The sentinel tree concept (sentinel plantations, sentinel nurseries, sentinel arboreta)

Iva Franić

Swiss Federal Research Institute WSL

Training school - Invasive Forest Pests:

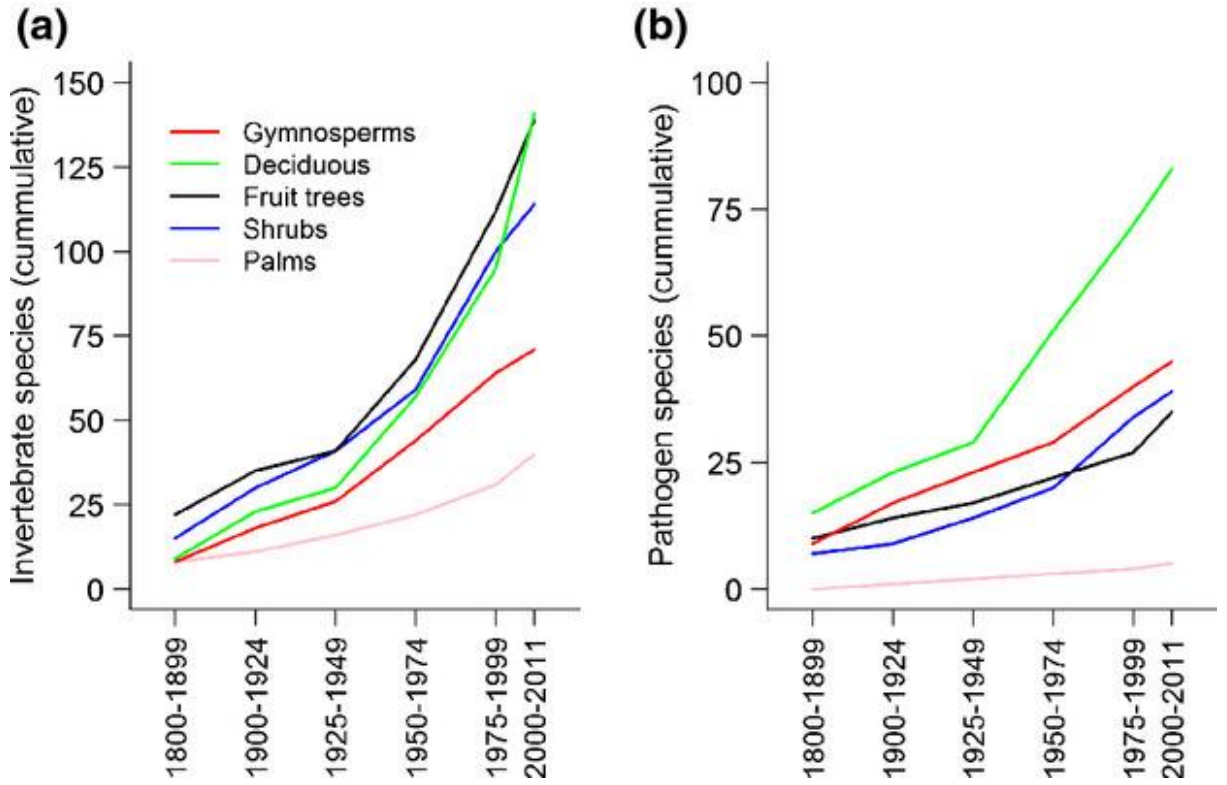
How to Tackle Them Before Invasion

Atatürk Arboretum

Istanbul, Turkey

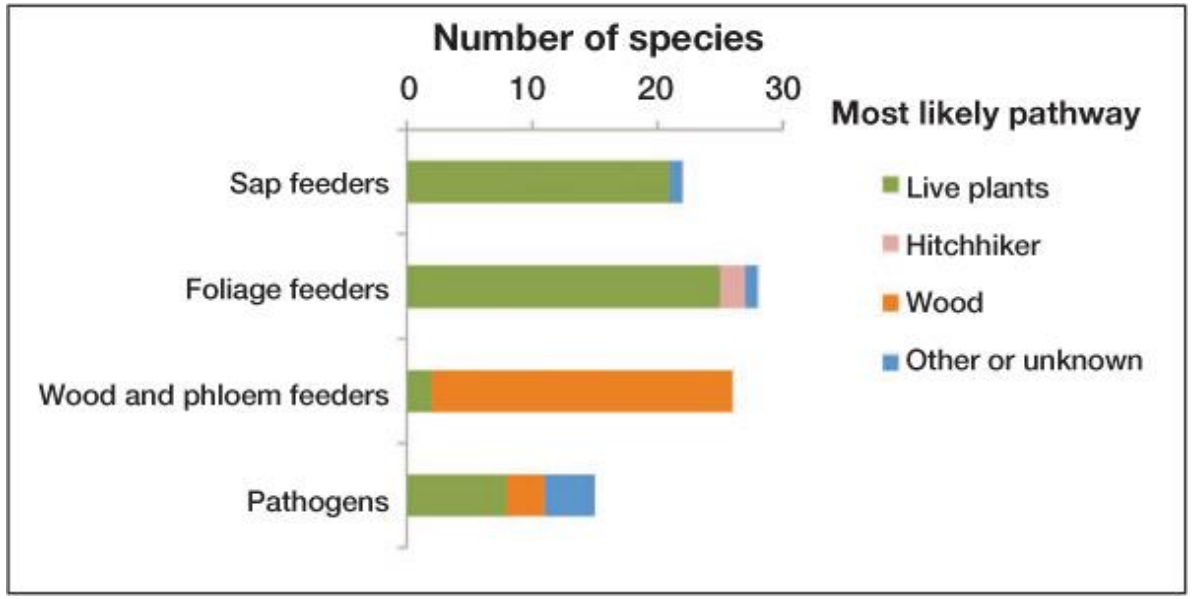
17-20 June 2025

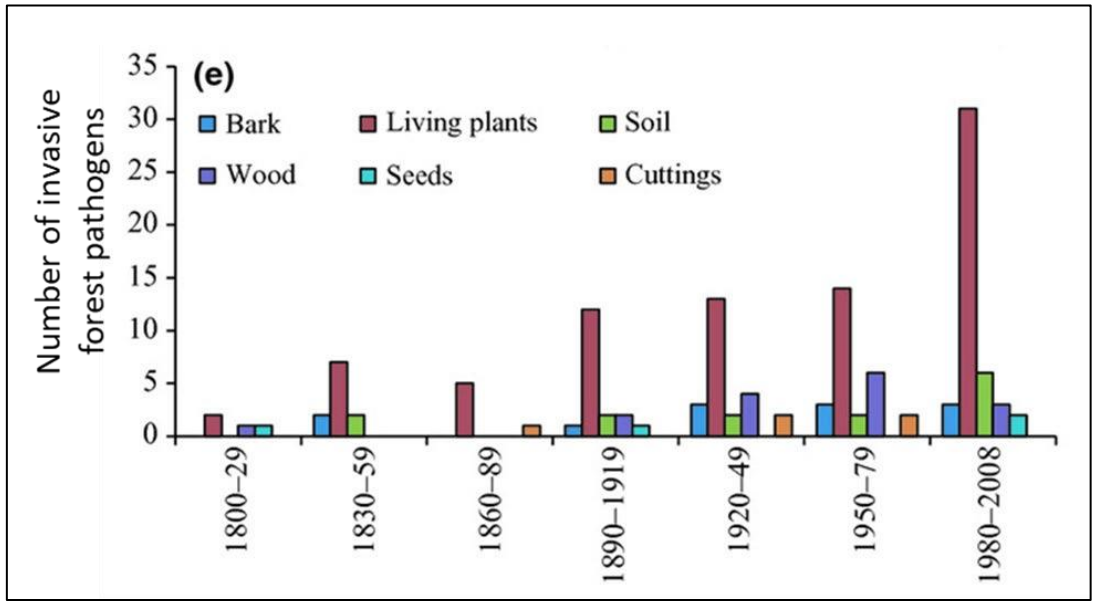
The number of non-native pests of woody plants has been increasing worldwide



Eschen et al., 2015 Diversity and Distributions

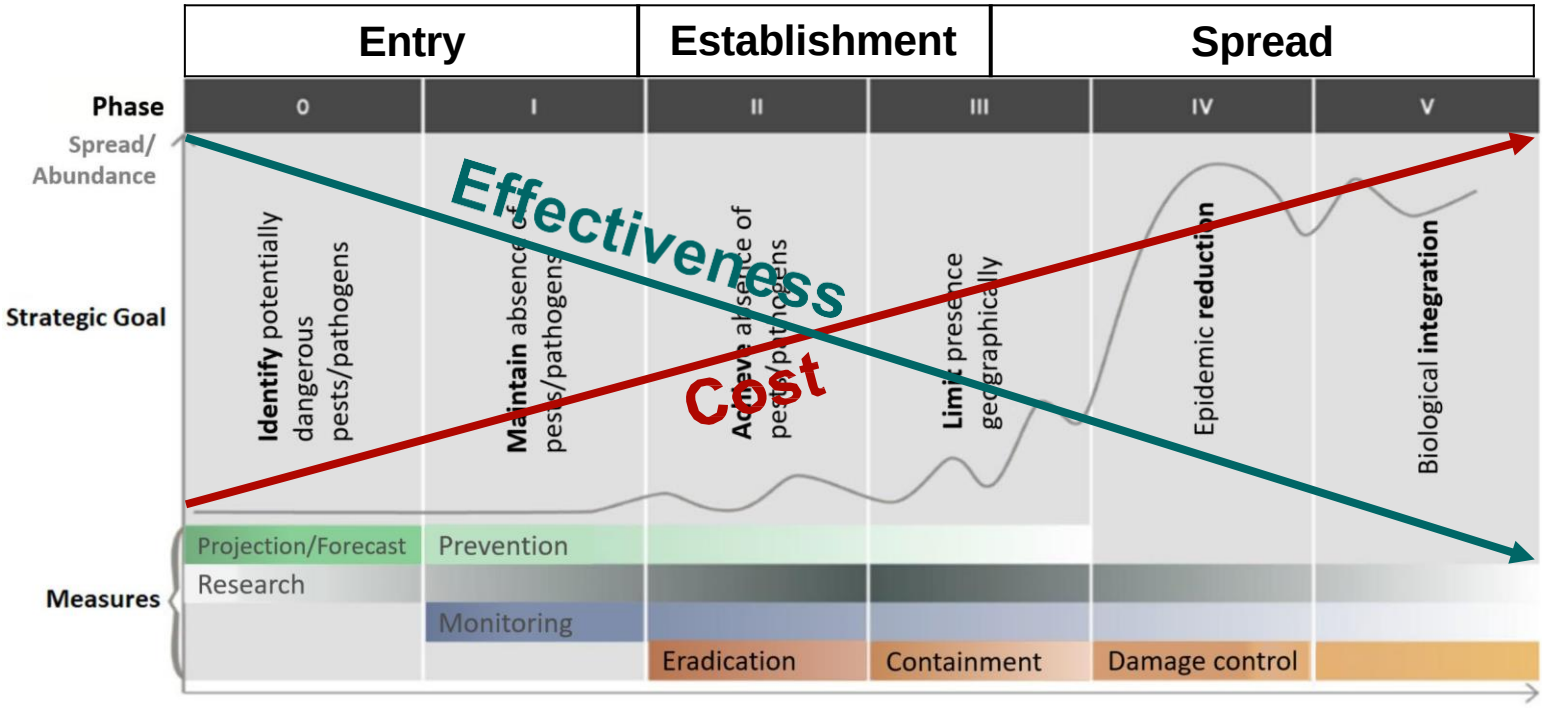
Plants for planting represent a main introduction pathway for non-native pests





Liebhold et al., 2012 Frontiers in Ecology and Environment; Santini et al., 2013 New Phytologist

Pest Risk Management



Phytosanitary regulations are in place to manage the risk of introducing harmful organisms

Table 2 – Summary of the measures stated in regulations, arranged by country. That a measure is required for all live plants imports is indicated with + and measures that are not required at all are indicated with —. Hash signs (#) indicate that additional measures are required for specific genus–origin combinations. In Europe, pathway risk analyses are carried out in exceptional cases, by the European and Mediterranean Plant Protection Organisation.

	New Zealand	Australia	USA	Canada	India	China	Brazil	Kenya	South Africa	EU
Phytosanitary certificate	+	+	+	+	+	+	+	+	+	+
Import permit	+	+	+	+	+	+	+	+	+	—
Import inspections	+	+	+	+	+	+	+	+	+	+
Pathway risk analysis	+	+	#	+	+	+	+	#	#	—
No contaminants/soil	#	#	#	+	#	+	+	+	#	#
Pre-export treatments	+	+	#	#	#	#	+	#	#	#
Pest free area	#	#	#	#	#	#	#	#	#	#
Pest free production site	#	#	#	#	#	#	#	#	#	#
Shipping in specific season	#	+	#	#	—	—	—	—	—	#
Post-entry quarantine	+	+	#	#	#	#	+	#	#	#

Eschen et al., 2015 Environmental Science & Policy

Risk mitigation is limited

- Phytosanitary measures target known, risky pests – many non-native pests are **not known** before the introduction and are thus not regulated.
- Data on pests and pest-host associations for **pest/commodity risk assessment** are lacking.
- Many pests are not detected during **inspections** & years can pass before they are discovered.

Emerald ash borer (*Agrilus planipennis*).
Photo by Debbie Miller, USDA Forest Service, Bugwood.org

Ash dieback fungus (*Hymenoscyphus fraxineus*).
Photo by Amadey Trnkoczy, mushroomobserver.org

Eschen et al., 2015 Environmental Science & Policy

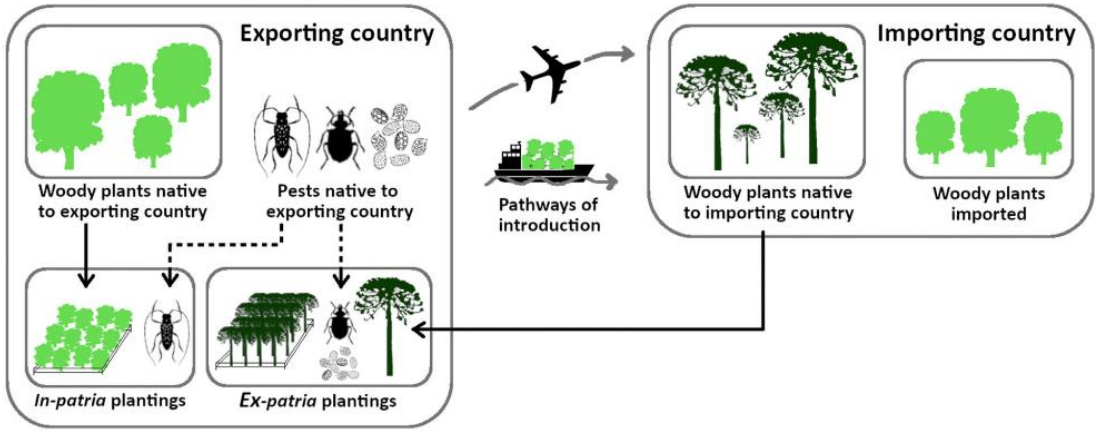
Detection and identification of pests **prior to their arrival** or establishment may allow the development of preventative **mitigation measures**.

Sentinel and trap trees

- A **sentinel** is a guard, a lookout, a person keeping watch.
- **Sentinel** plants/trees:
  - Trees present close to high-risk sites inspected regularly for signs and symptoms of pest attacks.
- **Trap** tress:
  - Trees treated with girdling, wounding, or with semiochemicals to render them attractive to a given target species.
- **Post-border** surveillance – eradication difficult or expensive.

Eschen et al., 2019 Journal of Pest Science

Sentinel plantings – a tool for identifying potential pests before they are introduced

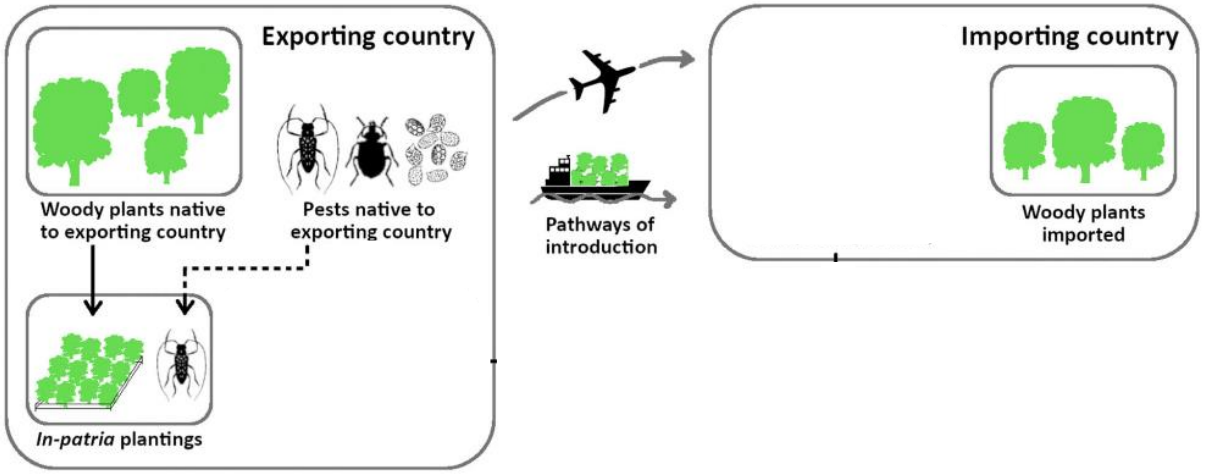


Eschen et al., 2019 Journal of Pest Science

- Located in the country of origin of the pest (**exporting country**).
- **Sentinel nursery** (*in-patria* plantings) – information about likelihood of introduction of non-native pests.
  - Newly established plantations.
- **Sentinel plantation** (*ex-patria* plantings) – identification of potential pests of a valuable plant species & their impact.
  - Newly established plantations or existing plantations (e.g., sentinel arboreta).

Sentinel nurseries (*in-patria* plantings)

Sentinel nursery (*in-patria* planting)



- Tree species **native** to exporting country exposed to pests **native** to the exporting country.
- Enables identification of a **broad range of pests** that may be introduced with traded plants.
  - Complements the traditional approach of identifying pests in the nature.

Eschen et al., 2019 Journal of Pest Science

Sentinel nursery (*in-patria* planting)

- Only **young trees** considered.
- Choice of sentinel plant species/cultivars:
  - Commonly **exported** or planned to be exported from the sentinel country to the importing country.
  - **Closely related** (same genus or family) to plants of importance to the importing country.
  - Currently prohibited for export to the importing country and the sentinel country is planning to gather evidence to **support a commodity risk assessment**.

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Sentinel nursery (*in-patria* planting)

- Newly set up plantings located **close to the commercial nurseries** that export similar plants.
- **No pest control** measures allowed.
- Monitoring needed over several years.
- Symptoms weak or absent – no indication of impact.

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OPEN

Sentinel nurseries to assess the phytosanitary risks from insect pests on importations of live plants

Marc Kenis[1], Hongmei Li[2], Jian-ting Fan[3], Beatrice Courtial[4], Marie-Anne Auger-Rozenberg[4], Annie Yart[4], René Eschen[1] & Alain Roques[4]

- Sentinel nurseries established in April 2012 in Beijing and Fuyang, China.
- Five **woody plant species commonly exported** from China to Europe were selected: *Acer palmatum, Ilex cornuta, Buxus microphylla, Fraxinus chinensis* and *Zelkova schneideriana*.
- The two nurseries were surveyed every two weeks from April to October, in 2012 and 2013, and once a month during the rest of the year.

Kenis et al., 2018 Scientific Reports

OPEN

Sentinel nurseries to assess the phytosanitary risks from insect pests on importations of live plants

Marc Kenis[1], Hongmei Li[2], Jian-ting Fan[3], Beatrice Courtial[4], Marie-Anne Auger-Rozenberg[4], Annie Yart[4], René Eschen[1] & Alain Roques[4]

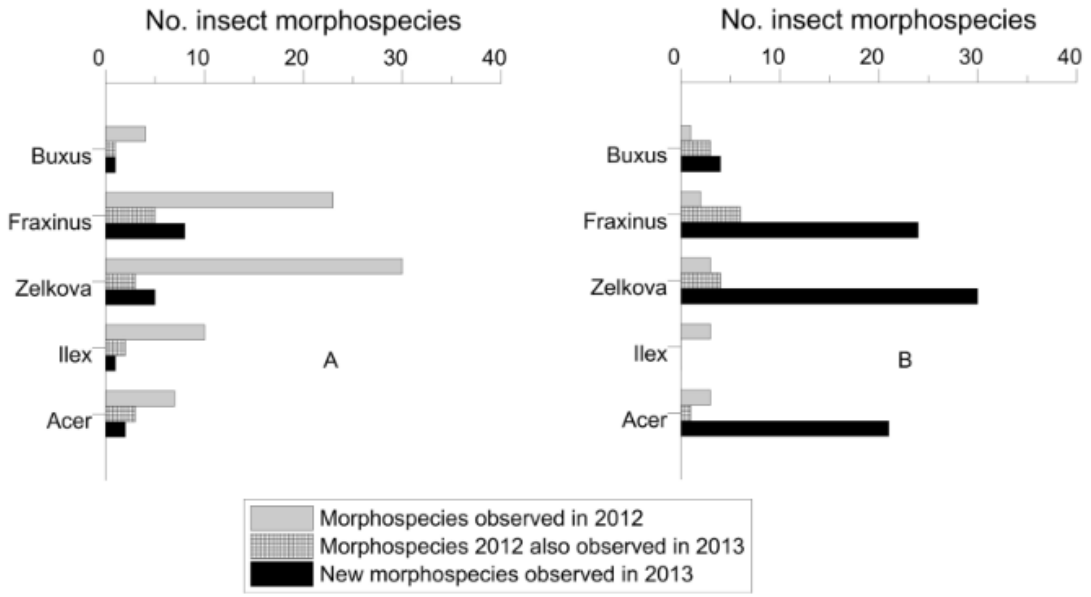
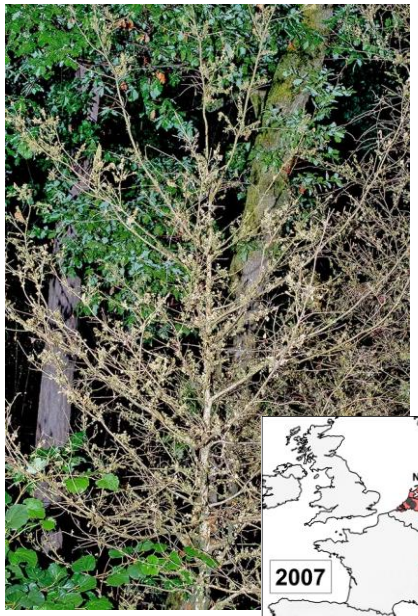


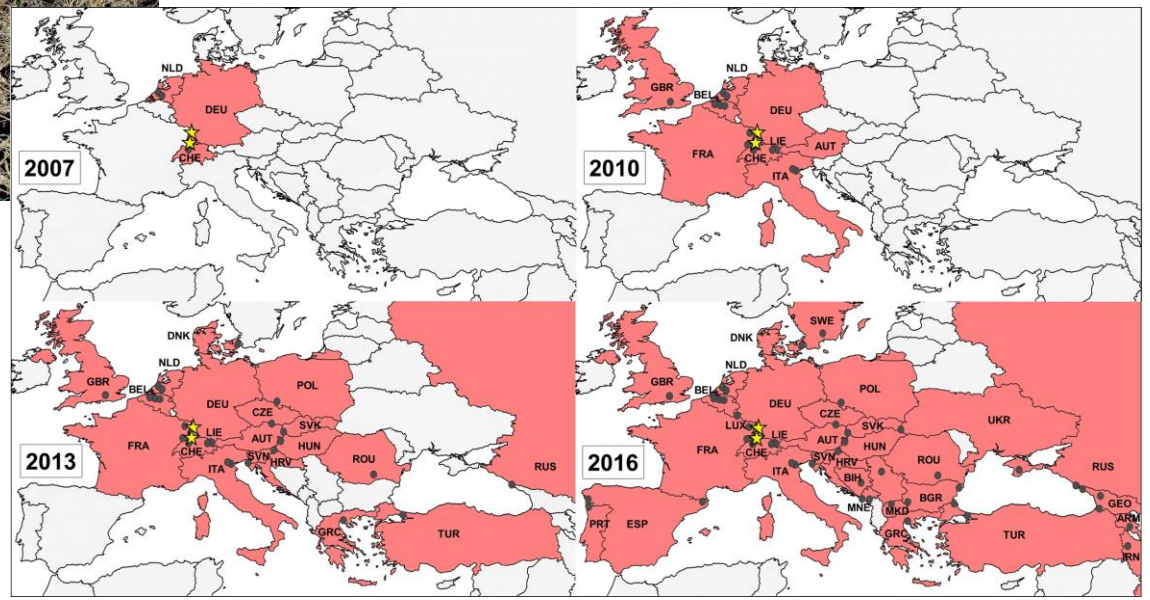
Figure 1. Number of insect morphospecies (including identified and unidentified species) found on the five tree species in Fuyang (left) and Beijing (right) in 2012 only, in 2012 and 2013, and in 2013 only.

- At each site, 105 **insect species-host associations** were found.
- Most of these associations **had not been previously recorded** in literature.
- Many specimens were **not identified** to genus/species.
- 9%, 7% and 84% of the insect records represent a high, moderate and low **likelihood of introduction**, respectively.

Kenis et al., 2018 Scientific Reports

Cydalima perspectalis

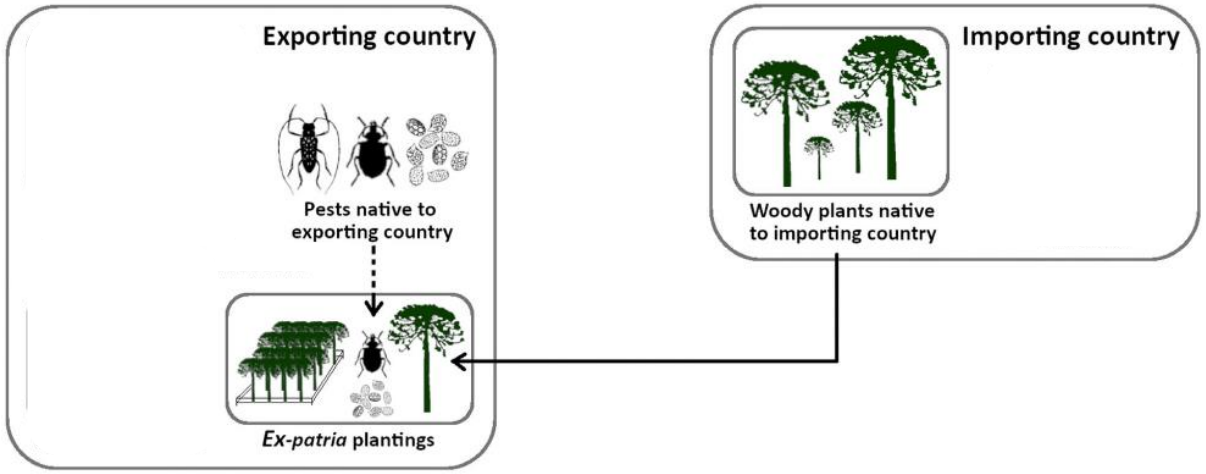




[Bras et al. 2019 Journal of Pest Science]

Sentinel plantations (*ex-patria* plantings)

Sentinel plantation (*ex-patria* planting)



- Tree species native to importing country exposed to pests native to the exporting country.
- Reliable **evidence** on the potential impact of non-native pests.

Eschen et al., 2019 Journal of Pest Science

Choice of sentinel plant species/cultivars

- Priority given to plant species/cultivars that are:
  - **Widely grown** or present in the importing country.
  - **Valuable** and/or **under threat** in the importing country.
  - **Ecologically significant** to the importing country.
- Plants from **different provenances** (i.e., different genotypes) within the importing country should be tested.
- **Young trees** in plantations limit the range of organisms that can be detected.

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Selection of sites

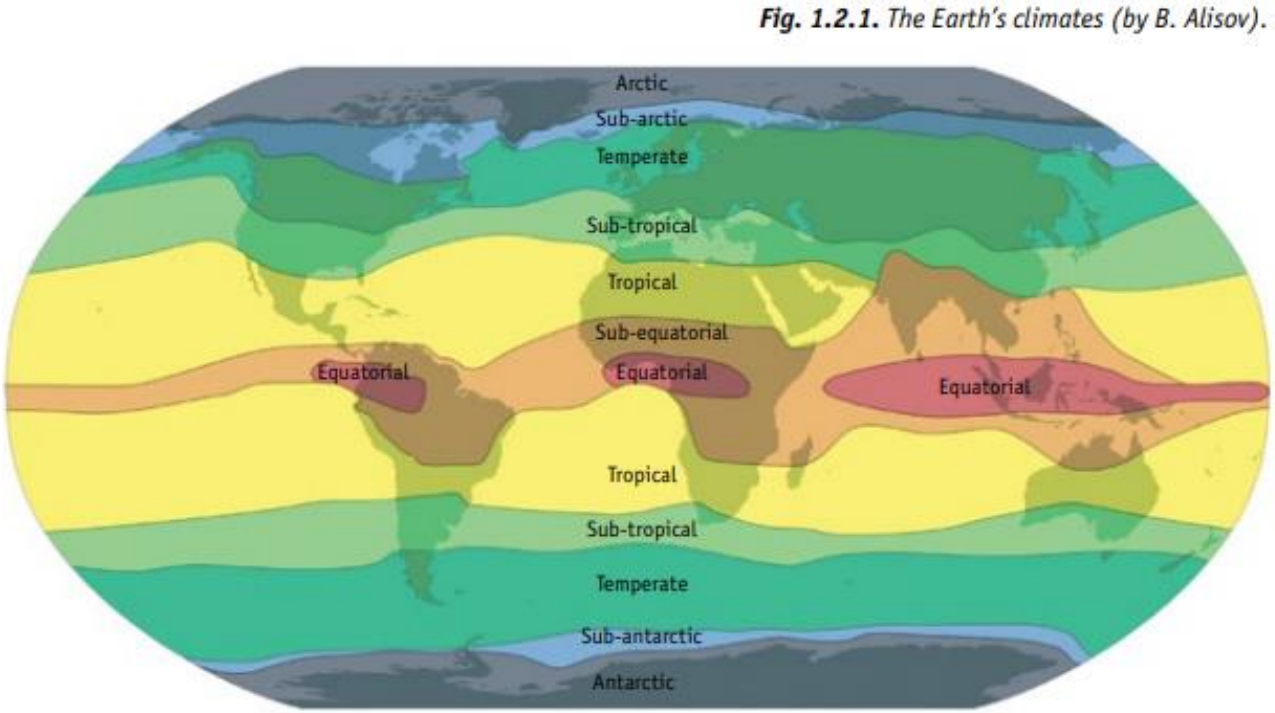

Fig. 1.2.1. *The Earth's climates (by B. Alisov).*

- A **close match** between the environmental conditions (e.g. climate, soil, habitat type, presence of closely related host genera) in the exporting and importing country.
- **Multiple trees** and **sites** covering combinations of environmental conditions may be needed for obtaining a complete inventory.

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Received: 22 March 2019 | Revised: 25 June 2019 | Accepted: 1 July 2019
DOI: 10.1111/jbi.13670

SYNTHESIS

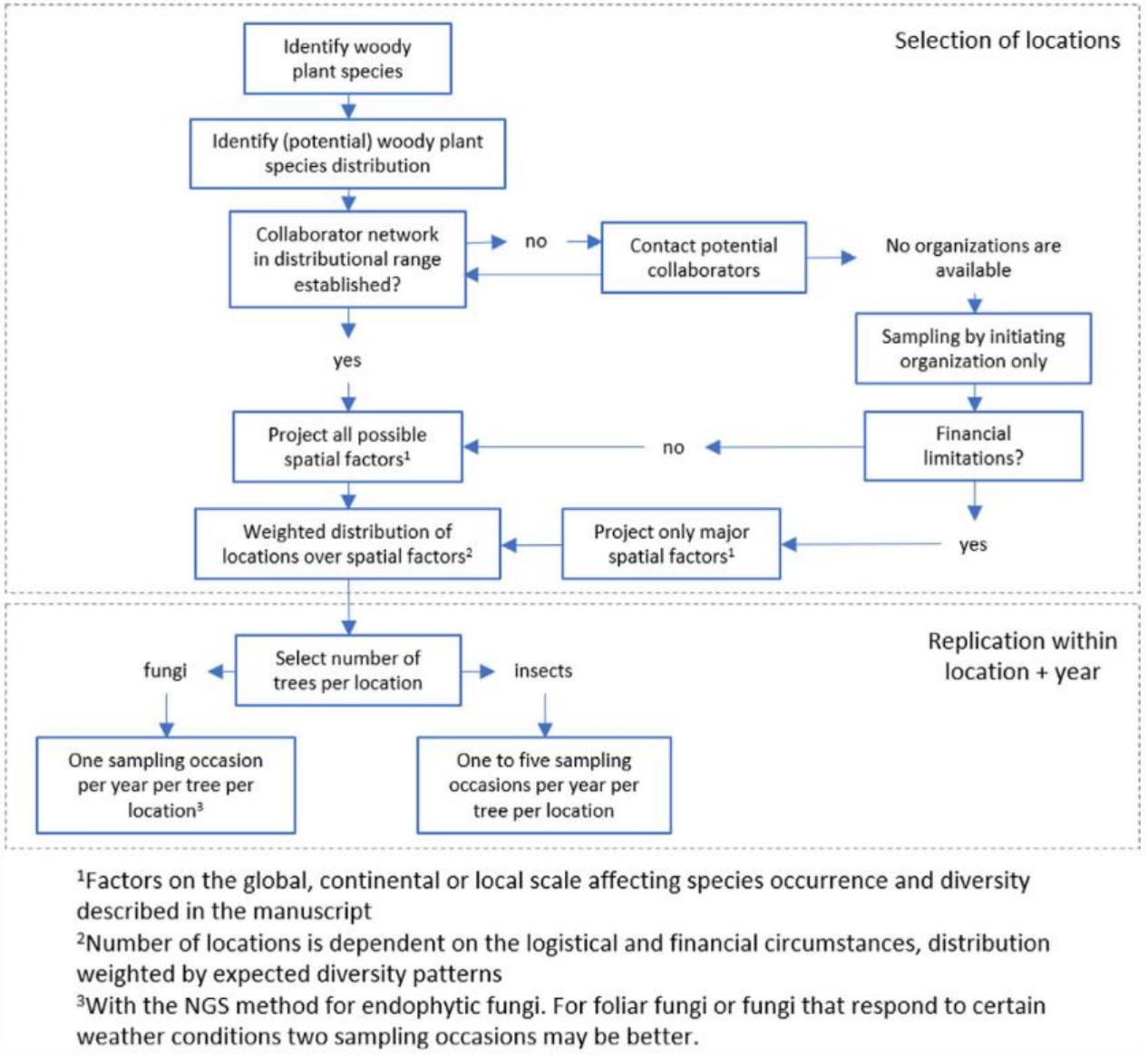
Journal of Biogeography WILEY

Spotting the pests of tomorrow—Sampling designs for detection of species associations with woody plants

René Eschen[1] | Maarten De Groot[2] | Milka Glavendekić[3] | Nikola Lacković[4] | Dinka Matosević[4] | Carmen Morales-Rodriguez[5] | Richard O Hanlon[6] | Funda Oskay[7] | Irena Papazova[8] | Simone Prospero[9] | Iva Franić[1,9,10]

Sampling design and strategy depends on multiple factors:

- Objective (all organisms vs pests)
- Woody plant species of interest (associated diversity & distribution)
- Existence of collaboration network
- Financial constrains



¹Factors on the global, continental or local scale affecting species occurrence and diversity described in the manuscript
²Number of locations is dependent on the logistical and financial circumstances, distribution weighted by expected diversity patterns
³With the NGS method for endophytic fungi. For foliar fungi or fungi that respond to certain weather conditions two sampling occasions may be better.

Eschen et al. 2019 Journal of Biogeography

Bronze birch borer (*Agrilus anxius*)

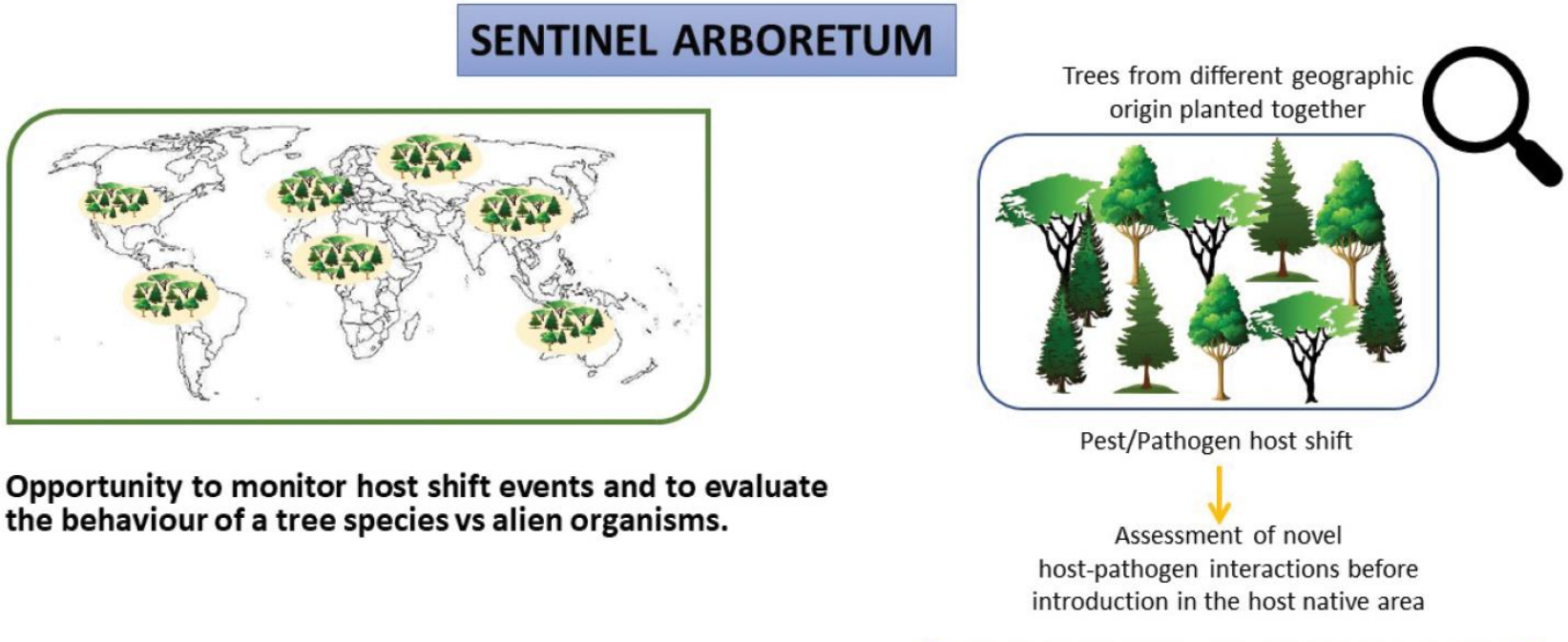
- In a 20-year common garden study in Ohio, USA, **BBB** infestation **caused complete mortality of Eurasian species** (*B. pendula*, *B. pubescens, B. maximowicziana, B. szechuanica*), but not of most individuals (>75%) of North American species (*B. papyrifera, B. populifolia, B. nigra*).
- PRA confirmed high potential risk for EPPO region, and the pest was added to **EPPO A1 List** of pests recommended for regulation.

EPPO 2011 EPPO Bulletin; Nielsen et al. 2011 Environmental Entomology

Photo: Whitney Cranshaw, Colorado State University, Bugwood.org, CC-BY-3.0-US

Sentinel arboreta

Sentinel arboreta



Morales-Rodríguez et al., 2019 Neobiota

Advantages (vs. newly established plantations)

- Cheaper, quicker and easier to implement.
- Trees more likely to be **mature**.
- Plant collections are normally well **curated**.
- The origin and identity of the plants is **known**.
- Knowledgeable **collaborators** on the site who can potentially carry out surveys of the plants of interest.

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Disadvantages (vs. newly established plantations)

- Not possible to choose the tree species or cultivars.
- A **limited number** of plants of each species or cultivars and their genetic diversity.
- Only trees that have survived are present.
- Potential use of **pesticides**.
- Climate-induced stress may modify plant susceptibility to pests leading to overestimation or underestimation of pest risk.

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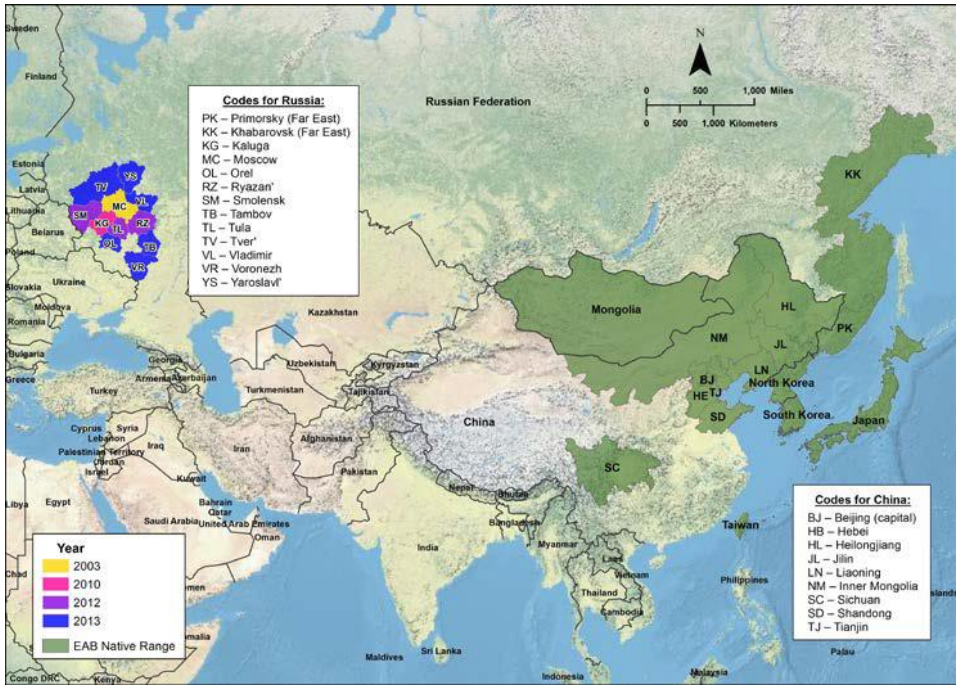
HOME / OUR WORK / PROJECTS AND CASE STUDIES

Emerald Ash Borer (EAB) in Eastern Europe

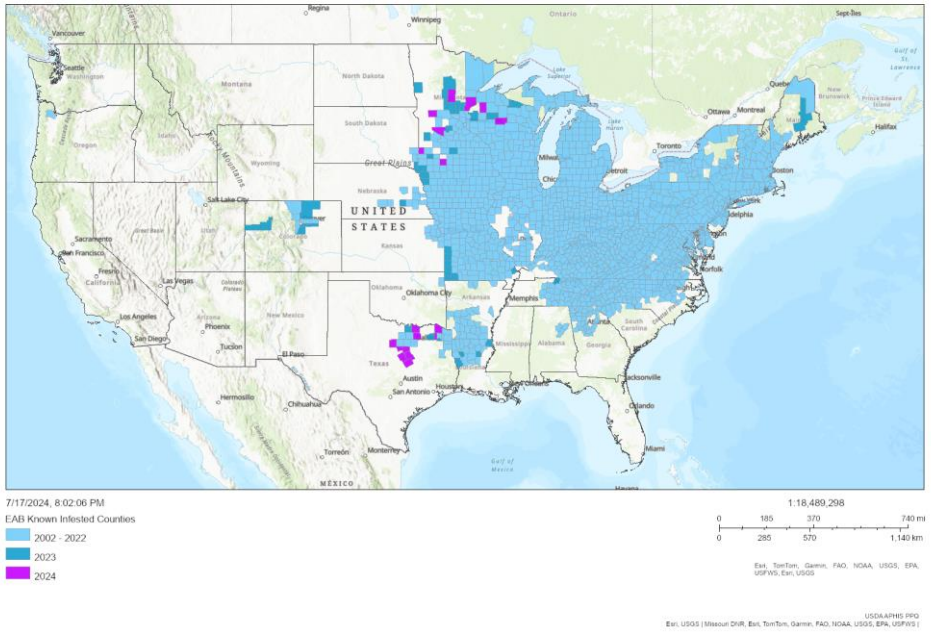
45 botanic gardens across 12 countries in Eastern Europe that house ash trees (*Fraxinus* spp.) in their collections.

Emerald ash borer (EAB)

- EAB killed several trees of the North American *Fraxinus pennsylvanica* in the botanic garden in the Russian Far East (Yurchenko and Turova 2007; Kirichenko et al. 2011).

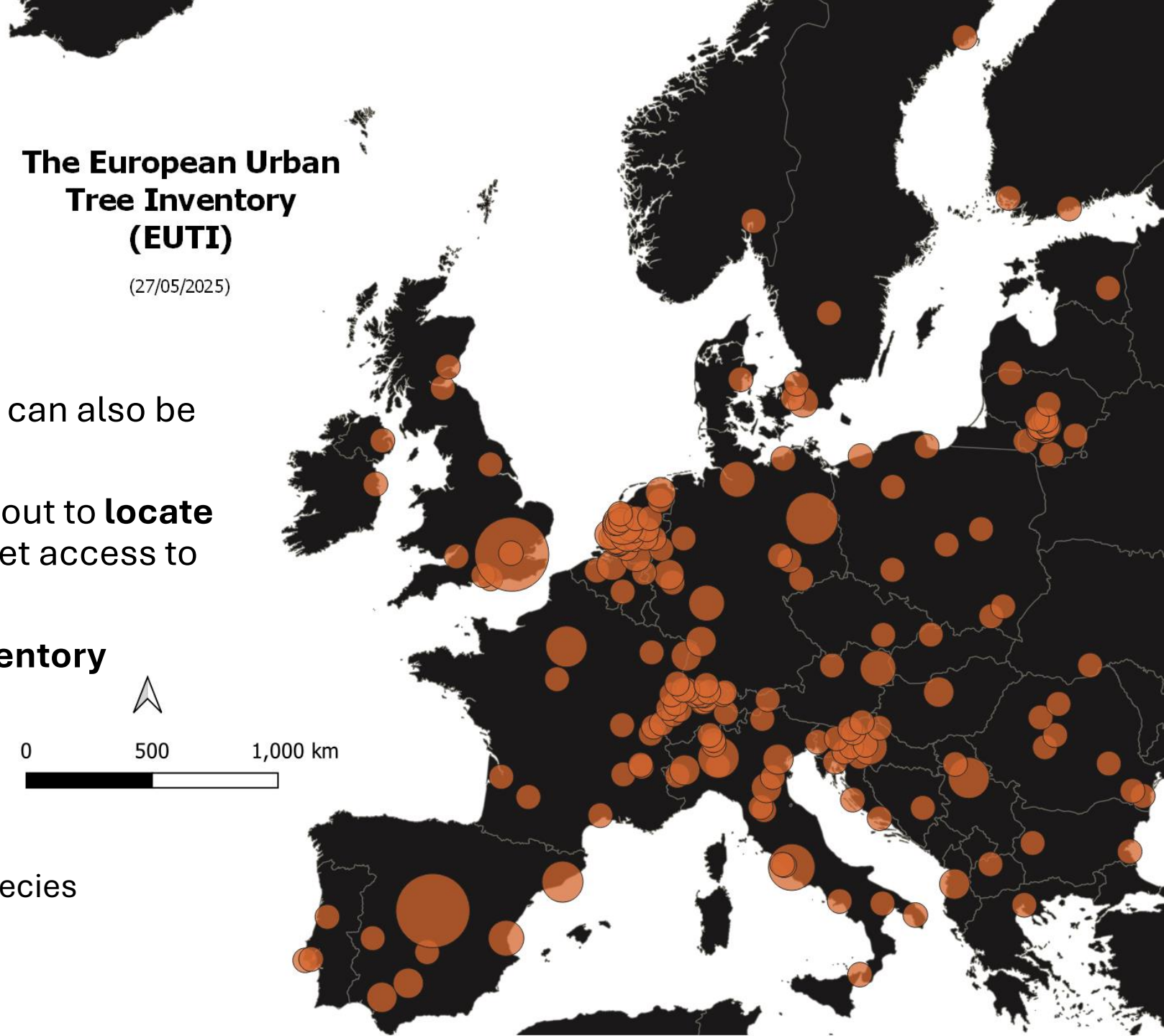


Emerald Ash Borer Beetle Known Infested Counties



Other existing sentinel plants – urban trees

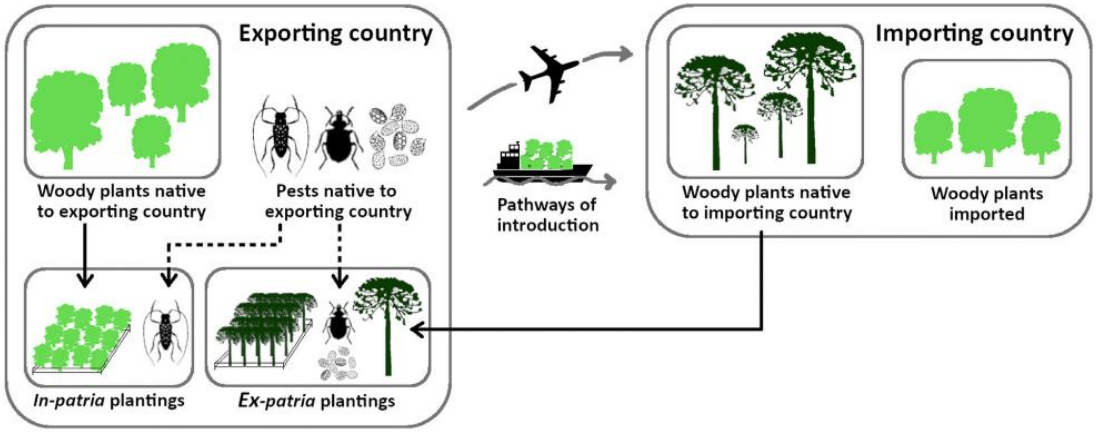
- Sentinel plants in **urban areas** can also be used for sentinel approaches.
- A survey has first to be carried out to **locate** these **sentinel plants** and to get access to private gardens.
- **The European Urban Tree Inventory** (Augustinus et al., in prep):
  - 183 municipalities
  - 31 countries
  - ~9.5mio trees
  - ~8.5mio trees identified to species



Paap et al. 2017 Biological Invasions

Conclusion

- A promising tool for **early warning** against pests of woody plants.
- Relevant information for **pest/pathway risk analysis** and development of **measures** against new pests.



- Strong **local expertise**, and **collaboration** between scientists and national plant protection organisations of importing and exporting country needed.
- **Standardised detection and identification methods** to reduce costs and facilitate interpretation of the results.

The EPPO PM 3/91(1) Sentinel woody plants: concepts and application.

Iva Franić

Swiss Federal Research Institute WSL

Training school - Invasive Forest Pests:

How to Tackle Them Before Invasion

Atatürk Arboretum

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17-20 June 2025

International Plant Protection Convention

International Plant Protection Convention

Food and Agriculture Organization of the United Nations

- Set the **standards for phytosanitary regulation** of trade to protect biodiversity and resources.
- Regulation must
  - **not discriminate** against imports from certain countries
  - must be based on **scientific evidence** and the level of **acceptable risk** set by the importing country.

What is EPPO?

- The European and Mediterranean Plant Protection Organization (**EPPO**) is an international organization responsible for **cooperation** and **harmonization** in **plant protection** within the European and Mediterranean region.

EPPO's objectives and main activities

The objectives of the Organization can be summarized as follows:

- To protect plant health in agriculture, forestry and the uncultivated environment.
- To develop an international strategy against the introduction and spread of pests (including invasive alien plants) that damage cultivated and wild plants, in agricultural and natural ecosystems and protecting biodiversity.
- To encourage harmonization of phytosanitary regulations and all other areas of official plant protection action.
- To promote the use of modern, safe, and effective pest control methods.
- To provide a documentation and information service on plant protection.

https://www.eppo.int/index

EPPO`s main activities

In order to achieve these objectives, the following main activities are conducted within EPPO:

- Setting regional standards for phytosanitary measures and plant protection products.
- Organizing technical meetings (Working Parties, Panels, Expert Working Groups) bringing together experts from all parts of the EPPO region.
- Participating in global activities related to phytosanitary measures coordinated by the IPPC Secretariat within FAO. **More details**
- Organizing international conferences and workshops for plant protection researchers, managers of plant protection organizations, phytosanitary inspectors.
- Publishing its official journal (Bulletin OEPP/EPPO Bulletin), the EPPO Reporting Service, databases and websites.

EPPO`s standards

EPPO Standards on phytosanitary measures

- **PM 1 – General Phytosanitary Measures**: recommendations on the use of phytosanitary certificates, the EPPO A1 and A2 Lists of pests recommended for regulation as quarantine pests, and standards on *Arthurdendyus triangulatus*.
- **PM 2 – Pest-specific Phytosanitary Measures**: all Standards in this series (previously called SQRs, Specific Quarantine Requirements) are now withdrawn.
- **PM 3 – Phytosanitary Procedures**: methods to be followed for performing inspections, tests or treatments of commodities moving in trade, or surveys of quarantine pests.
- **PM 4 – Production of Healthy Plants for Planting**: steps to be followed for the production of vegetatively propagated planting material whose health status is attested by an official certificate (ornamentals, fruit crops, and potatoes).
- **PM 5 – Pest Risk Analysis**: detailed guidance on the analysis of risk presented by certain pests, in relation to their potential status as quarantine pests or regulated non-quarantine pests.
- **PM 6 – Safe use of Biological Control**: guidelines for assessing and reducing the risks associated with various aspects of the introduction and use of biological control agents and, as appropriate, for comparing them with the benefits in terms of efficacy.
- **PM 7 – Diagnostics**: internationally agreed diagnostic protocols for regulated pests and horizontal standards on diagnostic issues.
- **PM 8 – Commodity-specific Phytosanitary Measures**: recommendations about phytosanitary measures which should be used or required by EPPO member countries for certain commodities moving in trade to prevent introduction and spread of quarantine pests.
- **PM 9 – National Regulatory Control Systems**: procedures to be followed for official control with the aim of containing and eradicating pests.
- **PM 10 – Phytosanitary Treatments**: methods to be followed for treatments of commodities and treatments of crops for containment or eradication of regulated pests.

EPPO Standards on plant protection products

- **PP 1 – Efficacy Evaluation of Plant Protection Products**: Standards on how to evaluate the efficacy of insecticides, acaricides, fungicides, herbicides, plant growth regulators and other products.
- **PP 2 – Good Plant Protection Practice**: Standards on optimal practice in protecting specific crops against their pests, including pathogens and weeds.
- **PP 3 – Environmental Risk Assessment of Plant Protection Products**: These Standards on the assessment of potential risks of environmental damage which may be caused by the use of plant protection products were withdrawn in 2018.

https://www.eppo.int/RESOURCES/eppo_standards

- **Recommendations** addressed to the NPPOs.
- In order to ensure international acceptance, draft standards go through an **approval procedure**, by all EPPO member countries.
- **Final decisions** are obtained by consensus and EPPO Standards are officially adopted by the EPPO Council.
- Following approval, EPPO Standards are **published** in the EPPO Bulletin and can also be retrieved via EPPO`s website

Bulletin OEPP/EPPO Bulletin (2020) **50** (3), 429–436 ISSN 0250-8052. DOI: 10.1111/epp.12698

European and Mediterranean Plant Protection Organization
Organisation Européenne et Méditerranéenne pour la Protection des Plantes PM 3/91 (1)

Phytosanitary procedures

PM 3/91(1) Sentinel woody plants: concepts and application

- Provides NPPOs and other institutions, including national forest agencies, with an **explanation of the concept** of sentinel plants.
- Gives **guidance** on the **types** and **objectives** of sentinel programmes, **surveillance** of sentinel plants, **interpretation of results** and their use for early warning or horizon scanning and risk analysis.
- Written from the **perspective of the importing country** which wants to protect its woody plant resources and ecosystems.

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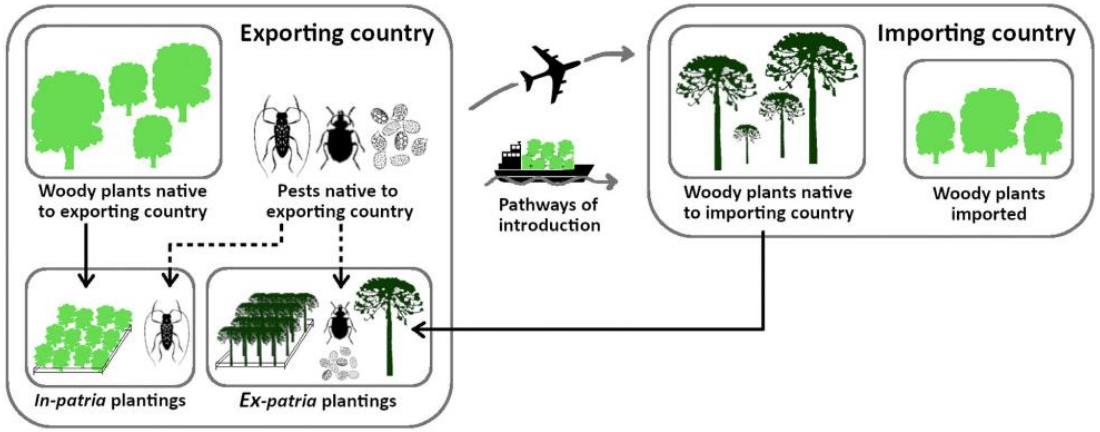
Sentinel plantings



- Which two types of sentinel plantings exist?
- What are their objectives?
- Which tree species are planted in each type of sentinel plantings?
- What is a typical age of plants in the two types of plantings?
- In which types of plantings we focus on symptomatic plants?
- In which types of plantings we focus on asymptomatic plants?
- Which type of plantings can be established in existing plantations?
- Which type of plantings is easier to establish when newly established plantations are used?

Table 1. Summary of the main characteristics of the two types of sentinel programmes

Type of sentinel programme	Objective	Type and choice of sentinel plant species	Feasibility for planted sentinel site/plots	Feasibility of monitoring of existing plants in existing plantations (e.g. parks, botanical gardens, etc.)
Sentinel plants for early warning In literature: **Sentinel plantation** Sentinel arboretum/ sentinel collection *Ex patria* planting	Early warning system to identify new pest species of a specific plant species to be protected	Species non-indigenous to the sentinel country Choice is based on economic, social or environmental value of the plants species to be protected Example: European oak, Mediterranean plant species, European forestry species	Difficult to organize, due to common plant quarantine prohibition of import of non-indigenous plant species (import for scientific use)	Non-indigenous plant species are present in botanical gardens and sentinel arboreta Survey on the presence of the sentinel plant species in existing plantations (species may have a restricted distribution in parks, botanical gardens, etc.) **Sentinel arboretum/sentinel collection**
Sentinel plants for commodity risk assessment In literature: **Sentinel nursery** *In patria* planting	Information for commodity risk assessment of current or future trade Identify the pests of concern in the country of origin of the plants for planting	Plant species indigenous in the sentinel country Specific plant species for which commodity risk assessment is conducted Example: Ornamental species non-native to EPPO region	Relatively easy to organize because the plant species are available in the sentinel country	Surveys of sentinel plants in non-treated existing plantations (i.e. outside commercial nurseries)

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Import of sentinel plants to sentinel country

- The import of the **safest categories of plants for planting** should be considered (e.g., seeds, cuttings or tissue cultures).

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ECOLOGICAL APPLICATIONS
ECOLOGICAL SOCIETY OF AMERICA

Article

Are traded forest tree seeds a potential source of nonnative pests?

Iva Franić, Simone Prospero, Martin Hartmann, Eric Allan, Marie-Anne Auger-Rozenberg, Niklaus J. Grünwald, Marc Kenis, Alain Roques, Salome Schneider, Richard Sniezko, Wyatt Williams, René Eschen

First published: 13 July 2019 | https://doi.org/10.1002/eap.1971 | Citations: 34

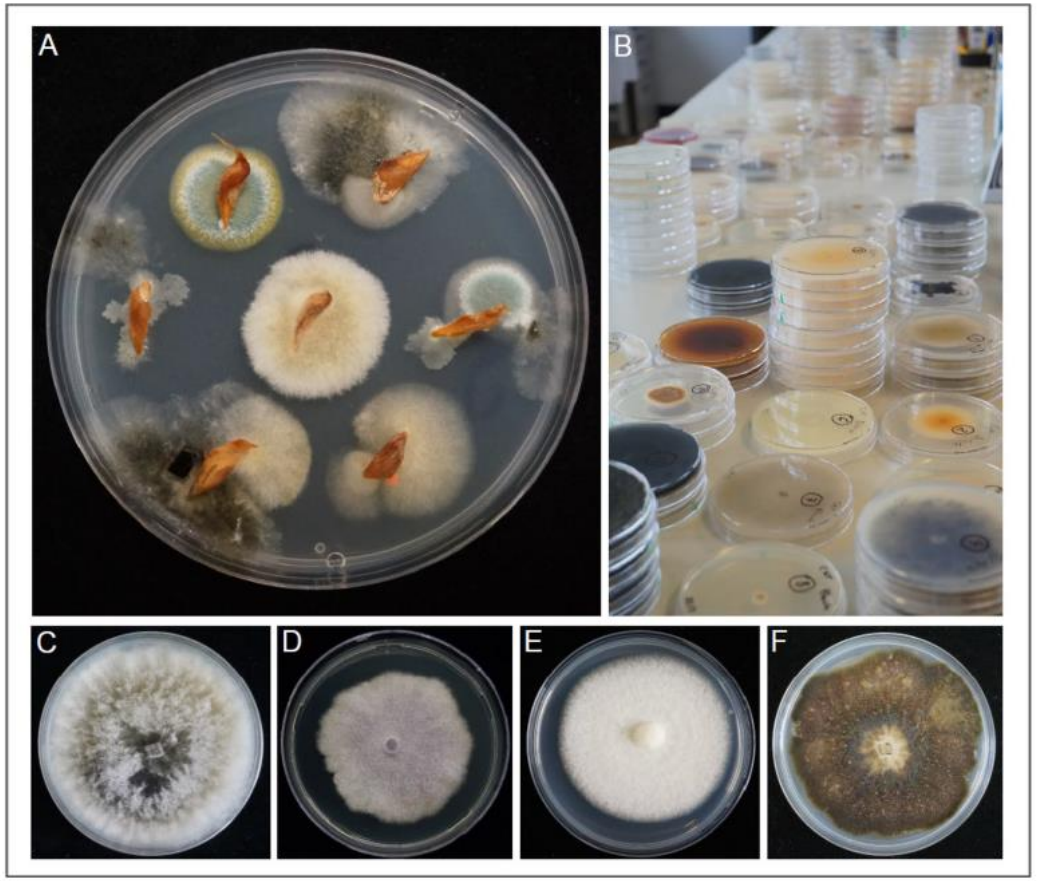
Current Forestry Reports (2024) 10:89–102
https://doi.org/10.1007/s40725-023-00211-3

FOREST PATHOLOGY (J WITZELL, SECTION EDITOR)

The Biosecurity Risks of International Forest Tree Seed Movements

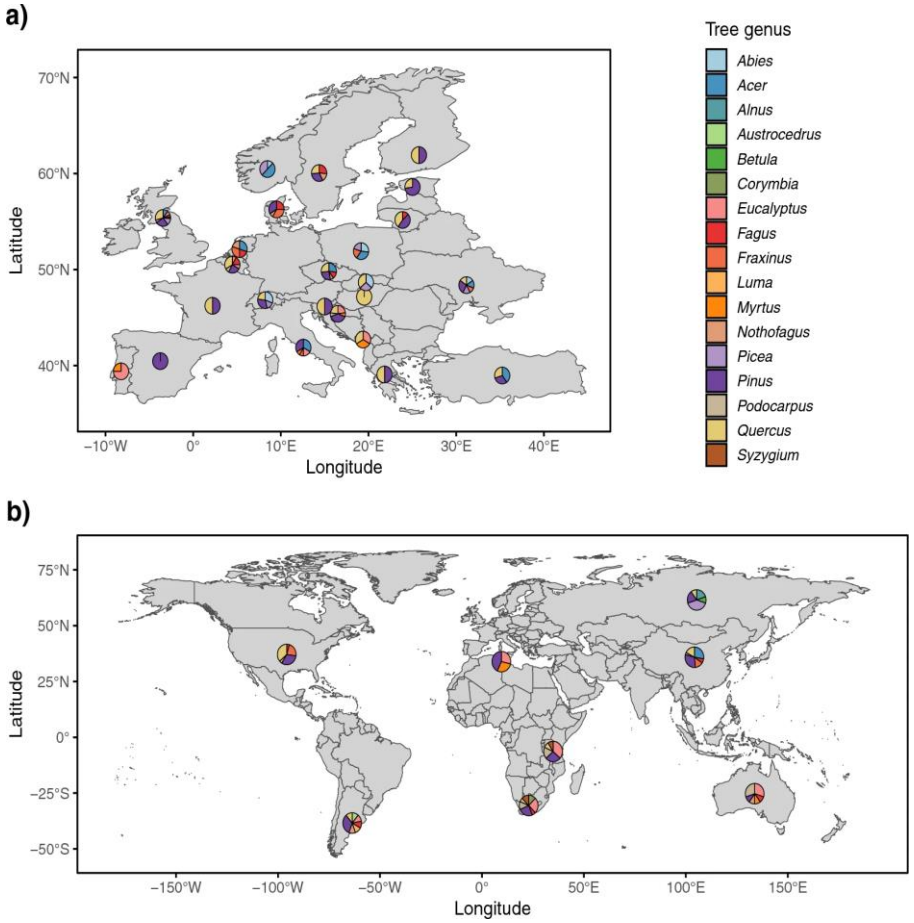
Iva Franić[1,2] · Michelle Cleary[2] · Ayşe Gülden Aday Kaya[3] · Helena Bragança[4,5] · Guro Brodal[6] · Thomas L. Cech[7] · Anne Chandelier[8] · Tuğba Doğmuş-Lehtijärvi[9] · René Eschen[10] · Asko Lehtijärvi[9] · Michael Ormsby[11] · Simone Prospero[1] · Katharina Schwanda[7] · Katarzyna Sikora[12] · Hanna Szmidla[12] · Venche Talgø[6] · Miłosz Tkaczyk[12] · Anna Maria Vettraino[13] · Ana Perez-Sierra[14]

Accepted: 16 December 2023 / Published online: 29 December 2023



Risk of transport and introduction of seed-borne insects and fungi is high, establishment is limited by the presence of host species, and risk of spread and impact is largely unknown.

High diversity of insects and fungi in dormant tree twigs



Data Descriptor | Open access | Published: 01 March 2022

Worldwide diversity of endophytic fungi and insects associated with dormant tree twigs

Iva Franić, Simone Prospero, Kalev Adamson, Eric Allan, Fabio Attorre, Marie Anne Auger-Rozenberg, Sylvie Augustin, Dimitrios Avtzis, Wim Baert, Marek Barta, Kenneth Bauters, Amani Bellahirech, Piotr Boroń, Helena Bragança, Tereza Brestovanská, May Bente Brurberg, Treena Burgess, Daiva Burokienė, Michelle Cleary, Juan Corley, David R. Coyle, György Csóka, Karel Černý, Kateryna Davydenko, ... René Eschen
+ Show authors

Scientific Data **9**, Article number: 62 (2022) | Cite this article

Article | Open access | Published: 18 July 2023

Climate, host and geography shape insect and fungal communities of trees

Iva Franić, Eric Allan, Simone Prospero, Kalev Adamson, Fabio Attorre, Marie-Anne Auger-Rozenberg, Sylvie Augustin, Dimitrios Avtzis, Wim Baert, Marek Barta, Kenneth Bauters, Amani Bellahirech, Piotr Boroń, Helena Bragança, Tereza Brestovanská, May Bente Brurberg, Treena Burgess, Daiva Burokienė, Michelle Cleary, Juan Corley, David R. Coyle, György Csóka, Karel Černý, Kateryna Davydenko, ... René Eschen
+ Show authors

Scientific Reports **13**, Article number: 11570 (2023) | Cite this article

Import of sentinel plants to sentinel country

- The import of the **safest categories of plants for planting** should be considered (e.g., seeds, cuttings or tissue cultures).
- When importing plants for planting, it is important to assess the **presence of pests on the imported material** at the time of planting.
- Plants of a **suitable size** need to be grown before the sentinel planting can be established, which may take several years.

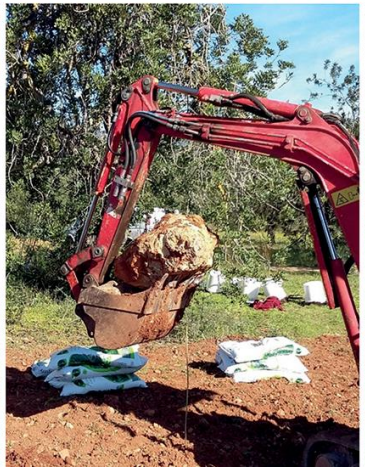
EPPO 2020 EPPO Bulletin

Source of sentinel plants

- The easiest and cheapest option is to obtain plants in the sentinel (exporting) country.
- If this is not possible the use of imported plants can be considered.
- Most countries require an **import permit** for all live plant imports, **do not allow** the import of plants with **soil** attached and some require that all live plants are submitted to **post-entry quarantine** before being released.

Eschen et al., 2015 Environmental Science & Policy

Casarin et al., 2023 Neobiota



Field Guide for the Identification of Damage on Woody Sentinel Plants

Edited by Alain Roques, Michelle Cleary, Iryna Matsiakh and René Eschen

Inspection of plants, sampling and diagnosis

- Three basic steps in the monitoring of pests in a sentinel programme:
  - Assessment of signs and symptoms
  - Isolation of potential pests
  - Identification of the pest species.

https://www.cost.eu/publication/field-guide-for-the-identification-of-damage-on-woody-sentinel-plants/

Inspection of plants, sampling and diagnosis

NeoBiota 47: 95–123 (2019)
doi: 10.3897/neobiota.47.34276
http://neobiota.pensoft.net

RESEARCH ARTICLE

A peer-reviewed open-access journal
NeoBiota
Advancing research on alien species and biological invasions

Forewarned is forearmed: harmonized approaches for early detection of potentially invasive pests and pathogens in sentinel plantings

Carmen Morales-Rodríguez[1], Sten Anslan[2], Marie-Anne Auger-Rozenberg[3], Sylvie Augustin[3], Yuri Baranchikov[4], Amani Bellahirech[5], Daiva Burokienė[6], Dovilė Čepukoit[6], Ejup Çota[7], Kateryna Davydenko[8,26], H. Tuğba Doğmuş Lehtijärvi[9], Rein Drenkhan[10], Tiia Drenkhan[10], René Eschen[11], Iva Franić[11], Milka Glavendekić[12], Maarten de Groot[13], Magdalena Kacprzyk[14], Marc Kenis[15], Natalia Kirichenko[4,29], Iryna Matsiakh[16], Dmitry L. Musolin[17], Justyna A. Nowakowska[18], Richard O'Hanlon[19], Simone Prospero[20], Alain Roques[21], Alberto Santini[22], Venche Talgø[23], Leho Tedersoo[24], Anne Uimari[25], Andrea Vannini[1], Johanna Witzell[26], Steve Woodward[27], Antonios Zambounis[28], Michelle Cleary[26]

[Morales-Rodríguez et al. 2019 NeoBiota]

1. Each part of the sentinel plants should be **inspected**. Samples should be taken from a range of representative **symptomatic parts** of the plant.
2. Before samples are taken, high-resolution **photographs** should be taken of the whole plant, the damaged part of the plant and if present and visible the pest itself.
3. Samples can also be taken from **non-symptomatic plants** to test for latent infection.
4. Sampling **instruments** should be **sterilized** after taking each sample to prevent cross-contamination.
5. If possible, inspections and samples should be taken at least **three times a year**, in the spring, summer and autumn.
6. Samples should also be taken from apparently **healthy plants/tissue** to provide an indication of what healthy tissue looks like during normal growth.
7. **Labels** should include at least locality, GPS coordinates, host plant, date of collection, collector and a unique identifying number.

[EPPO 2020 EPPO Bulletin]

Arrangements between importing and sentinel countries

1. ***Phytosanitary import requirements***. Imported plants for planting should meet the phytosanitary import requirements of the sentinel country. A relevant agreement between NPPOs may be useful to simplify export and import phytosanitary procedures.
2. ***Permission to plant sentinel plants on the territory of the sentinel country*.** Such permission should be granted by the relevant authority in the sentinel country and may be included in the agreement between NPPOs to simplify export and import procedures.
3. ***Land for sentinel nurseries or sentinel plantations*.** The land for establishment of sentinel nurseries or sentinel plantations may be provided by different authorities. The arrangement with these authorities should be reached in advance and either be the subject of a separate agreement or included in the agreement between NPPOs.
4. ***Funding*.** It should be agreed who will fund the sentinel plant programme, including export, import, transport, planting and survey of the sentinel plants
5. ***Reporting*.** Partners of the sentinel plant programmes should come to an agreement as to who will write the report of the results and how and when they will be published. The results concerning information on pest distribution and pest risks should be made available to all interested parties. This should be provided by the NPPO of the sentinel country.

EPPO 2020 EPPO Bulletin

Towards a global sentinel plants research strategy to prevent new introductions of non-native pests and pathogens in forests. The experience of HOMED

Duccio Migliorini[‡], Marie-Anne Auger-Rozenberg[§], Andrea Battisti[|], Eckehard Brockerhoff[¶,#], René Eschen[¤], Jian-ting Fan[«], Hervé Jactel[»], Christophe Orazio[^], Trudy Paap[˅], Simone Prospero[¦], Lili Ren[˃], Marc Kenis[¤], Alain Roques[§], Alberto Santini[‡]

Environmental Entomology, 52(3), 2023, 289–300
https://doi.org/10.1093/ee/nvad039
Advance Access Publication Date: 21 April 2023
Review

ENTOMOLOGICAL SOCIETY OF AMERICA
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OXFORD

Review

Insect wood borers on commercial North American tree species growing in China: review of Chinese peer-review and grey literature

Yiyi Dong[1,•], Jie Gao[2,3,•], Jiri Hulcr[1,*,•]

On-going sentinel plants project in the USA, Italy, Sweden and China led by Enrico Bonello.

https://chadwickarboretum.osu.edu/research-and-education/sentinel-plant-research

Annual Review of Phytopathology

The Global Forest Health Crisis: A Public-Good Social Dilemma in Need of International Collective Action

Geoffrey M. Williams,[1,2] Matthew D. Ginzel,[2,3] Zhao Ma,[2] Damian C. Adams,[4] Faith Campbell,[5] Gary M. Lovett,[6,*] María Belén Pildain,[7] Kenneth F. Raffa,[8] Kamal J.K. Gandhi,[9] Alberto Santini,[10] Richard A. Sniezko,[11] Michael J. Wingfield,[12] and Pierluigi Bonello[13]

SUMMARY POINTS

1. The challenge posed by biotic invasions is inherently international in scope and universal in consequence.
2. The forest health crisis is intimately connected with many of the most prominent and existential grand challenges to ecological and economic sustainability in the Anthropocene.
3. We have outlined short-term actions that can be taken to move toward a more sustainable stable state for the world's forests and society.
4. Even the most genuine and well-resourced efforts to address the forest health crisis will eventually fail if they do not fully embrace the collective action principles outlined in this work.
5. In order to reduce the rate of introductions, effectively detect and respond to new invasions, manage established insects and pathogens, and bolster resistance and resilience of ecosystems and society to forest health threats, there is a need for trust, coordinated cooperation, continued public education and awareness, a common vision, locally adapted strategies, and shared investment.

A research institute
of the ETH Domain

The assessment of tree seed mycobiomes using Illumina and Nanopore metabarcoding and traditional plating

Jana Mittelstrass[1], Renate Heinzelmann[1], René Eschen[2], Martin Hartmann[3], Quirin Kupper[1], Salome Schneider[1], Simone Prospero[1], Iva Franić[1]

[1] Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf, Switzerland

[2] CABI, Delémont, Switzerland

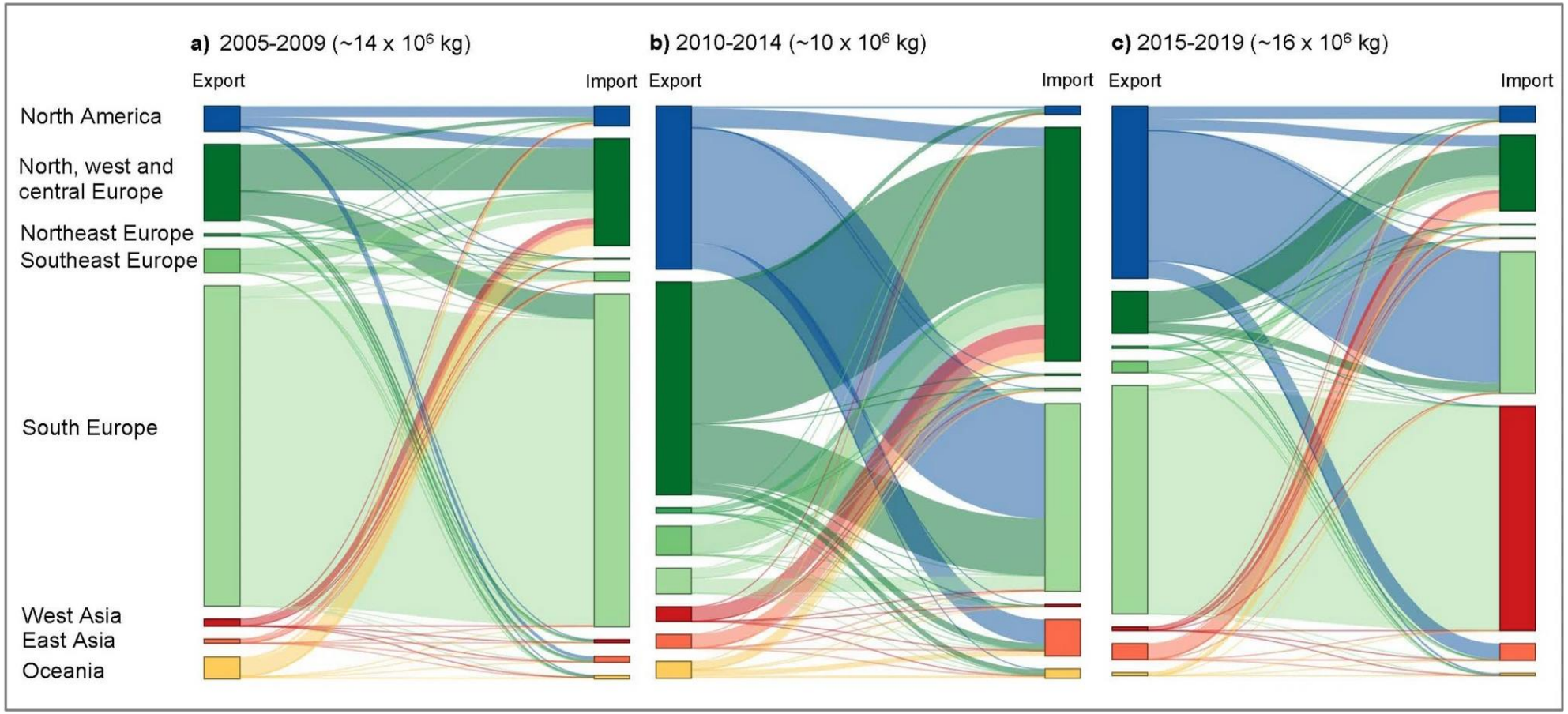
[3] Institute of Agricultural Sciences, ETH Zürich, Zürich, Switzerland

Forestry depends on a constant supply of good quality seed

- Almost one third of European forests are **artificially regenerated**.
- Propagation material for artificial forest regeneration is often **locally sourced**.
- Around **2.5 million kg** of tree seeds are **traded internationally** every year.

Central Forest Nursery, Valladolid, Spain

Seed imports vary over time



Franić et al. 2024

Few restrictions target tree seed exchange in Europe

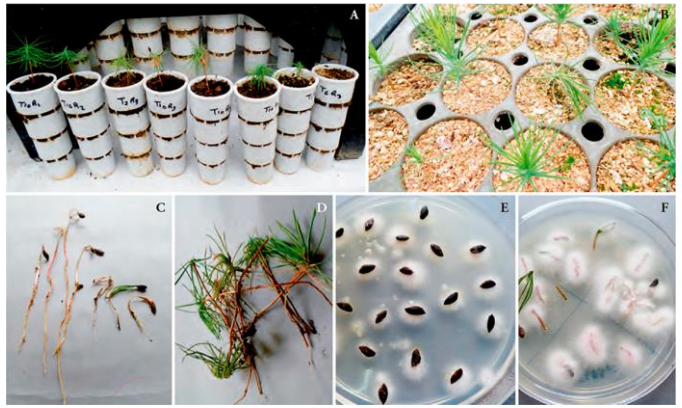
- All tree seed needs **phytosanitary certification**.
- Specific **phytosanitary requirements** for the movement of *Pinus* spp. and *Pseudotsuga menziensii* seed.
- *Fusarium circinatum* is the only quarantine forest pest that is known as **seed-transmitted**.

Tree seeds carry known plant pathogens

Diplodia tip blight
(*Sphaeropsis sapinea*)

Quambalaria eucalypti

Pine pitch canker
(*Fusarium circinatum*)



Stem canker of Eucalyptus
(*Teratosphaeria zuluensis*)

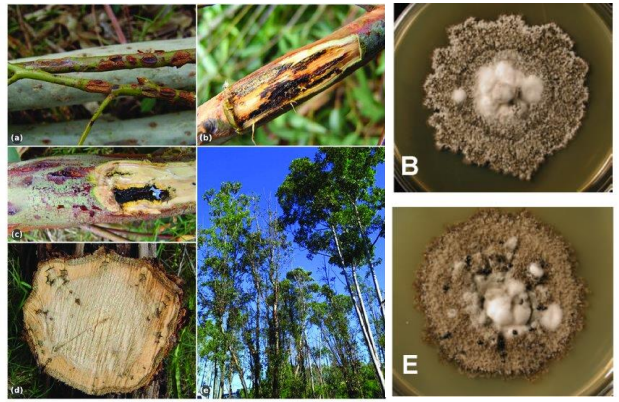


Photo credit: Blumenstein et al. 2021 Journal of Fungi and Wiktoria Breza; Braganca et al. 2015 Forest Pathology; García-Díaz et al. 2017 Agrociencia; Aylward et al. 2018 Molecular Plant Pathology; Cortinas et al. 2006

Current Forestry Reports (2024) 10:89–102
https://doi.org/10.1007/s40725-023-00211-3

Euphresco

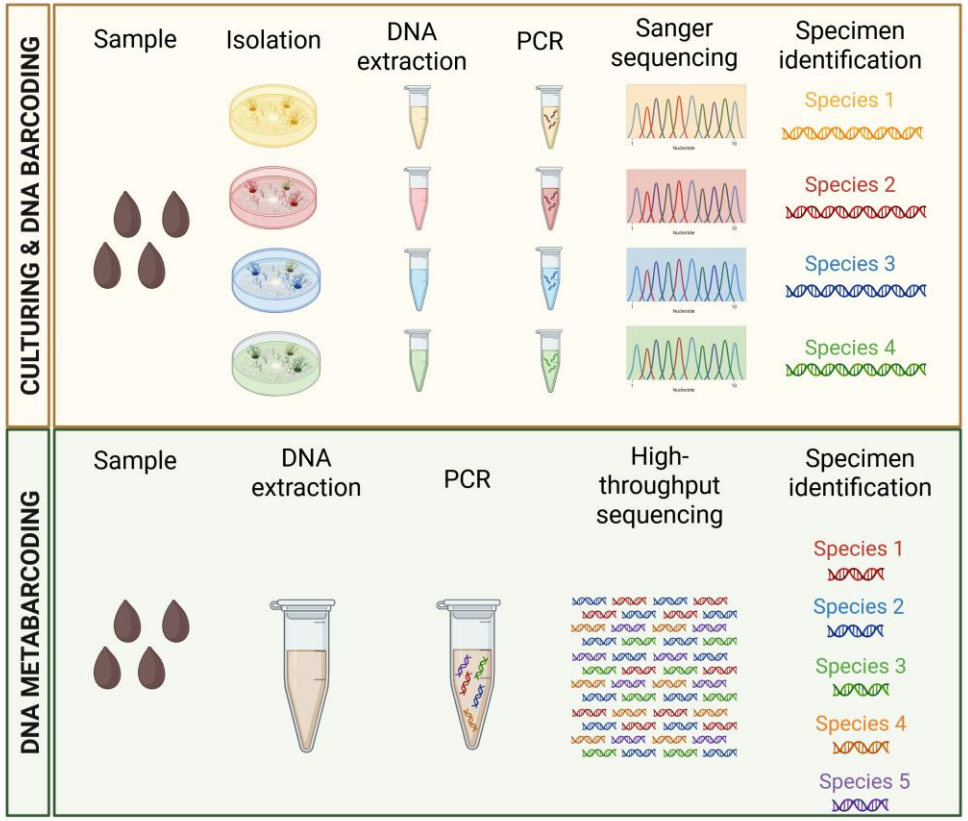
FOREST PATHOLOGY (J WITZELL, SECTION EDITOR)

Check for updates

The Biosecurity Risks of International Forest Tree Seed Movements

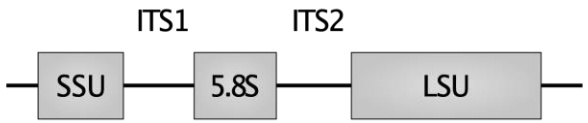
Iva Franić[1,2] · Michelle Cleary[2] · Ayşe Gülden Aday Kaya[3] · Helena Bragança[4,5] · Guro Brodal[6] · Thomas L. Cech[7] · Anne Chandelier[8] · Tuğba Doğmuş-Lehtijärvi[9] · René Eschen[10] · Asko Lehtijärvi[9] · Michael Ormsby[11] · Simone Prospero[1] · Katharina Schwanda[7] · Katarzyna Sikora[12] · Hanna Szmidla[12] · Venche Talgø[6] · Miłosz Tkaczyk[12] · Anna Maria Vettraino[13] · Ana Perez-Sierra[14]

Metabarcoding reveals highly diverse communities of seed-borne fungi



- **Complete** and **accurate assessment** of fungal pathogens is crucial for phytosanitary risk assessment.
- Phytosanitary measures can only target described and named **species**.
- Metabarcoding allows a **rapid parallel assessment** of many individuals, including unculturable taxa.
  - Large fraction of **unknown species** using Illumina platforms.

Long-read sequencing may facilitate improved identification of fungi



DNA barcoding (Sanger)

Long-read metabarcoding (Nanopore)

Short-read metabarcoding (Illumina)

Taxonomic resolution	Diversity coverage
High	Low
High	Medium/High
Medium/Low	High

Ecological Applications, 29(7), 2019, e01971

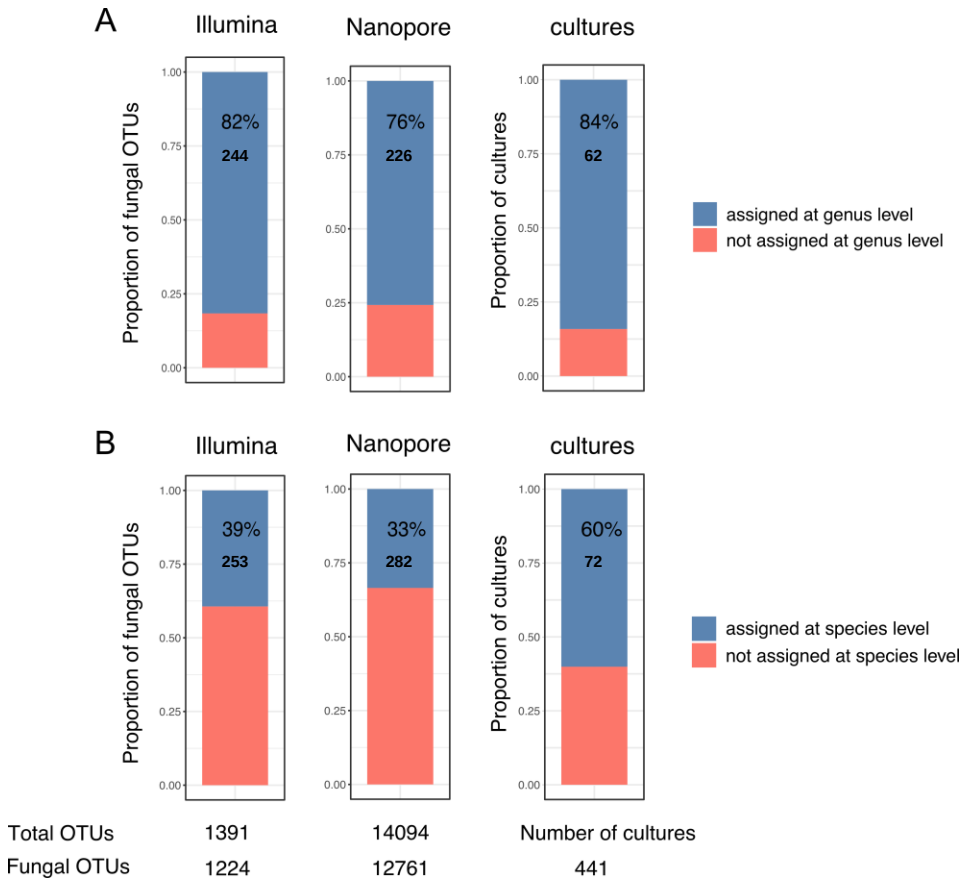
Are traded forest tree seeds a potential source of nonnative pests?

Iva Franić,[1,2,3,9] Simone Prospero,[2] Martin Hartmann,[4] Eric Allan,[3] Marie-Anne Auger-Rozenberg,[5] Niklaus J. Grünwald,[6] Marc Kenis,[1] Alain Roques,[5] Salome Schneider,[2] Richard Sniezko,[7] Wyatt Williams,[8] and René Eschen[1]

Tree species	Common names	Family	Group	Origin	No. seed lots
Acer macrophyllum Pursh	bigleaf maple, Oregon maple	Sapindaceae	Angiosperm	North America	6
Quercus garryana Douglas ex Hook	Garry oak, Oregon white oak, Oregon oak	Fagaceae	Angiosperm	North America	6
Pinus ponderosa Douglas ex C. Lawson	Ponderosa pine, bull pine, blackjack pine, western yellow-pine	Pinaceae	Gymnosperm	North America	8
Tsuga heterophylla (Raf.) Sarg.	western hemlock, western hemlock–spruce	Pinaceae	Gymnosperm	North America	7
Acer pseudoplatanus L.	sycamore	Sapindaceae	Angiosperm	Europe	3
Fagus sylvatica L.	common beech	Fagaceae	Angiosperm	Europe	6
Pinus sylvestris L.	Scots pine	Pinaceae	Gymnosperm	Europe	5
Picea abies (L.) H. Karst.	Norway spruce, European spruce	Pinaceae	Gymnosperm	Europe	5
Acer palmatum Thunb.	palmate maple, Japanese maple, smooth Japanese maple	Sapindaceae	Angiosperm	Asia	5
Pinus tabuliformis Carrière	Manchurian red pine, southern Chinese pine, Chinese red pine	Pinaceae	Gymnosperm	Asia	4
Larix gmelinii (Rupr.) Kuzen.	Dahurian larch	Pinaceae	Gymnosperm	Asia	3

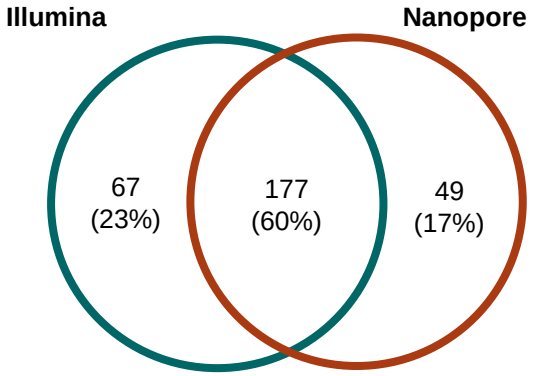
Fungi assessed directly from 100 seeds per SL using culturing and short- and long-read metabarcoding (Illumina and Nanopore, respectively).

Similar proportion of OTUs assigned to genera and species in Illumina and Nanopore datasets

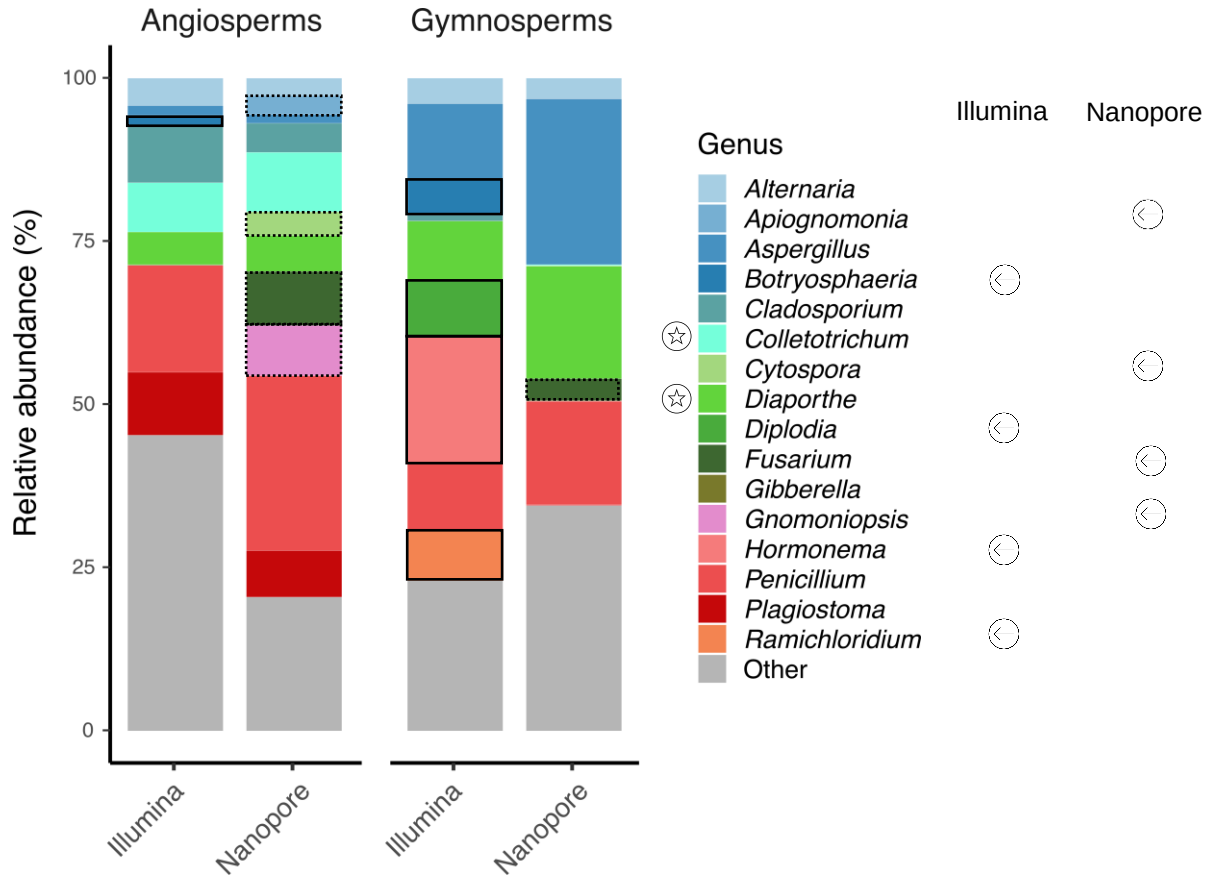


- Culturing revealed one **quarter** of genera/species captured by metabarcoding.
  - **Most reads** in short-read metabarcoding dataset belong to cultured fungi.
- With short- and long-read metabarcoding, **similar number** of fungal reads and OTUs were assigned to comparable number of genera and species.
  - Long reads **do not** improve taxonomic resolution, possibly due to high error rates and lack of reference sequences.

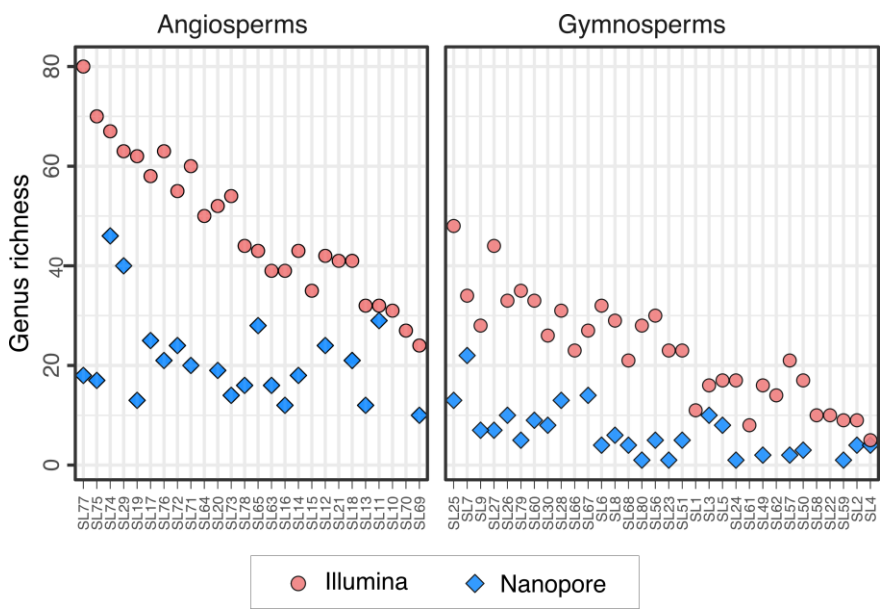
Metabarcoding with Illumina and Nanopore reveal distinct communities of seed-borne fungi

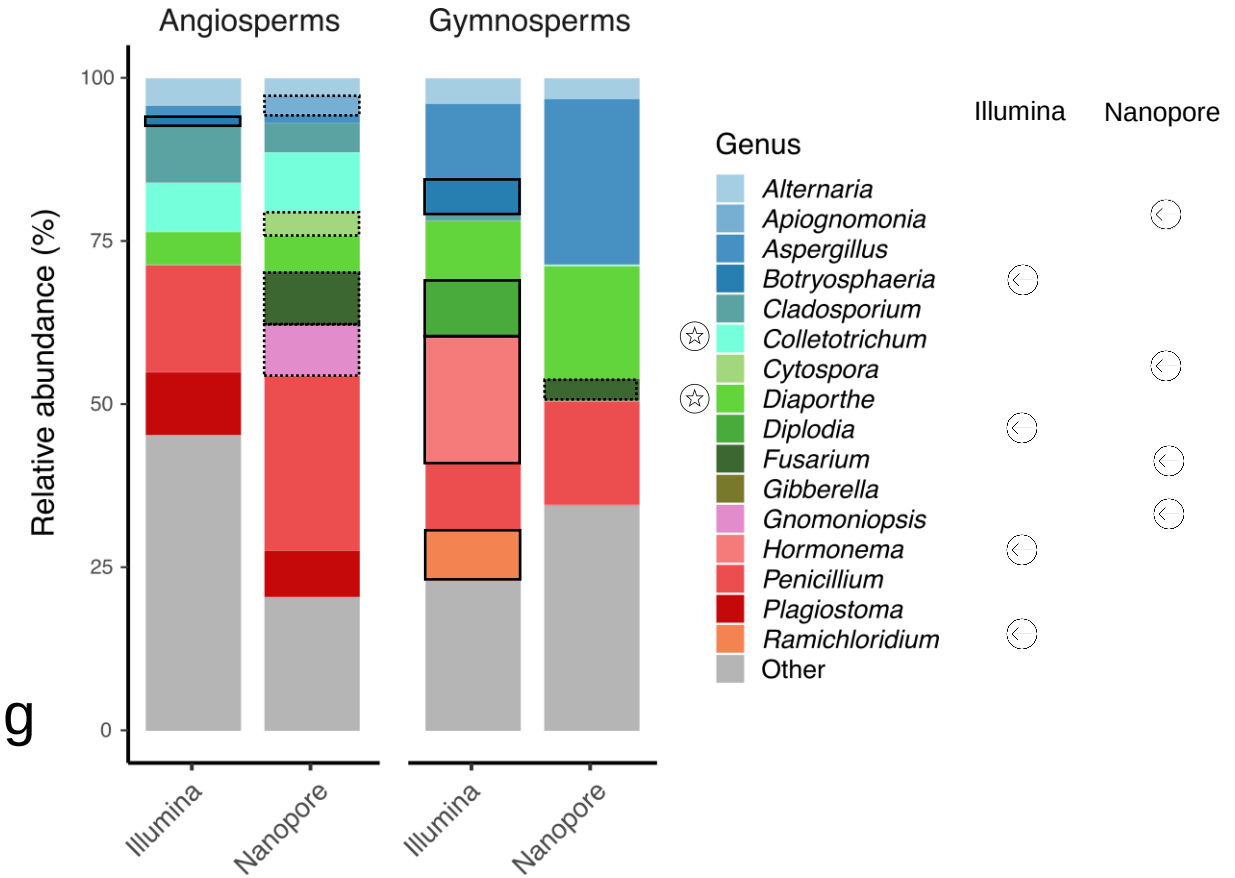


- Possibly due to different primer sets used in the metabarcoding approaches.



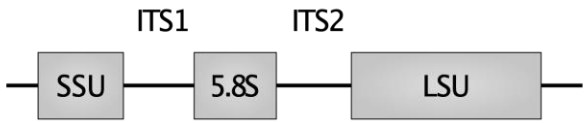
Lower diversity coverage with Nanopore than Illumina metabarcoding





- Possibly due to lower sequencing depth and higher error rates.

Long-read sequencing did not improve identification of fungi



DNA barcoding (Sanger)

Long-read metabarcoding (Nanopore)

Short-read metabarcoding (Illumina)

Taxonomic resolution	Diversity coverage
High	Low
~~High~~ Medium/Low	Medium/~~High~~
Medium/Low	High

Summary

- **No improvement in taxonomic resolution in Nanopore vs Illumina metabarcoding**, possibly due to high error rates and lack of sequences in reference databases.
- Lower sequencing depth and higher error rates result in **lower diversity coverage in Nanopore vs Illumina metabarcoding.**

Conclusions

- **Short-read** metabarcoding optimal for fungal **diversity screening** due to high sequencing depths and diversity coverage.
- As error rates decrease, reference databases expand, and throughput improves**, long-read** metabarcoding may become a strong candidate for future **diagnostic** studies of fungi.
- Traditional **culturing** captures most of the fungi from short-read metabarcoding and remains valuable for obtaining **isolates** for further research.
- **Combined approach** recommended for complete and accurate assessment of fungal pathogens needed for phytosanitary risk assessment.

Swiss National Science Foundation

Phytopathology Group WSL

A research institute
of the ETH Domain

Thank you for your attention.

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Mittelstrass *et al. Environmental Microbiome* (2025) 20:53
https://doi.org/10.1186/s40793-025-00712-7

Environmental Microbiome

RESEARCH Open Access

Metabarcoding with Illumina and Oxford Nanopore Technologies provides complementary insights into tree seed mycobiota

Jana Mittelstrass[1*], Renate Heinzelmann[1], René Eschen[2], Martin Hartmann[3], Quirin Kupper[1], Salome Schneider[1], Simone Prospero[1] and Iva Franić[1]