrifrugis*.
7. *Retithrips syriacus*.
8. *Xylella taiwanensis*.

**E)**

List of pests identified to develop further the quantitative risk assessment (phase 1 and phase 2) methodology followed for plant pests, to include in the assessments the effect of climate change for plant pests (for more details see Annex 3).

1. *Leucinodes orbonalis*.
2. *Leucinodes pseudorbonalis*.
3. *Xanthomonas citri* pv. *viticola*.

### 1.2. Interpretation of the Terms of Reference

*Elasmopalpus lignosellus* is one of the eight plant pest species listed in Annex 1A of the terms of reference. As such, following the pest categorisation of *E. lignosellus* which concluded that the species satisfies the EU criteria, which are within the remit of EFSA to assess, for it to be regarded as a potential Union quarantine pest (EFSA PLH Panel, 2021), EFSA should proceed to conduct phase two of the risk assessment. In phase two, entry pathways, spread, establishment and impact are to be evaluated. An analysis of risk reduction options is also required. It was noted that the quantitative method used for assessing pest risk should deliver an express risk assessment. This could be achieved by taking into account the methods used to (i) assess pest freedom when conducting risk assessments for pests associated with high-risk plant commodities (EFSA PLH Panel, 2019) (thus informing the likelihood of pest entry) and (ii) inform decision-making regarding candidate Union priority pests, in particular with regard to a pest's spread and impact (EFSA, 2019). The Panel therefore undertook a quantitative pest risk assessment according to the principles laid down in its guidance on quantitative pest risk assessment (EFSA PLH Panel, 2018) while recognising the need of the Commission for an express risk assessment.

In addition, after consideration of the availability of data necessary to conduct the assessment, the Panel conducted also an assessment to identify EU regions that could become suitable for establishment of *E. lignosellus* in future taking climate change scenarios into account.

## 2. Data and methodologies

To obtain a deeper understanding of the organism and to inform the necessary steps in the risk assessment, a literature review was conducted using the Web of Science databases. Findings built on the information collected for the pest categorisation (EFSA PLH Panel, 2021). The scientific and common names of the pest were used as search terms, and no filters (limits) for either time of publication nor language were implemented, and all Web of Science databases were selected. The following search string was used to retrieve results: 'lesser cornstalk borer' OR 'kleiner Maisstengelbohrer' OR 'lagarta-do-colo-do-milho' OR 'Elasmopalpus' OR 'barrenador menor del maíz' OR 'lagarta' OR 'barrenador menor del tallo de maíz' OR 'gusano perforador del brote' OR 'taladrador menor' OR 'barrenador gusano saltarín' OR 'gusano saltarín' OR 'barrenador del cuello' OR 'coralillo' OR 'gusano picador de la hoja' OR 'pyrale du maïs et du riz' OR 'Elasmopalpus lignosellus' OR 'E.lignosellus' OR 'Dasypyga carbonella' OR 'Elasmopalpus anthracellus' OR 'Elasmopalpus carbonella' OR 'Elasmopalpus incautella' OR 'Elasmopalpus major' OR 'Elasmopalpus puer' OR 'Elasmopalpus tartarella' OR 'Pempelia lignosella' OR 'Salebria lignosella' OR 'sugarcane jumping borer'. The Web of Science search resulted in 2,894 hits. An additional search was conducted via the Google Scholar search engine to specifically find literature published in Spanish/Portuguese, with the following Spanish names inserted individually (with number of results in parentheses): barrenador del cuello (2,410 results), barrenador menor (10,100 results), lagarta –do –colo –do milho (2,030 results), gusano perforador del brote (955 results), taladrador menor (15,300 results), gusano saltarín (753 results), gusano picador de la hoja (1,290 results), coralillo (2,540 results). Both the Web of Science and the Google Scholar searches were conducted on 18 March 2022, numbers of results were recorded on 30 January 2023.

Additional searches, limited to retrieve documents, were run when developing the opinion. The available scientific information, including the previous EFSA pest categorisation (EFSA PLH Panel, 2021) and the relevant literature and legislation e.g. Regulation (EU) 2016/2031 and Commission Implementing Regulation (EU) 2019/2072, was taken into account.

In performing the risk assessment, the following assessment steps were distinguished:

- Estimating the number of *E. lignosellus* individuals that enter the EU,
- Identifying the areas where *E. lignosellus* can establish in the EU,

- Quantifying the number of *E. lignosellus* individuals entering NUTS2 areas of the EU where climatic conditions are suitable for establishment and transfer to a host in those areas, leading to the initiation of a founder population,
- Estimating the duration of the lag period before a founder population begins to spread as well as the steady rate of spread,
- Estimating the potential loss in yield of cereal and legume crops in situations with and without specific pest management of *E. lignosellus* being used by farmers.

Judgements made in each assessment step were based on a combination of literature review, meta-analysis, information collected during interviews with hearing experts and expert knowledge elicitation (EKE) involving Panel members and EFSA staff to assess quantities that could not be well identified from the literature or databases alone (EFSA, 2014). To link commodity entry volumes into the EU with the assessment of establishment, imported commodities were assumed to be distributed across the EU in proportion to human population.

According to ISPM 5 (FAO, 2018a), entry is 'movement of a pest into an area where it is not yet present, or present but not widely distributed and being officially controlled' while establishment is 'perpetuation, for the foreseeable future, of a pest within an area after entry'. Introduction, according to the same ISPM5, is 'the entry of a pest resulting in its establishment'. In the assessment of entry, the Panel first identified pathways for entry of *E. lignosellus* into Europe, finding there is one main pathway, fresh asparagus from Peru. The volume of trade to the EU was estimated, as well as the proportion of infested asparagus (Section 2.1). A pathway model was developed. Attention was subsequently diverted from the pathway modelling of entry to mapping establishment to identify which areas are at risk of establishment following entry. Methods are described in Sections 2.2.1–2.2.5. After identification of the areas at risk using CLIMEX and Köppen–Geiger climate mapping, the pathway modelling was continued in Section 2.2.6. In this section, the entry flow is partitioned to parts of Europe suitable for establishment and not suitable for establishment. Transfer is modelled using a stochastic pathway model only for the areas with a risk of establishment, assuming that no populations of *E. lignosellus* will be founded in areas that are not suitable for its establishment. Section 2.2.7 presents the overall pathway model for introduction, encompassing both entry and establishment.

## 2.1. Entry

### 2.1.1. Identifying pathways

*Elasmopalpus lignosellus* is a polyphagous pest that feeds on plants in at least 27 plant families (EFSA PLH Panel, 2021). There are many different hosts that could provide a pathway for entry into the EU. Taking into account the biology of the pest, it was clear that the larvae feed and develop on young plants, and only burrow a short distance into young stems (Appendix A). The Panel made an inventory of host plants that are imported into the EU in a stage that could plausibly act as a vehicle for entry (e.g. Table 1). Entry would require the importation of young and tender stems of host plants as this is where the larvae live. Those stems should have been grown close to the soil surface as the larvae move back and forth between the plant stems and their resting tubes in the soil close to the stems. Efforts to identify plausible pathways focussed on (i) commodities on which interceptions had been found and (ii) hosts that are imported into the EU as rooted young plants for planting from countries where *E. lignosellus* is known to occur.

Interceptions: EU data of interceptions are shown in the pest categorisation (EFSA PLH Panel, 2021) and information on interceptions in non-EU countries was collected from literature. Future trade flow of goods on which interceptions were found in the EU was estimated from Eurostat data. The Panel did not consider changes in trade volume in the future compared to the recent past as the data in Eurostat did not indicate a trend in the years 2016–2022. While the Panel made its assessment of future entry for the current composition of the EU (without the UK), it did make use of notifications of interceptions of *E. lignosellus* at Heathrow airport in 2019–2020 to inform the assessment of the proportion of infested asparagus spears in asparagus imports from Peru. There is no evidence that there was or is a difference in the level of infestation of imports of asparagus spears to the UK or to the EU (without the UK after Brexit on 31 January 2020). Differences in reported interceptions between European countries are interpreted as differences in reporting practices to Europhyt, as a result of non-quarantine status of *E. lignosellus* in current plant health regulations.

Transfer of the pest to host plants in the EU territory suitable for establishment was assessed. The trade flow was apportioned to NUTS2 regions to assess how many infested units of plant product arrive in regions that contain suitable climatic conditions and where hosts occur allowing for potential establishment.

The climatic suitability for pest establishment in each NUTS2 region was informed by mapping climate zones and developing a CLIMEX model for *E. lignosellus*. The apportioning of imported plant products to NUTS2 regions was done on the basis of human population in each NUTS2 region, on the assumption that consumer demand is proportional to population size. Human population data were sourced from Eurostat (EFSA PLH Panel, 2018).

Plants for planting: When collecting data on trade imports, it is usual to search within data systems used for customs and tariff purposes. The Combined Nomenclature (CN) is the 8-digit trade classification system used by the EU for statistical and tariff purposes. The system builds on the 6-digit harmonised system (HS) used by the vast majority of trading nations throughout the world. However, chapter 06 of the HS and CN systems, which codifies live trees and other plants, poorly discriminates between species of plants for planting and was found unsuitable to identify possible pathways involving plants for planting at a species level. More detailed import data for the year 2021 were obtained from the NPPO of the Netherlands as this country is a major European importer of plants for planting, and the Dutch PPO was willing to share these data. The data provided the number of plants at the genus or species level imported into the Netherlands during 2021 from countries in the Americas where *E. lignosellus* is known to occur. Judgements were made on whether imported host plants for planting were likely to provide a pathway taking into account probable production practices such as whether plants were grown in open fields or greenhouses and the part of the plant imported, e.g. unrooted cuttings, were deemed not to provide a pathway because larvae infest roots and young stems close to ground level.

The WG was able to identify and focus on the pathway most likely to lead to pest entry after excluding hosts whose import practice was judged unlikely to provide a pathway.

### 2.1.2. Scenario definition for entry

An evidence dossier to support judgements of entry was developed based on literature review. The collected evidence is summarised in Appendix C and was reviewed during the EKE to develop a pathway model for entry.

Estimates of the probability of units of the imported commodity being infested with *E. lignosellus* were made and uncertainties identified using expert judgement following EFSA guidance (Annex B.8 of EFSA Scientific Committee, 2018).

*Scenario 1: considering existing practices and phytosanitary measures*

To estimate the number of host commodity units entering the EU and containing *E. lignosellus*, the Panel developed a general scenario with the following description:

- The host commodity is fresh asparagus (green or white), the only commodity *E. lignosellus* has been intercepted from in the EU and UK; the majority is green spears.
- Overlapping generations (up to 5 per year) of *E. lignosellus* occur in the fields growing asparagus in Peru, the country of origin of all interceptions of *E. lignosellus* in the EU and UK and second largest exporter of asparagus (https://www.fao.org/faostat/en/#rankings/countries_by_commodity_exports).
- Pest management involves use of unspecified pesticides applied to the soil and management of irrigation.
- Asparagus spears are harvested by hand, spears seen to be infested are rejected in the field.
- Asparagus is cleaned, graded and packed at origin. Packs are from 250 g to 500 g.
- Producers exporting to the EU aim to comply with export procedures designed by the NPPO of Peru (i.e. spears have 0% infestation of *E. lignosellus*). Samples of 300 spears are taken from each shipment at the packing house to ensure pest freedom.
- The asparagus arrives by air from Peru and imports take place every month of the year, although import volumes are not constant throughout the year (see Appendix C, Figure C.1)
- Consignments are flown to the EU and arrive in chilled containers (chilling temperature ranges between 0.5°C and 2.2°C)
- Consignments vary in size from 800 to 3,200 kg and consist of boxes of packs weighing 5–20 kg
- *E.lignosellus* does occur in the production fields in Peru.
- The NPPO of Peru certifies the exports and has 'zero tolerance' for *E.lignosellus* to the EU.

The specific question for EKE was: 'How many out of 10,000 spears of fresh asparagus will be on average infested with *E. lignosellus*, when entering the EU from Peru?'

- The risk assessment used spears of asparagus as the most suitable unit because data are available on sampling procedures used for inspection, both at the origin and at entry in the EU. The sampling protocols use the asparagus spears as a unit of sampling.

The uncertainties associated with the EKE were taken into account and quantified in the probability distribution applying the semi-formal method described in Section 3.5.2 of the EFSA-PLH Guidance on quantitative pest risk assessment (EFSA PLH Panel, 2018).

Regarding an evaluation of risk reduction options, the Panel recognises that an analysis of risk reduction options was requested. However, the Peruvian asparagus export procedures and requirements, published in December 2022, indicate that Peru effectively considers that the EU treats *E. lignosellus* as a quarantine pest (The National Agrarian Health Service of Peru, Unified vegetable export procedure, PRO-Mo4.02.01, Annex 4.3 Pest tolerance in phytosanitary inspection of export shipments, 7th Dec 2022 (NAHS, 2022)). The update may have resulted from Peru being notified of interceptions of *E. lignosellus* in Peruvian asparagus by European countries. Since at least December 2022, there has been a 0% tolerance for asparagus spears to be contaminated with *E. lignosellus* if the asparagus is to be exported to the EU. No additional risk reduction options were identified and so no analysis of risk reduction options could be performed.

Of interest there is also a 0% tolerance for *E. lignosellus* in asparagus exported from Peru to Australia, Chile, China and Japan (NAHS, 2022). Further information on the entry model can be found in Annex A which is available under the Supporting Information section on the online version of the scientific output.

## 2.2. Establishment

To inform the assessment of establishment, information on the global distribution of *E. lignosellus* was collected together with the organism's ecophysiological responses. Identifying areas suitable for establishment informs the assessment of pest transfer from the pathway into the wider environment and the initiation of a founder population.

### 2.2.1. Literature search on the global distribution and ecophysiology of *Elasmopalpus lignosellus*

An extensive literature search for *E. lignosellus* global distribution was conducted on Web of Science (all databases, excluding Data Citation Index and Zoological Record) and Scopus on 14 September 2022 (Rossi et al., 2023). The search string was based only on the scientific and common names of the pest. No other keywords were used such as 'biology', 'physiology' and 'temperature' not to limit the retrieval of distribution data, often reported as secondary information. The review followed a two-step approach, the first step based on the title and abstract screening, the second one based on the full text. A full description of the literature search methodology and results are available in Rossi et al. (2023).

### 2.2.2. Köppen–Geiger climate matching

The SCAN-Clim tool was used to produce climate suitability maps based on the Köppen–Geiger climate classification approach (MacLeod and Korycinska, 2019; EFSA and Maiorano, 2022). The approach is based on the reanalysis of the Köppen–Geiger climate classification of Kottek et al. (2006). The reanalysed Köppen–Geiger map was downscaled to a higher resolution of 0.08 degrees with the method described by Rubel et al. (2017) and considers the period 1986–2010 (available at http://koeppen-geiger.vu-wien.ac.at/present.htm).

### 2.2.3. CLIMEX analysis under current climate

CLIMEX (version 4.1.0.0) (Kriticos et al., 2015) was used to assess the potential of *E. lignosellus* to establish in the EU. CLIMEX is based on ecophysiological requirements of an organism to complete the life cycle across a geographic region, given historic climate data. CLIMEX assesses the influence of weather-related stress factors (cold, heat, drought, humidity) on survival and growth through the calculation of growth-related indices and stress-related indices. The two groups of indices are combined together into an Ecoclimatic Index (EI), which quantifies suitability for establishment of the pest in a specific location based on the climate and the requirements of the species (Kriticos et al., 2015). The model was run using the climate data set available in CLIMEX, CM30 1995H V2 WO (www.climond.org), package v4.1. This data set is based on the 0.5° world grid of historical meteorological data (30 years centred on 1995) originating from the Climate Research Unit (Norwich, UK), and transformed using the methods of Kriticos et al. (2012). Parameter values were fixed according to information found in the literature (parameters related to response to temperature for growth, degree-days for one generation, soil moisture) or adjusted iteratively (parameters related to cold stress, heat stress and dry stress accumulation rates) until the simulated climate suitability was consistent with the observed distribution (full parameter list in Appendix D). For illustrative purposes, Figure 1 shows the relation between growth and stress temperature parameters, used to model *E. lignosellus* climate suitability.

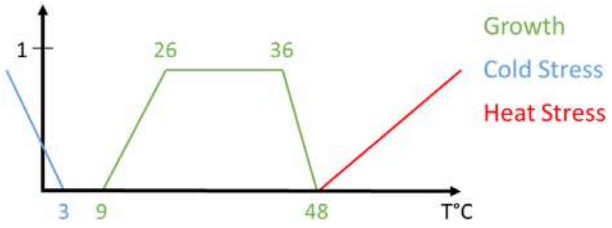


**Figure 1:** Conceptual graph illustrating temperature thresholds used in CLIMEX for *E. lignosellus*. Actual parameter values used in CLIMEX are given in Appendix D, Table D.1

The ecoclimatic index EI runs from 0 to 100, where 0 means that a place is unsuitable for the organism whereas 100 means a place is highly suitable. It is expected that with increasing EI, the density and impact of an organism will increase. According to Kriticos et al. (2015), a value of EI greater than 30 demarcates areas where climate is (very) favourable for the species whereas areas where EI < 30 are less favourable. They state: 'An EI of more than 30 represents a very favourable climate for a species, as it means that during the (say) six months suitable for growth with a maximum GIA of 50, the species has achieved 60% of the potential population growth'. However, a precise threshold value for establishment and impact cannot be given and any cut-off value of EI may be species-specific and should be operationally defined on the basis of additional evidence. The Panel used the threshold of EI > 30 to demarcate areas where higher population levels of *E. lignosellus* and impact of the insect are expected while it assumed that population levels would be lowered to levels of lesser concern to growers if EI would be below 30. This inference was made on the basis of the observation that areas in the Americas reporting substantial impacts of *E. lignosellus* (e.g. Georgia, USA; up to 100% loss of seedlings; Figure 7; Appendices F and G) had EI values above 30 (see also Section 3.4).

### 2.2.4. CLIMEX irrigation scenario

*E. lignosellus* does not thrive when the soil is humid. To consider the potential effects of irrigation, two CLIMEX scenarios were run, one considering no irrigation, the other considering the application of a top-up irrigation of 2.5 mm/day if rainfall fell below an average of 2.5 mm/day in a week's time, which is the time step of CLIMEX.

The irrigation scenario was applied only in the irrigated areas identified by Meier et al. (2018). Data from Meier et al. (2018) are based on a binary (irrigated vs. not irrigated) 0.008° grid. Since CLIMEX simulations are on a 0.5° grid, the irrigation data were upscaled to the same resolution and the information on irrigation summarised as the percentage of irrigated 0.008° pixels inside each 0.5° pixel. A 0.5° × 0.5° cell containing a value higher than 5% of irrigated 0.008° × 0.008° pixels was considered as an irrigated area.

### 2.2.5. Climate change scenarios and CLIMEX simulation ensemble

The potential effects of climate change on the climate suitability of *E. lignosellus* were analysed for a relatively near-term period, using projected climate in 2040–2059, the same period as previously used in the EFSA quantitative PRA for *Xanthomonas citri* pv. *viticola* (EFSA PLH Panel, 2022). The outputs of four regional climate models (i.e. ACCESS 1.0, CNRM-CM5, GFDL-ESM-2M, NorESM1-M) for the representative emission scenario RCP8.5, 'business as usual', were used as input to CLIMEX Kriticos et al. (2012). The outputs of the four simulations were averaged to get a CLIMEX simulation ensemble. Model parameterisation was the same as the one used under current climate data.

### 2.2.6. Transfer and initiation of a founder population

While most imported asparagus will be consumed, a proportion is discarded at various steps along the supply chain by importers, wholesalers and retailers, e.g. due to damage during handling and transport, physical quality problems, market conditions and pest finds (Gould and Maldonado, 2006). There is a possibility that live larvae in discarded asparagus will develop to adulthood, escape from discarded material and find a mate resulting in eggs being laid. Should the subsequent progeny develop and reproduce, a founder population would have been initiated. The process of transfer and initiation of a founder population was broken down into four steps:

- Estimating the proportion of imported asparagus discarded by commercial stakeholders in the supply chain due to e.g. infestation, physical damage, substandard quality or oversupply,
- The proportion of larvae that develop to adulthood and escape from discarded material,
- The proportion of females that find a mating partner and lay eggs,
- The likelihood that adults develop from the eggs to reproduce and initiate a founder population.

Information to support judgements relating to these steps necessary for establishment was assembled from the literature review by the EFSA PLH Panel. The collected evidence was reviewed during the EKE and is summarised in Appendix D (Section 2.2).

### 2.2.7. Overall model for introduction (entry and establishment)

The pathway model for introduction is a product of the following components:

- Import quantity of asparagus from Peru into the EU.
- Inverse weight of a single asparagus spear (to calculate the number of imported spears as the volume of trade (kg) divided by the weight of a single spear).
- Proportion of infested spears entering the EU.
- Proportion of infested spears imported to suitable NUTS2 regions (two scenarios: current climate and climate change).
- Proportion of asparagus disposed of as waste.
- Probability of a discarded larva surviving to become an adult.
- Probability of a female mating
- Probability of a mated female initiating a persisting founder population.

Figure 2 illustrates the model for introduction.

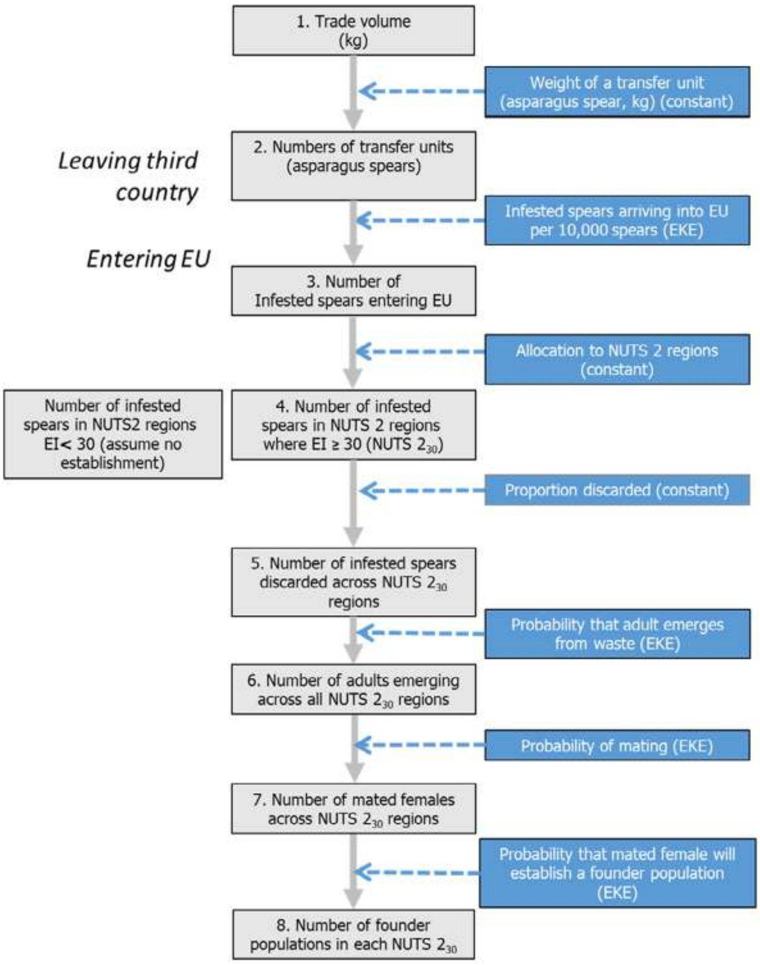


**Figure 2:** Conceptual model to quantitatively estimate the likelihood of introduction of *E. lignosellus* into the EU

## 2.3. Spread

Population spread is expected to follow a sigmoid curve (Figure 3). After an initial lag phase of slow spread during which the founder population builds up, spread accelerates and reaches a constant rate for some time before declining again as the suitable area gets fully colonised (saturation phase). Rather than estimate the parameters for logistic spread (i.e. Figure 3), this assessment followed the method of EFSA (2019) to estimate the duration of the lag phase and the linear rate of range spread when it is fastest. In this way, spread assessment is simplified.

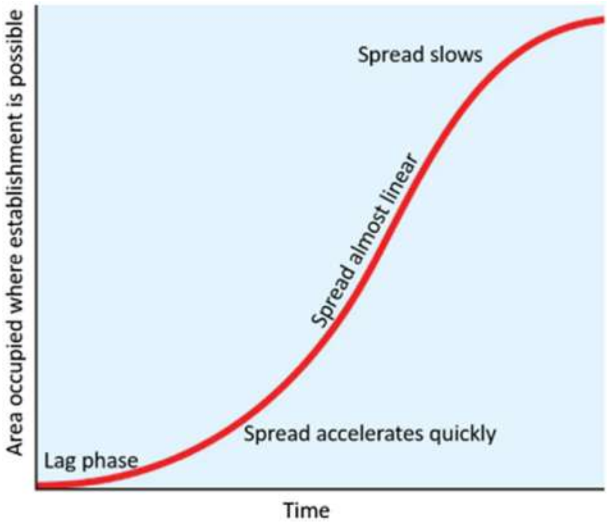


**Figure 3:** Stages of conceptual logistic spread: Following the lag phase (lag period), spread accelerates, becomes almost linear, then slows

For pests spread via commodities moved or traded by people, spread is not just expansion of a contiguous area but also may include distant satellite populations (Muirhead et al., 2006; Robinet et al., 2009; Herms and McCullough, 2014). The effect was integrated with the rate of natural spread.

An evidence dossier on spread was assembled from the literature review by the EFSA PLH Panel. It was analysed to inform the assessment of spread using EKE. The assessment of spread of *E. lignosellus* considered both natural dispersal and local human-assisted spread (Section 3.3). Assessors took part in the semi-formal EKE using behavioural aggregation (EFSA, 2014). The collected evidence was reviewed during the EKE and is summarised in Appendix E.

### 2.3.1. Scenario definition for spread

*Scenario for spread: considering existing practices and phytosanitary measures*

To estimate the lag period and rate of linear range expansion, the Panel developed a general scenario with the following description:

- The pest initiates a founder population at a single point somewhere within the area of potential establishment where the CLIMEX EI is greater than 30 (see Sections 2.2.3 and 3.2).
- Host availability is not a limiting factor. The founder population can always feed on hosts given the polyphagous nature of the pest (over 70 species in 27 plant families) and the presence of wild hosts at the right life stage (with young tender stems near the soil surface) throughout the year.
- Allee effects (already considered during the assessment of establishment) do not cause the founder population to die out.
- During the lag period, the population size increases until it reaches a local steady state in the centre of the population (determined by the habitat-carrying capacity).
- By reaching the local habitat-carrying capacity (saturation), the population enters the spread phase, pushing the outer edge of the saturated population at a constant rate into suitable, unoccupied neighbouring habitats.
- The spread assessment considers the outcome of the combined contributions of natural and local human-assisted spread. The human-assisted component only includes operations related to production and local movement (e.g. common agricultural practices) but no post-harvest movements, such as the trade in commodities (EFSA, 2019).
- Spread occurs within regions where the CLIMEX EI Index is greater than 30 (see Section 2.2).

## 2.4. Impact

An evidence dossier on impact was assembled by EFSA staff and Working Group members. It was analysed to conceptualise the impact elements of risk and to inform the assessment of impact using EKE.

The scientific literature on *E. lignosellus* was screened for information on impact of the pest on host plants. The main impacts reported in the literature are loss of seedlings due to insect feeding and damage to peanuts. Peanuts are vulnerable to *E. lignosellus* because they are growing below-ground when they are in a fresh and tender stage suitable for the insect to feed on. Data were extracted from the papers reporting impact to determine the average proportion of plants lost due to insect feeding and the average proportion of peanut pods or nuts attacked. Data were analysed using linear regression to determine the average proportion of damage across all studies and determine whether differences in percentage of plants lost occur between different plant species and between seedlings and peanut fruit. Two scenarios were considered in the information retrieval from the literature: (1) plants lost under pesticide-free treatments, (2) plants lost despite the use of pesticides. Data were extracted and analysed separately to determine the damage done by *E. lignosellus* with and without chemical control.

The results of meta-analysis were used as input for the EKE on impact of *E. lignosellus* on host plants with and without chemical control.

The collected evidence was reviewed during the EKE and is summarised in Appendix F.

### 2.4.1. Scenario definition for impact

*Scenario 1 (baseline): assuming no pest control is applied (*i.e. *artificial situation, akin to experimental 'control' plots in a trial)*

To estimate potential impact in terms of yield loss, a scenario with the following characteristics was defined:

- The pest has spread to its maximum extent.
- Within the area of potential establishment, pest presence depends on the heterogeneity of the patches where the host occurs. It is therefore not necessarily the case that the pest is present in all suitable patches.
- In each location where the pest occurs, its abundance is in equilibrium with the available resources (e.g. host plants) and environmental conditions (including climate, ecosystem resistance and resilience) (e.g. Grimm and Wissel, 1997).
- No action was taken for pest control – yield loss data (% of plants lost) in control plots of field trials were extracted from the literature and the subsequent meta-analysis used to inform losses when no control options are applied (representing worst-case conditions).
- Current crop production practices (e.g. chemical insecticides are not used).
- The assessment of impact assumes a situation in which *E. lignosellus* has been established in a climatically suitable area (EI $\geq$ 30) for a long enough period of time to have reached carrying capacity and maximum impact.
- Potential impact of transient populations was not considered i.e. in NUTS2 regions with low suitability for establishment (EI $<$ 30).
- Different susceptibilities of host plants (e.g. species, cultivars, rootstocks) or the detailed biological characteristics of *E. lignosellus* (e.g. dispersal, feeding activity) are not considered in the assessment of impact.
- The focus was on cereal and legume hosts present in the NUTS2 of southern Europe suitable for establishment (EI $\geq$ 30) e.g. Mediterranean Coastal areas.
- Categorise the vulnerability of the plants in the typical production systems (assumption: seedlings and young plants are vulnerable/orchard trees are not under risk).

*Scenario 2 (with pest management in place): considering existing practices and any additional pest management by farmers to target the pest*

To estimate potential impact in terms of yield loss under scenario 2, the Panel envisaged scenario 1 with the following additional conditions:

- Pest control practices would be applied by farmers.

- Cropping practices and management options are those currently in place in the area of potential pest distribution, considering differences with those applied in countries where *E. lignosellus* is present (and evidence was collected).
- The effect of currently applied control against other pests is taken into account (e.g. yield losses in EU crops given existing pest pressures were considered – how much more would *E. lignosellus* add to the existing burden of pests in the EU?).
- In a scenario where the pest is widely established and there would be no statutory action by NPPOs in the EU against *E. lignosellus*.

## 2.5. Evaluation of risk mitigation measures

As noted in Section 2.1.2, the EFSA PLH Panel did plan to evaluate how additional risk mitigation measures may reduce the likelihood of pest entry. However, during the collection of evidence, it was found that the most recent updates of exporting practices for asparagus by the Peruvian authorities already used a zero tolerance level for *E. lignosellus* in fresh asparagus exported to the EU (NAHS, 2022). This opinion therefore presents an assessment of pest risk based on recently updated existing measures alone.

## 2.6. Temporal and spatial scales

The pathway model calculates the flow per year, on average, over the next 5 years (2024–2028).

The distribution of potentially infested plant material entering the EU was assessed using NUTS2 spatial resolution using EU census data from 2021 (Eurostat, accessed 31/12/2022).

The Köppen–Geiger climate classification and CLIMEX both used 30 years of climate data, 1981–2010. The Köppen–Geiger climate classification uses a 10-km world grid and CLIMEX a 0.5° world grid.

# 3. Assessment

A synthesis of the biology of *E. lignosellus* based on the literature review is provided in Appendix A together with some examples of the pictures presenting the pest and the damage it causes. A list of cultivated hosts and wild/weed hosts is provided in the pest categorisation for *E. lignosellus* (EFSA PLH Panel, 2021). In relation to entry, key features of note are that females mostly lay eggs in or on the soil close to young host plants. For example, Cheshire and All (1990) found that of 558 eggs detected, 86% were in the soil, a mean distance of 3.2 cm from the nearest maize seedling; 14% of eggs were on seedlings. Similarly, growing peanuts in a greenhouse experiment, Smith et al. (1981) found approximately 93.8% of *E. lignosellus* eggs were laid in the soil; 6.1% on soil surface and $<0.1\%$ eggs laid on peanut plants. When the study was conducted in the field, 2.4% of eggs were found on peanut plants; hence, the majority of eggs (97.4%) were laid in or on the soil. Smith et al. (1981) reported 79% of eggs were within 10 cm of a peanut plant. Studying *E. lignosellus* in soybean, Molinari and Gamundi (2010) reported eggs being found in the soil, at the base of the stalk of seedlings and on lower leaves although the proportion of eggs at each site was not given.

## 3.1. Entry

### 3.1.1. Identifying pathways (interceptions on produce)

The Panel searched for interceptions of *E. lignosellus* in Europhyt (1995 to until May 2020) and TRACES (June 2020-ongoing database, last check 7 March 2023).

In Europhyt, 25 interceptions were found. These interceptions were on asparagus from Peru, and 23 interceptions were made on air-transported asparagus at Heathrow airport and 2 at the airport of Dublin. The 25 interceptions were made between 12 August 2019 and 1 March 2020 (Figure 4). The last record was of an interception made at Heathrow airport on 1 March 2020, 1 month after the withdrawal of the United Kingdom from the European Union (EU) at 23:00 GMT on 31 January 2020. A peak in interception occurred in September 2019 (Recall that the NPPO of Peru published export procedures indicating a 0% tolerance for *E. lignosellus* in December 2022).

Using the TRACES system, three interceptions on asparagus from Peru were retrieved after 2022. Two interceptions were made in Ireland and another one in Belgium.

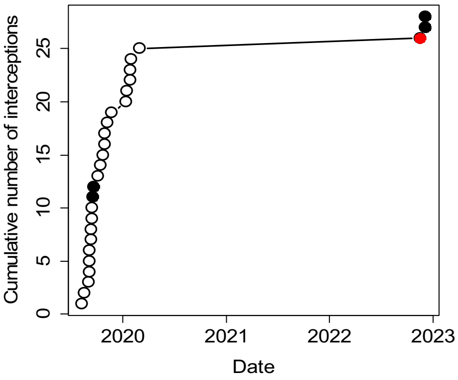


**Figure 4:** Plot of the cumulative number of interceptions of *E. lignosellus* at European ports of entry according to records in Europhyt and TRACES. Twenty-eight interceptions were recorded, 23 at Heathrow airport in London (open symbols), all reported in Europhyt before the UK left the EU, and four at the airport of Dublin, Ireland (closed symbols), two of which were retrieved from Europhyt and two of which were retrieved from TRACES. A single interception (red symbol) was made in Belgium

Solis (2006) reports 'interceptions' in the USA including on asparagus, but there were no details regarding the origin of the material or the part of the plant *E. lignosellus* was found on.

Chile intercepted *E. lignosellus* on asparagus from Peru and did a PRA concluding that *E. lignosellus* qualified as a quarantine pest for Chile. The most likely route of introduction into Chile was judged to be through asparagus turions (spears) for fresh consumption. The Chilean NPPO then changed their legislation for importing fresh asparagus from Peru and Argentina (SAG, 2016a,b). EPPO GD indicates *E. lignosellus* became a quarantine pest for Chile in 2019. Appendix B gives the quarantine status of *E. lignosellus* as recorded by regional plant protection organisations.

### 3.1.2. Identifying pathways (plants for planting)

As with other Lepidoptera, adults are unlikely to be carried on hosts. When disturbed adults alight and fly short distances. The handling and movement of plants at origin would cause adults to leave plants to seek shelter in an undisturbed location. Several authors report larvae feeding on, and tunnelling in, host seedlings and young plants (Table 1). The import of young seedlings as plants for planting was therefore further investigated as a potential pathway for entry. Further evidence that larvae primarily feed on young plants comes from Martins and Silveira (1959) who reported that *E. lignosellus* larvae stop feeding on maize when maize plants reach approx. 30 cm. Bessin (2019) reported *E. lignosellus* did not feed on maize plants beyond the sixth leaf growth stage. In Texas, the collar of the sixth leaf of maize is visible approximately 3 weeks after emergence (Bell, 2017).

**Table 1:** Examples of hosts which are attacked as seedlings by larvae of *Elasmopalpus lignosellus*

| Host | Description of where larvae feed | References |
|---|---|---|
| *Cornus florida* (flowering dogwood) | On seedlings | Dixon (1982) |
| *Gossypium* sp. (cotton) | On seedlings | Abrahao and Amante (1970);<br>Dupree (1965) |
| *Juniperus silicicola* (southern red cedar) | On seedlings | Dixon (1982) |
| *Nyssa sylvatica* (black tupelo) | On seedlings | Dixon (1982) |
| *Phaseolus vulgaris* (common bean) | On seedlings or young plants, 10–12 cm tall with 2 leaves | Fernández (2016) |
| *Pinus clausa* (sand pine)<br>*P. elliottii* (slash pine)<br>*P. taeda* (loblolly pine) | On seedlings | Dixon (1982) |
| *Platanus occidentalis* (sycamore) | On seedlings | Dixon (1982) |

| Host | Description of where larvae feed | References |
|---|---|---|
| *Robinia pseudoacacia* (Black locust) | On seedlings | Dixon (1982) |
| *Saccharum officinarum* (sugarcane) | On young shoots | Fewkes (1966) |
| | On seedlings | Segura (1990) |
| | On young sugarcane, 30–40 days after planting | Saldana and Ayquipa (2021) |
| | On young plants | Isely and Miner (1944); Heu (1988) |
| *Taxodium distichum* (bald cypress) | On seedlings | Dixon (1982) |
| *Zea mays* (maize) | On seedlings in springtime | Calderon and Mendoza (2006); Vilchez et al. (2014) |
| | On seedlings up to 15 days old | Toledo et al. (1994) |

On reviewing Dutch data on the genera of host plants for planting imported from the Americas (Table 2) and taking into account the likely production process (e.g. indoor or open field) and the nature of the plant part imported (e.g. cuttings or growing plants with roots), no plants for planting were identified as feasible pathways for introduction of *E. lignosellus*. Reasons include the following:

- *E. lignosellus* eggs are primarily laid on or in soil and soil is prohibited from entering the EU,
- *E. lignosellus* is not known as a pest in protected cultivation; even if females did enter protected conditions, indoor-rooted cuttings are likely sufficiently well irrigated to deter oviposition,
- *E. lignosellus* larvae feed and develop on young plants and tender stems; larvae do not feed on branches and foliage of hosts used for ornamental purposes,
- *E. lignosellus* larvae would not occur on unrooted cuttings,
- Strawberry propagating material from USA is very carefully managed and rigorously inspected then certified if it meets the necessary health standards. The very strict cropping requirements including the preplanting treatments of the runners (dipping of the plant material prior to planting), crop monitoring (including obligatory field inspections) and isolation requirements would severely inhibit the likelihood of *E. lignosellus* being present on strawberry plants for planting from the USA. Strawberry mother plants would not be shipped with soil from the USA to the EU.

Pineapple plants (*Ananas comosus*) from Costa Rica could provide a possible pathway if they were grown outdoors and shipped as young plants. Solis (2006) indicated that *E. lignosellus* had been intercepted on *Ananas* in the USA. However, each Dutch consignment of *Ananas* imported from Costa Rica consisted of only one plant. It was thought that single plants were unlikely to be young plants. If they were mature plants (a more likely scenario for single plant imports), then they would not be suitable hosts. Single plants would also be highly unlikely to provide sufficient propagule pressure for pest establishment.

In general, young plants for planting destined for the EU are highly likely to have been grown in compost and well-watered and females would avoid damp conditions for oviposition as high soil moisture increases larval mortality. Existing EU phytosanitary measures require plants for planting be either grown in non-soil growing media or fumigated or heat treated; or use an effective systems approach, and the growing media must be kept pest free; or in the 2-week period before export, plants are washed and replanted in growing media free from EU quarantine pests (EU 2019/2072 Annex VII, 1). Such general requirements further support the assertion that such plants for planting do not provide a suitable pathway for *E. lignosellus* introduction.

### 3.1.3. Identifying pathways (produce, but no interceptions)

- Root and tuber produce: potato, sweet potato, radish and turnip are among *E. lignosellus* hosts. While larvae are known to feed on roots, the Panel found no evidence that tubers or taproots were tunnelled.
- Leguminous produce: *E. lignosellus* is a pest of a range of peas and beans. However, roots and the stems of young plants are fed upon by larvae. Larvae are not reported to infest the aerial (harvested) pods. However, larvae can be a serious pest of peanuts (groundnuts); literature from the USA reports larvae feeding on the pegs (young fruit) and pods of peanuts. However,

processing of nuts prior to export, such as drying to prevent the development of aflatoxins, and roasting in shell (160°C for 40–60 min) (Anonymous, 1995) would kill any contaminating egg or larva.

- Brassicas: *E. lignosellus* is not known as a pest that infests cabbage or other brassicaceous plants (John All, Univ. of Georgia (USA) pers. comm.).
- Tomatoes: *E. lignosellus* has not been found on tomato fruits (John All, Univ. of Georgia (USA), pers. comm.). Recall larvae feed on roots and low down in stems.
- Cereals: *E. lignosellus* is known as a pest of cereals, especially maize in South America and southern USA. Larvae attack seedlings and young plants. Harvested grain and cobs do not provide a feasible pathway as eggs are primarily laid in the soil, or close to soil level, and larvae burrow in stems of young plants only to a limited height and so will not be present in harvested cereals.

**Table 2:** Number of consignments of *E. lignosellus* host plants entering the Netherlands in 2021 from countries in the Americas

| HS_Description | Genus or species (as provided by Dutch NPPO) | Common Name | HS Code | Comment | Pathway? | Colombia | Costa Rica | Guatemala | Mexico | USA |
|---|---|---|---|---|---|---|---|---|---|---|
| Indoor rooted cuttings and young plants (excl. cacti) | *Ananas* | Pineapple plant | 0602 9070 | *E. lignosellus* not known to be a greenhouse pest | No | | 36 | | | |
| | *Brassica oleracea* | Cabbage (ornamental) | 0602 9070 | " | No | | | 1 | | |
| | *Helianthus* | An ornamental | 0602 9070 | " | No | | | | | 5 |
| | *Ipomoea batatas* | Sweet potato | 0602 9070 | " | No | | | | | 1 |
| | *Maranta* | PRAYER plant | 0602 9070 | " | No | | | 12 | | |
| | *Miscanthus* | Chinese silver grass | 0602 9070 | " | No | | | 38 | | 1 |
| Live indoor plants and cacti (**excluding** rooted cuttings, **young plants** and flowering plants) | *Ananas* | Pineapple plant | 0602 9099 | Not young plants | No | | 41 | | | |
| Foliage, branches and other parts of plants, suitable for bouquets or ornamental purposes | *Brassica oleracea* | Ornamental cabbage | 0604 2090 | Pest not on plant part | No | | | | | 3 |
| Unrooted cuttings and slips | *Ananas* | Pineapple plant | 0602 1090 | " | No | | 9 | | | |
| | *Helianthus* | Sunflower | 0602 1090 | " | No | 4 | | | | |
| | *Ipomoea* | An ornamental | 0602 1090 | " | No | | | | | 4 |
| | *Maranta* | Prayer plant | 0602 1090 | " | No | | 2 | 104 | | |
| | *Mentha* | Mint | 0602 1090 | " | No | 11 | | 14 | 1 | |
| | *Miscanthus* | Chinese silver grass | 0602 1090 | " | No | | | 2 | | |

| HS_Description | Genus or species (as provided by Dutch NPPO) | Common Name | HS Code | Comment | Pathway? | Colombia | Costa Rica | Guatemala | Mexico | USA |
|---|---|---|---|---|---|---|---|---|---|---|
| Pineapple plants | *Ananas comosus* | Pineapple plant | 0602 9020 | Assume young plants (see text for details) | No | | 2 | | | |
| Vegetable and strawberry plants | *Fragaria* | Strawberry | 0602 9030 | High quality/ certified | No | | | | | 6 |

### 3.1.4. Pathway evaluation (EKE results)

Based on an estimate of the quantity of future imports, the weight of asparagus spears and the proportion of spears infested by larvae of *E. lignosellus*, the median number of infested asparagus spears entering the EU each year was estimated to be approximately 8,600 (90% CR is from approximately 1,300 to 58,500) (Table 3).

**Table 3:** Model output results illustrating the range in estimates of mean imports and subsequent range in number of infested *Asparagus* spears entering the EU each year (each infested spear is assumed to be infested with one live larva)

| Percentile | 1% | 5% | 25% | 50% | 75% | 95% | 99% |
|---|---|---|---|---|---|---|---|
| Import of fresh asparagus from Peru into the EU (million kg) | 15.76 | 17.39 | 19.72 | 21.40 | 22.96 | 25.28 | 26.92 |
| Average weight of one asparagus spear (kg) (constant) | 0.026 | | | | | | |
| Number of asparagus spears imported from Peru (million) | 602.2 | 664.7 | 753.6 | 815.4 | 877.2 | 966.1 | 1,028.6 |
| Infestation rate of Asparagus from Peru (per 10,000 spears) | 0.007 | 0.016 | 0.049 | 0.106 | 0.232 | 0.716 | 1.579 |
| Number of infested spears (larvae) entering the EU | 567 | 1,259 | 3,919 | 8,606 | 18,839 | 58,486 | 127,605 |

### 3.1.5. Uncertainties affecting the assessment of entry

- Volumes of asparagus from Peru may change in future: Irrigation of asparagus in Peru is controversial (Brunori et al., 2016; Vazquez-Rowe et al., 2016) and competition for scarce water resources might reduce future imports.
- In the future, asparagus from Mexico could become more significant and provide a pathway although most Mexican asparagus is exported to USA, in the future more could come to EU.
- The assessment of the proportion of infested spears was made on the basis of information on the total volume of asparagus coming annually to the EU at a time when the UK was part of the EU, the average size of the imported consignments (800–3200 kg; assumed average 1000 kg), the assumption that 5% of consignments would be inspected using a sample of 300 spears, and information in Europhyt that in a bad season (2019/2020), 23 consignments imported to the UK were infested.
- There is uncertainty on the distribution of consignment sizes, the percentage of consignments inspected in each country, the sample size at inspection and the chance of detection of infestation if an inspector evaluates a spear.

### 3.1.6. Conclusion on the assessment of entry

The pathway most likely to provide a route for entry of *E. lignosellus* into the EU was judged to be fresh asparagus from Peru. In the order of several thousand spears infested with *E. lignosellus* are expected to enter the EU each year (median estimate approximately 8,600; 90% CR approximately 1,300–58,500). Infested spears represent a small proportion (approximately 0.001%, i.e. one in 100,000 spears) of the total number of spears that are imported from Peru, which is in the order of hundreds of millions each year (median approximately 815 million; 90% CR 664–966 million).

## 3.2. Establishment

Climatic mapping is a common approach to identify new areas that might provide suitable conditions for the establishment of alien organisms (Baker, 2002; Venette, 2017). Climatic mapping is based on combining information on climate in the known distribution of a poikilothermic organism, the organisms' physiological responses to environmental conditions and the climate in the risk area. The current distribution of *E. lignosellus* is presented in Section 3.2.1. The results of climatic mapping are presented in Sections 3.2.2–3.2.5.

### 3.2.1. Global distribution of *Elasmopalpus lignosellus*

The extensive literature search yielded 295 documents including 271 documents containing information on pest distribution, and 65 on ecophysiology. From these documents, 588 records of the presence of *E. lignosellus* were extracted, out of which 261 were specified locations with geographic coordinates, or very small administrative units (e.g. small provinces) for which coordinates from Google Earth were used (Figure 5A), and 327 records mentioned the presence of the species in larger administrative units (Figure 5B).

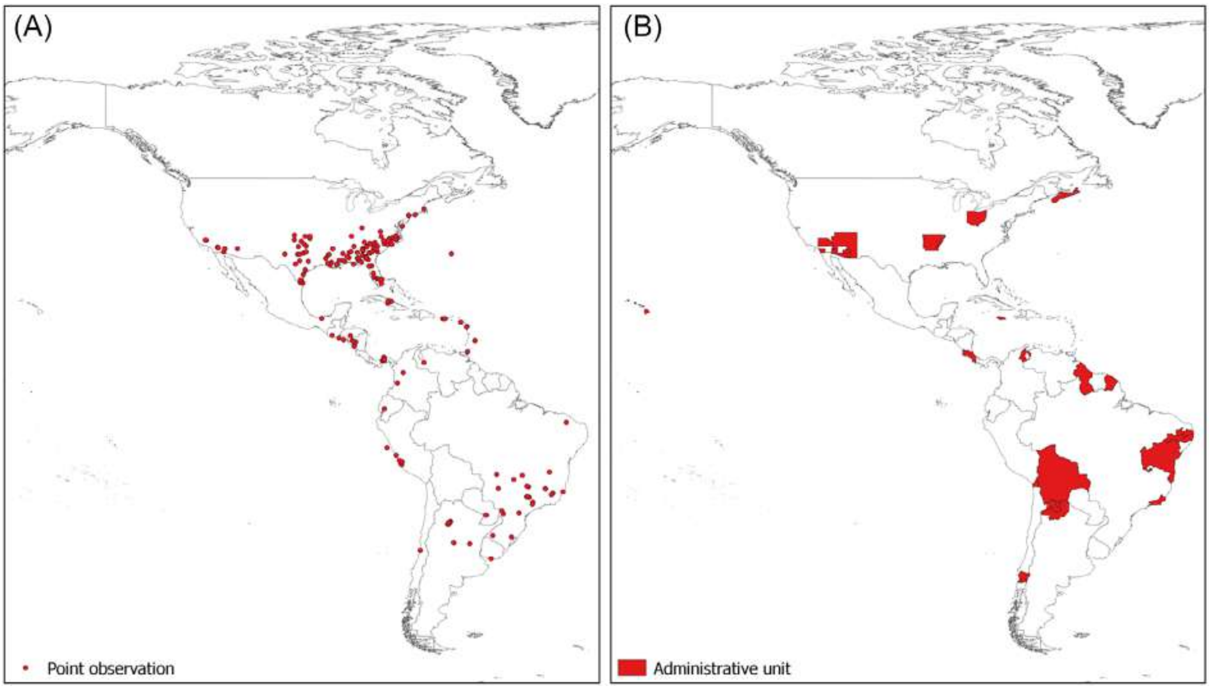


**Figure 5:** Observed distribution of *E. lignosellus*. Red dots in the left map (A) indicate point observations with location coordinates. Red polygons in the right map (B) indicate administrative units where the pest was observed and for which no specific coordinates were reported

### 3.2.2. Köppen–Geiger climate matching

The climate types present in the observed locations of *E. lignosellus* were identified and mapped. Since the area of the assessment is the EU, the output maps show only climate types that are present in this area. If the organism occurs in a climate type that does not occur in the EU, this climate is not mapped as a relevant climate for the assessment. Administrative units where the pest was observed are highlighted with black borders, while point observations are indicated with red dots. *E. lignosellus* has been observed in the following Köppen–Geiger climate types that also occur in the EU: hot semi-arid (BSh), cold semi-arid (BSk), humid subtropical (Cfa), temperate oceanic (Cfb), Mediterranean hot summer (Csa) and Mediterranean warm summer (Csb). Climate type Cfb is relatively rare in the Americas but common across EU. There is uncertainty on the suitability of climate type Cfb for establishment of *E. lignosellus* in part because the area of Cfb in the Americas is small. In fact, Cfb occurs in only two of the 220 point locations (one in Paraná, Brazil and the other one in the department of Antioquia, Colombia), and in few pixels of large administrative units of the USA, Brazil, Mexico and the mountainous region of the Andes. Hence, Figure 6 presents the global distribution of EU climate types in which *E. lignosellus* has been observed, but without Cfb. A map including the Cfb climate is shown in Rossi et al. (2023).

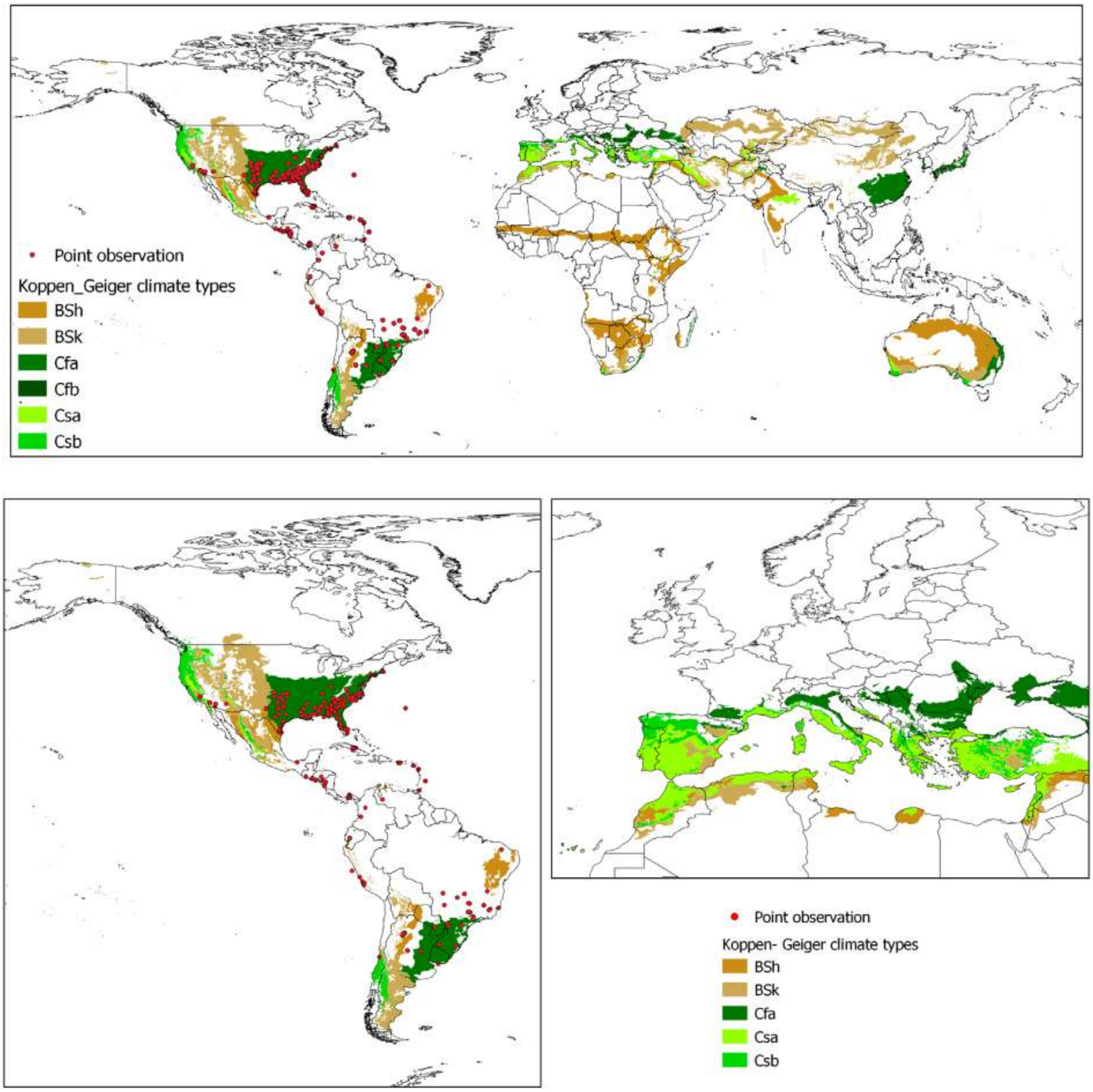


**Figure 6:** World map with zoomed-in insets for the Americas and Europe, showing Köppen-Geiger climate zones occurring in Europe as well as presence points of *E. lignosellus* in the Americas in those same climate zones. Only the European climate zones with the presence of *E. lignosellus* in the Americas are shown. Climate Cfb is widespread in Europe but was excluded from the maps as it is very rare in the Americas (see text for details)

### 3.2.3. CLIMEX projection under current climate

A CLIMEX model was parameterised to describe the relationship between climatic conditions and occurrence of *E. lignosellus*. The parameterisation of CLIMEX is based on a literature review (Rossi et al., 2023). Appendix D describes how parameters used in the CLIMEX tool were determined.

Figure 7 shows the CLIMEX Ecoclimatic Index (EI) for *E. lignosellus* for the Americas and Europe. Ecoclimatic index values $> 1$ are found along the Mediterranean coasts of the EU, Portugal, areas of Spain and France, Southern Ireland, the Netherlands and Belgium. Substantially higher EI levels are shown only for Mediterranean coastal area, similar to the Köppen–Geiger climate matching (Figure 6). EI > 30 was used by the Panel as a threshold for areas at risk of pest establishment with consequences for agriculture and the environment. Regions with EI < 30 do not completely rule out establishment, but the number of generations and impact are expected to be lower than where EI > 30 and such areas are therefore assessed to be at lower risk.

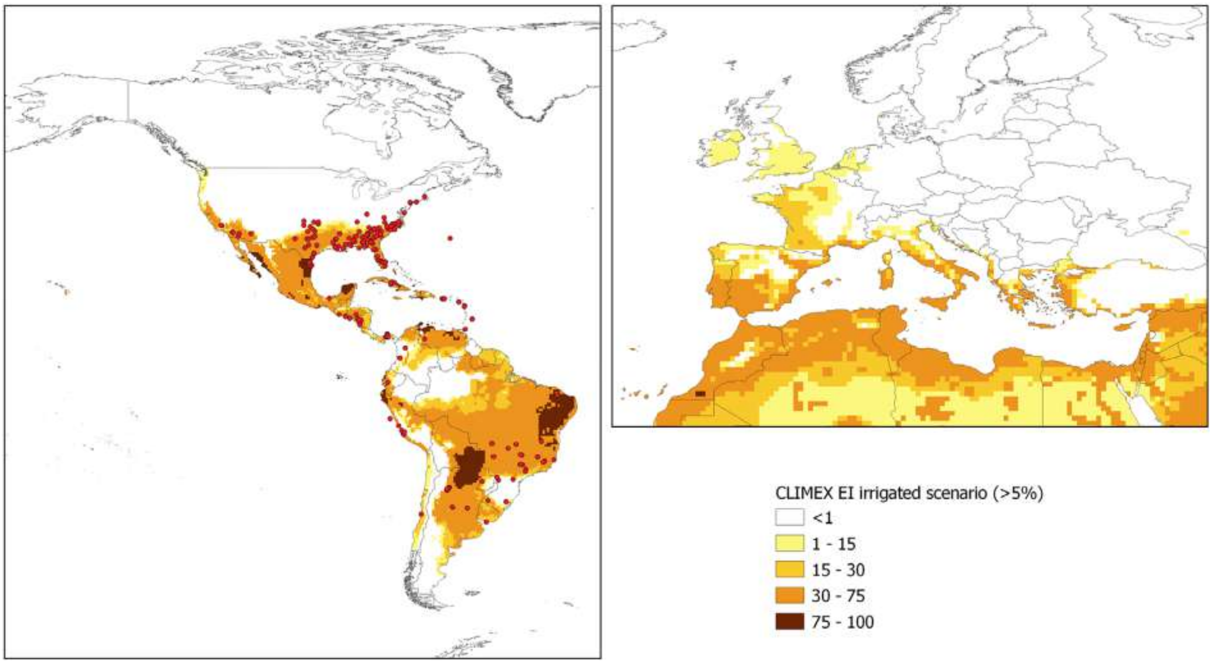


**Figure 7:** CLIMEX Ecoclimatic Index (EI) for *E. lignosellus*. The simulation is based on the reference parameterisation and includes top-up irrigation (rainfall + irrigation up to 2.5 mm/day) applied only on irrigated pixels (see Rossi et al., 2023)

### 3.2.4. Identifying suitable NUTS2 regions for establishment

Importation of asparagus spears infested with *E. lignosellus* has consequences if the insect enters in areas that are suitable for establishment. In this assessment, it is assumed that asparagus is apportioned across the NUTS2 regions of the EU according to their number of inhabitants, as an indicator of consumer demand. While food consumption does vary regionally, Blandford (1984) found the differences in food consumption between OECD countries were decreasing, suggesting diets were converging and are becoming increasingly similar in the overall structure of their diet. When comparing diets within Europe, Elsner and Hartmann (1998), Mauracher and Valentini (2006) and Schmidhuber and Traill (2006) found European diets were also converging. Within the EU diets thus have become more homogeneous.

Having used CLIMEX to identify areas of the EU where climatic conditions could support establishment (Figure 7), NUTS2 regions where a substantial proportion of grid cells in the region showed EI > 30 were identified. An EI threshold of 30 was selected based on Kriticos et al. (2015), and on the distribution of *E. lignosellus* in the USA and the locations where damage is reported. Regions with EI < 30 do not completely rule out establishment, but the number of generations is lower than where EI > 30 and such areas are therefore assessed to be at lower risk of establishment and impact. In these places, crop destructive populations would be restricted to locations with hot, dry, summer environments and particularly in non-irrigated fields on sandy soils (John All, pers. comm.). Figure 8 delineates the NUTS2 regions with substantial area proportions with EI > 30.

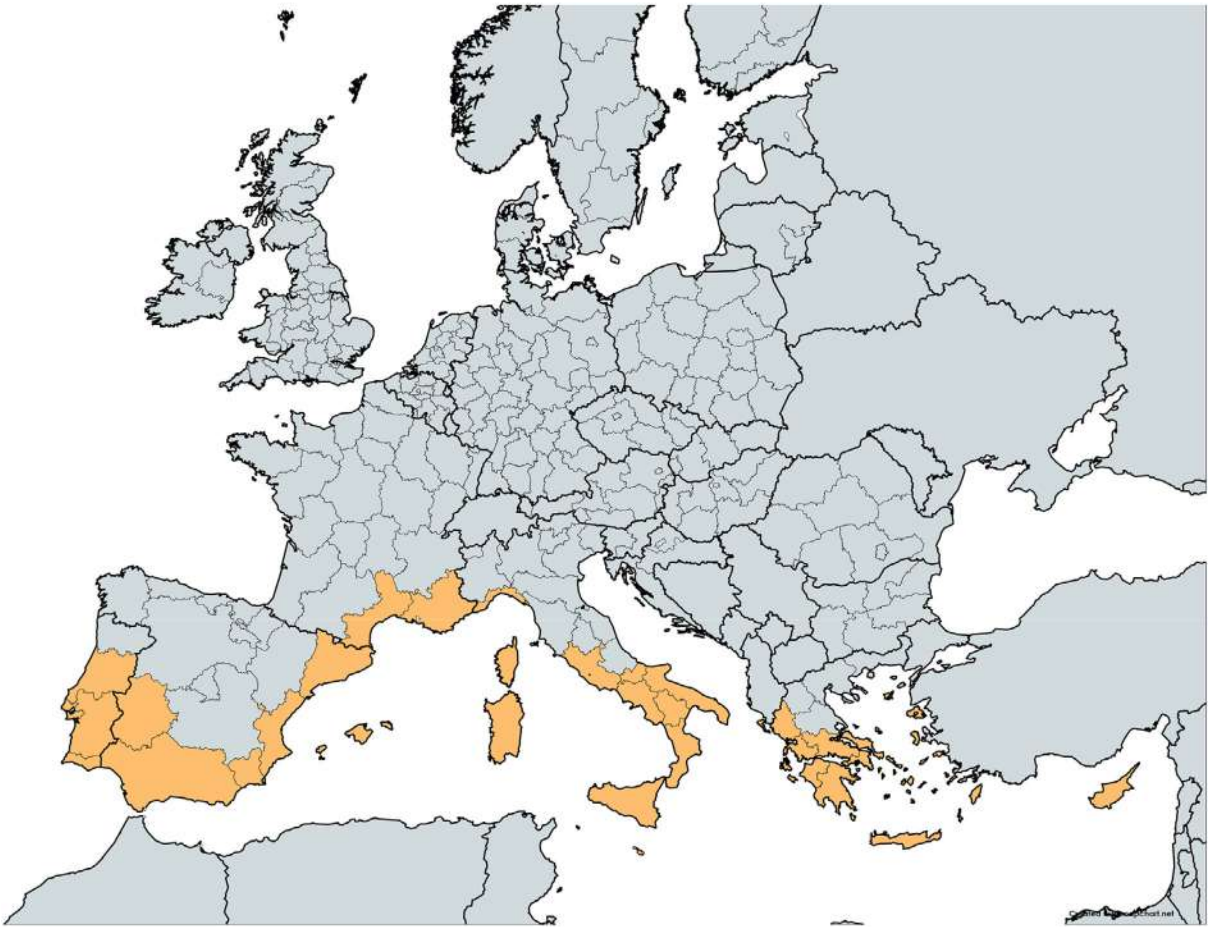
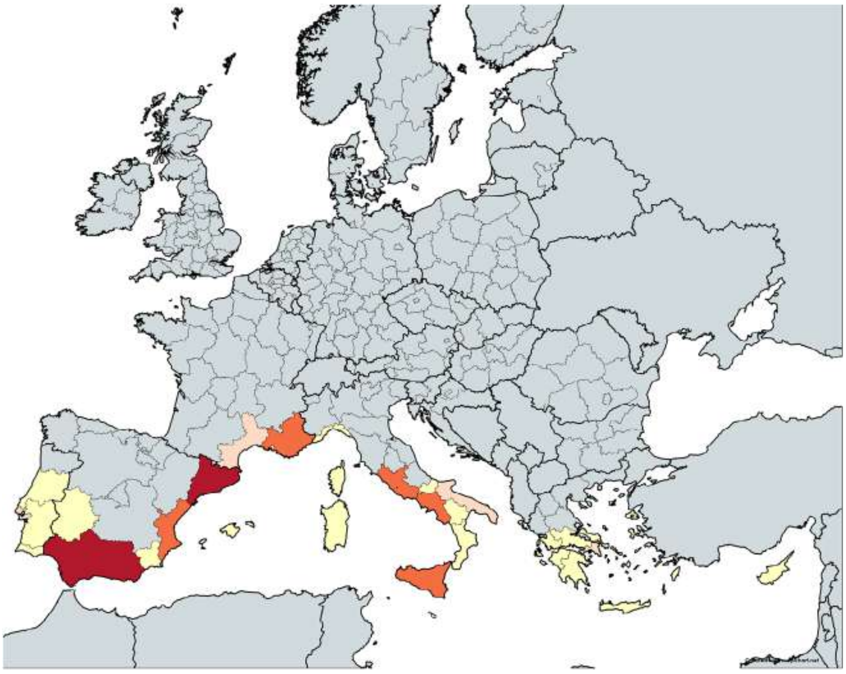


**Figure 8:** NUTS2 regions where a large proportion of grid cells have EI > 30 (current climate conditions with irrigation, lower cold tolerance threshold 3°C)

When the infested spears are allocated to suitable NUTS2 regions (EI > 30 under current climate) proportional to the human population, median values of infested spears are expected between 4 and approximately 160 in each suitable NUTS2 area, based on the median number of infested spears entering into suitable NUTS2 regions. These numbers are higher when using the 95 percentile and lower when using the 5 percentile (Figure 9). Numbers entering into a NUTS2 area are used when assessing the likelihood of mate finding of emerged female adults. The fewer adults emerge in a NUTS2 area in a year's time, the lower the chance that any female will find a mate.



| Range of estimates of number of infested spears entering annually | | | |
|---|---|---|---|
| % EU population | 5th percentiles | Medians | 95th percentiles |
| 0.01–0.50 % | 1–6 | 4–43 | 29–293 |
| 0.51–1.00 % | 8–11 | 55–76 | 375–516 |
| 1.01–1.50 % | 14–16 | 93–110 | 633–751 |
| 1.51–2.00 % | 22–24 | 148–164 | 1,009–1,114 |

**Figure 9:** Model outputs indicating the range in number of infested spears entering EU NUTS2 regions where current climatic conditions are suitable for establishment (EI > 30)

Andalusia and Catalonia are the NUTS2 regions receiving the highest number of asparagus spears where current climatic conditions would support establishment. The median number of infested spears entering Andalusia is estimated to be 165 each year (90% CR 25–1,110). The median number of infested spears entering Catalonia is estimated to be 150 each year (90% CR 20–1,005).

### 3.2.5. Climate change: simulation ensemble under climate change scenarios

Figure 10 shows the increase in pixels with EI > 30 simulated by CLIMEX under climate change scenario (ensemble simulation using the outputs of four climate models) compared to the simulation under current climate. The results show a substantial increase in Spain and France, and to a lesser extent but still relevant, also in Italy and Greece. In general, the CLIMEX results based on any single climate model are in agreement with the ensemble simulation (Appendix D; Figure D.6).

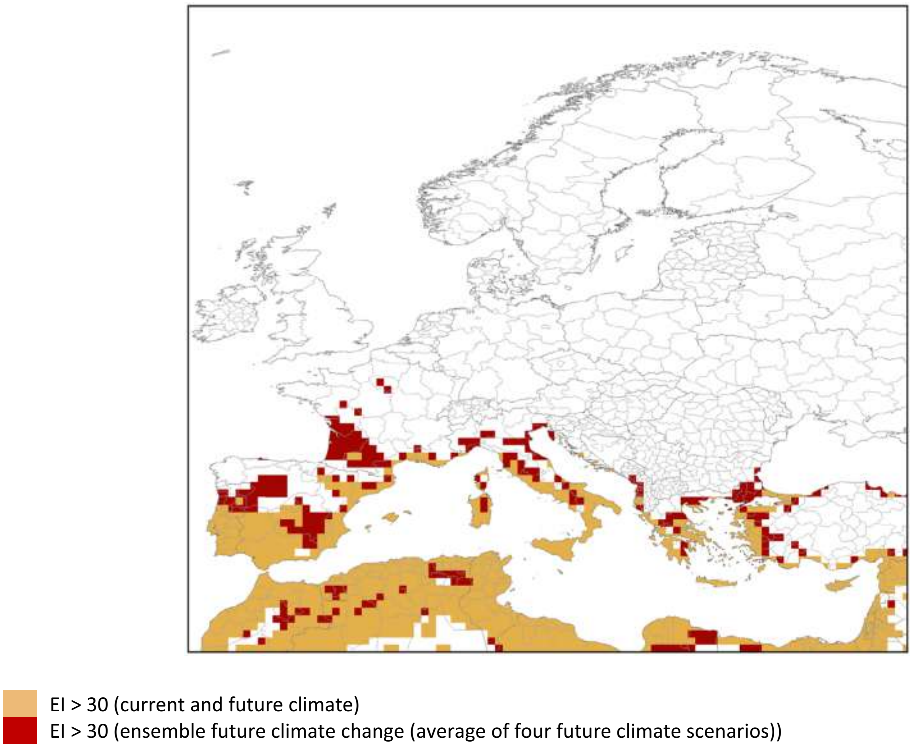


**Figure 10:** Areas where climate is suitable for establishment of *E. lignosellus* now (sandy colour) and under the future climate change scenario (sandy and red)

Results for each of the four future scenarios can be seen in Appendix D (Figure D.6).

Based on the ensemble of climate change scenarios, Figure 11 shows additional NUTS2 regions with EI > 30 under climate change only (dark red) and with EI > 30 with current climate (sandy colour).

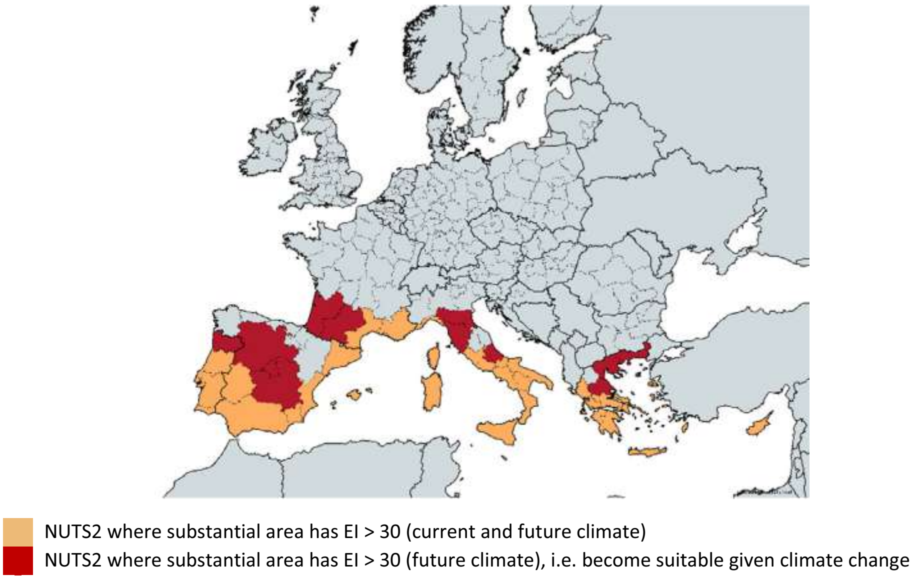
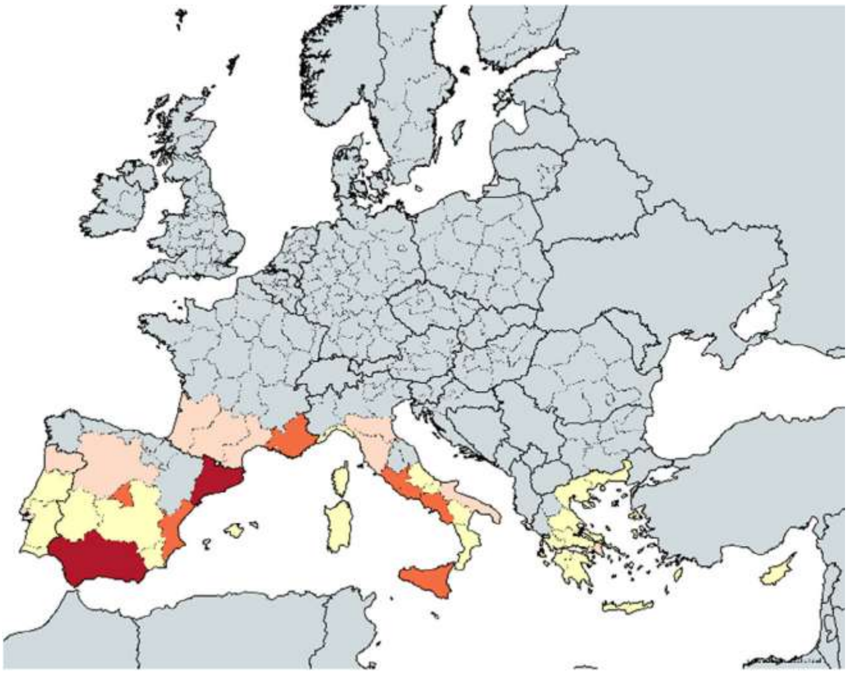


**Figure 11:** NUTS2 regions where climate is suitable for establishment of *E. lignosellus* now (sandy colour) and under the future climate change scenario (sandy and red)

Based on current climate, 32 NUTS2 regions are identified as regions where EI > 30; under the future climate scenario, the number of NUTS2 regions where EI > 30 increases to 44. Figure 12 indicates the range in number of infested asparagus spears entering NUTS2 regions where EI > 30 under the future climate scenario.



| | % EU population | Range of estimates of number of infested spears entering annually<br>5th percentiles | <br>Medians | <br>95th percentiles |
|---|---|---|---|---|
| 🟨 | 0.01–0.50 % | 1–6 | 4–43 | 29–293 |
| 🟪 | 0.51–1.00 % | 7–13 | 46–85 | 311–581 |
| 🟧 | 1.01–1.50 % | 14–16 | 93–110 | 633–751 |
| 🟥 | 1.51–2.00 % | 19–24 | 130–164 | 886–1,114 |

**Figure 12:** Model outputs indicating the range in number of infested spears entering EU NUTS2 regions where future climatic conditions are suitable for establishment (EI > 30). Note that the percentage apportioning of infested asparagus spears equals the percentage of consumers relative to the whole EU

### 3.2.6. Conclusions on identifying NUTS2 regions suitable for establishment

Under current climatic conditions, there are 32 NUTS2 regions in the EU where majority of the grid cells indicate an EI of 30 and above. The NUTS2 regions are identified and listed in Appendix D (Table D.2), together with the size of the human population in each NUTS2 region (2021 population estimates). Assuming EU imports are distributed across the EU in relation to human population, approximately 16.4% of asparagus imports from Peru go to these NUTS2 regions.

In a climate change scenario, the climate in 12 NUTS2 regions changes sufficiently such that 44 NUTS2 regions become suitable for establishment of *E. lignosellus*. This increases the proportion of imported asparagus reaching areas suitable for establishment to 24.0%.

### 3.2.7. Introduction of *Elasmopalpus lignosellus* into the EU

The entry and establishment of a pest results in pest introduction (FAO, 1997). The Panel used Monte Carlo simulations with a probabilistic pathway model to assess the number of infested spears entering each year into those parts of the EU that are suitable for establishment. The model quantifies then the subsequent steps of waste production, escape of adult insects from waste, mating and initiation of a founder population by an egg-laying female. Table 4 reports percentiles of each of the parameters in the pathway model together with percentiles of the subsequent calculation of the number of remaining infested spears. The numbers of infested spears entering the EU (8,606 as a median; 90% CR 1,259–58,486) are reduced by the steps of the pathway model to a final number of expected new founder populations per year (0.00013 as a median, and 0.000005–0.0022 as a 90% certainty range). The expected waiting time until the next founder population is 1/0.000133 = 7,519 years as a median and 1/0.0022–1/0.000005 = 455 to 200,000 years as a 90% certainty range (Table 4 and Figure 13). Additional details are given in Appendix D.

**Table 4:** Model output results illustrating the range in estimates for each model step from entry to initiation of founder population

| **Model step** | **Percentile** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **1%** | **5%** | **25%** | **50%** | **75%** | **95%** | **99%** |
| Number of infested spears entering the EU | 567 | 1,259 | 3,919 | 8,606 | 18,839 | 58,486 | 127,605 |
| Proportion of spears entering NUTS2 regions where EI > 30 (current climate) | 16.43% | | | | | | |
| Number of infested spears in suitable climatic regions (current climate) | 93 | 207 | 644 | 1,414 | 3,096 | 9,611 | 20,969 |
| Proportion of discarded infested spears | 10% | | | | | | |
| Number of discarded infested spears in areas suitable for establishment (current climate) | 9.3 | 20.7 | 64.4 | 14.1 | 309.6 | 961.1 | 2,096.9 |
| Proportion of adults emerging from the waste | 0.001 | 0.001 | 0.004 | 0.012 | 0.024 | 0.042 | 0.050 |
| Number of emerged adults in risk areas | 0.03 | 0.09 | 0.45 | 1.43 | 4.21 | 16.7 | 40.6 |
| Proportion of females finding mating partner | 0.00007 | 0.00018 | 0.00049 | 0.00081 | 0.00119 | 0.00171 | 0.00199 |
| Number of mated females in risk areas | 0.00001 | 0.00002 | 0.00015 | 0.00052 | 0.00163 | 0.00750 | 0.01982 |
| Probability of founder population being initiated | 0.0301 | 0.0764 | 0.1974 | 0.3033 | 0.3980 | 0.4796 | 0.5014 |
| Number of founder populations in EU per year (current climate) | 0.000001 | 0.000005 | 0.000036 | 0.000133 | 0.000447 | 0.002219 | 0.006242 |
| Number of infested spears in suitable climatic regions (future climate) | 136 | 302 | 942 | 2,068 | 4,527 | 14,054 | 30,664 |
| Number of founder populations in EU per year (future climate) | 0.000002 | 0.000007 | 0.000052 | 0.000194 | 0.000654 | 0.003245 | 0.009129 |

(Recall each infested spear is assumed to be infested with one live larvae (See Appendix A)).

Each year approximately 200–9,600 infested spears (90% CR) enter the EU into regions climatically suitable for establishment under current climate conditions. Starting a founder population requires that the infested spears are discarded (10%), larvae develop into females that emerge from the waste and find a mate that has emerged from waste at approximately the same time and place, and the eggs laid by such a female need to result in larvae that survive in large enough numbers to found a viable population. The resulting yearly probability of establishment of a founder population ranges from approximately 0.000005 to 0.002219 (90% CR). (Table 4 and Figure 13). The corresponding predicted waiting time until a new founder population is in the Panel's estimation 450–200,000 years.

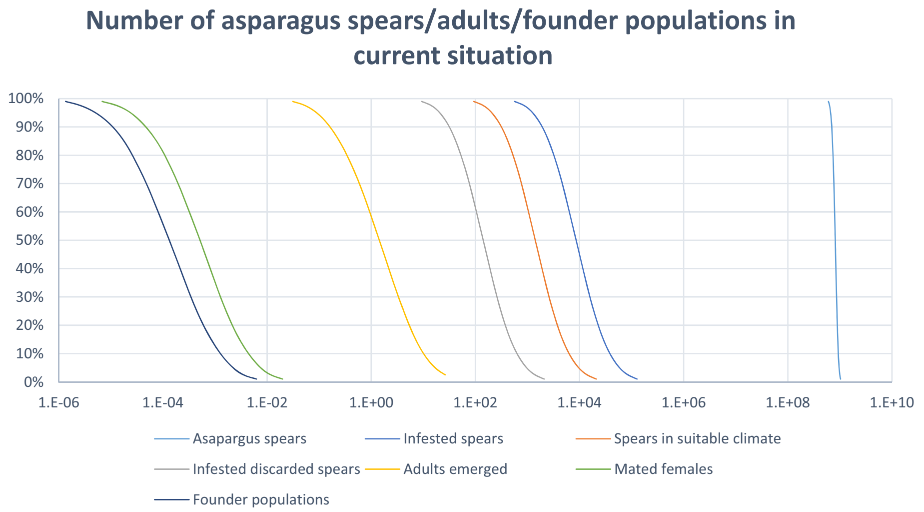


**Figure 13:** Descending cumulative probability curves for each step of the model for introduction of *E. lignosellus* (current climate)

Under a future climate change scenario, the likelihood of establishment of a founder population increases. This likelihood ranges from approximately 0.000007 to 0.003245 (Table 4 and Figure 14).

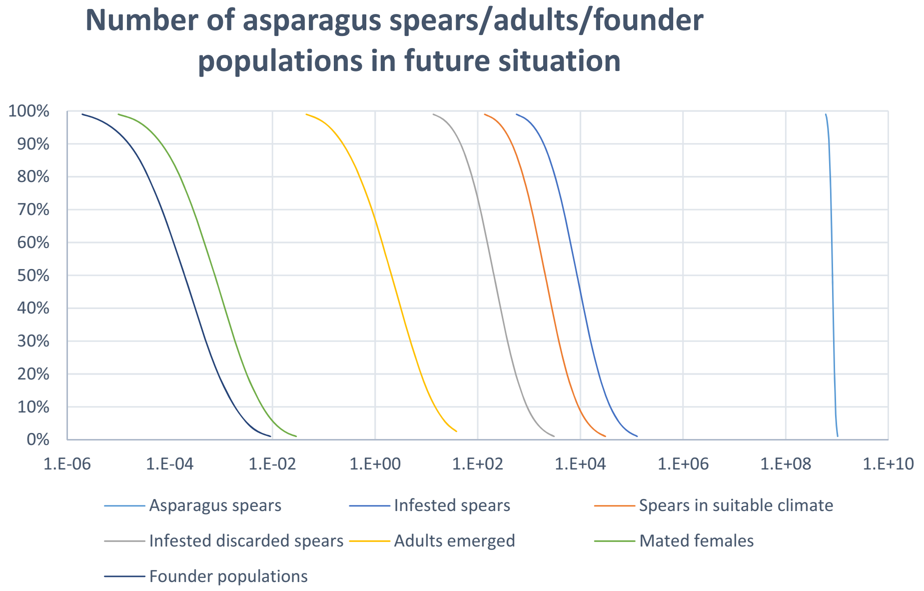


**Figure 14:** Descending cumulative probability curves for each step of the model for introduction of *E. lignosellus* (future climate scenario)

### 3.2.8. Uncertainties affecting the assessment of introduction

- The assessment focused on asparagus from Peru, other potential pathways exist but were considered less relevant after detailed consideration.
- The time horizon for the estimate of quantity of future imports was set at 5 years hence, however, the climate change scenario centres around 2050 when the quantity of asparagus from Peru could be different (as noted in Section 3.1.5).
- Changes in the areas irrigated in the EU in future may alter where environmental conditions are suitable for establishment of *E. lignosellus*.
- Changes in pest management regime (e.g. loss of pesticides, increased use of biological control) can affect future likelihood of establishment in opposing directions.

- What happens to organisms invading a new area is a field of invasion biology that is little known or understood (Puth and Post, 2005); hence, there is uncertainty e.g. regarding the likelihood of pest transfer to alternative host and initiation of a founder population.

### 3.2.9. Conclusion on entry and establishment (Pest introduction)

Based on size of the trade and evidence of interceptions, the importation of asparagus from Peru was judged to be the most likely pathway for entry of *E. lignosellus* into the EU. Using EKE and pathway modelling, the median number of infested asparagus spears entering the EU annually is estimated to be approximately 8,600 (90% CR approximately 1,300–58,500). Each infested spear is likely to contain only one larva (Appendix A). Conditions are most suitable for establishment in the southern EU, especially around the Mediterranean basin. Under current climatic conditions, around 16% of spears enter regions of the EU suitable for establishment which equates to approximately 1,410 spears (median; 90% CR, approximately 210–9,610). Under the climate change scenario considered, the number rises to approximately 2,070 spears (90% CR approximately 300–14,050 spears). Of these infested spears, 10% are discarded before reaching the final consumer. Further, 1.2% (median; 90% CR, 0.1–4.2%) of larvae survive to adulthood and escape from waste. When the resulting numbers of adults emerge across NUTS2 regions, the likelihood that a female will find a mate depends on the window of encounter in space and time.

In combination with the likelihood that the subsequent progeny survives to initiate a founder population, the number of established founder populations was estimated to be 0.00013 per year (90% CR 0.000005–0.0022). Thus, the Panel would not expect new founder populations within the time horizon of 5 years of this assessment. The predicted waiting time until a new founder population with current climate is in the Panel's estimation 455–200,000 years, while with climate change (2040–2059), this waiting time would be 310–143,000 years, which is both beyond the time frame of the assessment and beyond the time frame of the climate change projection.

## 3.3. Spread

### 3.3.1. Assessment of spread

The lag period is the time from the first introduction and reproduction of the pest, i.e. initiation of a founder population, to its establishment with constant spread into pest-free areas, i.e. constant rate of range expansion (Figure 3). The duration of the lag period in the regions where *E. lignosellus* could potentially establish was estimated to be approximately 18.5 years (90% CR 3.3–43.8 years).

After the lag period, *E. lignosellus* is estimated to spread at a rate of 7.4 km/year (90% CR 0.6–18.2 km/year). More details are available in Appendix E (Spread).

### 3.3.2. Uncertainties affecting the assessment of spread

- The duration of the lag period is mainly driven by the effect of EU agricultural practices and by the presence of natural enemies and control measures targeted at other Lepidopteran species (e.g. the European corn borer *Ostrinia nubilalis* Hübner (Crambidae), *Pseudobissetia terrestrellus* Christoph (Crambidae) and the Mediterranean corn borer *Sesamia nonagrioides* Lefèbvre (Noctuidae)). These factors were not evaluated but are sources of uncertainty.
- The expansion rate is driven by the dispersal ability of the insect, which is not well known, and by the effect of the host species communities in terms of species composition, patchiness and distance among suitable patches and availability in the EU environments compared to the observations collected from the area of origin. Information is lacking to assess this in detail.

### 3.3.3. Conclusions on spread

Were *E. lignosellus* to be introduced into the EU, the panel estimates that it would take between 3.3 and 43.8 years (90% CR) (median 18.5 years) for populations to grow sufficiently before a steady rate of spread of approximately 7.4 km/year (90% CR 0.6–18.2 km/year) was reached.

## 3.4. Impact

*E. lignosellus* is polyphagous; larvae feed on over 70 species in 27 plant families (Funderbank et al., 1985). However, over 80% of 176 papers examined in which some impact to a host species was reported refers to impacts in Poaceae such as sugarcane and the cereals maize, sorghum, rice and wheat; or Fabaceae (legumes) such as beans (unspecified), cowpeas, peanuts and soybeans. The assessment of impact therefore focused on potential impacts in EU cereals and legumes.

### 3.4.1. Assessment of impact

In terms of being regarded as pests by US farmers, populations of *E. lignosellus* that can be destructive to crops are restricted to locations with hot, dry summer environments and particularly in non-irrigated fields (John All, Univ. of Georgia (USA) pers. comm.). Literature reporting yield losses in cereal and legume crops in the Americas were generally from regions where $EI > 30$. Impacts in the EU were therefore considered to be limited to regions where $EI > 30$. Such locations coincide with the area for establishment, hence transient populations outside regions where $EI < 30$ were judged not to be able to cause measurable impacts.

Two meta-analyses (Appendices: Appendix G and H) were conducted to summarise the information on the literature on the impact of *E. lignosellus* on cultivated host species in the Americas. The first meta-analysis focused on percentage loss of seedlings under pesticide-free conditions. The second focused on percentage loss of seedlings with pest management against *E. lignosellus* in place.

In a scenario where no chemical pest management is in place, the median annual yield loss in crops of EU cereals and legumes grown in NUTS2 regions suitable for *E. lignosellus* establishment (current climate Figure 8, future climate Figure 11) was estimated to be 9.6% (90% CR from 1.5% to 24.4%).

In a scenario with pest management in place, the median annual yield loss in crops of EU cereals and legumes grown in NUTS2 regions suitable for *E. lignosellus* establishment (current climate Figure 8, future climate Figure 11) was estimated to be 0.95% (90% CR from 0.18% to 2.81%).

### 3.4.2. Uncertainties affecting the assessment of impact

The main uncertainties affecting the impact assessment are related to the transferability of reports from the Americas on impacts caused by *E. lignosellus* to the EU situation. Several reports from the Americas focussed on crops such as peanuts and sugarcane, crops that are grown only in small areas of some EU MSs.

- The future likely loss of chemical insecticides could constrain the effectiveness of control of seedling pests such as *E. lignosellus*.
- The development of alternative non-chemical alternatives (e.g. mating disruption, mass trapping) could potentially improve control. Climate change would be expected to influence the pest cycle, with higher temperatures increasing population growth and number of generations per year; however, increased irrigation could counter population development as the insect is vulnerable to humid conditions.
- Attacked crops could exhibit growth compensation such that although feeding by *E. lignosellus* destroyed individual plants in a field, the actual total yield from the field was maintained via compensation due to lower competition. This issue is relevant under the current climate and also in future climate scenarios.

### 3.4.3. Conclusions on impact

In a scenario where *E. lignosellus* enters, establishes and spreads within the EU and the population reaches an approximate equilibrium such that EU farmers consider the organism a member of the general pest fauna, estimated median yield losses in crops of cereals and legumes are estimated to be 0.95% (90% CR 0.2–2.8%).

## 4. Overall uncertainty

*Entry pathways*

This assessment focused on asparagus from Peru as a pathway. Peru is the biggest exporter of asparagus to the EU, but import from other countries (e.g. Mexico) is increasing. This may change the relative importance of pathways over time.

The Panel evaluated other potential pathways (e.g. strawberry plants for planting) but did not identify any for which there was evidence of a close enough association of the pest with the commodity to warrant further quantification. What happens to organisms that arrive in a country where they are not already established is an area of invasion biology that is little known or understood (Puth and Post, 2005). This is because such steps are largely unobserved and there is little empirical evidence around the processes involved although successful invasion is often attributed to propagule pressure (Leung et al., 2004; Simberloff, 2009).

*Transfer & establishment of founder populations*

Our assumption that imported asparagus is distributed according to population in the EU may be incorrect. However, the EFSA PLH Panel has no other simple and efficient basis on which to distribute imported products that will aid the identification of points for pest introduction.

There is little information on production of waste, and the Panel used information on waste production from the USA. Assessments of the escape of adult insects from discarded waste were made without the support from empirical data, which contributes to wide ranges reflecting high uncertainty on the true values. There is no empirical data on the founding of new persisting populations by single mated female moths, and this negatively affects the certainty of the estimates.

*Climatic modelling of establishment*

Establishment modelling results in maps of relative likelihood of establishment, and the threshold of $EI > 30$ for establishment and high enough population densities to cause impact, is arbitrary and based on modellers' experience (i.e. Kriticos et al., 2015) and cannot be used to distinguish areas where the insect can and cannot establish. Maps cannot be translated 1:1 in expected population densities, but zones with higher EI are more likely to have higher population densities and higher impacts, than zones with lower EI. Cross continents, zones with similar EI are expected to have similar pest pressure if the organism establishes outside the native range, but other factors than those accounted for in the model may affect pest pressure, e.g. natural enemies and cultivation practices.

*Spread*

Estimates of lag phase and constant rate of range expansion were made without access to data on the dispersal ability of the insect and its ability to build a local population large enough to start spreading. The lack of data affects the certainty of the estimates.

*Impact*

Many studies have been done on impact of this pest. Most studies expressed impact as incidence (number of plants affected), but yield loss is more related to severity than incidence, and in the case of seedling pests, it is more closely related to the number of plants remaining. This causes uncertainty. Studies on impact are done under conditions that are conducive to impact in order to increase the power of comparing treatments in experiments, but this reduces the representativeness of the resulting data. Experiments that result in low impact may never be published because treatment comparisons would likely be inconclusive. Again, this lowers representativeness of the studies.

*Uncertainty decomposition*

The decomposition of uncertainty with the pathway model (Table 5) indicates that the largest uncertainty is within the estimate of the amount of infestation in asparagus spears at the origin of the pathway (69.8% of model uncertainty). The level of pest infestation is often the largest uncertainty in quantitative pest risk assessments (e.g. EFSA PLH Panel, 2016a,b, 2017a,b). The next largest uncertainty in the model is the estimate of likelihood that larvae would complete their development, emerge as an adult and escape from discarded asparagus (18.0%) followed by the probability of mating (7.5%); the likelihood of founder populations being initiated from eggs laid by a female (4.7%) and lastly the volume of trade, accounting for only 0.1% of overall model uncertainty. Combining the factors involved in transfer, 30.2% of the model uncertainty is due to lack of information about transfer which is an area of invasion biology that typically lacks empirical evidence on the detailed steps involved.

**Table 5:** Decomposition of explained variance in the pathway model for introduction of *E. lignosellus*. $R^2$ in the second column gives the partial $R^2$ of each regressor in a linear regression meta-model of pathway model results in which the number of founder populations is the response variable and the parameter values in the model are regressors. The third column indicates the relative contribution of each parameter to explained variance. Here, variance represents the uncertainty in pathway model calculations, and the contribution of each parameter is the contribution to uncertainty

| Parameter | $R^2$ | % of explained variance |
|---|---|---|
| Proportion infested asparagus at packing house at origin (Peru) | 0.28 | 69.8% |
| Proportion of individuals of *E. lignosellus* emerging from waste as adults | 0.07 | 18.0% |
| Proportion of females finding a mate | 0.03 | 7.5% |
| Probability of founding a population per mated female | 0.02 | 4.7% |
| Trade volume | 0.00 | 0.1% |
| Sum | 0.40 | 100% |

# 5. Conclusions

Following a request from the European Commission, the EFSA Panel on Plant Health performed a pest risk assessment of *E. lignosellus* for the EU. The quantitative assessment focused on pathways and likelihood of entry, climatic conditions allowing establishment, the distribution of imported material within the EU after entry, the likelihood of establishment, the rate of spread following a lag period and potential impacts to cereal and legume crops.

*E. lignosellus* is a polyphagous pest and a variety of potential pathways were identified and considered. *E. lignosellus* is not known to occur outside of the Americas although it has been intercepted in the EU on asparagus spears for consumption. Based on the size and frequency of imports, and with evidence of interceptions in Europe, the importation of fresh asparagus from Peru, was identified as the most likely pathway for entry. Other hosts are less likely to be infested prior to export and/or are imported in much smaller volumes and/or less frequently.

Using stochastic pathway modelling with parameter values based on Eurostat data and EKE, the Panel estimates the median number of infested asparagus spears entering the EU annually is approximately 8,600 (90% certainty range (CR) approximately 1,300–58,500). This is about 0.001% of the total number of spears that are imported from Peru, which is in the order of hundreds of millions each year (median estimate approximately 815 million; 90% CR 664 million to 966 million).

Two scenarios for establishment were considered (i) under current climatic conditions, and (ii) under a future climate based on an ensemble of four climate models. Climate matching and CLIMEX modelling indicate that conditions are most suitable for establishment of *E. lignosellus* in parts of the southern EU, especially around the Mediterranean Sea. Under current climatic conditions, around 16% of asparagus spears enter regions of the EU suitable for establishment; this rises to 24% in the climate change scenario considered.

The Panel estimates that under the current climate, there are approximately 200–9,600 infested spears (90% CR; median estimate approximately 1,400) entering the EU annually into regions climatically suitable for establishment. In the climate change scenario assessed, this rises to between approximately 300 and 14,100 infested spears each year (90% CR; median 2,070). Each infested asparagus spear entering the EU is likely to contain only one larva, as such an important limiting factor in establishing a founder population is the likelihood of a male and a female emerging in temporal and spatial proximity to locate each other and mate.

With respect to the need of larval development to adulthood from discarded asparagus, then mating and the progeny surviving, the number of newly established founder populations developing under current climate conditions was estimated to be 0.00013 per year (90% CR 0.000005–0.0022). In the climate change scenario, the EFSA PLH Panel estimated the number of newly established founder populations to range from 0.000007 to 0.0032 each year (90% CR; median 0.00019).

After establishing as a founder population, *E. lignosellus* would likely remain local for a number of years; each life stage suffers relatively high mortality (Flores, 2016) and the lag period before sustained spread was estimated to be 18.5 years (90% CR 3.3–43.8 years) following the establishment of a founder population. *E. lignosellus* is not considered to be a strong flyer. Were *E. lignosellus* to establish, the median rate of natural spread was estimated to be 7.4 km/year (90% CR 0.6–18.2 km/year).

Impact assessment focused on cereal and legume host species. In a scenario where *E. lignosellus* has spread and is managed by farmers as part of the general pest fauna, i.e. no specific official phytosanitary measures are in place against it, estimated median yield losses in cereals and legumes were estimated to be 0.95% (90% CR 0.2–2.8%).

Concluding overall, this opinion shows that *E. lignosellus* could establish in the EU and could cause damage if it established. However, it is unlikely to be introduced because of the low likelihood that it can successfully mate and initiate a founder population even though with current trade and industry practices, the Panel estimates that in the order of thousands of infested asparagus spears enter the EU each year.

## References

Abrahao J and Amante E, 1970. Fungos e insetos causadores de tombamento de mudas de algodoeiro no ano agricola 1969–70. Biologico, 36, 24–25.

All JN and Gallaher RN, 1976. Insect infestations in no-tillage corn cropping systems. Georgia Agricultural Research, 17, 17–19.

All JN and Gallaher RN, 1977. Detrimental impact of no-tillage corn cropping systems involving insecticides, hybrids, and irrigation on Lesser Cornstalk Borer infestations. Journal of Economic Entomology, 70, 361–365.

All JN, Gallaher RN and Jellum MD, 1979. Influence of planting date, preplanting weed control, irrigation, and conservation tillage practices on efficacy of planting time insecticide applications for control of Lesser Cornstalk Borer in field corn. Journal of Economic Entomology, 72, 265–268.

Anonymous, 1995. AP-42: Compilation of Air Emission Factors. Peanut Processing Final Section, January 1995. Environmental Protection Agency. Available online: https://www.epa.gov/sites/default/files/2020-10/documents/c9s10-2b.pdf

Anonymous, 2014. European Union Committee – Tenth Report. Counting the cost of food waste: EU Food Waste Prevention. Available online: https://publications.parliament.uk/pa/ld201314/ldselect/ldeucom/154/15402.htm

APHIS, 2022. APHIS Seeks Comment on Draft Pest Risk Assessment for the Importation of Asparagus from Peru. Available online: https://www.aphis.usda.gov/aphis/newsroom/stakeholder-info/stakeholder-messages/plant-health-news/asparagus-peru-pra

Aragón L, Castillo J and Fernández-Northcote EN, 2013. Boletín Técnico Fitosanitario de Maíz en Apoyo a la Toma de Decisiones en Bioseguridad. Proyecto LAC-Biosafety, Perú. Instituto de Biotecnología, Universidad Nacional Agraria La Molina, Lima-Perú. 63 p.

Arauz AH and Arteta JA, 2014. Efecto de la gertilización qorgánica y mixta en el rendimiento del cultivo de Maíz (*Zea mays*) H-INTA 991. Tesis Monográfica para optar al título de Ingeniero en Agroecología Tropical. Universidad Nacional Autónoma de Nicaragua-Leon. vi + 60 p. http://riul.unanleon.edu.ni:8080/jspui/handle/123456789/3413

Azimi K, Ferrero C, Loucky J, Olivares H and Rojas A, 2012. Asparagus in Peru. Microeconomics of Competitiveness. Harvard Business School. Available online: https://www.isc.hbs.edu/Documents/resources/courses/moc-course-at-harvard/pdf/student-projects/Asparagus%20Cluster-%20Final%20Report.pdf [Accessed 25th April 2021].

Baker RHA, 2002. Predicting the limits to the potential distribution of alien crop pests. In: GJ Hallman and CP Schwalbe (eds). Invasive Arthropods in Agriculture: problems and solutions. Science Publishers Inc, Enfield, USA. pp. 207–241.

Bell J, 2017. Corn Growth Stages and Development. Texas A&M University Available online: https://amarillo.tamu.edu/files/2017/07/CORN-GROWTH-STAGES-AND-DEVELOPMENT.pdf

Barros RG and Barrigossi JAF, 2005. Costa JLS.2005 Efeito do armazenamento na compatibilidade de fungicidas e inseticidas, associados ou não a um polímero no tratamento de sementes de feijão. Bragantia, 64, 459–465.

Berberet RC, Sander DA and Wall RG, 1979. Parasitism of the lesser cornstalk borer *Elasmopalpus lignosellus* in cultivars Florunner and Spanhoma peanuts by native hymenopterous species in Oklahoma USA Peanut. Science, 6, 106–109.

Bessin R, 2019. Lesser Cornstalk Borer, Entfact-129. University of Kentucky, College of Agriculture, Food and Environment. 1 p. https://entomology.ca.uky.edu/ef129

Blandford D, 1984. Changes in food consumption patterns in the OECD area. Review of Agricultural Economics, 11, 43–64.

Bowen KL and Mack TP, 1993. Relationship of damage from the Lesser Cornstalk Borer to *Aspergillus flavus* contamination in peanuts. Journal of Entomological Science, 28, 29–42.

Brunori G, Galli F, Barjolle D, Van Broekhuizen R, Colombo L, Giampietro M, Kirwan J, Lang T, Mathijs E, Maye D and De Roest K, 2016. Are local food chains more sustainable than global food chains? Considerations for assessment. Sustainability, 8, 449. Available online: https://www.mdpi.com/2071-1050/8/5/449

Calderon OD and Mendoza CI, 2006. Evaluación de la incorporación de fríjol mungo (*Vigna radiata*) como mejorador de las características químicas del suelo y su efecto en la producción de maíz en tres comunidades del municipio de León. Doctoral dissertation, 92 pp. Available online: http://riul.unanleon.edu.ni:8080/jspui/bitstream/123456789/936/1/199709.pdf

Caley P, Ingram R and De Barro P, 1984. Entry of exotic insects into Australia: does border interception count match incursion risk? Biological Invasions, 17, 1087–1094.

Campbell WV and Wynne JC, 1980. Resistance of groundnuts to insects and mites. Proceedings of the International Workshop on Groundnuts. International Crops Research Institute for the Semi-Arid Tropics, Andhra Pradesh, India. pp. 149–157.

Cargohandbook.com, 2023. Available online: https://www.cargohandbook.com/Asparagus.

Carrola HL, 1984. Edaphic studies on the population biology of the lesser cornstalk borer (*Elasmopalpus lignosellus* (Zeller)). Texas A&M University. Libraries. https://www.proquest.com/openview/87d495765765547f1a7f8f35a7518087/1?pq-origsite=gscholar&cbl=18750&diss=y

Chang V and Ota AK, 1987. The lesser cornstalk borer: a new important pest of young sugarcane, pp. 27-30 In Annual Report, 1986. Experiment station. Hawaiian Sugar Planter's Association, Pahala, HI.

Chapin JW and Thomas JS, 1993. Effects of chlorpyrifos on pod damage, disease incidence, and yield in two peanut fungicide programs. Peanut Science, 20, 102–106.

Chapin JW and Thomas JS, 1999. Lesser cornstalk borer control with alternative application methods. Saxena, K N Arthropod Management Tests 261.

Chapin JW, Thomas JS and Joost PH, 2001. Tillage and chlorpyrifos treatment effects on peanut arthropods – an incidence of severe burrower bug injury. Peanut Science, 28, 64–73.

Cheshire JM and All JN, 1990. Autoradiographic detection of Lesser Cornstalk Borer (Lepidoptera: Pyralidae) eggs in soil environments. Journal of Entomological Science, 25, 458–462.

Corseuil E, Terhorst A. 1971. Ensaio de controle a *Elasmopalpus lignosellus* (Zeller, 1848) (Lepidoptera, Phycitidae). Arquivos Do Museu Nacional, in 1971, in volume 54, pp 41–42. Available online: https://biostor.org/reference/248857

Corrales Castillo J, González Herrera A, Rodríguez Arrieta A, Vargas Martínez A and Villalobos Mora K, 2017. Principales plagas de artrópodos en el cultivo de arroz en Costa Rica – Guía ilustrada de artrópodos adultos en campo y grano almacenado. 2nd edn. Universidad Nacional de Costa Rica. 88 p. https://www.mag.go.cr/bibliotecavirtual/H10-10932.pdf

Cruz I, Oliveira LJ and Santos JP, 1983. Efeito de diversos inseticidas no controle da lagarta-elasmo em milho. Pesquisa Agropecuária Brasileira, Brasília, 18, 1293–1301.

Davis TC, Goggans JF and Meier RJ, 1974. Pest control problems encountered in seedling production of Arizona cypress in Alabama. Tree Planters' Notes, 7–9.

Dixon WN, 1982. Lesser Cornstalk Borer, *Elasmopalpus lignosellus* (Zeller) (Lepidoptera: Pyralidae). Entomological Circular, 236, 1–2.

Dupree M, 1965. Observations on the life history of the Lesser Cornstalk Borer. Journal of Economic Entomology, 58, 1156–1157.

EFSA (European Food Safety Authority), 2014. Guidance on Expert Knowledge Elicitation in Food and Feed Safety Risk Assessment. EFSA Journal 2014;12(6):3734, 278 pp. https://doi.org/10.2903/j.efsa.2014.3734

EFSA (European Food Safety Authority), 2018. Guidance on use of EFSA Pesticide Residue Intake Model (EFSA PRIMo revision 3). EFSA Journal 2018;16(1):5147, 43 pp. 'Average of European unit weights (EU mean) of "asparagus" reported in the EFSA Primo model to estimate the acute pesticide intake (RAC)'. ModeL:www.efsa.europa.eu/sites/default/files/applications/EFSA_PRIMo_rev3.1.xlsm

EFSA (European Food Safety Authority), Baker R, Gilioli G, Behring C, Candiani D, Gogin A, Kaluski T, Kinkar M, Mosbach-Schulz O, Maria-Neri F, Siligato R, Stancanelli G and Tramontini, S. 2019. Report on the methodology applied by EFSA to provide a quantitative assessment of pest-related criteria required to rank candidate priority pests as defined by Regulation (EU) 2016/2031. EFSA Journal 2019;17(6):5731, 61 pp. https://doi.org/10.2903/j.efsa.2019.5731

EFSA (European Food Safety Authority) and Maiorano A. 2022. SCAN-Clim: a tool to support pest climate suitability analysis based on climate classification. EFSA Journal 2022;20(2):7104, 18 pp. https://doi.org/10.2903/j.efsa.2022.7104

EFSA PLH Panel (EFSA Panel on Plant Health), Jeger M, Bragard C, Caffier D, Candresse T, Chatzivassiliou E, Dehnen-Schmutz K, Gilioli G, Gregoire J-C, Jaques Miret JA, MacLeod A, Navajas Navarro M, Niere B, Parnell S, Potting R, Rafoss T, Rossi V, Van Bruggen A, Van Der Werf W, West J, Winter S, Mosbach-Schulz O and Urek G, 2016a. Scientific opinion on the risk to plant health of *Ditylenchus destructor* for the EU territory. EFSA Journal 2016;14(12):4602, 124 pp. https://doi.org/10.2903/j.efsa.2016.4602

EFSA PLH Panel (EFSA Panel on Plant Health), Jeger M, Bragard C, Chatzivassiliou E, Dehnen-Schmutz K, Gilioli G, Jaques Miret JA, Mac Leod A, Navajas Navarro M, Niere B, Parnell S, Potting R, Rafoss T, Urek G, Van Bruggen A, Van der Werf W, West J, Winter S, Maresi G, Prospero S, Vettraino AM, Vloutoglou I, Pautasso M and Rossi V, 2016b. Scientific opinion on the risk assessment and reduction options for *Cryphonectria parasitica* in the EU. EFSA Journal 2016;14(12):4641, 54 pp. https://doi.org/10.2903/j.efsa.2016.4641

EFSA PLH Panel (EFSA Panel on Plant Health), Jeger M, Bragard C, Caffier D, Candresse T, Chatzivassiliou E, Dehnen-Schmutz K, Gilioli G, Gregoire J-C, Jaques Miret JA, MacLeod A, Niere B, Parnell S, Potting R, Rafoss T, Rossi V, Urek G, Van Bruggen A, Van Der Werf W, West J, Winter S, Bergeretti F, Bjorklund N, Mosbach-Schulz

O, Vos S and Navajas Navarro M, 2017a. Scientific Opinion on the pest risk assessment of *Eotetranychus lewisi* for the EU territory. EFSA Journal 2017;15(10):4878, 122 pp. https://doi.org/10.2903/j.efsa.2017.4878

EFSA PLH Panel (EFSA Panel on Plant Health), Jeger M, Bragard C, Caffier D, Candresse T, Chatzivassiliou E, Dehnen-Schmutz K, Gilioli G, Gregoire J-C, Jaques Miret JA, MacLeod A, Navajas Navarro M, Niere B, Parnell S, Potting R, Rafoss T, Rossi V, Van Bruggen A, Van Der Werf W, West J, Winter S, Schans J, Kozelska S, Mosbach-Schulz O and Urek G, 2017b. Scientific opinion on the pest risk assessment of *Radopholus similis* for the EU territory. EFSA Journal 2017;15(8):4879, 265 pp. https://doi.org/10.2903/j.efsa.2017.4879

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, Dehnen-Schmutz K, Di Serio F, Gonthier P, Jacques M-A, Jaques Miret JA, Fejer Justesen A, MacLeod A, Magnusson CS, Milonas P, Navas-Cortes JA, Parnell S, Reignault PL, Thulke H-H, Van der Werf W, Vicent Civera A, Yuen, J, Zappala L, Jeger MJ, Gardi C, Mosbach-Schulz O, Preti S, Rosace MC, Stancanelli G and Potting R, 2019. Guidance on commodity risk assessment for the evaluation of high risk plants dossiers. EFSA Journal 2019;17(4):5668, 16 pp. https://doi.org/10.2903/j.efsa.2019.5668

EFSA PLH Panel (EFSA Panel on Plant Health), Bragard C, Dehnen-Schmutz K, Di Serio F, Gonthier P, Jacques MA, Jaques Miret JA, Justesen AF, Magnusson CS, Milonas P, Navas-Cortes JA, Parnell S, Potting R, Reignault PL, Thulke H-H, Van der Werf W, Vicent Civera A, Yuen J, Zappala L, Malumphy C, Czwienczek E, Kertesz V, Maiorano A and MacLeod A, 2021. Scientific Opinion on the pest categorisation of *Elasmopalpus lignosellus*. EFSA Journal 2021;19(6):6663, 24 pp. https://doi.org/10.2903/j.efsa.2021.6663

EFSA PLH Panel (EFSA Panel on Plant Health), Bragard C, Baptista P, Chatzivassiliou E, Di Serio F, 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, Yuen J, Zappala L, Cubero J, Gilioli G, Makowski D, Mastin A, Maiorano A, Mosbach-Schulz O, Pautasso M, Pautasso S, Tramontini S and Vicent Civera A, 2022. Scientific Opinion on the risk assessment of *Xanthomonas citri* pv. *viticola* for the EU. EFSA Journal 2022;20(12):7641, 67 pp. https://doi.org/10.2903/j.efsa.2022.7641

EFSA Scientific Committee, 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, Younes M, Craig P, Hart A, Von Goetz N, Koutsoumanis K, Mortensen A, Ossendorp B, Martino L, Merten C, Mosbach-Schulz O and Hardy A, 2018. Guidance on Uncertainty Analysis in Scientific Assessments. EFSA Journal 2018;16(1):5123, 39 pp. https://doi.org/10.2903/j.efsa.2018.5123

Elsner K and Hartmann M, 1998. Convergence of Food Consumption Patterns Between Eastern and Western Europe. Institut für Agrarentwicklung in Mittel und Osteuropa, Saale.

EPPO Reporting Service, 2019. *Elasmopalpus lignosellus* (Lepidoptera: Pyralidae - Lesser cornstalk borer): addition to the EPPO Alert List. EPPO Reporting Service, 2019, 237.

FAO (Food and Agriculture Organization of the United Nations), 2007. Agro-industries characterization and appraisal: Asparagus in Peru. Available online: https://www.fao.org/3/ap297e/ap297e.pdf

FAO (Food and Agriculture Organization of the United Nations), 2018a. ISPM (International Standards for Phytosanitary Measures) 5. Glossary of phytosanitary terms. FAO, Rome, Italy. Available online: https://www.ippc.int/static/media/files/publication/en/2018/06/ISPM_05_2018_En_Glossary_2018-05-20_PostCPM13_R9GJ0UK.pdf

FAO (Food and Agriculture Organization of the United Nations), 2018b. ISPM (International Standards for Phytosanitary Measures) 31. Methodologies for sampling of consignments. FAO, Rome, Italy. Available online: https://www.ippc.int/static/media/files/publication/en/2016/01/ISPM_31_2008_En_2015-12-22_PostCPM10_InkAmReformatted.pdf

FAO (Food and Agriculture Organization of the United Nations), 2021. International Standards for Phytosanitary Measures. ISPM 5 Glossary of phytosanitary terms. FAO, Rome. Available online: https://www.fao.org/3/mc891e/mc891e.pdf

Fernández JE, 2016. Influencia del daño de *Elasmopalpus lignosellus* (Barrenador menor) en hibridos de maíz (*Zea mays* [sic]) en la zona de Babahoyo. Ing.Agr. thesis, Universidad Técnica de Babahoyo, Ecuador, [5] + 42 pp.

Fewkes DW, 1966. Some Observations on the Biology of "Jumping Borer" (Lepidoptera Phycitidae) on Sugarcane in Trinidad. Brit. West Indies Sugar Technol. Proc. 1966: 223–235.

Flores BV, 2016. Evaluación de la eficiencia y residualidad de los insecticidas spinoteram, chlorantraniliprole y clorpirifos como rotación en el control de larvas de *Elasmopalpus lignosellus* (Lep. Pyralidae) en espárrago blanco (*Asparagus officinalis*). Tesis para obtener el título profesional de ingeniero agrónomo, Universidad Privada Antenor Orrego, Facultad de Ciencias Agrarias, Escuela Profesional de Ingeniería Agrónoma, Trujillo, Perú, xiii + 69 pp. translated by Dr Julia Lopez Mercadal.

Forbes SA, 1905. Twenty-third report of the State Entomologist on the noxious and beneficial insects of the state of Illinois, viii + 273 pp. Available online: https://www.biodiversitylibrary.org/item/82431#page/5/mode/1up

Funderburk JE, Boucias DG, Herzog DC, Sprenkel RK and Lynch RE, 1984. Parasitoids and pathogens of larval Lesser Cornstalk Borers (Lepidoptera: Pyralidae) in northern Florida. Environmental Entomology, 13, 1319–1323.

Funderburk JE, Herzog DC and Lynch RE, 1984. Method for Determining Age Structure of Adult Populations of the Lesser Cornstalk Borer (Lepidoptera: Pyralidae). Journal of Economic Entomology, 77, 541–544. 10.1093/jee/77.2.541

Funderburk JE, Herzog DC, Mack TP and Lynch RE, 1985. Sampling lesser cornstalk borer (Lepidoptera: Pyralidae) adults in several crops with reference to adult dispersion patterns. Environmental Entomology, 14, 452–458.

Gill HK, Capinera JL and McSorley R, 2000. Lesser Cornstalk Borer, *Elasmopalpus lignosellus* (Zeller) (Insecta: Lepidoptera: Pyralidae). University of Florida. IFAS Extension, EENY155, 1–7. Available online: https://www.academia.edu/27729573/Lesser_Cornstalk_Borer_Elasmopalpus_lignosellus_Zeller_Insecta_Lepidoptera_Pyralidae_1?auto=citations&from=cover_page

Glick PA and Noble LW. 1961. Airborne movement of the pink bollworm and other arthropods, Technical Bulletin 1255. USDA. Available online: https://books.google.co.uk/books?hl=en&lr=&id=0L4XAAAAYAAJ&oi=fnd&pg=PA1&dq=elasmopalpus+flight+distance&ots=RqlIkCb1og&sig=m-9MaQTOQy0UvW08EbIQ-_88TM#v=onepage&q&f=false

Gould JR and Maldonado MH, 2006. *Copitarsia decolora* (Lepidoptera: Noctuidae) larvae escaping from discarded asparagus: data in support of a pathway risk analysis. Journal of Economic Entomology, 99, 1605–1609.

Gould JR, Caton BP and Venette RC, 2006. A pathway assessment of the risk of establishment in the contiguous United States by *Copitarsia decolora* (Guenne) on Asparagus from Peru. USDA APHIS. Available online: https://www.yumpu.com/en/document/read/27534062/copitarsia-asparagus-peru-original

Grimm V and Wissel C, 1997. Babel, or the ecological stability discussions: an inventory and analysis of terminology and a guide for avoiding confusion. Oecologia, 109, 323–334. https://doi.org/10.1007/s004420050090

Guillebeau P, Hinkle N and Roberts P, 2006. Summary of losses from insect damage and cost of control in Georgia 2006. Dept. of Entomology, Uni. Georgia. https://s3.amazonaws.com/na-st01.ext.exlibrisgroup.com/01GALI_UGA/storage/alma/A6/8B/24/AE/FA/5C/5B/6F/DB/66/74/64/D2/8E/61/27/SurveyLoss06.pdf?response-content-type=application%2Fpdf&X-Amz-Algorithm=AWS4-HMAC-SHA256&X-Amz-Date=20230508T123719Z&X-Amz-SignedHeaders=host&X-Amz-Expires=119&X-Amz-Credential=AKIAJN6NPMNGJALPPWAQ%2F20230508%2Fus-east-1%2Fs3%2Faws4_request&X-Amz-Signature=fa713f8e8dbab3756026b25a775ca6f2d9356cfffd31e39443bd71ed757bc8a0

Harding JA, 1960. Control of the Lesser Cornstalk Borer attacking peanuts. Journal of Economic Entomology, 53, 664–667.

Herms DA and McCullough DG, 2014. Emerald ash borer invasion of North America: History, biology, ecology, impact and management. Annual Review of Entomology, 59, 13–30.

Heu R, 1988. *Elasmopalpus lignosellus* (Zeller). Proceedings. Hawaiian Entomological Society. https://scholarspace.manoa.hawaii.edu/server/api/core/bitstreams/845cc74e-eeaf-44b7-8b82-086c6f982ef4/content

Hill DS, 1987. Agricultural insect pests of temperate regions and their control. Cambridge University Press. https://books.google.it/books?hl=en&lr=&id=3-w8AAAAIAAJ&oi=fnd&pg=PP11&dq=Agricultural+insect+pests+of+temperate+regions+and+their+control.+Cambridge+University+Press.&ots=90ZZWlJYHZ&sig=lXHrhocoJChbpLxDL72gIlHO-k0#v=onepage&q=Agricultural%20insect%20pests%20of%20temperate%20regions%20and%20their%20control.%20Cambridge%20University%20Press.&f=false

Holloway RL and Smith JW Jr, 1975. Lesser Cornstalk Borer 1 Response to Photoperiod and Temperature 2. Environmental Entomology, 5, 996–1000.

Holloway RL and Smoth JW Jr, 1976. Lesser cornstalk borer response to photoperiod and temperature. Environmental Entomology, 5, 997–1000.

Huang X and Mack TP, 2002. Collection and determination of Lesser Cornstalk Borer (Lepidoptera: Pyralidae) larval attractant from peanut plants. Environmental Entomology, 31, 15–21. https://doi.org/10.1603/0046-225X-31.1.15

Hudson JC and Johnson C. 1969. Post-harvest treatments in burnt fields in Barbados with special reference to the control of jumping borer (*Elasmopalpus lignosellus*). West Indies Sugar Technologies, Proceedings of the 1969 Meeting held in Trinidad, November 1969.

Isas M, Pérez MLP, Salvatore A, Gastaminza G, Willink E and White W, 2016. Impacts of crop residue on damage by sugarcane pests during the tillering phase in Argentina. Florida Entomologist, 99, 1–5. https://doi.org/10.1653/024.099.0102

Isely D and Miner FD, 1944. The Lesser Cornstalk Borer, a pest of fall beans. Journal of the Kansas Entomological Society, 17, 51–57.

Johnson SJ and Smith JW Jr, 1980. Biology of *Orgilus elasmopalpi* (Hym.: Braconidae) with *Elasmopalpus lignosellus* (Lep.: Pyralidae) as host. Annals of the Entomological Society of America, 73, 572–575.

Johnson SJ and Smith JW Jr, 1981. Ecology of *Elasmopalpus lignosellus* parasite complex on peanuts in Texas. Annals of the Entomological Society of America, 74, 467–471.

Kenis M, Rabitsch W, Auger-Rozenberg MA and Roques A, 2007. How can alien species inventories and interception data help us prevent insect invasions? Bulletin of Entomological Research, 97, 489–502.

King DR, Harding JA and Langley BC, 1961. Peanut insects in Texas. The Agricultural and Mechanical College of Texas, Texas Agricultural Experiment Station. 14 p.

Kobayashi T and de Aguero G, 1988. Singular occurrence of soybean insect pests and the control of them under severe drought condition in Paraguay. Tarc note. JARQ, 22.

Kottek M, Grieser J, Beck C, Rudolf B and Rubel F, 2006. World Map of the Köppen-Geiger climate classification updated. Meteorologische Zeitschrift, 15, 259–263. https://doi.org/10.1127/0941-2948/2006/0130

Kriticos DJ, Webber BL, Leriche A, Ota N, Macadam I, Bathols J and Scott JK, 2012. CliMond: global high resolution historical and future scenario climate surfaces for bioclimatic modelling. Methods in Ecology and Evolution, 3, 53–64. https://doi.org/10.1111/j.2041-210X.2011.00134.x

Kriticos DJ, Maywald GF, Yonow T, Zurcher EJ, Herrmann NI and Sutherst RW, 2015. CLIMEX Version 4: Exploring the effects of climate on plants, animals and diseases. CSIRO, Canberra. 184 p.

Leuck DB, 1966. Biology of the Lesser Cornstalk Borer in South Georgia. Journal of Economic Entomology, 59, 797–801.

Leuck DB and Dupree M, 1965. Parasites of the Lesser Cornstalk Borer. Journal of Economic Entomology, 58, 779–780.

Leung B, Drake JM and Lodge DM, 2004. Predicting invasions: propagule pressure and the gravity of Allee effects. Ecology, 85, 1651–1660.

Luginbill P and Ainslie GG, 1917. The Lesser Corn Stalk-Borer. United States Department of Agriculture Bulletin, 539, 1–27. Available online: https://www.biodiversitylibrary.org/item/190787#page/3/mode/1up

Lynch RE, 1984. Damage and preference of Lesser Cornstalk Borer (Lepidoptera: Pyralidae) larvae for peanut pods in different stages of maturity. Journal of Economic Entomology, 77, 460–363.

Lynch RE and Wilson DM, 1991. Enhanced infection of peanut, *Arachis hypogaea* L., seeds with *Aspergillus flavus* group fungi due to external scarification of peanut pods by the Lesser Cornstalk Borer, *Elasmopalpus lignosellus* (Zeller). Peanut Science, 18, 110–116.

Mack TP and Backman CB, 1984. Effects of temperature and adult age on the oviposition rate of *Elasmopalpus lignosellus* (Zeller), the Lesser Cornstalk Borer. Environmental Entomology, 13, 966–969.

Mack TP and Appel AG, 1986. Water Relations of Immature and Adult Lesser Cornstalk Borers, *Elasmopalpus lignosellus*. Pyralidae, Lepidoptera.

Mack TP and Backman CB, 1987. Density of the Lesser Cornstalk Borer, *Elasmopalpus lignosellus* (Zeller) in Peanut Fields: Endemic and Outbreak Population Configurations. Peanut Science, 14, 61–66.

Mack TP and Backman CB, 1990. Effects of two planting dates and three tillage systems on the abundance of Lesser Cornstalk Borer (Lepidoptera: Pyralidae), other selected insects, and yield in peanut fields. Journal of Economic Entomology, 83, 1034–1041.

Mack TP, Smith JW and Reed RB, 1987. A mathematical model of the population dynamics of the lesser cornstalk borer, *Elasmopalpus lignosellus*. Ecological Modelling, 39, 269–286.

Mack TP, Appel AG, Backman CB and Trichilo PJ, 1988. Water Relations of Several Arthropod Predators in the Peanut Agroecosystem. Environmental Entomology, 17, 778–781.

Mack TP, Buckelew LD and Peterson CM, 1990. Characterization of Lesser Cornstalk Borer injury to the root-hypocotyl region of peanut plants. Peanut Science, 17, 58–61. https://doi.org/10.3146/i0095-3679-17-2-3

MacLeod A, 1999. Attraction and retention of *Episyrphus balteatus* DeGeer (Diptera: Syrphidae) at an arable field margin with rich and poor floral resources. Agriculture, Ecosystems and Environment, 73, 237–244.

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

MacLeod A, Wratten SD, Sotherton NW and Thomas MB, 2004. ‘Beetle banks’ as refuges for beneficial arthropods in farmland: long-term changes in predator communities and habitat. Agricultural and Forest Entomology, 6, 147–154.

Mantilla Lobaton KD, 2019. Plagas entomológicas en cultivos de espárrago (*Asparagus officinalis* L.) en el Perú: identificación taxonómica mediante morfología y el código de barras de ADN. Thesis. Translated by Dr Julia Lopez Mercadal.

Martins L and Silveira F, 1959. Influência da umidade do solo sôbre o ataque de lagartas de *Elasmopalpus lignosellus* ao milho, em condições de campo. Boletim Técnico do Instituto Agronomico do Sul, 22, 3–9.

Mauracher C and Valentini M, 2006. Tipicità e convergenza alimentare dei PECO. Economia Agro-Alimentare, 3, 115–136.

Meier J, Zabel F and Mauser W, 2018. A global approach to estimate irrigated areas – a comparison between different data and statistics. Hydrology and Earth System Sciences, 22, 1119–1133. https://doi.org/10.5194/hess-22-1119-2018

Molinari AM and Gamundi JC, 2010. *Elasmopalpus lignosellus* (Zeller), un barrendor esporádico en soja. EE Oliveros-INTA, 1, 121–122. Available online: https://inta.gob.ar/sites/default/files/script-tmp-elasmopalpus-lignosellus-_zeller_-un-barrenador-espor.pdf

Muirhead JR, Leung B, van Overdijk C, Kelly DW, Nandakumar K, Marchant KR and MacIsaac HJ, 2006. Modelling local and long-distance dispersal of invasive emerald ash borer *Agrilus planipennis* (Coleoptera) in North America. Diversity and Distributions, 12, 71–79.

NAHS (The National Agrarian Health Service of Peru), 2022. Unified vegetable export procedure, PRO-Mo4.02.01, Annex 4.3 Pest tolerance in phytosanitary inspection of export shipments, 7th Dec 2022. Available online: https://www.gob.pe/institucion/senasa/campa%C3%B1as/5741-procedimiento-unificado-de-exportacion-vegetal

Neunzig HH, 1979. Systematics of immature phycitines (Lepidoptera: Pyralidae) associated with leguminous plants in the southern United States. United States Department of Agriculture, Technical Bulletin No. 1589, iv + 119 pp.

Oerke EC, 2006. Crop losses to pests. Journal of Agricultural Science, 144, 31–43.

Oerke E-C and Dehne H-W, 2004. Safeguarding production-losses in major crops and the role of crop protection. Crop Protection, 23, 275–285.

Oerke EC, Dehne HW, Schönbeck F and Weber A, 1994. Crop production and crop protection: estimated losses in major food and cash crops. 1st edn. Elsevier.

Ortega A, 1987. Insectos nocivos del maíz – una guía para su identificación en el campo. Centro Internacional de Mejoramiento de Maíz y Trigo, México. vi + 106 p.

Puth LM and Post DM, 2005. Studying invasion: have we missed the boat? Ecology Letters, 8, 715–721.

Robinet C, Roques A, Pan H, Fang G, Ye J, Zhang Y and Sun J, 2009. Role of human-mediated dispersal in the spread of the pinewood nematode in China. PLoS One, 4, e4646.

Roques A, Auger-Rozenberg MA, Blackburn TM, Garnas J, Pyšek P, Rabitsch W, Richardson DM, Wingfield MJ, Liebhold AM and Duncan RP, 2016. Temporal and interspecific variation in rates of spread for insect species invading Europe during the last 200 years. Biological Invasions, 18, 907–920.

Rossi E, Maiorano A, Campese C, Muñoz Guajardo I and Stancanelli G, 2023. EFSA Climate Suitability Analysis of *Elasmopalpus lignosellus*. Zenodo. https://doi.org/10.5281/zenodo.7648553

Rubel F, Brugger K, Haslinger K and Auer I, 2017. The climate of the European Alps: Shift of very high resolution Köppen-Geiger climate zones 1800–2100. Meteorologische Zeitschrift, 26, 115–125.

SAG, 2016a. Resolution 5018: Establishes phytosanitary requirements for the importation into Chile of asparagus turions (*Asparagus officinalis*) for fresh consumption from Peru and modifies resolution No. 4,657 of 2006 of this service. Ministry of Agriculture; Undersecretariat of agriculture, Agricultural and Livestock Service (SAG). Available online: https://www.bcn.cl/leychile/nafegar?idNorma=1095126&idParte=0

SAG, 2016b. Resolution 5036: Modifies resolution no. 4,658 of 2006, which establishes requirements for the entry of fresh vegetables, for consumption, from Argentina Ministry of Agriculture; Undersecretariat of agriculture. Agricultural and Livestock Service (SAG). Available online: https://www.bcn.cl/leychile/navegar?idNorma=1095127

Saldana RI, 2013. Efecto de tres trampas de alimentación en la captura de adultos de *Elasmopalpus lignosellus* y *Diatraea saccharalis* (Lep. Pyralidae), en el cultivo de caña azúcar. Santiago de Cao. – La Libertad. Biol. Thesis, Universidad Nacional de Trujillo, Facultad de Ciencias Biológicas, Trujillo, Perú, x + 34 pp.

Saldana CF and Ayquipa GE, 2021. Efecto del cebo tóxico con trampa de melaza en el control de *Elasmopalpus lignosellus* Zeller. Manglar, 18, 45–50.

Sanchez LO, 1960. The biology and control of the Lesser Cornstalk Borer, *Elasmopalpus lignosellus* Zeller. Ph.D. thesis, Graduate School of the Agricultural and Mechanical College of Texas, vii + 74 pp.

Sánchez G and Sánchez J, 2008. Manejo integrado del cultivo del espárrago en el Perú. Instituto Peruano del Espárrago y Hortalizas, Lima, Perú.

Sanchez-Velasquez G and Sanchez Vigo J. 2010. Manejo integrado del cultivo del espárrago en el Perú. available online https://www.slideshare.net/AVJEICA/manejo-integrado-de-plagas-en-el-cultivo-de-esparrago

Sandhu HS, Nuessly GS, Webb SE, Cherry RH and Gilbert RA, 2010a. Temperature-Dependent Development of *Elasmopalpus lignosellus* (Lepidoptera: Pyralidae) on Sugarcane Under Laboratory Conditions. Environmental Entomology, 39, 1012–1020. https://doi.org/10.1603/EN09284

Sandhu HS, Nuessly GS, Webb SE, Cherry RH and Gilbert RA, 2010b. Life Table Studies of *Elasmopalpus lignosellus* (Lepidoptera: Pyralidae) on Sugarcane. Environmental Entomology, 39, 2025–2032. https://doi.org/10.1603/EN10038

Schaaf AC, 1974. Jumping borer, *Elasmopalpus lignosellus*. Handbook of Pests of Sugarcane. Technical Bulletin 1/75. Sugar Industry Research Institute Mandeville, Jamaica. pp. 31–34.

Schauff ME, 1989. A new species of *Horismenus* (Hymenoptera: Eulophidae) parasitic on the Lesser Cornstalk Borer, *Elasmopalpus lignosellus* (Lepidoptera: Pyralidae). Proceedings of the Entomological Society of Washington, 91, 534–537.

Schmidhuber J and Traill WB, 2006. The changing structure of diets in the European Union in relation to healthy eating guidelines. Public Health Nutrition, 9, 584–595. https://doi.org/10.1079/phn2005844

Schuster DJ, Peters DC, Kamal SS and Berberet RC, 1975. Field comparison of peanut varieties resistant to the Lesser Cornstalk Borer. Journal of Economic Entomology, 68, 704–706.

Segura L, 1990. Guía de campo para el manejo de insectos plagas en sorgo y maíz. ASIAVA, 179–182. Available online: https://repository.agrosavia.co/bitstream/handle/20.500.12324/30876/28457_18821.pdf?sequence=1

Simberloff D, 2009. The role of propagule pressure in biological invasions. Annual Review of Ecology, Evolution, and Systematics, 40, 81–102.

Simón MR, Dietz JI and Schierenbeck M, 2018. Capítulo 6 – Maíz: Manejo de plagas. In: MR Simón and SI Golik (eds). Cereales de verano. Editorial de la Universidad Nacional de La Plata (EDULP), Facultad de Ciencias Agrarias y Forestales. pp. 101–132. Available online: http://sedici.unlp.edu.ar/handle/10915/68613

Smith JW, Johnson SJ and Sams RL, 1981. Spatial distribution of Lesser Cornstalk Borer eggs in peanuts. Environmental Entomology, 10, 192–193.

Solis MA, 2006. Key to selected Pyraloidea (Lepidoptera) larvae intercepted at U.S. ports of entry: revision of Pyraloidea in 'Keys to some frequently intercepted Lepidopterous larvae' by Weisman 1986 (updated 2006). Proceedings- Entomological Society of Washington, 101.

Stewart SD, Bowen KL, Mack TP and Edwards JH, 1997. Impact of row spacing and planting date on the canopy environment, abundance of Lesser Cornstalk Borer and other arthropods, and incidence of aflatoxigenic fungi in peanuts. Peanut Science, 24, 52–59.

Toledo ZD, Ajmat de, Valverde L and Popich SB, 1994. Survey of Lepidoptera on maize crops in Tucumán Province, Argentina. Revista de Investigación-Centro de Investigaciones para la Regulación de Poblaciones de Organismos Nocivos, 9, 15–22.

Vazquez-Rowe I, Kahhat R, Quispe I and Bentín M, 2016. Environmental profile of green asparagus production in a hyper-arid zone in coastal Peru. Journal of Cleaner Production, 112, 2505–2017. Available online: https://www.sciencedirect.com/science/article/abs/pii/S0959652615013037

Venette RC, 2017. Climate analyses to assess risks from invasive forest insects: simple matching to advanced models. Current Forestry Reports, 3, 255–268. Available online: https://www.fs.usda.gov/nrs/pubs/jrnl/2017/nrs_2017_venette_001.pdf

Vilchez MN, Pozo HY, Martínez JV, Díaz FO and Caballero Á, 2014. Evaluación del desarrollo fenológico y productivo de dos variedadas criollas (checo blanco y copaleño blanco) proprias de pequeños productores, y una mejorada (NB6) de maiz (*Zea mays*) Somoto-Madriz, ciclo primera 2014. Thesis, Universidad Nacional Autónoma de Nicaragua–León, 58 pp.

# Abbreviations

| | |
|---|---|
| CN | Combined nomenclature (8-digit code building on HS codes to provide greater resolution) |
| CR | certainty range |
| DD | degree days |
| EI | ecoclimatic index (an index of climatic suitability used by CLIMEX) |
| EKE | Expert Knowledge Elicitation |
| EPPO | European and Mediterranean Plant Protection Organisation |
| HS | Harmonised System (6-digit World Customs Organisation system to categorise goods) |
| IPM | Integrated Pest Management |
| MS | Member state (of the EU) |
| NUTS | Nomenclature Units for Territorial Statistics |
| RRO | risk reduction option |
| ToR | Terms of Reference |

## Appendix A – Biology of *Elasmopalpus lignosellus*

The main features of the biology and life cycle of *E. lignosellus* are summarised in the first phase assessment (pest categorisation) by EFSA PLH Panel (EFSA PLH Panel, 2021). *E. lignosellus* is a polyphagous pest that has been reported to feed on plants of at least 27 plant families. The economically most important crops affected by *E. lignosellus* are Poaceae, like corn and sugarcane, Fabaceae such as peanuts, beans and soybeans, and asparagus (Asparagaceae). Larvae 'show a decided fondness for the Gramineae [Poaceae] and probably would confine themselves almost exclusively to plants belonging to this order if always obtainable' (Luginbill and Ainslie, 1917). When feeding on corn (Poaceae), freshly hatched larvae develop faster to the pupal stage than when feeding on beans (Fabaceae), and their survival rate is higher (Isely and Miner, 1944). In peanuts, larvae also feed on the developing pegs, pods and kernels (Harding, 1960; King et al., 1961; Schuster et al., 1975; Campbell and Wynne, 1980; Lynch, 1984; Chapin and Thomas, 1993; Stewart et al., 1997; Chapin et al., 2001). Scarification of peanut pods caused by *E. lignosellus* feeding was positively correlated with infestation of *Aspergillus flavus*-like fungi (Lynch and Wilson, 1991; Bowen and Mack, 1993); early planting of peanuts appears to effectively decrease the impact of *E. lignosellus* infestation in conventionally tilled and reduced-tillage fields (Mack and Backman, 1990). Arizona cypress seedlings, occasionally attacked by *E. lignosellus*, do not suffer serious damage as long as secondary infections by fungi are controlled (Davis et al., 1974).

Even though the species is very frequent in spring in the Southern hemisphere (Arauz and Arteta, 2014), *E. lignosellus* is considered as a sporadic pest in the Americas (Segura, 1990; Saldana, 2013) usually in sandy soils and predominant during extreme/long-term drought periods with high temperatures (Segura, 1990; Fernández, 2016; Segura, undated; Simón et al., 2018). A no-tillage approach significantly reduced *E. lignosellus* infestation in corn fields compared to traditional tilling practices (All and Gallaher, 1976), and even outperforms the impact of insecticides (All and Gallaher, 1977). Removal of the crop residue after harvesting, especially by burning, is beneficial for a strong development of *E. lignosellus* populations and should be avoided (Isas et al., 2016).

### Eggs:

The small (0.3–0.7 mm) oval, initially yellow-green, later reddening eggs are generally laid singly or in small clutches of 2–3 eggs, and exclusively at night at temperatures at and above 26°C (Luginbill and Ainslie, 1917). Fecundity (number of eggs laid per female) is temperature-dependent and ranges from 29 to 165, at a rate of 1–73 (average 26.77) eggs per day (Luginbill and Ainslie, 1917; Sandhu et al., 2010b), but up to 200 eggs per female have been reported (Fernández, 2016). The large majority of eggs is deposited just below the soil surface, and close to the host plants (Smith et al., 1981; Cheshire and All, 1990; Gill et al., 2000), although this varies between hosts and soil types (Sandhu et al., 2010a). With this species being polyphagous, eggs are usually laid randomly in disturbed environments without much cover vegetation, and the hatched caterpillars move to whatever plants are close by for feeding and moisture (Arauz and Arteta, 2014; John All, pers. comm.). The adult moths can sense fire smoke and are attracted to burned areas as oviposition sites. Egg development requires about 2–4 days at favourable temperatures, with a survival rate of 48–78% of eggs (Sandhu et al., 2010a). 33°C appears to be the ideal temperature for development, although survival rate of eggs, larvae, prepupae and pupae in lab rearings on sugarcane was found to be highest at 27°C (Sandhu et al., 2010a).

### Larvae:

Larvae (Figure A.1) develop through five to seven instars (Luginbill and Ainslie, 1917), with 2–5 days for each instar at favourable temperatures (21–33°C) except for the last instar, which takes approximately twice the time; the total time for larval development ranges from 14 to 27 days at favourable temperatures (Luginbill and Ainslie, 1917; Sandhu et al., 2010a). Freshly hatched larvae are yellowish, and later turn green, green–blue and finally brown with violet–red transverse bands, whitish longitudinal stripes and a brown head capsule (Ortega, 1987; Gill et al., 2000; Molinari and Gamundi, 2010; Aragón et al., 2013; Fernández, 2016; Corrales Castillo et al., 2017). Larval length ranges from 1.7 (first instar) to 25 mm (last instar) (Luginbill and Ainslie, 1917; Ortega, 1987; Aragón et al., 2013; Fernández, 2016; Simón et al., 2018). *E. lignosellus* strongly prefers sandy, dry soils, facilitating the caterpillars' construction of the silken tubes, and population outbreaks are associated with long-term drought periods with high temperatures (Segura, 1990; Fernández, 2016; Simón et al., 2018).

**Figure A.1:** Photo of *E. lignosellus* damage [a courtesy of ©Paulo Viana (EMBRAPA)] *E. lignosellus* damage. Top left: adult moths, illustrating the sexual dimorphism, with the darker female (left) and the light-coloured male (right); top right: mature larva; bottom left: symptomatic 'deadheart' damage; bottom centre and right: bore holes at the stem base of host plants

Conversely, precipitation and high soil moisture are detrimental to the larval development, and irrigation has been proven a useful means to keep numbers of larvae low, although not always (All et al., 1979). The larvae reside close to their host plant in resting tubes from silk (Figure A.2), plant debris, excrement and soil, which they leave for feeding while always attached to a silken thread (Luginbill and Ainslie, 1917; Ortega, 1987; Molinari and Gamundi, 2010; Aragón et al., 2013; Saldana, 2013). New tunnels are constructed as the larvae mature (Gill et al., 2000), and each is inhabited only by a single caterpillar. The caterpillars prefer only the driest of soils (Luginbill and Ainslie, 1917) and apparently can build their silk tunnels within the stems of asparagus in conditions of high soil humidity (Sánchez and Sánchez, 2008). When disturbed, the larvae skip and jump around for up to 4 s, a behaviour for which they are also known as 'jumping borers' (Luginbill and Ainslie, 1917; Schaaf, 1974; Fernández, 2016). Larvae appear to locate their host plants by means of carbon dioxide emitted from belowground plant parts, as shown for peanuts (Huang and Mack, 2002).

**Figure A.2:** Photo of *E. lignosellus* larval exoskeleton [a courtesy of ©Alma Solis (USDA, Smithsonian Institution)]

The first three larval instars feed on the surface (epidermis, leaves, roots) of young plants 30–40 days after planting (Gill et al., 2000; Molinari and Gamundi, 2010; Saldana, 2013; Simón et al., 2018; Saldana and Ayquipa, 2021), sometimes girdling the stem (Gill et al., 2000). Corn plants are usually attacked as seedlings at a height of 10–12 cm, with only two leaves developed and a stem of 5–6 mm diameter (Aragón et al., 2013; Fernández, 2016). The larvae will stop feeding on more mature corn plants after the six leaf growth stage, when they reach a height of 30 cm or more (Martins and Silveira, 1959; Bessin, 2019). Later instars enter the soil (up to 2 cm deep) and start to bore upwards into the plant stalk, forming up to 8 cm long tunnels, destroying nutrient- and water-conducting tissues and disrupting the water movement in the plant, causing wilting, withering of buds and stunted growth, with 'deadheart' symptoms due to the death of the plant's apical growing point, and frequent death of the affected plants (Leuck, 1966; Neunzig, 1979; Ortega, 1987; Mack et al., 1990; Molinari and Gamundi, 2010; Saldana, 2013; Simon et al., 2018). Larvae cannot tunnel developed plants due to the toughness of their epidermis, and only external girdling near the basis of the plant may occur (Simón et al., 2018). Fifth- and sixth-instar larvae are voracious feeders and represent the most destructive stages of the insect (Dupree, 1965). Although older literature (e.g. Forbes, 1905; Luginbill and Ainslie, 1917) mention multiple larvae (up to 15) per stalk for maize and sorghum, species of grasses that LCB larvae feed on, such as wheat, maize and sorghum, only contain a single larva per plant stalk (P. Viana & J. All pers. comms). Larvae move, even during the heat of the day, from one plant to another, and from weeds to crop plants, with a single caterpillar able to destroy several individual host plants (Isely and Miner, 1944). Injuries to plants by *E. lignosellus* sometimes resemble those caused by *Diabrotica undecimpunctata* (Chrysomelidae) (Luginbill and Ainslie, 1917).

**Pupae:**

Pupation occurs at the end of the larval tunnels in cocoons made with soil and silk (Gill et al., 2000; Fernández, 2016; Simón et al., 2018), with pupal development taking 12 days at 21°C, but as little as 6 days at 33°C (Sandhu et al., 2010a). The initially pale green pupa (Figure A.3) with yellowish abdominal segments later turns brown and eventually shiny black (Sanchez, 1960). It is 7–12 mm in length (Fernández, 2016).

**Figure A.3:** Photo of *E. lignosellus* pupa [a courtesy of ©Alma Solis (USDA, Smithsonian Institution)]

The species has three to four overlapping generations per year, with the overwintering generation being a temperature-prolonged one, and the pupa as the overwintering stage (Leuck, 1966). Development is strongly linked to temperature, while photoperiod has no influence (Holloway and Smith Jr., 1976; Sandhu et al., 2010a).

**Adults:**

Adults (Figures A.4 and A.5) are sexually dimorphic, with males having a largely pale yellowish forewing ground colour with an elongate dark streak, whereas females have a dark brown-greyish forewing ground colour. Wing span measures 18–25 mm (Ortega, 1987; Molinari and Gamundi, 2010; Saldana, 2013; Fernández, 2016). The adults live for 9–13 days (Aragón et al., 2013; Fernández, 2016), and up to 20 days under lab conditions (Mack and Backman, 1984). They spend the day hidden in low parts of plants and in soil clods, while being active at night, flying short distances at a low altitude (Holloway and Smoth Jr., 1976; Dixon, 1982; Aragón et al., 2013). Exposures to temperatures of 1–2°C (35°F) for periods longer than 7 days are lethal to the moths (Sanchez, 1960). Adults have a proboscis for sucking up fluids, but will not chew destructively on plants.

**Figure A.4:** Photos of *E. lignosellus* male adults [a courtesy of ©Alma Solis (USDA, Smithsonian Institution)]

**Figure A.5:** Photos of *E. lignosellus* female adults [a courtesy of ©Alma Solis (USDA, Smithsonian Institution)]

**Parasitoids:**

Parasitoids of *E. lignosellus* caterpillars are primarily braconid wasps (*Agathis rubricincta*, *Bracon mellitor*, *Chelonus* sp., *Macrocentrus ancylivorus*, *Macrocentrus muesebecki*, *Orgilus mellipes* (*laeviventris*), *Orgilus elasmopalpi*, *Orgilus* sp.), but also Eulophidae (*Horismenus apantelivorus*, *Horismenus elineatus*), Ichneumonidae (*Pristomerus spinator* (syns *P. pacificus appalachianus*, *Neopristomerus appalachianus*), *Pristomerus* sp.) and Scelionidae wasps (*Telenomus* sp.), and furthermore tachinid flies (*Plagiprospherysa trinitatis*, *Plagiprospherysa* sp., *Stomatomyia floridensis*, *Stomatomyia parvipalpus*) (Luginbill and Ainslie, 1917; Leuck and Dupree, 1965; Neunzig, 1979; Johnson and Smith Jr., 1980, 1981; Funderburk et al., 1984; Schauff, 1989).

# Appendix B – Quarantine status of *Elasmopalpus lignosellus* as recorded by Regional Plant Protection Organizations

A search of the EPPO Global Database (22/10/2022) revealed the quarantine status of *E. lignosellus* as recorded by Regional Plant Protection Organizations (RPPOs). Two RPPOs do not provide lists of pests recommended for regulation (CAHFSA and NEPPO), so EFSA PLH Panel cannot determine how *E. lignosellus* is regarded by these RPPOs.

| **Regional Plant Protection Organizations** | **Abbreviation** | **Does the organisation produce lists of pests recommended for regulation?** | **Is *Elasmopalpus lignosellus* recommended for regulation as a quarantine pest?** |
|---|---|---|---|
| Asia and Pacific Plant Protection Commission | APPPC | Yes | No |
| Caribbean Agricultural Health and Food Safety Agency | CAHFSA | No | – |
| Comunidad Andina | CAN | Yes | No |
| Comite de Sanidad Vegetal del Cono Sur | COSAVE | Yes | No |
| European and Mediterranean Plant Protection Organization | EPPO | Yes | (Alert list)* |
| Inter-African Phytosanitary Council | IAPSC | Yes | No |
| North American Plant Protection Organization | NAPPO | Yes | No |
| Near East Plant Protection Organization | NEPPO | No | – |
| Organismo Internacional Regional de Sanidad Agropecuaria | OIRSA | Yes | No |
| Pacific Plant Protection Organization | PPPO | Yes | No |

*: EPPO added *E. lignosellus* to its Alert List in November 2019 (EPPO Reporting Service, 2019). The EPPO alert list is designed to raise the awareness of EPPO member countries to a limited number of plant pests which possibly present a risk. In so doing the alert list acts as an early warning system.

# Appendix C – Entry

## C.1. Introduction model: Quantity of imports

Many potential pathways for entry were considered and investigated. The pathway 'fresh asparagus from Peru' was the sole pathway quantitatively assessed given the evidence of interceptions from Peru and the dominance of Peru as the main exporter of asparagus (Table C.1).

Estimates of future imports of asparagus into the EU are based on past imports. Given that the UK departed from the EU in 2020, UK imports are not shown in Table C.1, below.

**Table C.1:** EU imports of asparagus (fresh or chilled) from all sources (100 of kg) (Eurostat)

| Source/Year | 2018 | 2019 | 2020 | 2021 | 2022 | mean | Mean % Americas |
|---|---|---|---|---|---|---|---|
| **Peru** | 179,501 | 185,508 | 133,736 | 159,116 | 158,078 | 163,187.8 | 76.24 |
| **Mexico** | 35,678 | 40,759 | 32,992 | 73,929 | 68,858 | 50,443.2 | 23.57 |
| **United States** | 758 | 290 | 242 | 301 | 218 | 361.8 | 0.17 |
| **Chile** | 22 | 64 | 100 | 0 | 49 | 47 | 0.02 |
| **Brazil** | 12 | 0 | 31 | 0 | 0 | 8.6 | 0.00 |
| **Argentina** | 16 | 0 | 0 | 0 | 0 | 3.2 | 0.00 |
| **Honduras** | 0 | 0 | 0 | 0 | 0 | 0 | 0.00 |
| **Subtotal Americas** | 215,987 | 226,621 | 167,101 | 233,346 | 227,203 | 214,051.6 | |
| **Rest of the World** | 2,657 | 3,586 | 3,352 | 2,871 | 1,317 | | |

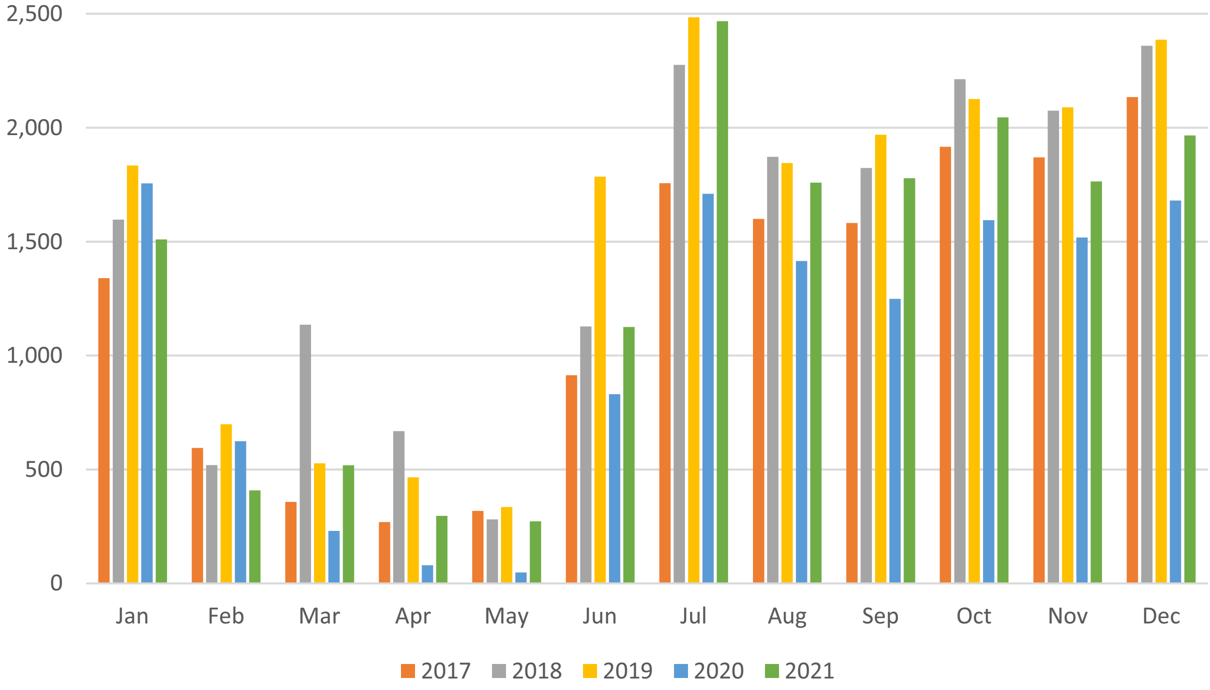


**Figure C.1:** Monthly imports of fresh *Asparagus* into EU from Peru (2016–2021) (tonnes by air)

### *Overview of model input estimates: Import quantity*

Based on EU imports of asparagus from Peru 2017–2022, the table below shows the range of anticipated future mean annual imports with the associated probability distribution shown below.

**Table C.2:** Mean annual import of fresh asparagus from Peru into EU (kg)

| **Question** | How many kg of fresh asparagus are imported on average (mean) into the EU per year from Peru? | | | | | | |
|---|---|---|---|---|---|---|---|
| **Results** | **Estimated mean annual import of fresh asparagus from Peru into EU (kg)** | | | | | | |
| Percentiles % | 1% | 5% | 25% | 50% | 75% | 95% | 99% |
| Fitted results (kg) | 15,760,241 | 17,394,737 | 19,722,267 | 21,339,494 | 22,956,942 | 25,283,332 | 26,916,988 |
| **Fitted distribution** | Normal (21,339,712, 2,398,003) | | | | | | |

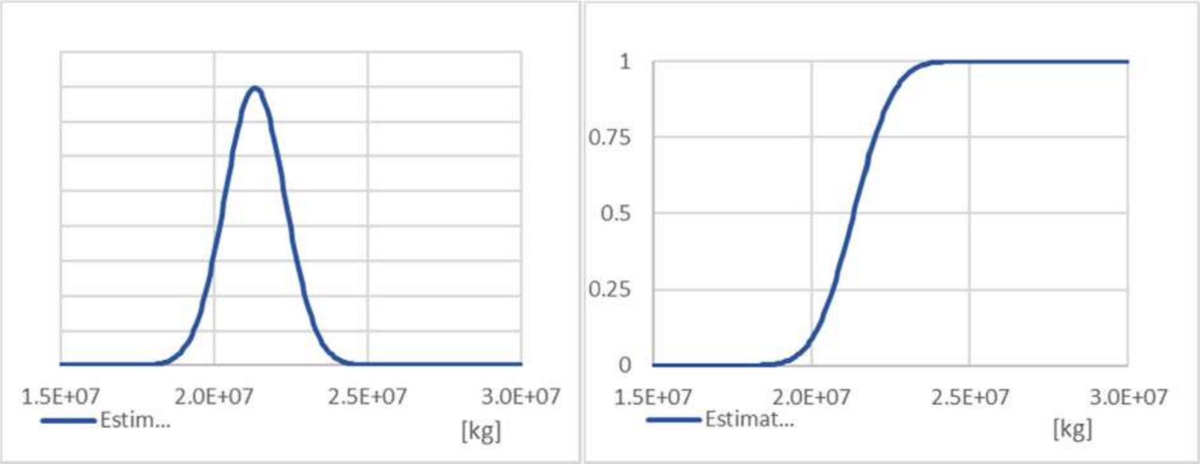


**Figure C.2:** Estimated future mean annual quantity of fresh asparagus imported into EU (kg). (Left hand chart shows probability density function; right hand chart shows cumulative distribution function)

The estimated annual median quantity of future asparagus imports into the EU is 21.3 million kg (90% CR is from 17.4 million to 25.3 million kg).

*Uncertainties*

The Panel assumed that trade over the next 5 years would be similar to trade in the recent past (2018–2022). In reality, trade may increase or decrease quickly in response to markets and consumer preferences. This uncertainty was not accounted for but was considered small compared to that in other parameters.

## C.2. Introduction model: Weight of an asparagus spear

A constant (0.026 kg) was used as the mean weight of an asparagus spear (EFSA, 2018).

*Uncertainties*

There is variation in weight of asparagus spears and uncertainty on the average, but willing to focus on more important uncertainties, the panel used a standard value from the EFSA PRIMo database (EFSA, 2018).

## C.3. Introduction model: Infestation rate of asparagus when entering the EU

To estimate the proportion of asparagus spears entering the EU infested with *E. lignosellus*, a dossier on asparagus production practices and pest management was collated. Dossier findings are summarised below.

*Asparagus production in Peru*

Notes used to inform entry EKE primarily from FAO (2007) and Azimi et al. (2012):

- Peru is the biggest exporter of fresh asparagus in the world and is the major third country supplier of fresh asparagus to the EU (Table C.1). After coffee, asparagus is the largest agricultural crop in Peru; the market for asparagus is divided into fresh asparagus (mostly green) and processed asparagus i.e. canned or frozen (mostly white). 87% of production is green asparagus.
- Asparagus is produced in seven coastal regions of Peru from Piura in the north to Arequipa in the south. The region of La Libertad in the north of Peru is the major source of production with 44% of national production occurring there. The climate of La Libertad is relatively dry throughout the year. December–March are the wettest months although rainfall is generally below 2 mm each month. Across the year, temperatures are rarely below 15°C or above 30°C and typically vary from 17°C to 28°C (Figure C.2).

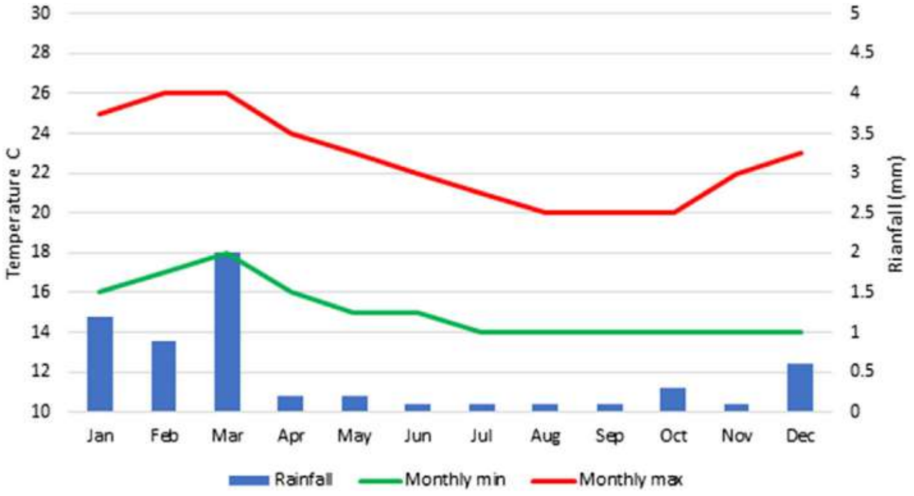


**Figure C.3:** La Libertad, Peru: Mean monthly maximum and minimum temperatures (°C) and total rainfall (mm). (Source: weatherspark.com)

- The region of Ica in the south of Peru is the next major asparagus production area with 39% of national production. In Ica, the summers (December to March) are warm and have the most rain, but still less than 6 mm total summer rainfall, this is drier than, for example, the summer months in Malaga, Spain, where summer rainfall is approximately 9.2 mm from June to August (Figure C.3). In Ica June, July and August (winter months) are cool and very dry (less than 0.3 mm rain each month); total winter rainfall is around 0.5 mm. In Malaga, winter rainfall is approximately 154 mm between December and February. In Ica across the year temperatures are rarely below 12°C or above 31°C and typically vary from 15°C to 28°C (Figure C.3) (https://weatherspark.com/y/22218/Average-Weather-in-Ica-Peru-Year-Round).

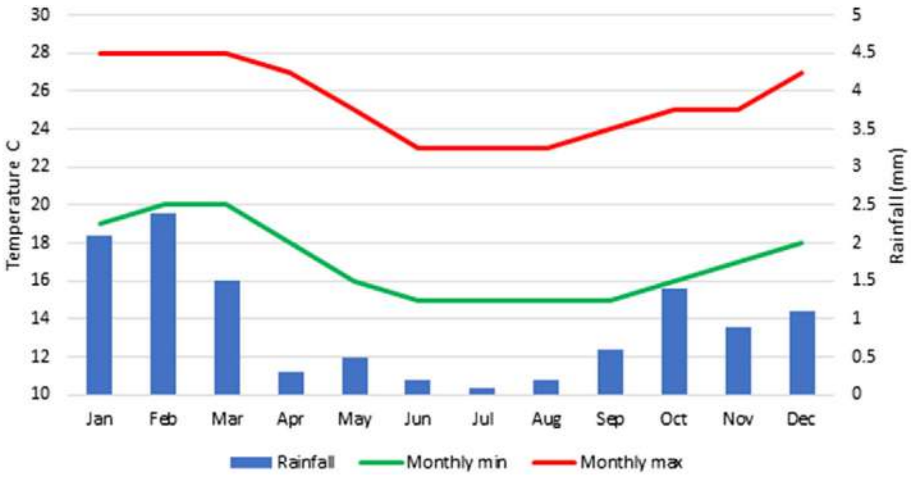


**Figure C.4:** Ica, Peru: Mean monthly maximum and minimum temperatures (°C) and total rainfall (mm). (Source: weatherspark.com)

- Since 1987 drip irrigation has been used to grow asparagus in what were previously desert areas of Peru. This led to a rapid increase in asparagus production. The export of fresh asparagus has been growing since the 1990s, the primary fresh export markets are USA and Europe; exports occur every month of the year (three crops can be obtained every 2 years).
- Peru does not produce much organic asparagus (asparagus is only 0.6% of all organic production in Peru).

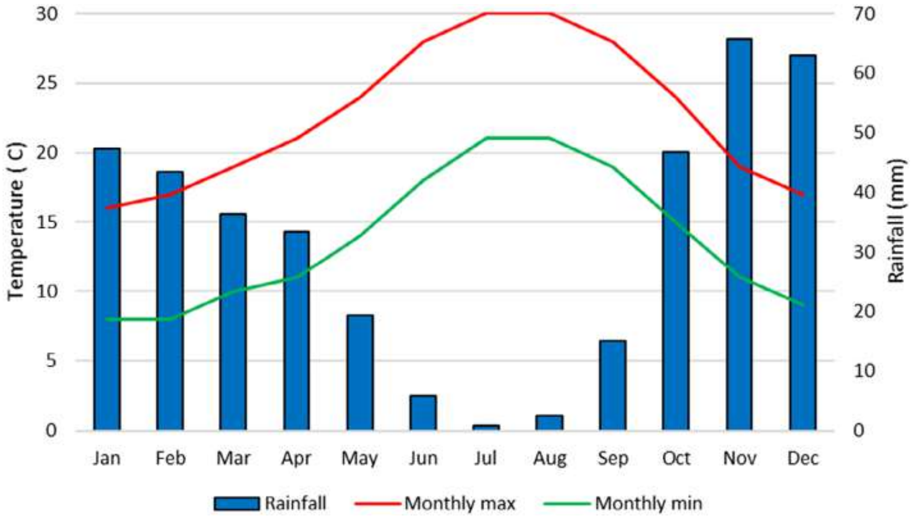


**Figure C.5:** Malaga, Spain: Mean monthly maximum and minimum temperatures (°C) and total rainfall (mm). (Source: weatherspark.com)

*Pest issues*

- From a market access perspective (access to USA), *Copitarsia decolora* Genée (Lepidoptera: Noctuidae) is a key pest and an important phytosanitary issue for the Peruvian asparagus industry. The USDA conducted a pest risk analysis on *C. decolora* in 2006 (Gould et al., 2006) and exports to USA have to be fumigated. An alternative risk mitigation in the form of a systems approach is being considered by USDA following public consultation (APHIS, 2022). In general, public and private efforts are in place to develop pest management systems with pest control addressed through the application of integrated pest and disease management programmes.
- Using light traps and yellow traps, Mantilla Lobaton (2019) reported finding 13 species of Lepidoptera in asparagus, including *E. lignosellus*. *E. lignosellus* is an important pest in asparagus given that it can cause high mortality in stalks. Larvae feed on stems at the time of harvest so control can be difficult (Flores, 2016). Sanchez and Sanchez (2010) reported *E. lignosellus* populations increased from October with peaks in January and March (the hottest months). They recommend using traps to reduce the adult population.

*Post-harvest*

- After harvest, asparagus continues to have a high metabolic rate and is among the most perishable of crops, and spears continue to elongate after harvest if not cooled. A 4-h delay in cooling can increase tissue toughening, lowering quality. Once harvested asparagus is cooled during the washing, grading, selection and packing processes and then further cooled to near 0°C after packing. To maintain freshness and quality, fresh asparagus is shipped under refrigerated conditions (Cargohandbook.com, 2023).
- The major large producers have standardised their production and logistic chain by using international standards designed by ISO and have built value in the brand 'produce of Peru' by meeting consistently high-quality standards. They have also vertically integrated production fields, packing facilities, logistics and refrigerated transportation up to the controlled temperature warehouses, where fresh asparagus are exported by air and processed asparagus by sea.
- 99% of Peruvian asparagus production is exported.

*Overview of model input estimates: infestation rate on arrival into EU*

Elicited mean annual rates of infestation per 10,000 asparagus spears are given in the table below with the probability distribution under the table. EKE estimates are values proposed by the expert working group as consensus estimates. Model inputs are derived from the distribution fitted to the EKE estimates.

**Table C.3:** Estimated mean number of asparagus spears infested with *E. lignosellus* when entering the EU (per 10,000 spears)

| **Question:** | How many out of 10,000 fresh asparagus spears will be on average infested with *Elasmopalpus lignosellus*, when entering the EU from Peru? | | | | | | |
|---|---|---|---|---|---|---|---|
| **Results** | Infestation rate of asparagus when entering the EU (per 10,000 spears) | | | | | | |
| **Percentiles: %** | 1% | 5% | 25% | 50% | 75% | 95% | 99% |
| **EKE estimates:** | 0.01 | – | 0.05 | 0.10 | 0.25 | – | 1.00 |
| **Fitted values: (spears infested per 10,000)** | 0.0071 | 0.016 | 0.049 | 0.11 | 0.23 | 0.72 | 1.6 |
| **Fitted distribution** | Lognorm (0.20823, 0.35138) | | | | | | |

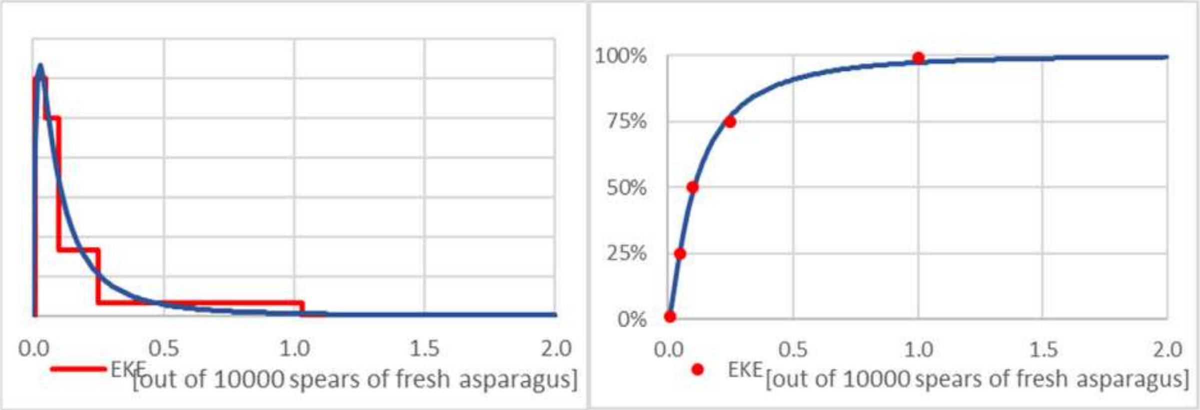


**Figure C.6:** Distribution of infestation rate of asparagus fitted to EKE estimates. (Left hand chart shows probability density function to describe the remaining uncertainties of the parameter; right hand chart shows cumulative distribution function (CDF) of the likelihood of the parameter)

The median rate of asparagus spear infestation is 0.11 per 10,000 (= 1.1 per 100,000); (90% CR is from 1.6 per million to 72 per million).

Factors influencing the lower limits:

- Pesticide treatments are used and are assumed to be effective.
- Low survival during cold transport/storage.
- Interceptions of dead larvae (indicate treatment works).
- Lower abundance of pest in Peru during summer (cooler period) when imports begin to increase.
- Asparagus is high quality, important for 'brand Peru'.
- Production from one site is integrated with supply chain.
- Clean material is used for replanting.
- Pest pressure is lower abundance during summer (cooler period).
- Later larvae will show clear damages, e.g. dry plants.
- Young larvae are outside and can be washed off.
- Soil stages will be reduced by irrigation.
- Insect is native in Peru where natural enemies could lower pest abundance.
- Occurrence of pest on harvested spears is recognised as an export problem to access EU markets.
- Real quality issue for the consumer.
- Inspection required before phytosanitary certificate is issued; 0% infestation tolerance for exports to EU (NAHS, 2022).

Factors influencing the upper limits:

- Overlapping generations, continuous development year round.
- Fast infestation of new plots.
- Early larvae does not show damage.
- Harvest is just after when the larvae entered the stem of asparagus.
- Unclear use of pesticide, e.g. product, period.
- Biological control not effective.
- Infestation can be difficult to detect.
- High pest pressure in the country of origin/production areas.
- High impact reported in other crops.
- Interceptions at EU border may not be reported (no need to notify as not QP).
- When exports are combined from many sites of production.

Median:

- The pest is prevalent under field conditions. Fields are eligible for harvesting for export provided not more than 7% of spears in the field are infested.
- Harvesting is done by hand, and harvesters would avoid bad looking spears or bad looking patches.
- Within the packing house stringent procedures are followed to ensure pest freedom.
- Pest freedom is of paramount interest to exporters.
- However, with the pest being prevalent under field conditions, and with human resources and time being limiting, zero infestation may not be reached in practice.

Inter-quartile range:

- At upper ranges reduces by factor of 2.5 (100 to 40; 15 to 6) but as numbers lower becomes more difficult to lower further hence reduce by factor of 2 (4 to 2, 2 to 1).

The Panel used the interceptions in the UK in the winter of 2019–2020 to infer a likely level of infestation of the imported spears at that time. Various assumptions were made in the calculations, as follows.

At the time, the UK imported approximately 11,500 tons of asparagus each year (data from Europhyt). Consignment sizes vary from 800 to 3,200 kg. The panel calculated the number of consignments imported per year assuming consignment sizes of 800, 1,600 and 3,200 kg. Of the imported consignments, a percentage would be inspected. This percentage is unknown. The Panel assumed that 1%, 5% or 10% of consignments were inspected. It was assumed that a sample size of 300 spears was used if a consignment was inspected. If one infested spear was detected, a notification would be entered into Europhyt.

If the true proportion of infested spears in a consignment is *p* and a sample size of $n = 300$ is used for detection, the probability of finding an infested spear in a consignment, assuming 100% detection chance if a larva is present, would be:

$$\mathrm{P}(\text{detection in a sample of n spears}) = 1 - \mathrm{P}(\text{no detection in a sample of n spears}) = 1 - \exp(-p * n)$$

(FAO, 2018b). Then, filling in the proportion of rejected consignments for $\mathrm{P}(\text{detection in a sample of n spears})$, and assuming a sample size of $n = 300$, the proportion of infested spears can be solved as:

$$p = -\frac{\ln\left(1 - \frac{20}{N}\right)}{300}$$

where 20 represents the number of consignments identified as being contaminated at Heathrow airport in the winter of 2019–2020, N represents the total number of consignments imported during a whole year (from the scenario) and 300 is the presumed sample size.

Table C.4 presents the calculation results under nine scenarios for combinations of assumptions described above. The calculations indicate that at the time that interceptions were made in the UK, less than one (i.c. 0.47) to a few (up to 27) spears per 10,000 would have been infested. These numbers were used as input for discussions preceding the EKE, taking into account that events in 2019–2020 represent a worst case, with fewer detections per year having been reported since, and no interceptions having been reported before 2019/2020.

**Table C.4:** Scenario calculations on the likely level of infestation with *E. lignosellus* in asparagus spears imported from Peru to the UK, and imported at Heathrow airport, London in 2019–2020

| | **Variable** | **Source** | **Scenario** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** |
| x1 | Import into UK of asparagus from Peru (tons/year) | From Eurostat | 11,500 | 11,500 | 11,500 | 11,500 | 11,500 | 11,500 | 11,500 | 11,500 | 11,500 |
| x2 | Weight of a single consignment (kg) | Three scenarios: 800, 1600 or 3200 | 3,200 | 1,600 | 800 | 3,200 | 1,600 | 800 | 3,200 | 1,600 | 800 |
| x3 | Number of consignments | Calculated: x1/x2 | 3,594 | 7,188 | 14,375 | 3,594 | 7,188 | 14,375 | 3,594 | 7,188 | 14,375 |
| x4 | Percentage of inspected consignments | Three scenarios: 1, 5, or 10% | 1 | 1 | 1 | 5 | 5 | 5 | 10 | 10 | 10 |
| x5 | Number of consignments inspected | Calculated: x3*x4/100 | 36 | 72 | 144 | 180 | 359 | 719 | 359 | 719 | 1,438 |
| x6 | Number of consignments found contaminated with *E. lignosellus* | Reported to Europhyt | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| x7 | Estimated proportion of infested spears | Calculated: -ln(1-x6/ x5)/300 | 0.002703 | 0.001085 | 0.000498 | 0.000393 | 0.000191 | 9.4E-05 | 0.000191 | 9.4E-05 | 4.67E-05 |
| x8 | Infested spears per 10,000 spears | Calculated: x7 × 10,000 | 27.0 | 10.8 | 5.0 | 3.9 | 1.9 | 0.9 | 1.9 | 0.94 | 0.47 |

# Appendix D – Establishment

This appendix describes the details of the CLIMEX approach used to map areas in the Americas and Europe that are climatically suitable for *E. lignosellus*. CLIMEX was also used to estimate the number of *E. lignosellus* generations that might develop in a year. Information from CLIMEX informed estimates of the lag period (Appendix E) and impacts (Appendix F). Moreover, this appendix details background information that was used to estimate parameters for a pathway model that was developed to calculate the number of adult *E. lignosellus* emerging from imported infested asparagus spears to go on to mate and transfer to hosts and start a founder population.

## D.1. CLIMEX projection under current climate

Results from the literature review (Section 2.2.1) informed the selection of CLIMEX parameters as described below.

*Temperature-dependent parameters*

Mack et al. (1987) reported a lower developmental threshold for *E. lignosellus* immature stages of 13.3°C calculated through the linear fitting of development time estimated in a temperature range of 15.6–35.6°C (Mack and Backman, 1987). Berberet et al. (1979) reported a common lower developmental threshold of 13°C for all stages of *E. lignosellus*. Sandhu et al. (2010a) reported that the larvae of the lesser cornstalk borer can regularly complete development at 13°C in controlled conditions (Sandhu et al., 2010a). Sandhu et al. fitted one linear and six nonlinear models commonly used to represent temperature-dependent development of poikilothermic insects to *E. lignosellus* development times observed at constant temperatures ranging from 13°C to 36°C in controlled conditions. The Briere-1 model provided the best fit and the estimated lower temperature for total development of immature stages was 9.35°C. The linear model indicates a lower temperature threshold of 9.46°C. The Taylor model indicated a lower temperature of 9.16°C. Therefore, the DV0 minimum value in CLIMEX was set to 9°C.

The lower temperature for optimal growth (DV1) was set to 26°C, considering data on the immature stages' development in laboratory conditions reported by Holloway and Smith (1976), Sandhu et al. (2010a) and Mack et al. (1987). In the experiments of Sandhu et al. (2010a) mentioned above, the developmental rate of LCB was positively correlated with temperature until 33°C for all the growth stages, and decreased at 36°C. However, Mack et al. (1987), testing development time in a temperature range like the one of Sandhu et al. (2010a) (15.6–35.6°C), observed no apparent depression of developmental rate at any temperature. Therefore, the upper optimal temperature for growth (DV2) was set to 36°C.

*E. lignosellus* larvae are often exposed to daily maximal temperatures of 40°C (Mack and Appel, 1986). Furthermore, Mack et al. (1988) stated that larvae, pupae and adults are adapted to xeric environments where the maximal daily temperatures in the soil can exceed 48°C with soil moisture levels of −5 to −20 bars, allowed by the reported low cuticular permeabilities and tolerance to body water losses (Mack et al., 1988). Therefore, the upper temperature threshold (DV3) was set to 48°C.

According to Sandhu et al. (2010a), LCB requires 543.5 degree-days to complete development considering a base temperature of 9.5°C (Sandhu et al., 2010a). The CLIMEX Threshold Annual Heat sum (PDD), i.e. the minimum degree day sum needed to complete a generation, was set to 543 degree-days.

*Moisture-dependent parameters*

The CLIMEX Moisture parameters were adjusted according to qualitative information on the effect of soil moisture on LCB development found in the scientific literature. *E. lignosellus* was reported to survive in strongly xeric conditions better than many of its common predators (Mack et al., 1988), indeed in dry soil eggs are laid beneath the soil surface where larvae remain protected from predators. However, with an increase of soil saturation, larvae tend to abandon their subterranean habit increasing predator-induced mortality (Mack et al., 1987). According to Carrola, egg mortality increases as clay content and saturation increase (Carrola, 1984). Hence, the lower soil moisture threshold (SM0) was set at 0, the lower optimal soil moisture (SM1) was set at 0.03, the upper optimal soil moisture (SM2) at 0.8 and the upper soil moisture threshold (SM3) at 1.6.

*Stress parameters*

Considering the pest's adaptability to xeric conditions, the CLIMEX Dry Stress process (SMDS, HDS) was not considered. Cold stress and heat stress parameter values were adjusted to match the *E. lignosellus* observation points on the maps. Thus, the cold stress temperature threshold (TTCS) was set to 3°C. The cold stress accumulation rate (THCS) was set to $-0.003$ week$^{-1}$. Following Mack et al. (1988), the heat stress temperature threshold (TTHS) was set to 48°C. The heat stress accumulation rate (THHS) was set to 0.5 week$^{-1}$. The wet stress parameters, namely the soil moisture wet stress threshold (SMWS) and the wet stress accumulation rate (HWS), were adjusted manually and set, respectively, to 1.6 and 0.005 week$^{-1}$.

*E. lignosellus* does not diapause (Carrola, 1984); therefore, diapause process was not considered. However, this pest may remain in a quiescent stage for several weeks (Holloway and Smith, 1975).

**Table D.1:** CLIMEX parameters for *E. lignosellus*. Parameters highlighted in grey were not adjusted and values already included in the CLIMEX 'semi-arid' template were used

| Parameter | Description | Value | Min | Max |
|---|---|---|---|---|
| **Moisture** | | | | |
| SM0 | Lower soil moisture threshold | 0 | | |
| SM1 | Lower optimal soil moisture | 0.03 | | |
| SM2 | Upper optimal soil moisture | 0.8 | | |
| SM3 | Upper soil moisture threshold | 1.6 | | |
| **Temperature** | | | | |
| DV0 | Lower temperature threshold | 9°C | 9°C | 13°C |
| DV1 | Lower optimal temperature | 26°C | 25°C | 33°C |
| DV2 | Upper optimal temperature | 36°C | 33°C | 36°C |
| DV3 | Upper temperature threshold | 48°C | 40°C | 48°C |
| **Cold stress** | | | | |
| TTCS | Cold stress temperature threshold | 3°C | | |
| THCS | Cold stress accumulation rate | $-0.003$ week$^{-1}$ | | |
| DTCS[1] | Cold stress will begin to accumulate when this threshold number of degree-days above DVCS is not achieved | | | |
| DHCS | Rate at which cold stress accumulates once the threshold number of degree-days above DVCS (DTCS) is not achieved | | | |
| TTCSA | Average weekly temperature below which cold stress accumulates | | | |
| THCSA | Rate at which cold stress accumulates once temperatures drop below the threshold value of TTCS1 | | | |
| **Heat stress** | | | | |
| TTHS | Heat stress temperature threshold | 48°C | | |
| THHS | Heat stress accumulation rate | 0.5 week$^{-1}$ | | |
| DTHS | Heat stress will begin to accumulate when this threshold number of degree-days above DV3 is exceeded | | | |
| DHHS | This is the rate at which heat stress accumulates once the threshold number of degree-days above DV3 (DTHS) is exceeded | | | |
| **Wet Stress** | | | | |
| SMWS | Soil moisture wet stress threshold | 1.6 | | |
| HWS | Wet stress accumulation rate | 0.005 week$^{-1}$ | | |
| **Threshold Annual Heat sum** | | | | |
| PDD | Minimum degree day sum needed to complete a generation | 543 600°C days | | |

*Additional CLIMEX simulation scenarios*

Starting from the reference parameterisation described above, two additional scenarios were run to explore two possible different responses to temperature and wet conditions:

- Increased sensitivity to wet stress: SMWS decreased to 0.9 (HWS was decreased to 0.002 week$^{-1}$ to partially counterbalance the strong reduction in SMWS).
- Decreased sensitivity to cold stress scenario: TTCS decreased to 1°C. This scenario was considered because of presence points in the north-eastern USA outside the area predicted to be suitable if a threshold of 3°C was used.

Figure shows the CLIMEX Ecoclimatic Index (EI) for *E. lignosellus* for the Americans and Europe. Results show that the Mediterranean coasts of the EU, Portugal, vast areas of Spain and France, Southern Ireland, the Netherlands and Belgium have an EI $>$ 1. Substantially higher EI levels are shown for Portugal and the Mediterranean coastal areas of Spain, Italy and Greece, Cyprus and Malta.

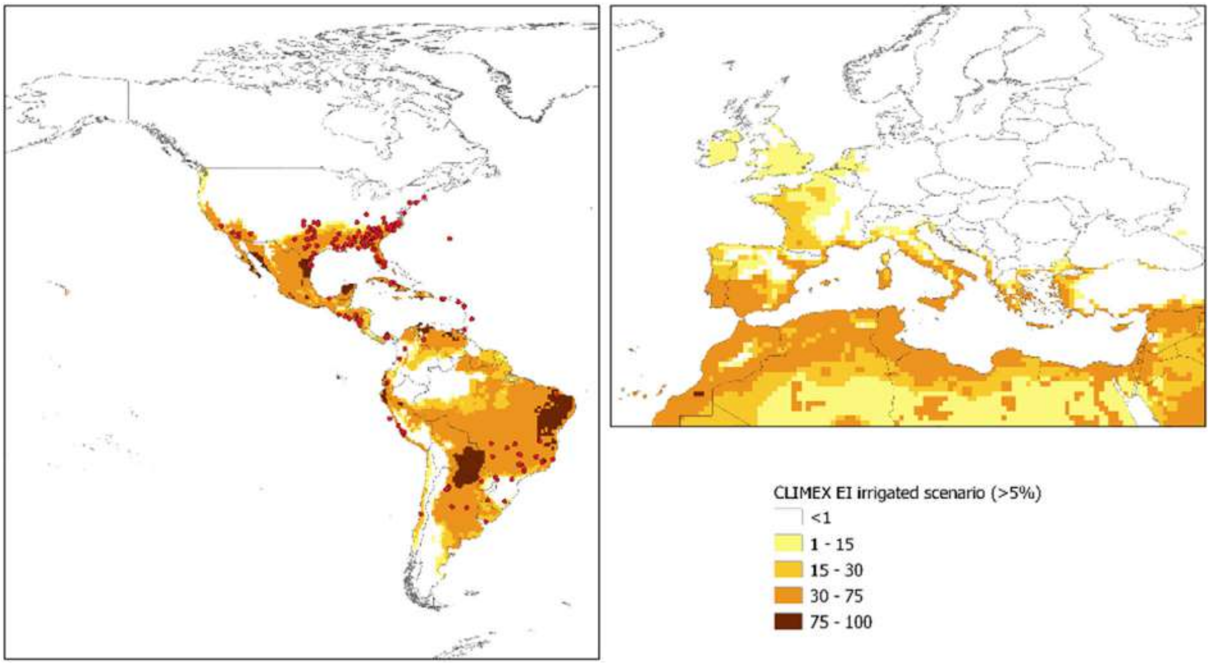


**Figure D.1:** CLIMEX Ecoclimatic Index (EI) for *E. lignosellus*. The simulation is based on the reference parameterisation and includes top-up irrigation (rainfall + irrigation up to 2.5 mm/day) applied only on irrigated pixels (same as Figure 7 in the main text, provided here for comparison with Figure D.2 without top-up irrigation)

No substantial differences are observed if the simulation is run without top-up irrigation (Figure D.2).

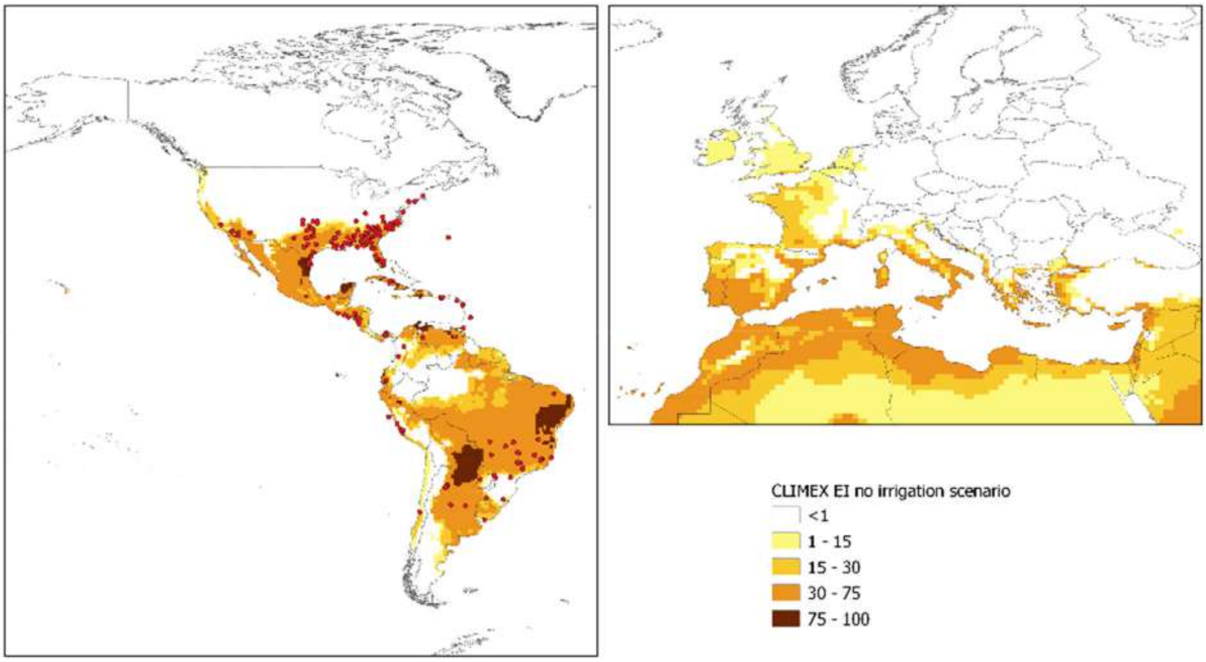


**Figure D.2:** CLIMEX Ecoclimatic Index (EI) without irrigation scenario

*CLIMEX stress parameters, projection with irrigation: Increased sensitivity to wet stress scenario*

Figure D.3 shows the EI of the scenario based on increased sensitivity to wet stress. The results show a decrease in Ecoclimatic Index (EI), especially in Castilla-La Mancha and in the eastern part of Andalusia, in Spain. In the coastal areas of south of France and in western Italy, the EI drops to values below 30.

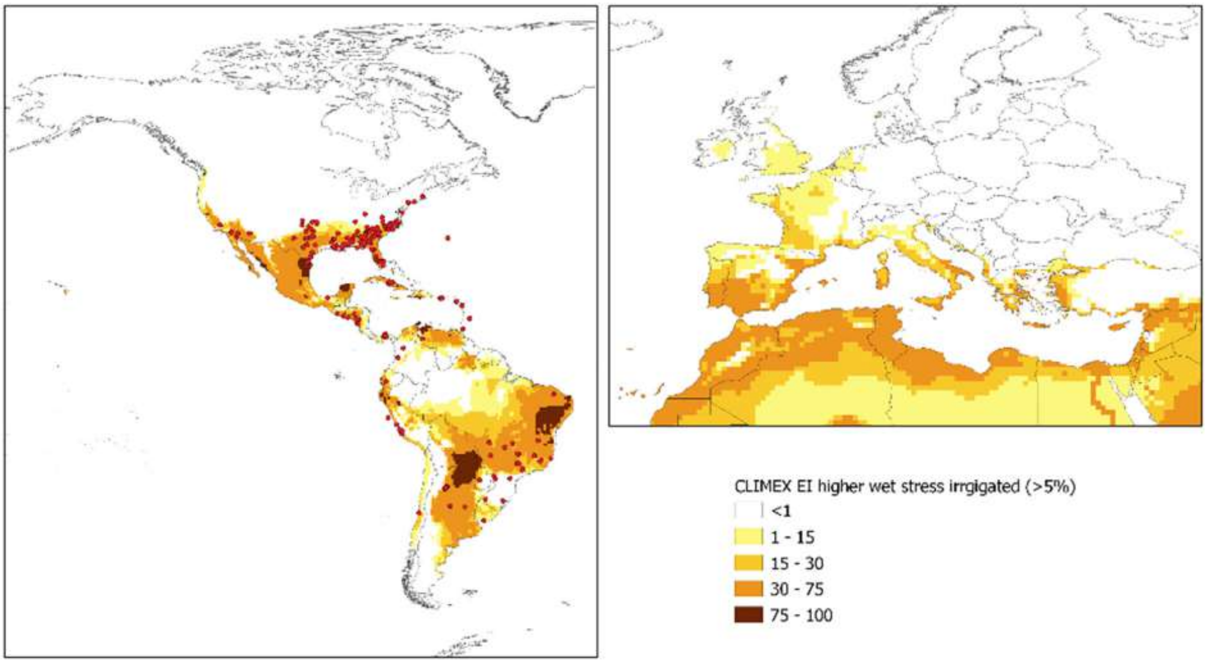


**Figure D.3:** CLIMEX Ecoclimatic Index (EI) including top-up irrigation in irrigated areas. Increased sensitivity to wet stress scenario

*CLIMEX stress parameters: Decreased sensitivity to cold stress scenario*

Figure D.3 shows the EI of the scenario based on decreased sensitivity to cold stress. The results show an increase in the area with an EI higher than one in the north of the USA. In Europe, this is translated to an overall increased EI. Most of the northern and eastern Countries (France, Germany, Poland, Czech Republic, Hungary and the Balkan peninsula) show an EI > 1 but always lower than 30. Furthermore, there is a shift of areas with EI > 30, that now push their boundaries from the Mediterranean coasts to further inland territories in Spain, Italy and Greece.

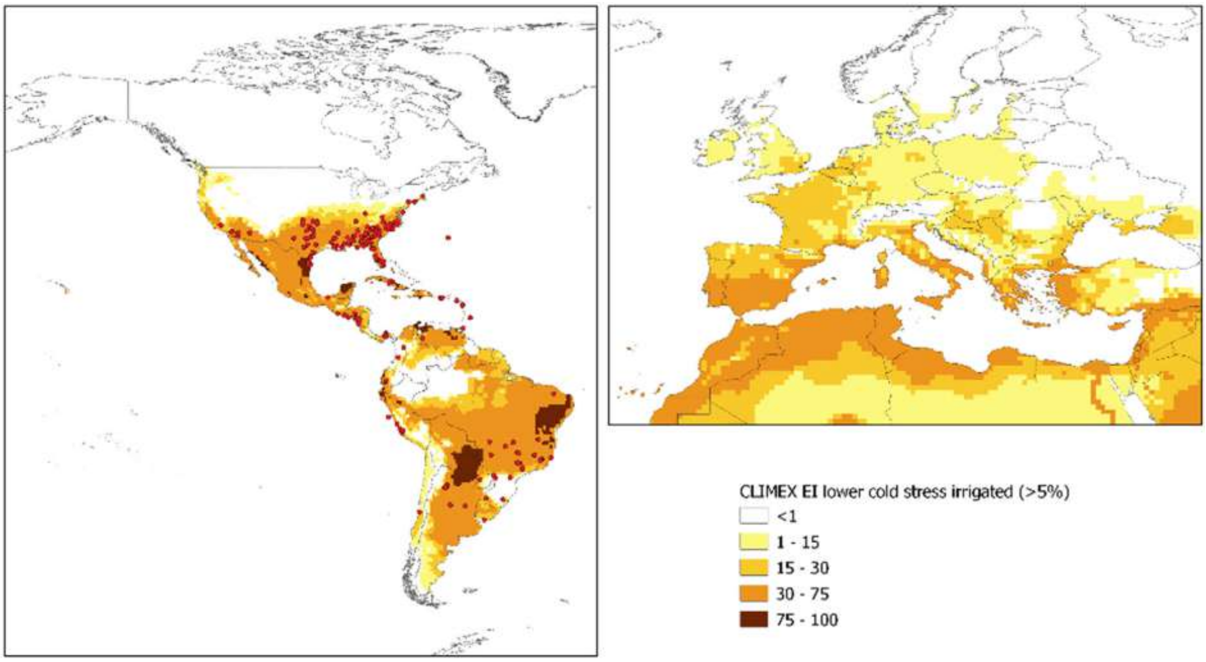


**Figure D.4:** CLIMEX Ecoclimatic Index (EI) including top-up irrigation in irrigated areas. Decreased sensitivity to cold stress scenario

The two maps using 1°C and 3°C as a cold threshold express the Panel's uncertainty regarding the area suitable for establishment as a result of uncertainty in the minimum temperature below which the insect will have increased mortality.

*Degree days and number of generations*

Degree-days and number of generations were estimated using CLIMEX. Figure D.5 shows degree-days accumulation for *E. lignosellus* in the Americas and in Europe using two different base temperatures. Literature reports three to four generations in Florida and Georgia (USA) (Leuck, 1966; Dixon, 1982). Same degree-days accumulations in Europe would theoretically sustain three to four life cycles of *E. lignosellus*.

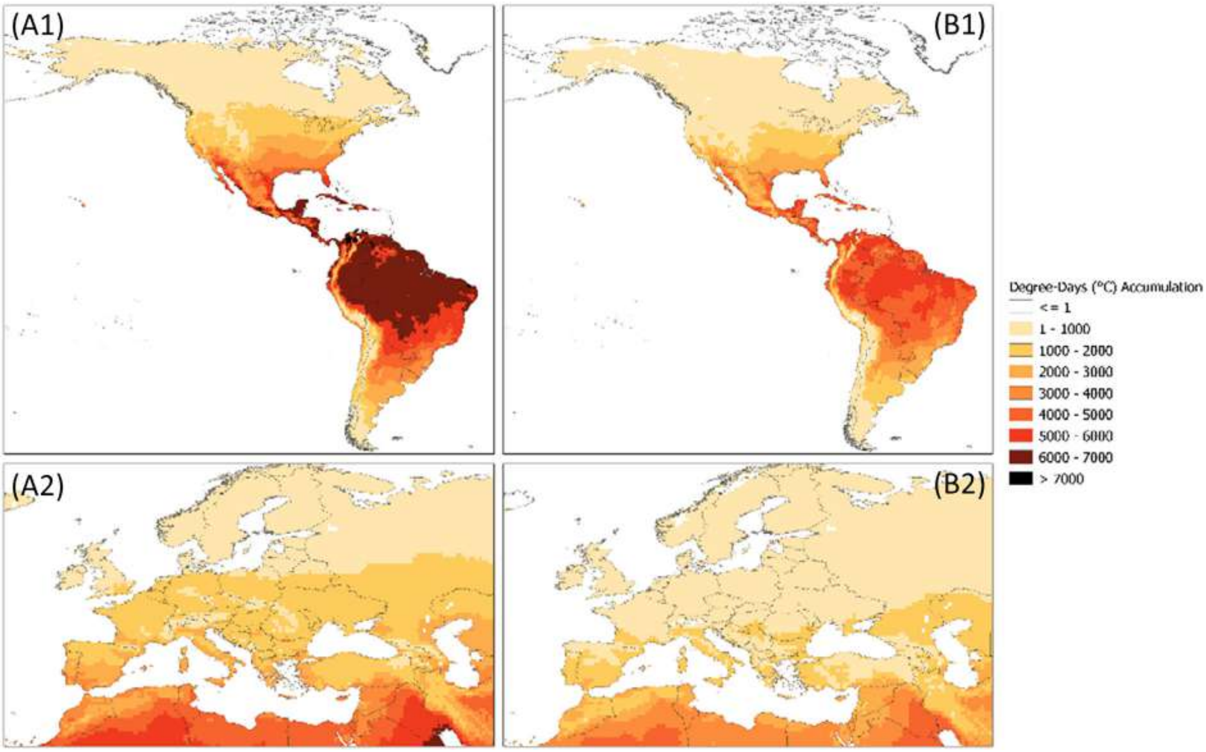


**Figure D.5:** Degree-days accumulation for *E. lignosellus* in the Americas and in Europe by CLIMEX, based on two different base temperatures. Figures A1 and A2 on the left are based on a base temperature of 9°C, while Figures B1 and B2 on the right are based on a base temperature of 13°C

## D.2. CLIMEX projection under climate change simulation ensemble

Figure D.6 shows the increase in pixels with EI > 30 simulated by CLIMEX under a climate change scenario based on an ensemble simulation using the outputs of four climate models compared to the simulation under current climate. The results show a substantial increase in Spain and France, and to a lesser extent but still relevant, also in Italy and Greece. The CLIMEX results based on the single climate model outputs (Figure 12) show some differences but in general they are similar and in line with the ensemble simulation.

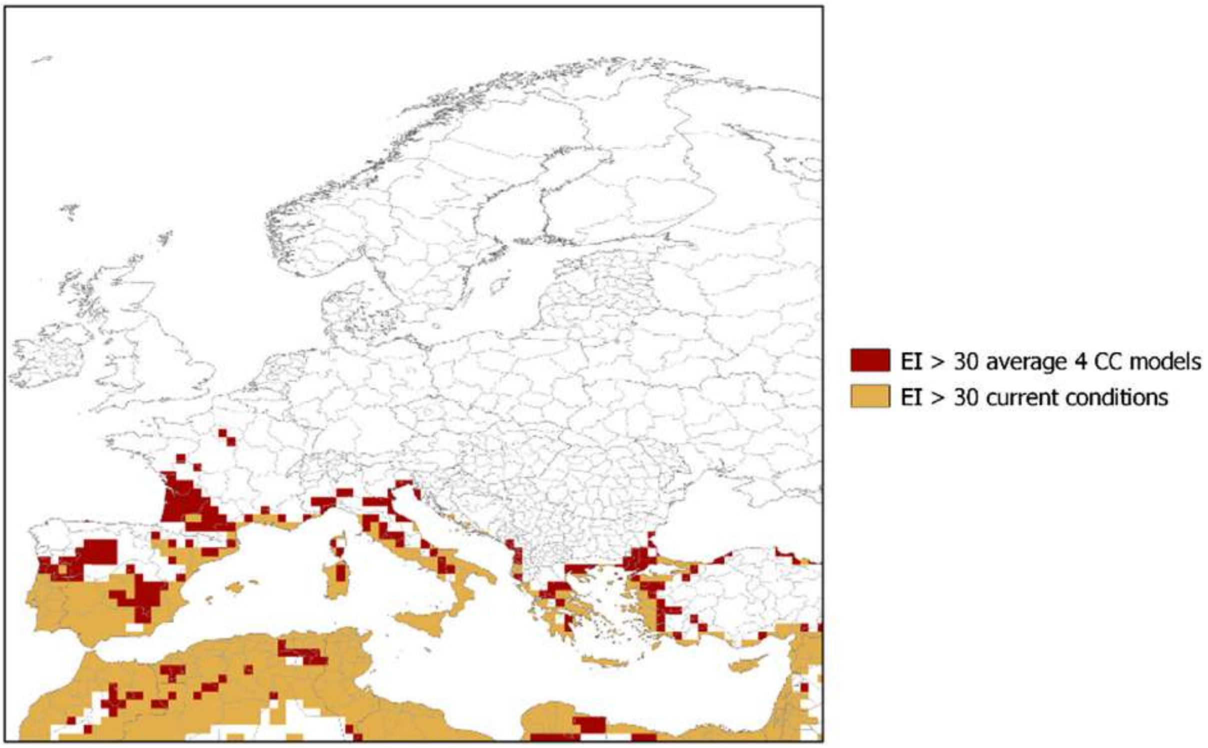


**Figure D.6:** Difference between the CLIMEX climate change simulation ensemble and the CLIMEX simulation under current observed climate. Difference is shown in terms of additional areas with Ecoclimatic Index > 30. Red is additional EI > 30 area under climate change scenario

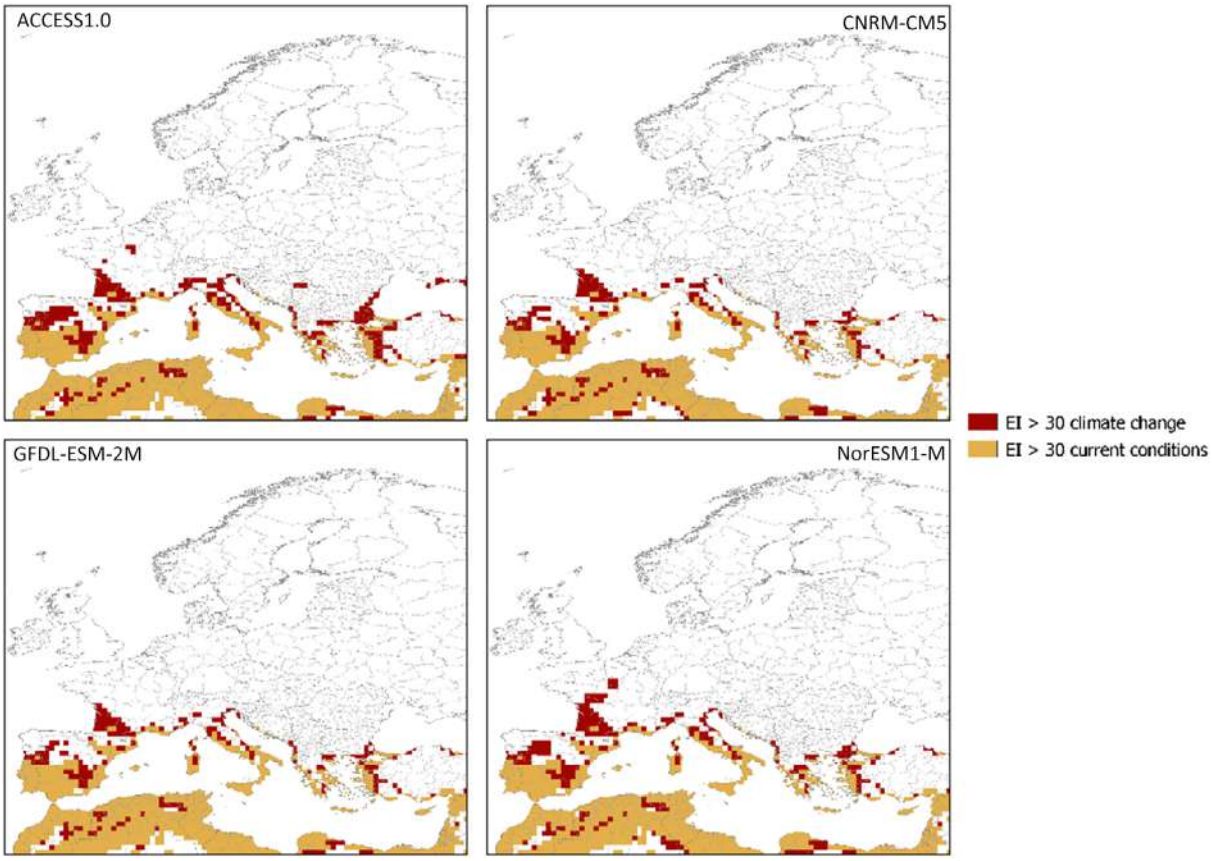


**Figure D.7:** Difference in CLIMEX EI under climate change scenario using different climate model outputs as input. Difference is shown in terms of additional areas with Ecoclimatic Index > 30. Red is additional EI > 30 area under climate change scenario

Figure D.8 shows the degree-days accumulation based on two different base temperatures, 9°C (A1 and A2) and 13°C (B1 and B2), under climate change scenario.

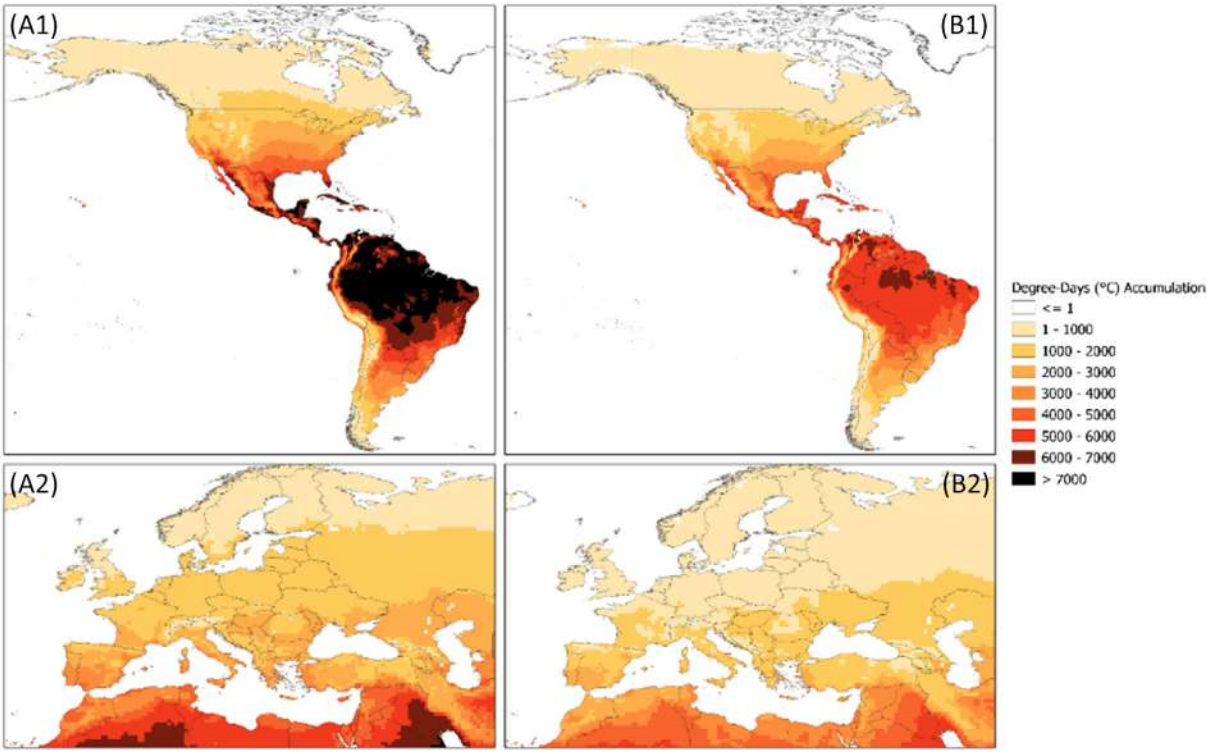


**Figure D.8:** Degree-days accumulation based on two different base temperatures, 9°C (A1 and A2) and 13°C (B1 and B2), under climate change scenario. CLIMEX simulation ensemble based on the output of four climate models

## D.3. Introduction model: Allocation to NUTS regions

Based on the results of CLIMEX, the pathway model for entry detailed in Appendix A was followed up with a step for the within-EU distribution of infested asparagus spears, the allocation to areas with Eco-climatic Index (IE) above 30, which is used as a pragmatic threshold for climatic suitability, and the following steps of asparagus waste production, escape of adult *E. lignosellus* from the waste, sex ratio, mating, host finding and initiation of founder populations in areas suitable for establishment. Using a CLIMEX Eco-climatic Index (EI) of 30 as a threshold, several NUTS2 regions appear to provide suitable conditions for establishment.

Following arrival in the EU, it is assumed that asparagus is distributed across EU NUTS regions in proportion to the human population. Eurostat reports that the population of the EU in 2021 was 447,207,489. Approximately 16.4% of the EU population occur in NUTS2 regions where EI > 30. In an ensemble of climate change scenarios, the number of NUTS2 regions where establishment appears most suitable increases; the EU population living within regions suitable for *E. lignosellus* becomes approximately 24% under climate change (Table D.2).

**Table D.2:** EU NUTS2 regions where Eco-climatic Index (EI) is 30 or more in many grid cells under current climatic conditions and/or under the future climate scenario

| n | EU MS | NUTS Code | NUTS Name | Current climate | Future climate | Population | % EU population | Median Infested asparagus spears to region |
|---|---|---|---|---|---|---|---|---|
| 1 | Cyprus | CY00 | Cyprus | Yes | Yes | 896,007 | 0.20 | 17 |
| 2 | France | FRJ1 | Languedoc-Roussillon | Yes | Yes | 2,893,969 | 0.65 | 56 |
| 3 | France | FRL0 | Provence-Alpes-Côte d'Azur | Yes | Yes | 5,116,360 | 1.14 | 98 |
| 4 | France | FRM0 | Corse | Yes | Yes | 346,610 | 0.08 | 7 |
| 5 | Greece | EL30 | Attiki | Yes | Yes | 3,736,737 | 0.84 | 72 |
| 6 | Greece | EL41 | Voreio Aigaio | Yes | Yes | 229,155 | 0.05 | 4 |
| 7 | Greece | EL42 | Notio Aigaio | Yes | Yes | 347,848 | 0.08 | 7 |
| 8 | Greece | EL43 | Kriti | Yes | Yes | 636,766 | 0.14 | 12 |
| 9 | Greece | EL62 | Ionia Nisia | Yes | Yes | 202,371 | 0.05 | 4 |
| 10 | Greece | EL63 | Dytiki Ellada | Yes | Yes | 646,670 | 0.14 | 12 |
| 11 | Greece | EL64 | Sterea Ellada | Yes | Yes | 553,235 | 0.12 | 10 |
| 12 | Greece | EL65 | Peloponnisos | Yes | Yes | 569,345 | 0.13 | 11 |
| 13 | Italy | ITC3 | Liguria | Yes | Yes | 1,518,495 | 0.34 | 29 |
| 14 | Italy | ITF2 | Molise | Yes | Yes | 294,294 | 0.07 | 6 |
| 15 | Italy | ITF3 | Campania | Yes | Yes | 5,624,260 | 1.26 | 109 |
| 16 | Italy | ITF4 | Puglia | Yes | Yes | 3,933,777 | 0.88 | 76 |
| 17 | Italy | ITF5 | Basilicata | Yes | Yes | 545,130 | 0.12 | 10 |
| 18 | Italy | ITF6 | Calabria | Yes | Yes | 1,860,601 | 0.42 | 36 |
| 19 | Italy | ITG1 | Sicilia | Yes | Yes | 4,833,705 | 1.08 | 93 |
| 20 | Italy | ITG2 | Palermo | Yes | Yes | 1,208,819 | 0.27 | 23 |
| 21 | Italy | ITI4 | Lazio | Yes | Yes | 5,730,399 | 1.28 | 110 |
| 22 | Malta | MT00 | Malta | Yes | Yes | 516,100 | 0.12 | 10 |
| 23 | Portugal | PT15 | Algarve | Yes | Yes | 437,970 | 0.10 | 9 |
| 24 | Portugal | PT16 | Centro | Yes | Yes | 2,229,331 | 0.50 | 43 |
| 25 | Portugal | PT17 | Área Metropolitana de Lisboa | Yes | Yes | 2,869,033 | 0.64 | 55 |
| 26 | Portugal | PT18 | Alentejo | Yes | Yes | 699,420 | 0.16 | 14 |
| 27 | Spain | ES43 | Extremadura | Yes | Yes | 1,057,999 | 0.24 | 21 |
| 28 | Spain | ES51 | Catalunya | Yes | Yes | 7,671,252 | 1.72 | 148 |
| 29 | Spain | ES52 | Comunitat Valenciana | Yes | Yes | 5,047,045 | 1.13 | 97 |
| 30 | Spain | ES53 | Illes Balears | Yes | Yes | 1,219,775 | 0.27 | 23 |
| 31 | Spain | ES61 | Andalucía | Yes | Yes | 8,502,216 | 1.90 | 164 |
| 32 | Spain | ES62 | Región de Murcia | Yes | Yes | 1,513,076 | 0.34 | 29 |
| *Sub-total (current climate)*: | | | | | | | 16.43 | 1,420 |
| 33 | France | FRI1 | Aquitaine | **No** | Yes | 3,511,921 | 0.79 | 68 |
| 34 | France | FRJ2 | Midi-Pyrénées | **No** | Yes | 3,119,320 | 0.70 | 60 |
| 35 | Greece | EL51 | Anatoliki Makedonia, Thraki | **No** | Yes | 594,905 | 0.13 | 11 |
| 36 | Greece | EL52 | Kentriki Makedonia | **No** | Yes | 1,858,755 | 0.42 | 36 |

| n | EU MS | NUTS Code | NUTS Name | Current climate | Future climate | Population | % EU population | Median Infested asparagus spears to region |
|---|---|---|---|---|---|---|---|---|
| 37 | Greece | EL61 | Thessalia | **No** | Yes | 709,808 | 0.16 | 14 |
| 38 | Italy | ITF1 | Abruzzo | **No** | Yes | 1,293,941 | 0.29 | 25 |
| 39 | Italy | ITH5 | Emilia-Romagna | **No** | Yes | 4,438,937 | 0.99 | 85 |
| 40 | Italy | ITI1 | Toscana | **No** | Yes | 3,692,865 | 0.83 | 72 |
| 41 | Portugal | PT11 | Norte | **No** | Yes | 3,566,374 | 0.80 | 69 |
| 42 | Spain | ES30 | Comunidad de Madrid | **No** | Yes | 6,755,828 | 1.51 | 130 |
| 43 | Spain | ES41 | Castilla y León | **No** | Yes | 2,386,649 | 0.53 | 46 |
| 44 | Spain | ES42 | Castilla-la Mancha | **No** | Yes | 2048656 | 0.46 | 40 |
| *Total (future climate)* | | | | | | | 24.03 | 2,076 |

## D.4. Introduction model: proportion of asparagus discarded

Having entered the EU as a pest contaminant of asparagus, if a founder population is to be initiated, larvae of *E. lignosellus* need to complete their development, find a mate and progeny need to survive to reproduce themselves.

An important factor to consider is that for larvae to complete their development, the contaminated asparagus they arrive in should be discarded before it is processed, e.g. cooked and consumed.

At this point in the pathway for introduction, the density of infested asparagus spears is thought to be very low and only asparagus discarded together by importers, wholesalers or retailers will be of sufficient quantity for there to be any chance that a male and female may emerge in sufficiently close proximity for them to find each other and mate to potentially initiated a founder population. Discards could be due to several reasons, for example, damage during handling & transport, physical quality problems, market conditions and pest finds.

In a study focused on another lepidopteran pest of asparagus, Gould et al. (2006) report that in the USA importers discarded 1% of imports, wholesalers discarded 2.3% and retailers 7.7% (combined 10.7% of all imports discarded before consumer has fresh asparagus). Consumer could also dispose of some asparagus but the likelihood of male and female emerging from the same pack of asparagus bought by individual consumer is so low as to be not measurable. It was therefore more realistic to consider only disposal by commercial actors.

**Table D.3:** Percentage of asparagus discarded at steps in supply chain following entry (Gould et al., 2006)

| Actor in chain | % discarded | Per 10,000 imported number discarded at each step | Remaining in supply chain |
|---|---|---|---|
| **Importer** | 1.0 | 100 | 9,900 |
| **Wholesaler** | 2.3 | 228 | 9,672 |
| **Retailer** | 7.7 | 745 | 8,927 |

*Uncertainty*: Whether EU importers, wholesalers and retailers discard the same % as in US

From Anonymous (2014), commercial discard could be due to, for example,

- Spoilage (rotting),
- off-spec production (lower quality)/out-grading,
- handling damage,
- disposal of excess stock.

Food waste is a data-poor area across the main sectors where it arises (Anonymous, 2014).

Based on Gould et al. (2006), a constant 10% was used as an estimate of the proportion of asparagus discarded, from which *E. lignosellus* could potentially continue to develop.

## D.5. Introduction model: Probability of larvae surviving to develop to adulthood then escape from discarded waste

- Eggs and pupae do not enter in asparagus as they occur in the soil, not in the spears
- Larval development takes about 27 days, pupal development 12 days at 21°C (Sandhu et al., 2010a)

**Table D.4:** Estimated probability of an adult emerging and escaping from discarded asparagus

| **Question:** | What is probability that a larva in the discard waste will result in an adult emerging from the waste? | | | | | | |
|---|---|---|---|---|---|---|---|
| **Results** | Likelihood that an adult will emerge from discarded asparagus waste | | | | | | |
| **Percentiles: %** | 1% | 5% | 25% | 50% | 75% | 95% | 99% |
| **EKE estimates:** | 0% | – | 0.5% | 1.0% | 2.5% | – | 5.0% |
| **Fitted values: (spears infested per 10,000)** | 0.10% | 0.12% | 0.42% | 1.2% | 2.4% | 4.2% | 5.0% |
| **Fitted distribution** | BetaGeneral (0.62255, 1.7287, 0.00099, 0.0555) | | | | | | |

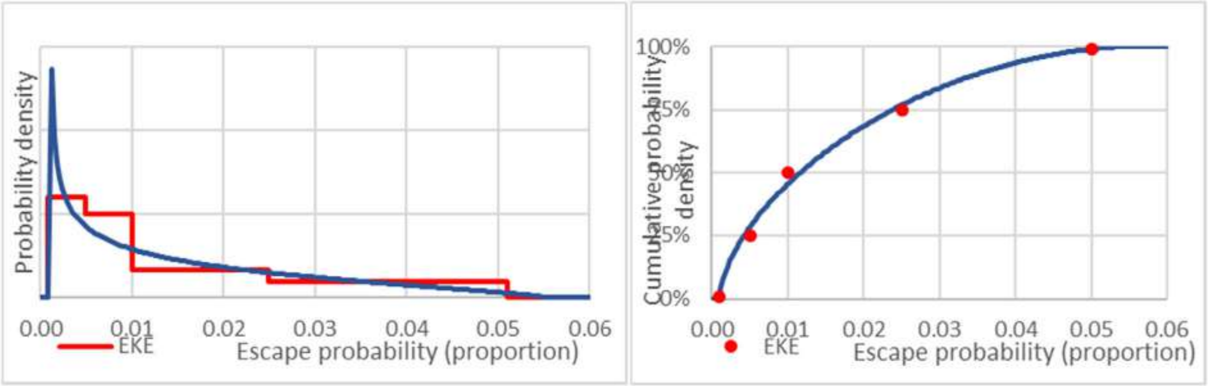


**Figure D.9:** Distribution of proportion of adults escaping from discard waste, fitted to EKE estimates. Left hand chart shows probability density function to describe the remaining uncertainties of the parameter. Right hand chart shows cumulative distribution function (CDF) of the parameter

The median likelihood that a larva discarded in waste will continue its development to emerge as an adult that escapes from waste was estimated to be 1.2% (90% CR from 0.12% to 4.2%).

## D.6. Introduction model: Proportion of adults mating

An important limiting factor in establishing a founder population is the likelihood of a male and a female emerging in temporal and spatial proximity to locate each other and mate. Recall that border interceptions of insects are a poor predictor of successful establishment (Kenis et al., 2007; Caley et al., 2015).

At this point in the model, there is a median of approximately 16 discarded asparagus spears, each with a single live larva in the NUTS2 region of Andalucia (90% CI 2–110), most likely in the time frame of June to January. The probability of mate finding is likely to be low at such low numbers, that are spread out in space as well as time.

Adults live for 10–20 days.

**Table D.5:** Estimated probability that an adult female will mate

| **Question:** | What is the probability that an escaped adult female will find a mate either before flying off to find a host or at a host? | | | | | | |
|---|---|---|---|---|---|---|---|
| **Results** | Proportion of females successfully mating | | | | | | |
| **Percentiles: %** | 1% | 5% | 25% | 50% | 75% | 95% | 99% |
| EKE estimates | 0.00% | | 0.05% | 0.08% | 0.12% | | 0.20% |
| Fitted values | 0.0071% | 0.018% | 0.049% | 0.081% | 0.12% | 0.17% | 0.20% |
| **Fitted distribution** | BetaGeneral (1.8097, 3.2291, 0, 0.0024) | | | | | | |

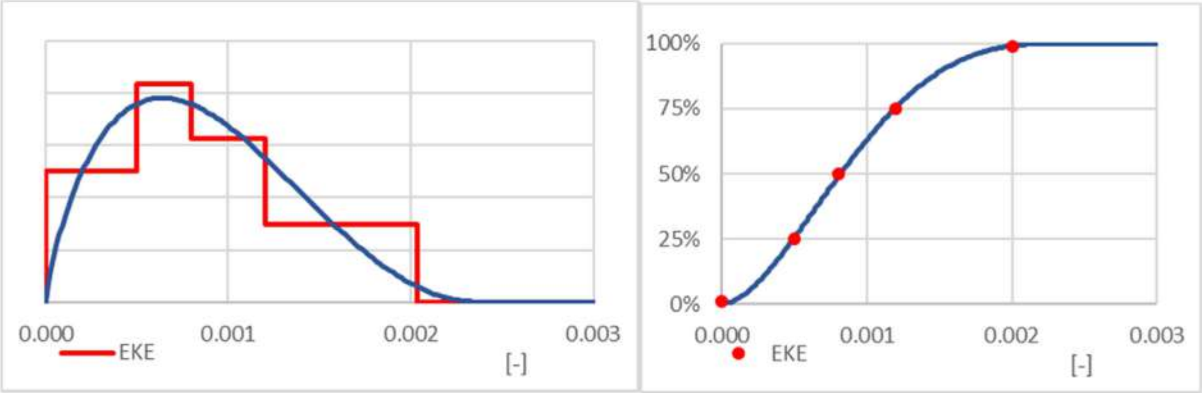


**Figure D.10:** Distribution of probability of mating fitted to EKE estimates. (Left hand chart shows probability density function to describe the remaining uncertainties of the parameter; right hand chart shows cumulative distribution function (CDF) of the likelihood of the parameter)

The median likelihood that an escaped adult female will successfully mate was estimated to be 0.081% (i.e. 8 in 10,000) (90% CR from 0.018% to 0.17%, approximately 2 in 10,000 to 17 in 10,000).

## D.7. Introduction model: Likelihood of founder population initiation

Once a female is mated, it may not have great difficulty finding a host as the host range is quite wide. The female is carrying many eggs that are laid singly near host plants. There are no specialised predators and parasitoids. Due to its hidden life style, *E. lignosellus* is not so susceptible to predators and parasitoids. Once a next generation emerges, males and females are likely to be present at the same location at a similar time, and hosts in suitable stages are also likely to be found. These factors make that the probability of a mated female founding a population that would persist was estimated to be not small, with an elicited lower bound of 1% of mated females founding a persistent population and the upper bound 50%.

**Table D.6:** Estimated probability that a founder population will be initiated following successful mating

| **Results** | Likelihood that a founder population will be initiated following successful mating | | | | | | |
|---|---|---|---|---|---|---|---|
| **Percentiles: %** | 1% | 5% | 25% | 50% | 75% | 95% | 99% |
| EKE estimates | 1% | – | 20% | 30% | 40% | – | 50% |
| Fitted values | 3.02% | 7.64% | 19.7% | 30.3% | 39.8% | 48.0% | 50.1% |
| **Fitted distribution** | BetaGeneral (1.7529,1.2895,0,0.51) | | | | | | |

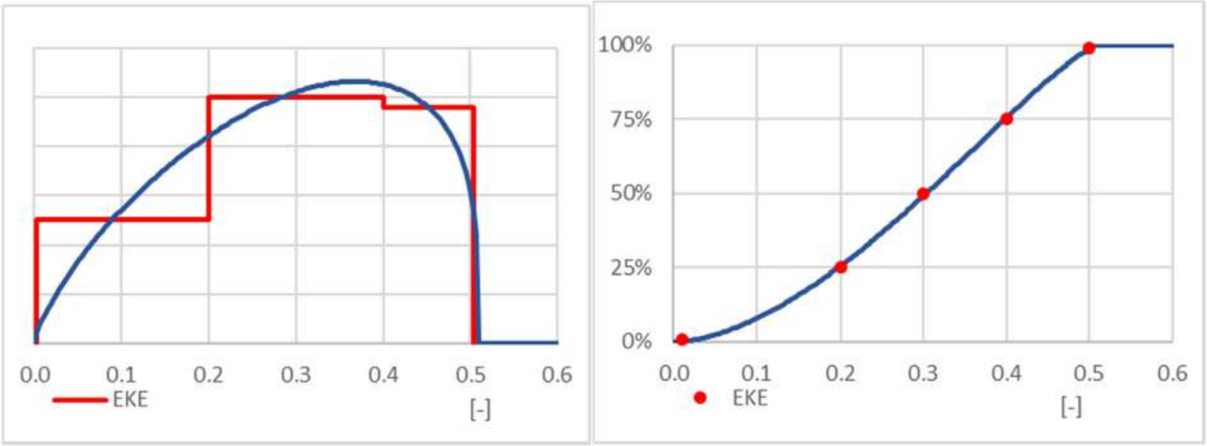


**Figure D.11:** Distribution of probability of a founder population being initiated following successful mating fitted to EKE estimates. (Left hand chart shows probability density function to describe the remaining uncertainties of the parameter; right hand chart shows cumulative distribution function (CDF) of the likelihood of the parameter)

The median likelihood that a founder population will be initiated following successful mating was estimated to be 30.3% (90% CR from 7.6% to 48.0%).

# Appendix E – Spread

To inform the assessment of spread, the panel first estimated the duration of the lag phase before estimating the linear rate of range expansion during the phase in which spread is at its fastest.

## E.1. Estimated duration of the lag phase

Table E.1 shows EKE estimates for the duration of the lag phase based on the evidence summarised as bullet points below.

**Table E.1:** Estimated duration of the lap phase

| **Question** | How long is the average duration of the lag phase, this means the time from the first introduction and reproduction of the pest (founder population) to its establishment with constant spread in pest free areas (constant expansion)? | | | | | | |
|---|---|---|---|---|---|---|---|
| **Results** | How long is the average duration of the lag phase? (years) | | | | | | |
| **Percentiles: %** | 1% | 5% | 25% | 50% | 75% | 95% | 99% |
| **EKE estimates** | 2.0 | – | 10 | 18 | 30 | – | 50 |
| **Fitted values** | 2.01 | 3.31 | 9.70 | 18.5 | 29.6 | 43.8 | 49.9 |
| **Fitted distribution** | BetaGeneral (1.0584, 1.9237, 1.65, 54.5) | | | | | | |

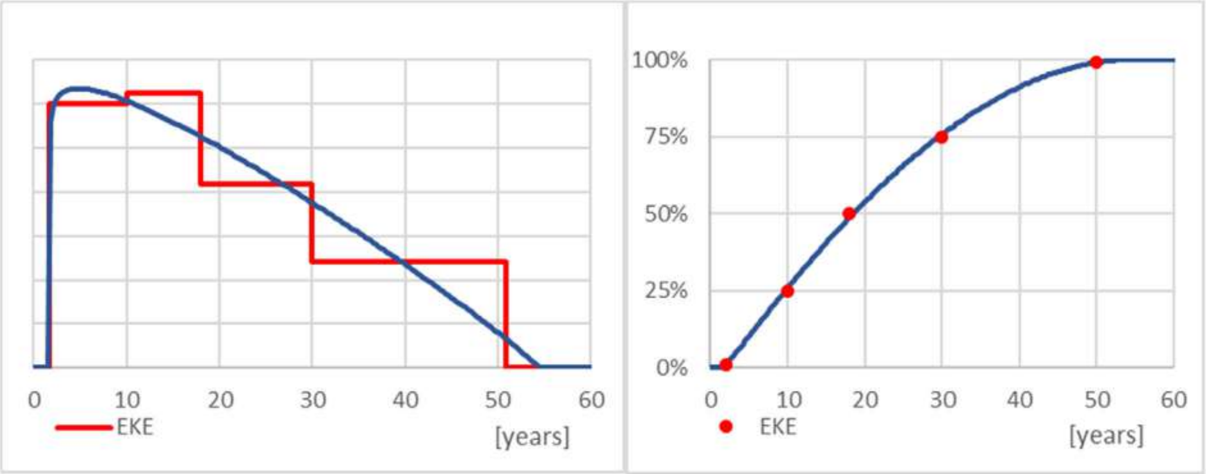


**Figure E.1:** Distribution of the estimated mean duration of the lag phase for founder populations of *E. lignosellus* (years) fitted to EKE estimates. (Left hand chart shows probability density function to describe the remaining uncertainties of the parameter; right hand chart shows cumulative distribution function (CDF) of the likelihood of the parameter)

The median estimate for the duration of the lag phase was 18.5 years (90% CR from 3.3 to 43.8 years).

*Reasoning*

- The lag phase is largely driven by the rate of population growth;
- Female about 200 eggs per life cycle;
- High mortalities (30–40%) in all life stages reported [lab study:];
- About three to four life cycles per year expected in EU (see Appendix D, Establishment: number of generations);
- Biological control is not promising.

| Uncertainty | Short lag phase scenario | Long lag phase scenario |
|---|---|---|
| Life cycles | 4 or more generations per year | 3 or less generations per year |
| Climatic conditions | EU climate is equally suitable | EU climate is less suitable (lower temperatures) |
| Environmental conditions | Wild environment is not irrigated (summer dry) | Prefers dry soil, not frequent in EU (irrigation) |
| | Good host conditions | Poor host conditions |
| Predators | No specific enemies in EU | Generalists will reduce the population |
| Initial population | One heavily infested consignment | Few mated females introduced |

Lower limit

- High multiplication rate (about 1,000×) assumed under good conditions.
- Some indications (Chang and Ota, 1987) that spread occurred rapidly after introduction in Hawaii.
- But assuming, small population as starting condition in Europe (infested consignment).
- Introduction in wild (non-monitored) environment.
- Good climatic, esp. dry, conditions, availability of many alternate hosts.
- Longer time to detect due to low spread capacity.

Upper limit

- Predators will limit the population size.
- Some evolutionary adaptation is needed in Europe.
- Cultivated areas will limiting the development by management practice.
- Generally, time to detection is long, lag phase is assumed to be similar to the time of detection.
- But risk area is generally suitable.

Median

- Tendency on shorter lag phases.

Inter-quartile range

- Medium uncertainty below and above the median.

## E.2. Estimated linear rate of range expansion (spread)

Table E.2 shows EKE estimates for the linear rate of spread based on the evidence summarised as bullet points below.

**Table E.2:** Estimated rate of linear spread (m/year)

| **Question** | What is the annual median rate of spread when the established population is spreading at a constant rate? | | | | | | |
|---|---|---|---|---|---|---|---|
| **Results** | | | | | | | |
| **Percentiles: %** | 1% | 5% | 25% | 50% | 75% | 95% | 99% |
| **EKE estimates** | 200 | – | 3,000 | 8,000 | 12,000 | – | 20,000 |
| **Fitted values (m/year)** | 199 | 601 | 3,246 | 7,388 | 12,539 | 18,212 | 20,000 |
| **Fitted distribution** | BetaGeneral (0.868, 1.3644, 125, 20,800) | | | | | | |

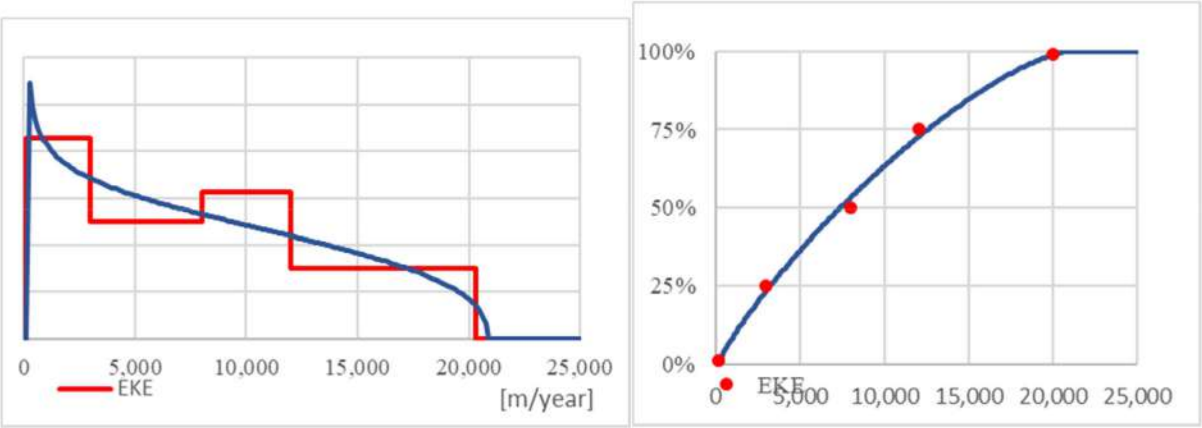


**Figure E.2:** Distribution of the estimated mean duration of the lag phase for founder populations of *E. lignosellus* (years) fitted to EKE estimates (Left hand chart shows probability density function to describe the remaining uncertainties of the parameter; right hand chart shows cumulative distribution function (CDF) of the likelihood of the parameter)

The median annual rate of spread for *Elasmopalpus lignosellus* was estimated to be approximately 7.4 km per year (90% CR from 0.6 to 18.2 km per year) during the period of constant rate of spread.

*Reasoning*

- The spread rate is the outcome of the contribution of natural dispersal together with local human-assisted spread.
- Spread due to post-harvest movement, such as the trade in commodities, was not included in the estimation.
- There is little quantitative data on the flight capability of *E. lignosellus*.
- Adults are not strong fliers (Fewkes, 1966).
- Adult flight is primarily nocturnal (Holloway and Smith, 1975).
- Fernández (2016) reported adults flying at night at 27°C, with high RH and no wind.
- When disturbed during daylight hours, its flight pattern is short and jerky (Holloway and Smith, 1975).
- Several papers indicate *E. lignosellus* is a poor flyer that flies at night, above the canopy (0.5 m height for traps; 20–30 cm above the canopy) (Aragón et al., 2013); however, adults have been found at 300 m above the ground during sampling of aerial insects using an airplane (Glick and Noble, 1961)
- Females fly towards burnt/burning fields (they are attracted to smoke) (Hudson and Johnson, 1969)
- Larvae can move from one plant to another, and from field weeds to crops (Isely and Miner, 1944; Funderbank et al., 19841984)
- In the situation of asparagus production in Peru fields seem quite large and adults need to move to complete its life cycle
- Adults successfully disperse between fields and field-marginal habitats
- *E. lignosellus* was first discovered infesting Hawaiian sugarcane on Kauai in July 1986 (Chang and Ota, 1987). The following year it was reported from all sugarcane growing islands (Chang and Ota, 1988). The apparent rapid spread of *E. lignosellus* over the islands of Hawaii may be due to recognition of a widespread pest after its first discovery. It is not strong evidence of rapid spread by the insect. Sugarcane is propagated primarily by planting of cuttings which would provide a plausible mechanism for human-assisted spread.
- Roques et al. (2016) provides an overview of the rates of spread of a range of insect pests introduced into Europe.
- The rate of spread of several similar pests (e.g. *Cactoblastis cactorum*), with similar characteristics and which have been studied more (hence, more published literature is available) informed estimates.

Lower limit:

- Insect is a poor flyer.
- Patchy infestations in fields.
- Could stay between wild and agricultural environments to conclude its life cycle.

Upper limit:

- Insect is a flyer, maybe promoted by wind, maybe attracted by burned fields (Hudson and Johnson, 1969).
- Several generations with need to move.
- Higher expansion rates are observed for other insects.
- But expansion rate is not individual flight, enough hosts available.

Inter-quartile range

- Lower uncertainty below the median.
- High uncertainty above the median.

## Appendix F – Impact

Appendix I shows the areas in the EU where crops are cultivated that are a host of *E. lignosellus*. EU crops that are potential hosts were considered in terms of their vulnerability to *E. lignosellus* (Table F.1). Although the majority could be hosts, literature from the Americas primarily reports losses from Poaceae (cereal crop species) and Fabaceae (pulses and beans; legumes) (Figure F.1).

Literature reporting yield losses in cereal and legume crops in the Americas was generally from regions where $\mathrm{EI} > 30$. Impacts in the EU were therefore considered to be limited to regions where $\mathrm{EI} > 30$. Such locations coincide to the area for establishment; hence, transient populations outside regions where $\mathrm{EI} < 30$ were judged not to be able to cause measurable impacts.

Two scenarios for impact were assessed (i) an artificial scenario, akin to experimental 'control' plots used when evaluating the efficacy of a pesticide or other management intervention, and (ii) a scenario where farmers have pest management in place against *E. lignosellus*.

**Table F.1:** *E. lignosellus* hosts in EU: Judgement regarding vulnerability to yield losses based on larvae being restricted to feeding on host as a young plant/seedling

| Production practice | Hosts | Main factors to consider (e.g. what time of year is host a seedling) | Vulnerable to *Elasmopalpus* larvae? |
|---|---|---|---|
| 1. Grown in open field from (true) seed | Cereals<br>Barley, wheat and spelt, grain maize and corn–cob mix, green maize, oats, rye, sorghum, *Durum wheat* (not a host?) | Around the Mediterranean, cereals such as wheat and rye are usually planted in late autumn/winter; seedlings emerge in autumn and benefit from winter rainfall. They are harvested in the late spring/early summer to avoid summer heat.<br>Maize is usually sown in spring/early summer (April/May) and harvested in late summer/early autumn (September/October). Some cereal varieties, especially of barley, can be sown in both winter and spring. | **Yes**, seedlings of spring cereal (probably mostly maize and barley) will be vulnerable; whether winter cereal seedlings will be vulnerable will depend on whether larvae will be developing and feeding in late autumn/early winter when crop is germinating. |
| | Sugar beet | Sown in springtime to avoid frosts | **Yes**, late spring/early summer seedlings could be vulnerable to stems being cut or bored. |
| | Rapeseed, soybeans, field peas, fresh peas, broad and field beans, fresh beans | Legumes are grown in open fields following direct seed drilling in spring after frosts and harvested in the summer. Beans grown and harvested in greenhouses maybe be transplanted. | **Yes**, seedling emerging in late spring/early summer can be attacked |
| | Cotton | Greece is main EU production area: planted in March–April, seedlings emerge in May, harvested in October–November https://agritrop.cirad.fr/445160/1/ID445160.pdf | **Yes**, late spring/early summer seedlings could be vulnerable to stems being cut or bored |
| | Sunflower | Sown in late spring (March to late May), harvested August–October. | **Yes**, early summer seedlings could be vulnerable to stems being cut or bored. |

| **Production practice** | **Hosts** | **Main factors to consider (e.g. what time of year is host a seedling)** | **Vulnerable to *Elasmopalpus* larvae?** |
|---|---|---|---|
| | Rice (dry rice also known as upland rice)<br>(EU grows both paddy rice and dry rice.) | Temperate japonica type rice can be sown in dry soil in the late spring or early summer and harvested in autumn. However, in Spain, it is never sown in dry soil (see paddy rice below). | **Yes**, summer seedlings could be vulnerable to stems being cut or bored. |
| | Leguminous cover crops | In Southern Europe, cover crops are used in vineyards and orchards to cover the soil, fix nitrogen (legumes), prevent erosion and improve water infiltration and improve soil organic matter. | **Yes**, poaceous and leguminous species used as cover crops may be vulnerable at the seedling stage. |
| 2. Grown in open fields from tubers | Potatoes | Around the Mediterranean coast of Spain, including the Balearic Islands, potatoes can be planted at almost any time e.g. late summer/early winter for harvest in late winter/early spring ('extra-early' varieties); 'early' varieties are planted in the winter (November–January) and harvested from March to May; main-crop and late varieties can be planted in the spring and summer and harvested in the autumn and winter. Irrigation is probably used during the summer. | **Yes**, larvae developing in the spring and summer could feed on main crop and late crop varieties. Irrigation could cause larval mortality.<br>If larvae are also developing in the winter when early varieties are germinating, or in the autumn when late, summer sown, potatoes are germinating the crop could also be damaged. |
| 3. Grown in open fields or under protected cultivation from dormant plants | Asparagus<br>https://www.asparagusseeds.com/blog/asparagus-production-and-marketing-in-spain | Dormant plants, known as 'crowns' are planted and harvested from winter to early summer then regrows, can last several years | **Yes**, larvae could infest stems in late spring/early summer (but would adults enter protected conditions to oviposit?) |
| 4. Transplanted into open fields as seedlings/young plants | Soya, Brassicas (excluding rapeseed, see above) | In Italy and Spain, brassicas (but not rapeseed) always come from nurseries and can be transplanted into open fields almost all year round. | **Yes**, brassicas would be vulnerable to larvae when they are transplanted (mostly in late summer?) |
| | Rice (paddy rice)<br>(EU grows both paddy rice and dry rice) | Paddy rice (seedlings transplanted into flooded fields)<br>https://om.ciheam.org/om/pdf/c24-2/CI011093.pdf<br>https://ipad.fas.usda.gov/highlights/2017/08/greeceitaly/index.htm<br>In Spain, most (paddy) rice is sown directly (above, row 1). Exceptionally some seedlings may be transplanted if something goes wrong with seed germination | **No**. Eggs not laid in water and larvae would not survive in flooded fields |
| | Strawberries | Planted out as small plants from mother stock. Mother stock would be secure from | **Uncertain**: When planted in soil could be vulnerable but less so when planted on |

| **Production practice** | **Hosts** | **Main factors to consider (e.g. what time of year is host a seedling)** | **Vulnerable to *Elasmopalpus* larvae?** |
|---|---|---|---|
| | | pests. When planted out, the material may be bare rooted or with roots in a growing media. Modern technique is to transplant plants for fruit production into bagged media on raised platforms in fields to ease harvest. Uncertain what proportion of production around the Mediterranean uses raised platforms. (Some strawberry production is hydroponic and is not at risk from *E. lignosellus*.) | raised platforms in growing media within bags. |
| 5. Transplanted into protected cultivation (plastic) houses and some to open fields as seedlings/young plants | Peppers (*capsicum*)<br>Tomatoes | Grown from seed under protection (e.g. plastic greenhouse), transplanted to production sites as tender plants making them potentially vulnerable. However, there is a substantial area of production grown in plastic greenhouses with plants growing in substrate, not free soil. Whether *E. lignosellus* would lay eggs in such an environment is unknown.<br>Some tomato and pepper production is hydroponic and is not at risk from *E. lignosellus*. | **Uncertain**: Adults would have to enter glasshouse to lay eggs.<br>Literature does not report *E. lignosellus* as a greenhouse pest in the Americas.<br>If hydroponic then no risk. |

https://ipad.fas.usda.gov/rssiws/al/crop_calendar/europe.aspx.

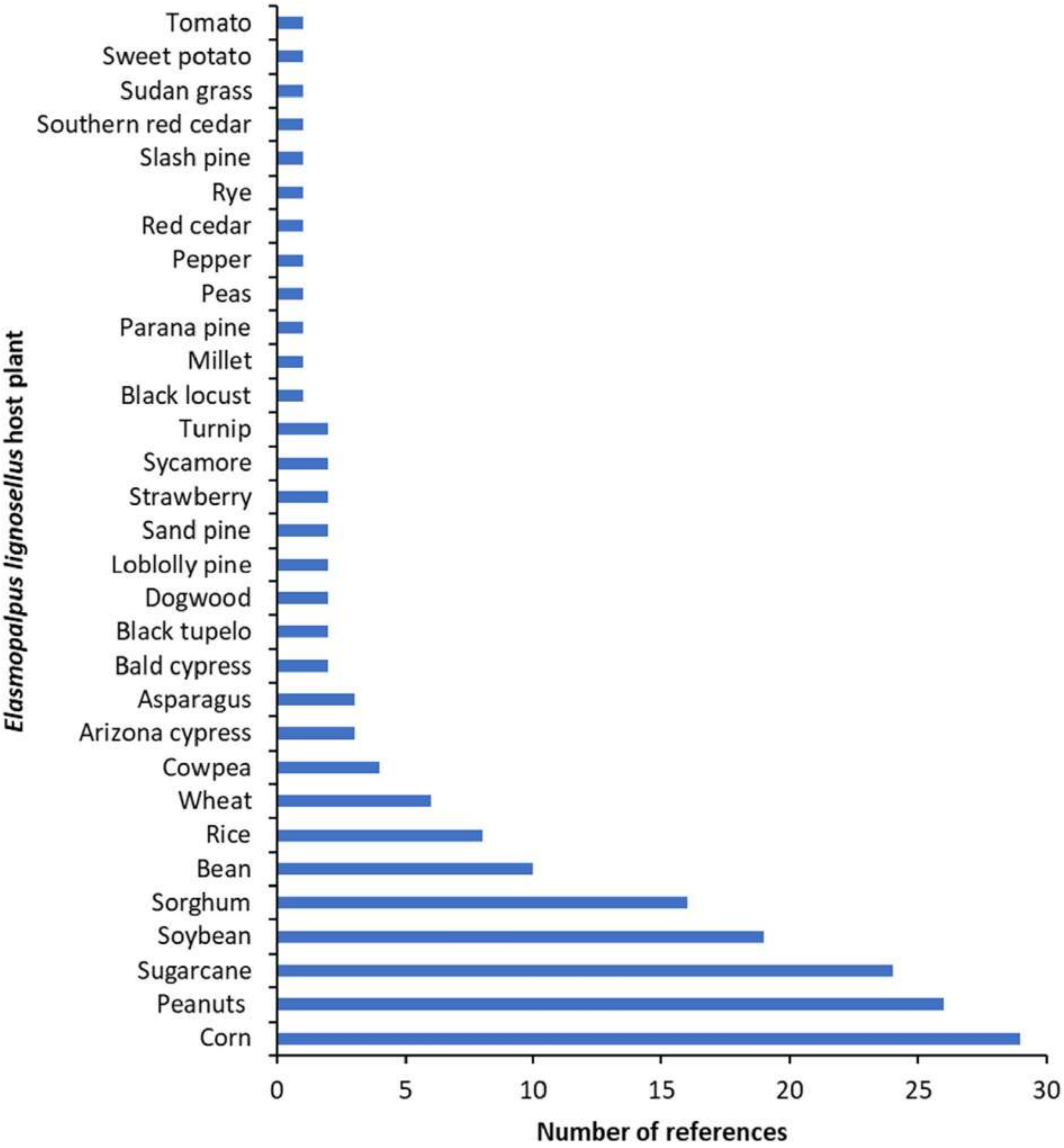


**Figure F.1:** Numbers of publications reporting *E. lignosellus* as a pest on specified host plants

## F.1. Estimated impact with no pest management practice in place

*This is an artificial scenario for a commercial farmer, but can be seen in experimental trials where pest management practices are excluded*.

Table F.2 shows EKE estimates for yield loss informed by a meta-analysis of losses (Appendix reported from control plots in pesticide trials and on the evidence summarised as bullet points below).

**Table F.2:** Estimated mean reduction in yield (yield loss) caused by *E. lignosellus* in the absence of pest control

| **Question** | What is the likely mean reduction of annual yield of cereals and Fabaceae where *E. lignosellus* is established and farmers do not apply any pest control? | | | | | | |
|---|---|---|---|---|---|---|---|
| **Results** | | | | | | | |
| **Percentiles: %** | 1% | 5% | 25% | 50% | 75% | 95% | 99% |
| **EKE estimates** | 0% | – | 5% | 10% | 15% | – | 30% |
| **Fitted values (% losses)** | 0.489% | 1.53% | 5.18% | 9.63% | 15.4% | 24.4% | 30.0% |
| Fitted distribution | BetaGeneral (1.4527, 4.0355, 0, 0.41) | | | | | | |

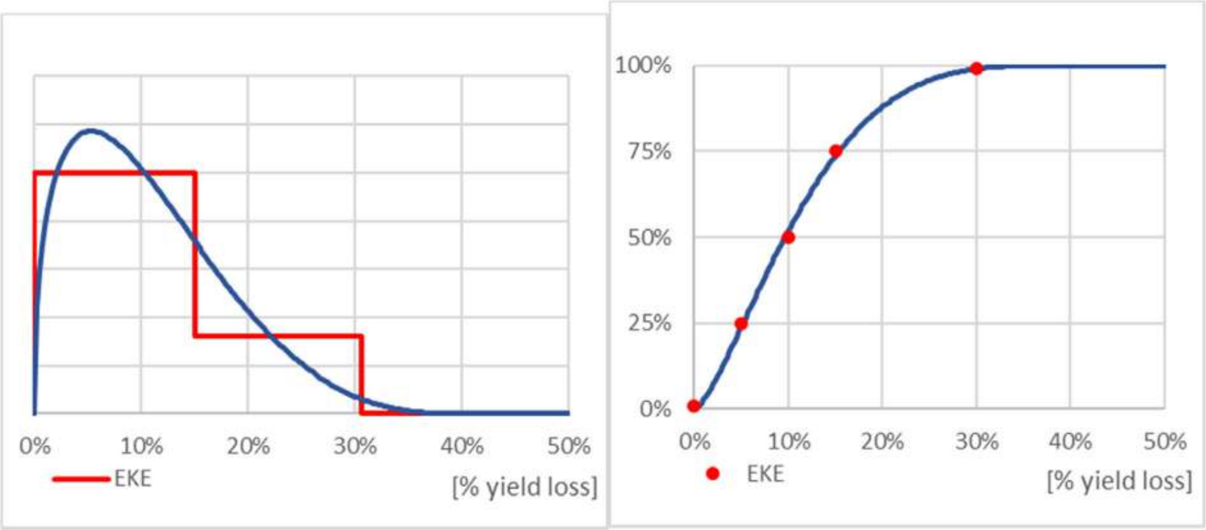


**Figure F.2:** Distribution of the estimated mean annual yield losses in crops of cereals and legumes in a scenario where no pest management interventions are in place (see text for detail) (Left hand chart shows probability density function to describe the remaining uncertainties of the parameter; right hand chart shows cumulative distribution function (CDF) of the likelihood of the parameter)

The median annual yield loss in crops of cereals and Fabaceae was estimated to be 9.6% (90% CR from 1.5% to 24.4%) in a scenario where no pest management is in place.

*Reasoning*

- EFSA PLHA Panel focus on hosts present in the Mediterranean Coastal area.
- Seedlings and young plants (soft and tender tissue) are vulnerable/orchard trees are not at threat.
- Consider impacts in corresponding NUTS2 regions (EI > 30).
- Consider losses from meta-analysis (no specific measures in place) from the literature (Appendix G).
- Assume experimental trials (data used in meta-analysis) were conducted in conditions very favourable for the pest.

## F.2. Impact with pest management practices in place

Table F.3 shows EKE estimates for yield loss informed by a meta-analysis of losses reported in pest management studies and taking into account estimated yield losses from existing crops pests in the EU (Table F.4) as indicated in Table F.4 bullet points below

**Table F.3:** Estimated mean reduction in yield (yield loss) caused by *E. lignosellus* with pest control in place

| **Question** | What is the likely mean reduction in annual yield of cereals and legumes attributable to *E. lignosellus* when the pest is present to its steady state and farmers manage *E. lignosellus* as a component of the general pest fauna? | | | | | | |
|---|---|---|---|---|---|---|---|
| **Results** | Mean annual yield loss in cereals and Fabaceae when managed as part of the general pest fauna | | | | | | |
| **Percentiles: %** | 1% | 5% | 25% | 50% | 75% | 95% | 99% |
| EKE estimates | 0.00 | – | 0.50 | 1.00 | 1.50 | – | 4.00 |
| Fitted values (% yield loss) | 0.07 | 0.18 | 0.52 | 0.95 | 1.56 | 2.81 | 3.97 |
| Fitted distribution | BetaGeneral (1.7876, 153.7, 0, 100) | | | | | | |

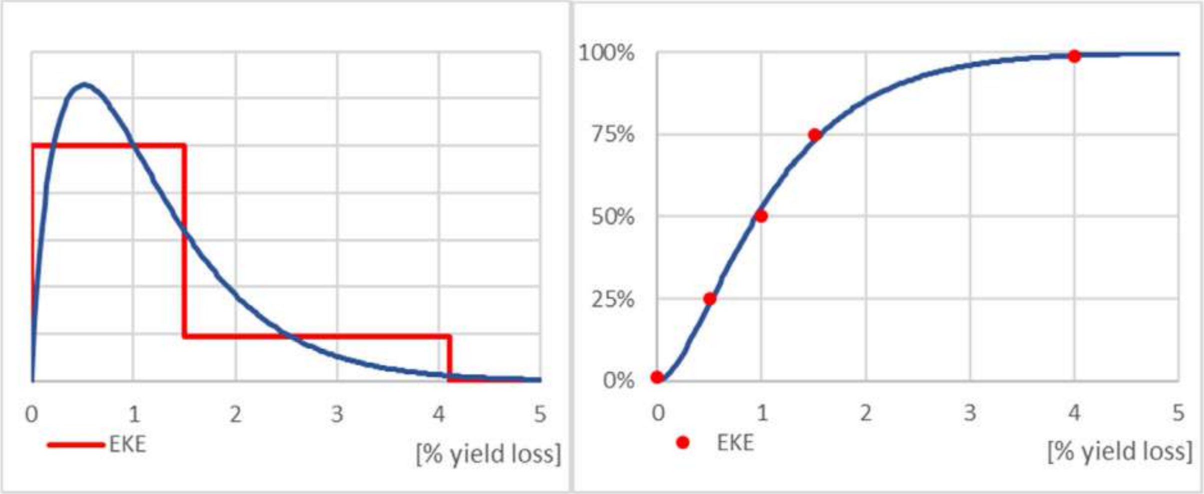


**Figure F.3:** Distribution of the estimated mean annual yield losses in crops of cereals and Fabaceae in a scenario where farmers apply routine pest management interventions and treat *E. lignosellus* as part of the general pest fauna (see text for detail) (Left hand chart shows probability density function to describe the remaining uncertainties of the parameter; right hand chart shows cumulative distribution function (CDF) of the likelihood of the parameter)

The median annual yield loss in crops of cereals and Fabaceae was estimated to be 0.95% (90% CR from 0.18% to 2.81%).

*Reasoning*

- Consider losses from meta-analysis (with control in place) from the literature (Appendix H).
- Meta-analysis indicates that pesticides reduced % of seedlings lost by approximately 62%.
- In Georgia, in sorghum, soil insects, mostly *E. lignosellus* caused sporadic damage in some fields at planting time (Guillebeau et al., 2006).
- In summarising losses from insect damage and costs of control in Georgia in 2006, Guillebeau et al. (2006) provide estimates for losses in each of 16 vegetable crops, specifying the insect pests or taxa to which losses were attributed. The vegetables detailed were aubergine, bell pepper, cabbage, cantaloupe, carrots, collard greens, cucumbers, mustard greens, onions, peas, snap beans, squash, sweetcorn, tomato, turnips and watermelons. *E. lignosellus* was only identified as a pest in snap beans where it was estimated to be responsible for 3.9% of yield loss (financial terms).
- *E. lignosellus* is the most costly pest of peanuts in Georgia (Guillebeau et al., 2006). (Peanuts not grown in EU).
- Pest management includes conventional practices such as timing of crop planting, crop rotation, use of pest resistant varieties, mulching, irrigation, use of pesticides, manipulation of the agri-environment e.g. growing flower strips (MacLeod, 1999) and developing 'beetle banks' (MacLeod et al., 2004) to encourage beneficials.

- Soil pests are not so easy to control (difficult to detect).
- Dr EC Oerke and colleagues have been publishing estimates of crop losses at a global and regional scale since the first edition of Crop production and crop protection: estimated losses in major food and cash crops in 1994 (Oerke, 1994). The 1994 book has been reprinted a number of times and estimates of crop losses have been updated in journal papers (e.g. Oerke and Dehne, 2004; Oerke, 2006). Table below is from Oerke (2006). For six major crops, it shows estimates of crop losses 2001–2003 from four groups of crop pests at a global and regional (continental) scale. In the scenario assessed for impact, where *E. lignosellus* is presumed to be well established in the EU, impacts were considered in terms of yield loss. Table F.4 provides context as to the level of yield losses due to existing pest types.
- *E. lignosellus is mostly a seedling pest. Some loss of seedlings can be tolerated without impact on crop yield. Only at high losses of seedlings are yields impacted, due to gaps in the canopy.*

**Table F.4:** Estimates of % loss in yield by type of pest in major crops around the world and at regional (approximately continental) scale

| **Pest type:** | **Animal pests(1)** | | | | **Weeds** | | | | **Pathogens** | | | | **Viruses** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Losses** | **potential losses(2)** | | **actual losses(3)** | | **potential losses** | | **actual losses** | | **potential losses** | | **actual losses** | | **potential losses** | | **actual losses** | |
| Crop\Scale | Worldwide | Regions | Worldwide | Regions(4) | Worldwide | Regions | Worldwide | Regions | Worldwide | Regions | Worldwide | Regions | Worldwide | Regions | Worldwide | Regions |
| Wheat | 8.7 | 7–10 | 7.9 | 5–10 | 23.0 | 18–29 | 7.7 | 3–13 | 15.6 | 12–20 | 10.2 | 5–14 | 2.2 | 2–3 | 2.4 | 2–4 |
| Rice | 24.7 | 13–26 | 15.1 | 7–18 | 37.1 | 34–47 | 10.2 | 6–16 | 13.5 | 10–15 | 10.8 | 7–16 | 1.7 | 1–2 | 1.4 | 1–3 |
| Maize | 15.9 | 12–19 | 9.6 | 6–19 | 40.3 | 37–44 | 10.5 | 5–19 | 9.4 | 8–13 | 8.5 | 4–14 | 2.7 | 2–6 | 2.7 | 2–6 |
| Potatoes | 15.3 | 14–20 | 10.9 | 7–13 | 30.2 | 29–33 | 8.3 | 4–14 | 21.2 | 20–23 | 14.5 | 7–24 | 8.1 | 5–9 | 6.6 | 5–9 |
| Soybeans | 10.7 | 4–16 | 8.8 | 3–16 | 37.0 | 35–40 | 7.5 | 5–16 | 11.0 | 7–16 | 8.9 | 3–16 | 1.7 | 0–2 | 1.2 | 0–2 |
| Cotton | 36.8 | 35–41 | 12.3 | 5–22 | 35.9 | 35–39 | 8.6 | 3–13 | 8.5 | 7–10 | 7.2 | 5–13 | 0.8 | 0–2 | 0.7 | 0–2 |

(1): Animal pests are: insects, mites, nematodes, slugs & snails, rodents, birds, mammals.
(2): Potential losses are estimates of losses without pest management practices being applied.
(3): Actual losses are yield losses despite pest management practices being applied.
(4): Of all the world regions, losses in western Europe are among the lower losses, hence actual losses in Europe from animal pests for the six crops are estimated to be: wheat 5%, rice 7%, maize 6%, potatoes 7%, soybeans 3%, cotton 5%.

- Oerke (2006) estimates annual yield losses in European wheat due to animal pests (insects, mites, nematodes, slugs, snails, rodents, birds and mammals) to be approximately 5% (Table F.4). The principal insect pests of maize in Europe are listed in Table F.5.

**Table F.5:** Principal insect pests of maize with a cosmopolitan or European distribution (Hill, 1987)

| Pest name | Common name | Family | Damage caused |
|---|---|---|---|
| *Agrostis* spp. | Cut worms | Noctuidae | Larvae eat roots, may destroy seedlings |
| *Delia platura* | Bean seed fly | Anthomyiidae | Larvae bore seeds and seedlings |
| *Diabrotica virgifera virgifera* | Western corn rootworm | Chrysomelidae | Larvae eat roots, can girdle stems |
| *Euxoa* spp. | Cut worms | Noctuidae | Larvae eat roots, may destroy seedlings |
| *Heliothis* spp. | Corn earworms | Noctuidae | Larvae eat cobs |
| *Melolontha* spp. | Chafer grubs | Scarabaeidae | Larvae in soil eat roots and seedlings |
| *Oscinella frit* | Frit fly | Chloropidae | Larvae eat stems, cause dead heart |
| *Ostrinia* spp. | Corn borers | Pyralidae | Larvae bore stems and cobs |
| *Rhopalosiphum maidis* | Corn leaf aphid | Aphididae | Infest foliage |
| *Schizonycha* spp. | Chafer grubs | Scarabaeidae | Larvae in soil eat roots and seedlings |
| *Sitophilus spp*. | Grain weevils | Curculionidae | Feeds on ripe grain in field and in storage |
| Examples of minor insect pests of maize | | | |
| *Hydraecia micacea* | Rosy rustic moth | Noctuidae | Larvae feed on seedlings, bore stems of older plants |
| *Laodelphax striatella* | Small brown planthopper | Delphacidae | Sap-sucker and virus vector |
| *Mesapameae secalis* | Common rustic moth | Noctuidae | larvae feed on seedlings, bore stems of older plants |
| *Nezara viridula* | Green stink bug | Pentatomidae | Infests foliage, sucks sap |
| *Schizaphis graminum* | Wheat aphid | Aphididae | Sucks sap |

## Appendix G – Meta-analysis of damage by *Elasmopalpus lignosellus* reported in the literature (without control)

The full texts of the publications on *Elasmopalpus lignosellus*, identified during the systematic search, were screened for information on damage. A total of 39 publications reported damage caused by *E. lignosellus* and about half of the damage reports was expressed in terms of loss of seedlings. In the case of peanut, 27 records were on loss of seedlings while 75 records were on feeding damage to the pegs (young pods just penetrating into the soil), the pods or the kernels. In the case of sugarcane, the quantification was of the proportion of deadhearts, i.e. growing points with feeding damage by the larvae. In all other cases, damage was expressed as the proportion reduction in number of seedlings. The data on the proportion of plants lost were extracted and analysed. Publications often had reports of multiple experiments or multiple species or varieties, such that each publication could contribute more than one value to the database. The data file thus consisted of 202 records. The majority of observations were made on peanut (102 records), sugarcane (41 records), maize (23 records) and soybean (12 records) (Table G.1). The other species had five or fewer records each (Table G.1).

**Table G.1:** Breakdown by species of records on percent of plants lost due to feeding by *E. lignosellus*

| Latin species name | Common species name | Number of records |
|---|---|---|
| *Arachis hypogea* | Peanut | 102 |
| *Saccharum officinarum* | Sugarcane | 41 |
| *Zea mays* | Maize | 23 |
| *Glycine max* | Soybean | 12 |
| *Pinus elliottii* | Slash pine | 5 |
| *Cupressus arizonica* | Arizona cypress | 5 |
| *Phaseolus vulgaris* | Common bean | 4 |
| *Juniperus silicicola* | Southern red cedar | 3 |
| *Sorghum bicolor* | Sorghum | 3 |
| *Sorghum sp.* | Sorghum | 2 |
| *Taxodium distichum* | Bald cypress | 1 |
| *Cornus florida* | Flowering dogwood | 1 |

The reported percentage damage ranged from 0.1 to 100% with a first quartile of 8.9% damage, a median of 25% damage, a third quartile of 44.75% damage and a maximum of 100% damage. A histogram of the data is shown in Figure G.1. The data show that under conditions conducive for *E. lignosellus* such as sandy soil, dry conditions, tilled soil, damage can be very high, up to 100% loss of seedlings.

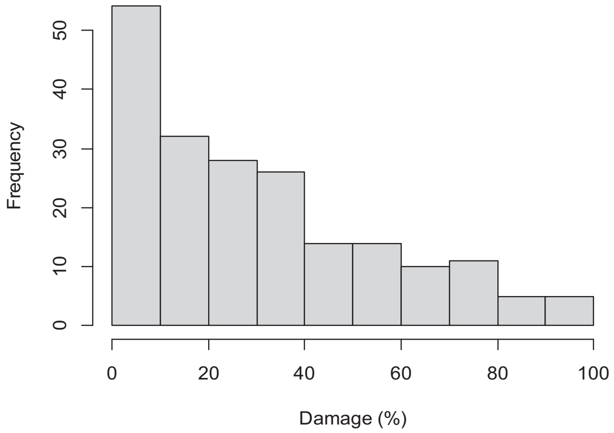


**Figure G.1:** Histogram of field estimates of damage by *E. lignosellus*. Damage was quantified as the percentage of plants (seedlings) affected, the percentage of deadhearts affected (sugarcane) or the percentage of pegs, pods or kernels of peanut affected

Two types of regression models were fitted to analyse the data: (1) ordinary least squares regression models, and (2) mixed effects models that accounted for the random effects associated with different experiments. Weights were not used because only 11 out of 202 data records had data on the SE. The outcomes of the two types of model were similar. The overall percentage of damage was 31.3 ± 1.8% using ordinary least squares and 28.2 ± 3.1% using mixed effects models. The random effects model had greater support from the data than the ordinary least squares regression model ($\Delta\text{AIC} = 39.2$; likelihood ratio = $41.2 \sim \chi^2_1$; $p < 0.001$). Hence, the mixed effects model was used for inference.

There was a marginally significant difference in damage between species if peanut seedlings and peanut fruit were considered as different 'species' in the mixed effects model ($\Delta\text{AIC} = 0.2$; likelihood ratio = $11.8 \sim \chi^2_6$; $p < 0.066$) but not if peanut was considered as a single group ($\Delta\text{AIC} = 4.1$ with the lower AIC for the model without groups). A summary of estimated group means is given in Table 2. In the expert knowledge elicitation, differences between species were not considered because of the high variability in the data and the inconclusive evidence for differences in damage between species. The average percentage damage in different plant species is shown in Table G.2.

**Table G.2:** Average percentage damage in different plant species

| Species group | Average percentage damage ± SE (ordinary least squares regression) | Average percentage damage ± SE (mixed effects model) | Number of records |
|---|---|---|---|
| Peanut | 38.7 ± 2.4 | 28.1 ± 5.2 | 102 |
| – Peanut seedlings | −41.1 ± 5.0 | −39.0 ± 7.0 | 24 |
| – Peanut fruit | −37.9 ± 2.8 | −24.0 ± 5.5 | 78 |
| Sugarcane | 18.3 ± 3.8 | 22.9 ± 7.2 | 41 |
| Maize | 25.9 ± 5.1 | 24.3 ± 6.5 | 23 |
| Soybean | 40.8 ± 7.0 | 51.3 ± 10.4 | 12 |
| Other crops | 27.5 ± 8.0 | 27.6 ± 10.3 | 9 |
| Tree seedlings | 20.2 ± 6.3 | 28.1 ± 11.0 | 15 |
| **Overall** | **31.3 ± 1.8** | **28.2 ± 3.1** | **202** |

# Appendix H – Meta-analysis of damage by *Elasmopalpus lignosellus* reported in the literature (with pesticide control) and of effectiveness of damage control with insecticides

The full texts of the publications on *Elasmopalpus lignosellus*, identified during the systematic search, were screened for information on damage when pesticides were used to control *E. lignosellus*. Seven publications reported damage with pesticidal control of *E. lignosellus* and six out of these publications reported results of a single experiment, while one publication reported results of three experiments. Hence, this meta-analysis is based on the results of nine independent experiments. Four publications reporting results of pesticide trials did not report the damage but only reported the percentage reduction in the damage. For instance, if the percentage of plants lost was reduced from 80% without pesticides to 40% with pesticides, those publications would report a reduction in damage of 50%. The data from these four publications were analysed separately from the data from the seven publications reporting on damage with insecticides against *E. lignosellus*. The panel did not calculate the percentage damage with pesticides based on data from publications reporting percent control because those publications did not report the percentage damage without pesticides, i.e. the absolute level of damage was not known, only the percentage reduction of damage due to pesticides.

The seven publications reporting damage used six different crop species to test the effectiveness of pesticides to prevent damage. Every paper thereby reported results on only one crop species, and only one crop species (soybean) was covered in two publications. The results are summarised in Table H.1. Due to the confounding between publication and host crop, and the great variation among publication and experiments (see meta-analysis on % damage under pesticide-free conditions) the separate effects of host and publication (experiment) are not identifiable.

**Table H.1:** Average percentage damage by *E. lignosellus* in pesticide-treated host crops. Results are presented separately for each publication as an overarching analysis across publications was hampered by heterogeneity of variance and confounding between publications and host crops

| **Publication** | **Host crop Latin name** | **Host crop common name** | **Average % damage ± SE** | **Number of data records** |
|---|---|---|---|---|
| Chapin et al. (2001) | *Arachis hypogaea* | Peanut | 2.5 ± 0.6 | 6 |
| Corseuil and Terhorst (1971 | *Glycine max* | Soybean | 16.7 ± 6.9 | 6 |
| Cruz et al. (1983) | *Zea mays* | Maize | 26.7 ± 1.2 | 34 |
| Davis et al. (1974) | *Cypressus arizonica* | Arizona cypress | 20.0 ± 1.0 | 2 |
| Dixon (1982) | *Tree seedlings*(1) | Tree seedlings | 1.8 (without SE) | 1 |
| Flores (2016) | *Asparagus officinalis* | Asparagus | 0.28 ± 0.17 | 5 |
| Kobayashi and De Aguero (1988) | *Glycine max* | Soybean | 6.5 ± 0.7 | 12 |
| Overall mean with ordinary least squares regression | | | 17.3 ± 1.6 | 66 |
| Overall mean with mixed effects model | | | | |

(1): Tree seedlings comprised *Taxodium distichum, Pinus clausa, Nyssa sylvatica, Cornus florida, Juniperus silicicola, Pinus clausa* and *Platanus occidentalis*.

A breakdown of the pesticides tested in these studies is given in Table H.2. Many of the tested insecticides are no longer registered for use in the EU.

**Table H.2:** Insecticides (active compounds) tested in studies on the control of *E. lignosellus* in the places of origin

| Insecticide | Number of records |
|---|---|
| Chlorpyrifos | 7 |
| Monocrotophos | 6 |
| Parathion | 6 |
| Chlorpyrifos-Spinetoram-Chlorantraniliprole | 5 |
| Endrin | 4 |
| Carbofuran | 4 |
| Methomyl | 3 |
| Isoprocarb | 3 |
| Cartap | 3 |
| Carbaryl | 3 |
| Acephate | 3 |
| Thiodicarb | 2 |
| Phorate | 2 |
| Aldrin | 2 |
| Aldicarb | 2 |
| Phosphamidon | 1 |
| Malathion | 1 |
| Lindane | 1 |
| Dimethoate | 1 |
| Carbofuran<br>Fensulfothion<br>Diazinon<br>Parathion | 1 |
| Dieldrin | 1 |
| Diazinon | 1 |
| DDT | 1 |
| Deltamethrin | 1 |
| Benzenehexachloride | 1 |
| AC 222–704 100 E (Pyrethroid) | 1 |

A histogram of the percentage damage with pesticides is shown in Figure H.1, combining data from the seven studies. The histogram is bimodal, and the second mode is due to data on maize from Cruz et al. (1983). This is illustrated in Figure H.2, which provides a breakdown of percentage damage according to publication and in Figure H.3, which provides a breakdown of percentage damage according to host species.

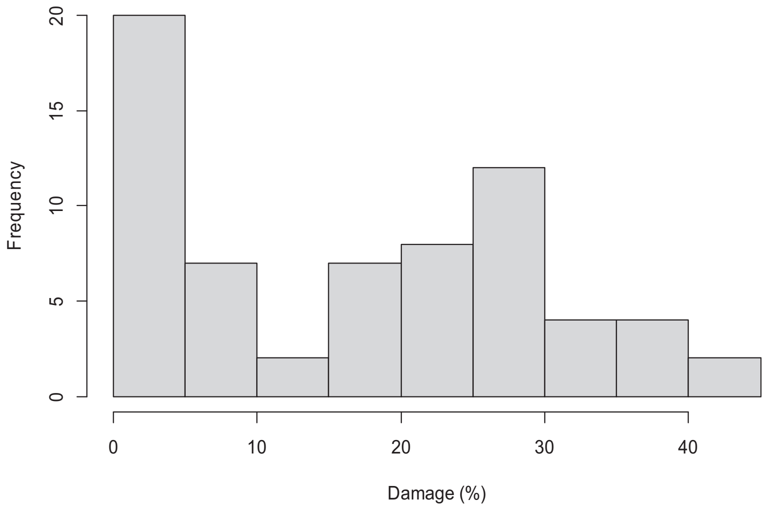


**Figure H.1:** Histogram of percentage damage by *E. lignosellus* in pesticide-treated host crops

The data do not provide conclusive evidence for a difference in damage between host crop species, due to the strong confounding between host crop and publication, where each publication is associated with a different set of environmental conditions. Hence, the panel estimated an overall average percentage of damage with use of insecticides against *E. lignosellus*. Using an ordinary least squares regression, the overall average percentage of damage with pesticides was estimated to be $17.3 \pm 1.6\%$. Using a mixed effects model accounting for between-study variability, the overall average percentage of damage with pesticides was estimated to be $14.6 \pm 3.9\%$. The two models received similar support from the data ($\Delta\text{AIC} = 0.7$, likelihood $\text{ratio} = 1.3 \sim \chi^2_1$, $p = 0.24$). Data from these studies indicate that under the conditions chosen for these studies, damage by *E. lignosellus* is substantial, even with the use of pesticides.

It needs to be kept in mind that pesticide trials tend to be conducted in situations where the impact of the pest is high, and results of experiments in which damage did not materialise may not have been published because they would be inconclusive, resulting in the possibility of publication bias (i.e. studies with low impact of *E. lignosellus* might not get published). Hence, presented results may not be representative for all fields with all host crops in the area of potential establishment of *E. lignosellus*.

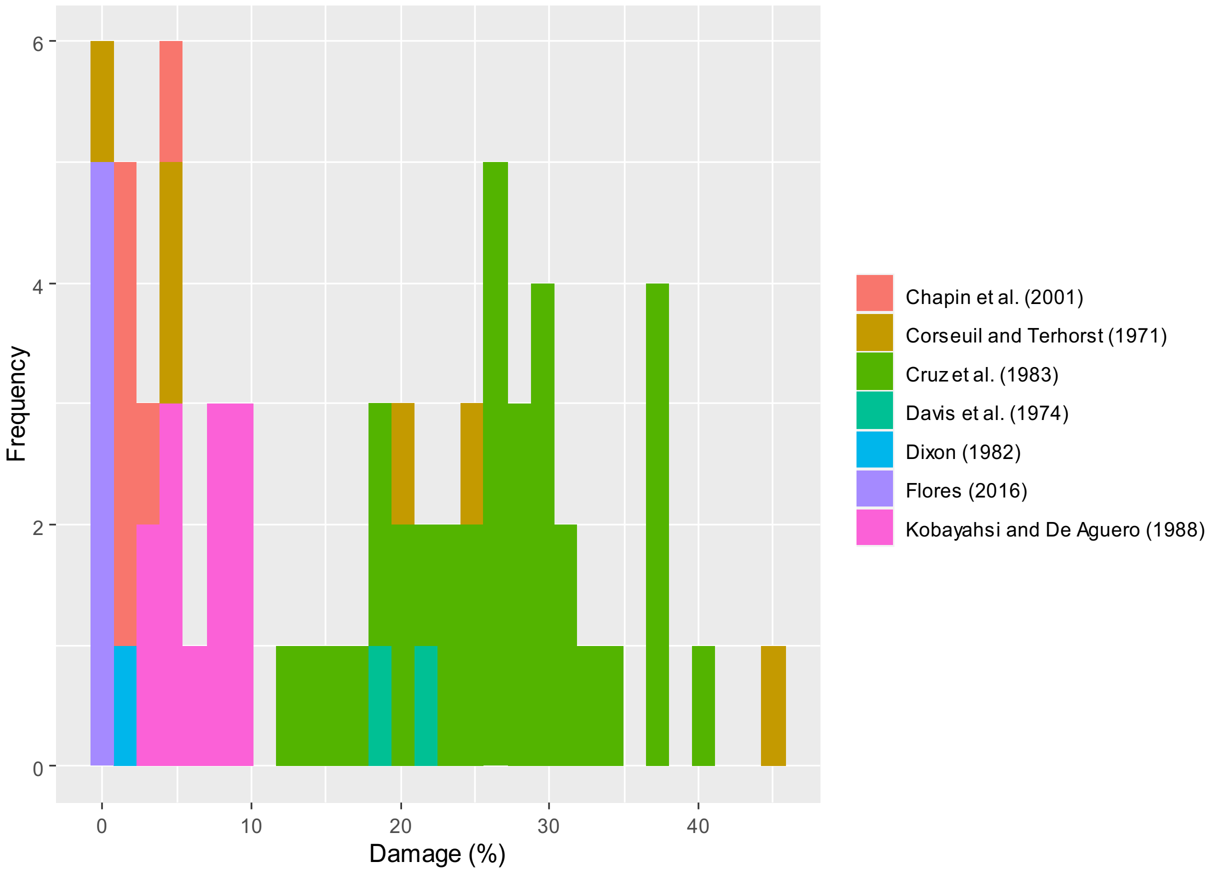


**Figure H.2:** Histogram of percentage damage by *E. lignosellus* in pesticide-treated host crops. Different source publications are shown in different colours to show differences between source publications. Note the confounding between publication and host crop (Figure H.3)

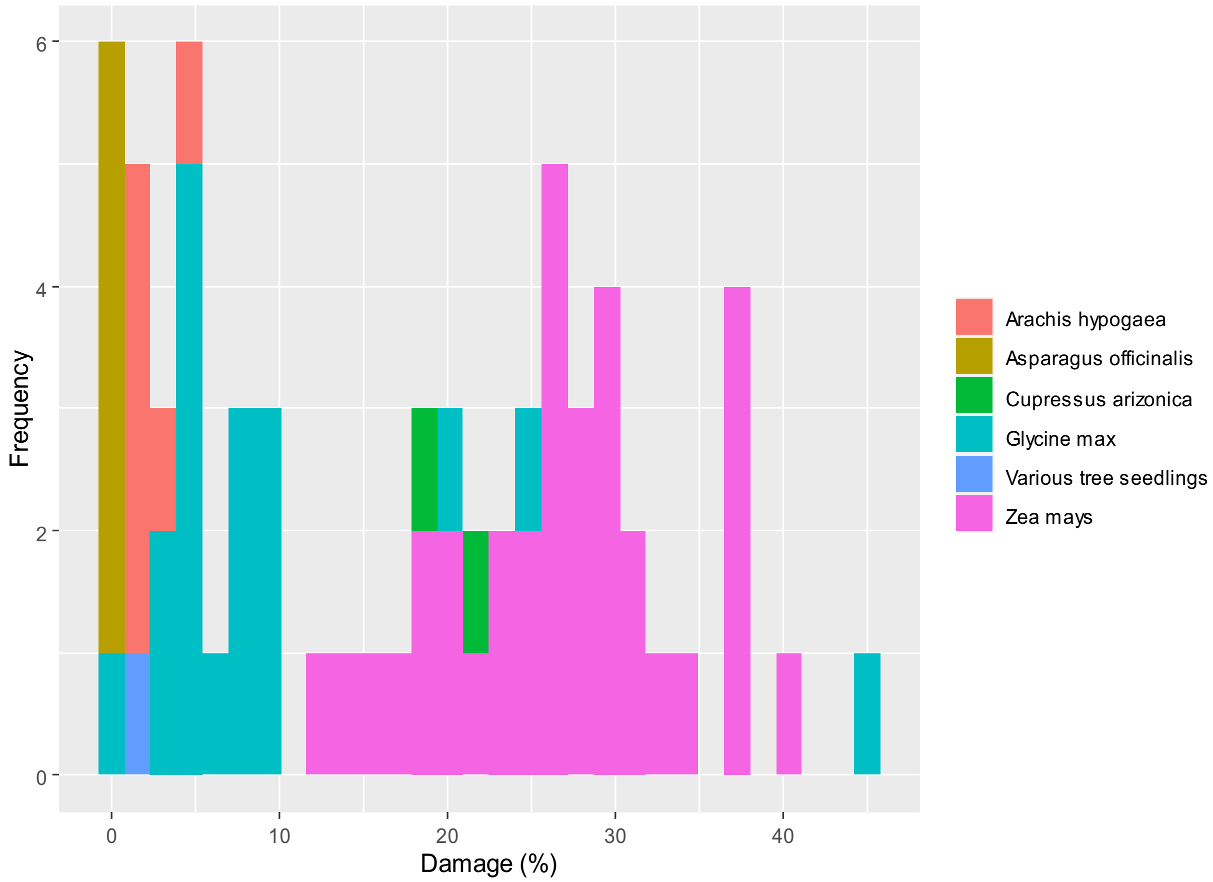


**Figure H.3:** Histogram of percentage damage by *E. lignosellus* in pesticide-treated host crops. Different host crops are shown in different colours to show differences between host crops. Note the confounding between publication and host crop (Figure H.2)

### Analysis of data from four publications reporting on insecticidal control of *E. lignosellus*

The effect of insecticide use against *E. lignosellus* varied from a minimum of 0 to a maximum of 100% reduction in damage (Figure 4). The first quartile of damage reduction was 44.25%, the median was 65.6% and the third quartile 85%. The mean percentage of damage control estimated with ordinary least squares regression was 62.3 ± 3.3% and with mixed effects modelling 61.1 ± 7.8%. The mixed effects model had greater support from the data, indicating significant differences between host crop species and/or conditions in the four experiments (likelihood ratio = 16.4 $\sim \chi_1^2; p < 0.001$) but with virtually no effect on the estimated overall mean percentage of damage reduction by using insecticides. Hence, insecticides are on average moderately effective, but with high variation. If the data were analysed with ordinary least squares regression using the function lm() in R, then the effect of publication or host crop on the percentage of damage control was significant ($F_{59}^3 = 9.7; p < 0.001$), indicating that there are significant differences in damage control between studies, but it is uncertain whether those differences are due to differences between host species tested in different studies or to difference circumstances in the studies (Figures H.5 and H.6). Hence, there is insufficient support for drawing a conclusion that effectiveness of insecticides differs between host species.

**Table H.3:** Reductions in damage by *E. lignosellus* achieved by insecticide usage

| Publication | Host crop Latin name | Host crop common name | Average % reduction in damage ± SE | Number of data records |
|---|---|---|---|---|
| All et al. (1979) | *Zea mays* | Maize | 48.2 ± 4.0 | 25 |
| Chapin and Thomas (1999) | *Arachis hypogaea* | Peanut | 51.8 ± 12.1 | 8 |
| Corseuil and Terhorst (1971) | *Glycine max* | Soybean | 63.3 ± 14.5 | 6 |
| Goncalves-Barros et al. (2005) | *Phaseolus vulgaris* | Common bean | 80.4 ± 2.5 | 24 |
| Overall mean with ordinary least squares regression (lm or gls) | | | 62.3 ± 3.3 | 63 |
| Overall mean with mixed effects model (lme) | | | 61.1 ± 7.8 | 63 |

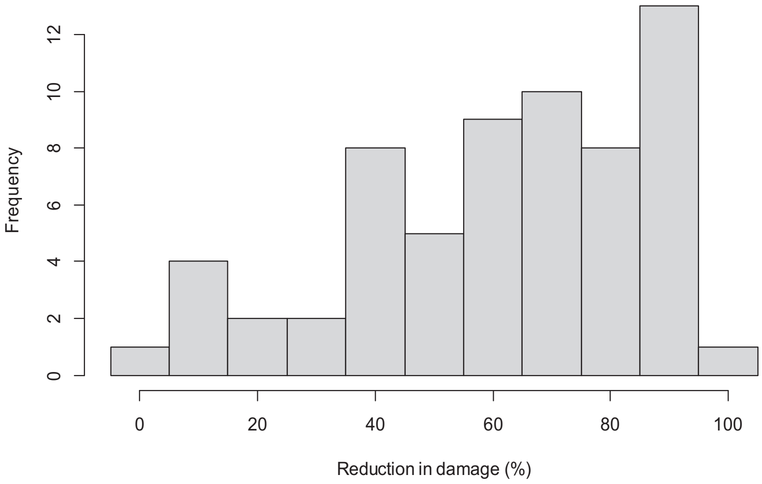


**Figure H.4:** Percentage reduction in damage by *E. lignosellus* in four publications reporting control effect of insecticides

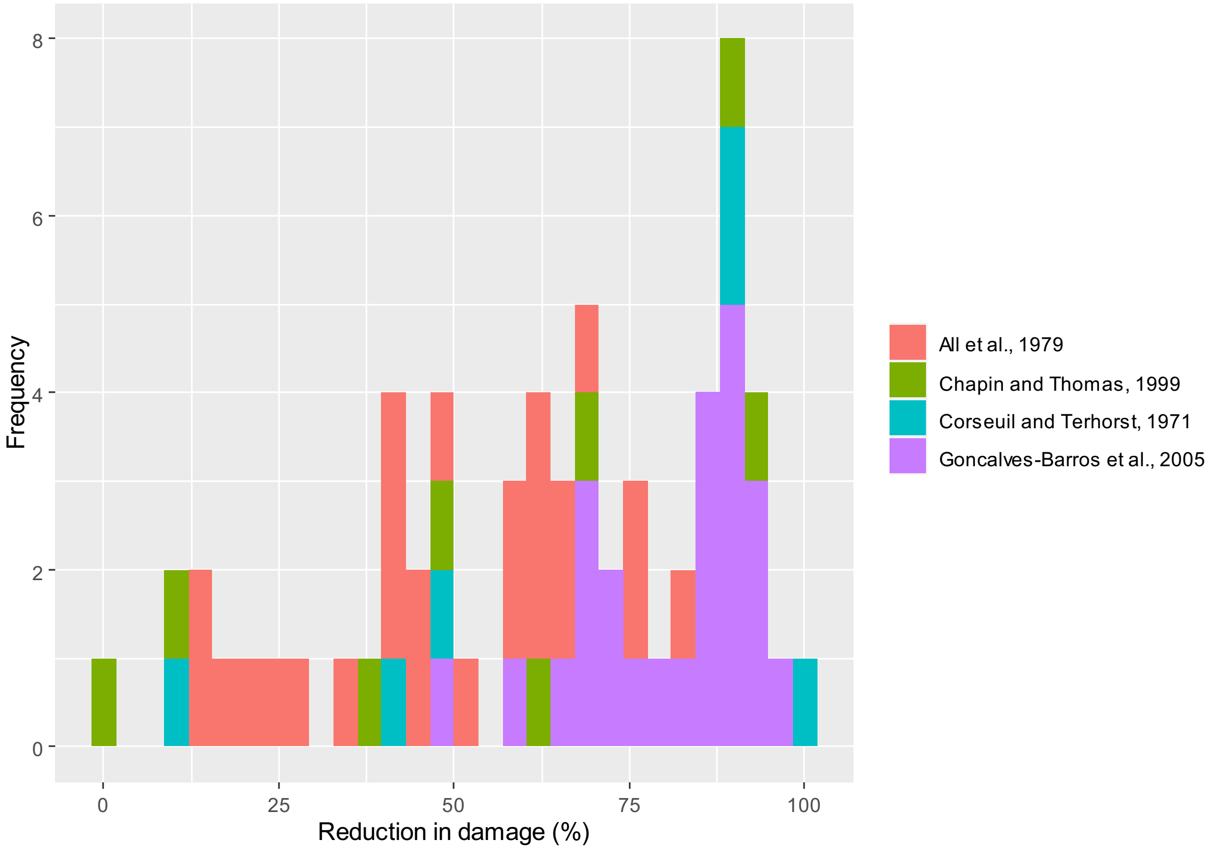


**Figure H.5:** Breakdown of percentage reduction in damage as a result of controlling *E. lignosellus* with insecticides. Breakdown is according to the source publication, using stacked bars. Note data heterogeneity between publications and confounding of source publication with host crop species (Figure H.6)

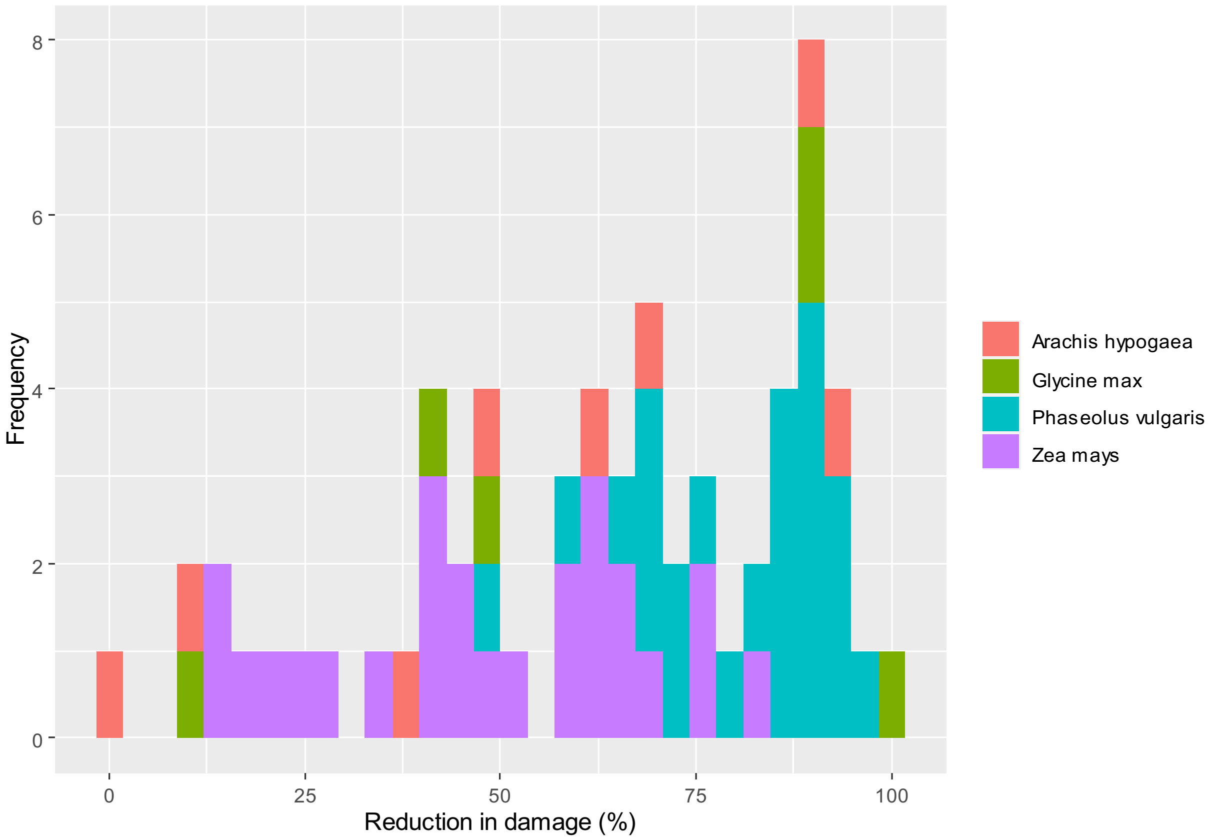


**Figure H.6:** Breakdown of percentage reduction in damage as a result of controlling *E. lignosellus* with insecticides. Breakdown is according to the host crop species, using stacked bars. Note data heterogeneity between host crop species and confounding of host crop species with source publication (Figure H.5)

## Appendix I – *Elasmopalpus lignosellus*, area of selected hosts cultivated in the EU, 2012–2021

| **Area (cultivation/harvested/ production) (1,000 ha) Source: Eurostat** | **Crops ranked by mean area** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Year** | | | | | | | | | | |
| **Crop** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** | **2018** | **2019** | **2020** | **2021** | **Mean area (‘000 ha)** |
| Wheat and spelt | : | : | : | : | 25,210 | 24,139 | 23,752 | 24,212 | 22,768 | 24,029 | 24,018 |
| Barley | 11,498 | 11,169 | 11,349 | 11,122 | 11,180 | 10,863 | 11,145 | 11,139 | 11,017 | 10,268 | 11,075 |
| Grain maize and corn–cob mix | 9,828 | 9,767 | 9,587 | 9,249 | 8,541 | 8,267 | 8,252 | 8,911 | 9,215 | 9,247 | 9,087 |
| Green maize | 5,725 | 5,847 | 5,997 | 6,106 | 6,061 | 5,986 | 6,135 | 6,210 | 6,325 | 6,054 | 6,045 |
| Sunflower seed | 4,313 | 4,623 | 4,266 | 4,198 | 4,133 | 4,312 | 4,026 | 4,338 | 4,397 | 4,369 | 4,297 |
| Oats | 2,544 | 2,488 | 2,409 | 2,394 | 2,477 | 2,521 | 2,567 | 2,391 | 2,570 | 2,554 | 2,491 |
| Durum wheat | 2,599 | 2,409 | 2,295 | 2,436 | 2,775 | 2,545 | 2,481 | 2,145 | 2,111 | 2,213 | 2,401 |
| Rye | : | : | : | : | 1,895 | 1,912 | 1,908 | 2,188 | 2,068 | 1,913 | 1,981 |
| Potatoes (including seed) | 1,649 | 1,602 | 1,522 | 1,527 | 1,551 | 1,601 | 1,563 | 1,604 | 1,463 | 1,401 | 1,548 |
| Sugar beet (excluding seed) | 1,534 | 1,461 | 1,517 | 1,330 | 1,412 | 1,645 | 1,621 | 1,533 | 1,487 | 1,487 | 1,503 |
| Soya | 444 | 478 | 581 | 893 | 831 | 962 | 955 | 908 | 943 | 940 | 794 |
| Field peas | 501 | 435 | 500 | 700 | 861 | 986 | 829 | 786 | 816 | 777 | 719 |
| Rice | 456 | 433 | 432 | 441 | 449 | 441 | 417 | 419 | 428 | 408 | 432 |
| Broad and field beans | 247 | 239 | 287 | 455 | 478 | 496 | 469 | 409 | 447 | 474 | 400 |
| Cotton fibre | : | : | 355 | 349 | 301 | 326 | 346 | 362 | 344 | 326 | 339 |
| Brassicas | : | : | : | 256 | 257 | 262 | 263 | 267 | 244 | 245 | 256 |
| Tomatoes | 230 | 231 | 248 | 254 | 254 | 248 | 239 | 243 | 228 | 231 | 241 |
| Sorghum | 119 | : | : | 139 | 124 | 136 | 148 | 190 | 218 | 153 | 153 |
| Fresh peas | 121 | : | 129 | 129 | 143 | 142 | 141 | : | 152 | 152 | 139 |
| Strawberries | 98 | 92 | 104 | 103 | 104 | 104 | 106 | 101 | 84 | 84 | 98 |
| Fresh beans | 95 | : | : | 92 | 96 | 99 | 97 | 91 | 96 | 94 | 95 |
| Peppers (capsicum) | 58 | 58 | 57 | 59 | 60 | 60 | 59 | 60 | 57 | 61 | 59 |
| Asparagus | 46 | 46 | 50 | 52 | 56 | 59 | 60 | 59 | 59 | 60 | 55 |
| Tomatoes* | 38 | : | : | 42 | : | : | : | : | : | : | 40 |
| Strawberries* | : | : | : | 16 | : | : | : | : | : | : | 16 |

**Key**: no data available; *under glass or high accessible cover. Also,
No data are available for cotton seed, clover and mixtures, Peppers (capsicum) – under glass or high accessible cover or nurseries (for young plants).
While peanuts and sugarcane are grown in the EU, they are only grown on a small scale and Eurostat does not include them as crops for which statistics are available.