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BOTANIC GARDENS AND PLANT HEALTH

Trap setting for Emerald Ash Borer monitoring at Nitra Botanic Garden

Welcome to this special edition of BG Journal, which focuses on plant health – a topic that has increasing relevance to horticulture and plant conservation due to the changing climate and the globalisation of the horticulture trade. This edition covers the many important roles that botanic gardens play in identifying, preventing and controlling plant health risks. On page 9, we are introduced to the International Plant Sentinel Network (IPSN), a global early warning network in which botanic gardens play the role of the canary in the coalmine, identifying new plant pests and pathogens before they gain a hold, raising awareness amongst plant health professionals and the general public and finding ways to prevent their spread. Now with >100 members worldwide, the IPSN has gone from strength to strength since its establishment in 2013. One of those members of the IPSN, Botanic Gardens of Sydney, is our featured garden and their article on page 12 covers the many roles that botanic gardens play in detection and surveillance, on the ground management (*ex situ* and *in situ*) and research.

SECTION A (pages 19-30) provides in depth case studies and perspectives on integrated pest and disease management from gardens in Brazil, Belgium and the United Kingdom.

SECTION B (pages 31-47) covers plant health monitoring and control of a wide range of pests and pathogens. In Argentina, we hear about insects and fungi affecting the genus *Quercus* (p. 31) while in Colombia, the Medellin Botanical Garden focuses its research on pests and diseases affecting nectar-producing plants in its butterfly house (p.34). On page 35, Rio de Janeiro Botanical Garden describes the control of fungal pathogens in medicinal plants, and on page 48 the botanical garden in Nitra, Slovakia, cover the insects and mites that they have to control. Pests and pathogens are not always notifiable species. However, as illustrated by the golden root mealybug case study from Edinburgh on page 43, they can still cause major problems.

SECTION C (pages 48-59) covers plant health in the urban environment, where without strict plant quarantine measures, botanic gardens can be the cause of outbreaks. More often, they can be part of the solution by carrying out vital research into controlling pests and diseases of street trees and urban planting.

SECTION D (page 60) provides a national sentinel case study, the Welsh Plant Health Surveillance Network, which has the primary aim of monitoring the presence and absence of native and invasive pests and pathogens that can pose a threat to the health of plants and trees across Wales, acting as an early warning system and monitoring tool.

SECTION E (page 63) explores the importance of communicating plant health issues to the general public, in this case how educating stakeholders reduces the stigma of plant health management efforts in public gardens.

Finally, do take the time to read our interview with Trudy Paap (page 16), a South African plant pathologist at the forefront of research focusing on the detection, identification, and management of tree pests and diseases, particularly in the context of climate change and invasive species.

Happy reading!

Dr Paul Smith,
BGCI Secretary General

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Embracing a decade of dedication: The IPSN journey, achievements and current members

IPSN
International Plant Sentinel Network

For over a decade, the International Plant Sentinel Network (IPSN) has been a leading force in plant health surveillance, exemplifying global collaboration to bolster resilience against emerging plant health threats. Since its inception in 2013, funded by the EUPHRESCO initiative, IPSN has grown into a robust hub of cooperation, information sharing, and innovation, with further financial support from the UK Department of Environment, Food and Rural Affairs (DEFRA), Horizon Europe, and the US Forest Service.

Alongside our diverse partners, we have developed standardized surveillance methodologies and tools, distributed essential training materials, and fostered a worldwide network of botanical gardens utilizing sentinel plants for pest and disease monitoring.

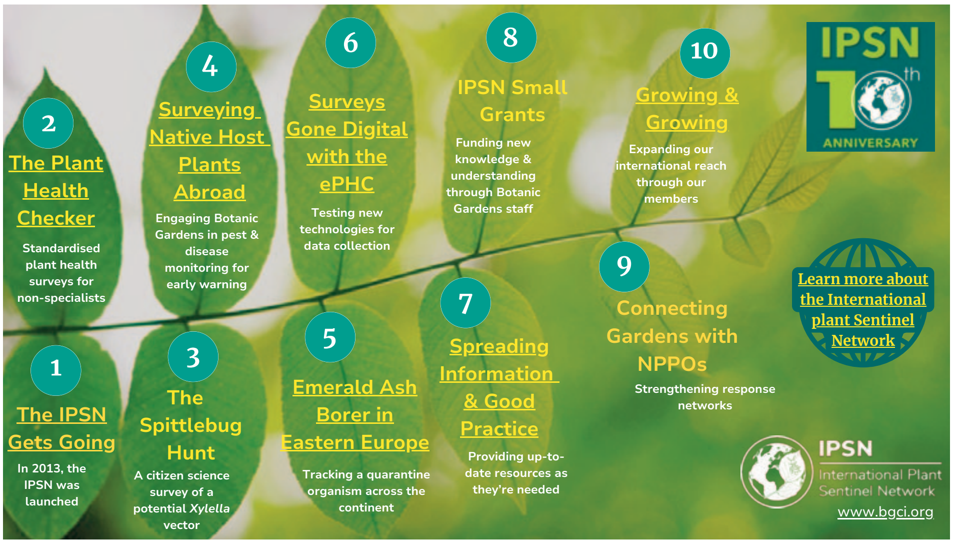
We invite you to explore our top 10 accomplishments in our IPSN milestone infographic and click through the links for more detailed information and resources.

In February 2024 IPSN officially surpassed 100 members! The milestone is a testament to the increasing global interest in biosecurity and pest and disease monitoring, highlighting the importance of strengthening our collaborations to maximize our efforts to protect plant health.

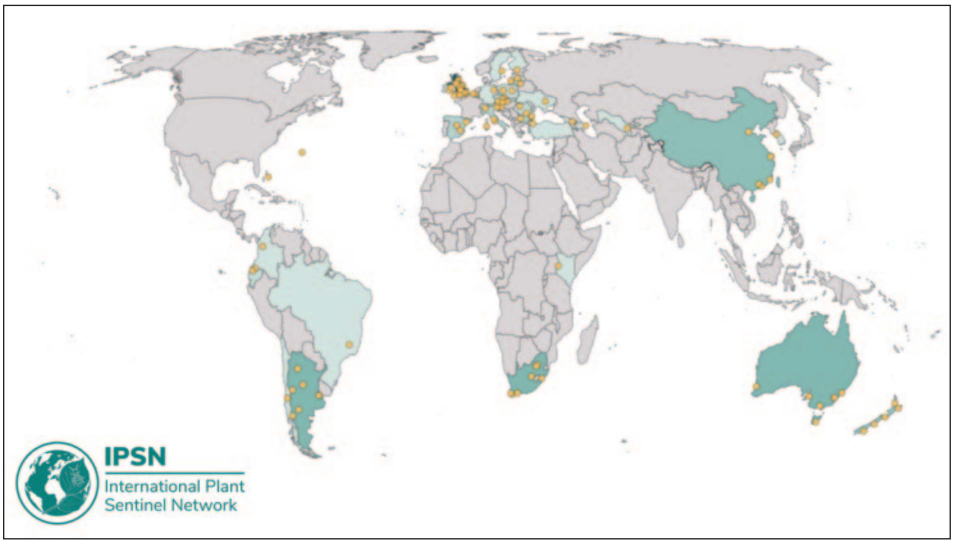
With currently 102 members across the globe, we recently welcomed our first members from the Caribbean region (Bahamas and Bermuda) as well as from Colombia, Brazil, Ukraine and Poland.

Join our expanding network and connect with other professionals dedicated to safeguarding our planet's botanical diversity through promoting plant health and biosecurity. We invite botanic gardens, arboreta and organisations involved in plant health management and biosecurity – such as NPPOs, research labs, etc. - to become part of the IPSN. As a member, your organisation will not only gain access to valuable resources, but also be part of a supportive global community and contribute to essential research, collaborative initiatives and monitoring efforts to enhance plant health.

Become a member today and play a vital role in the global mission to monitor emerging threats to plant health and enhance biosecurity practices and understanding. Together we can make a difference in protecting plant biodiversity worldwide.

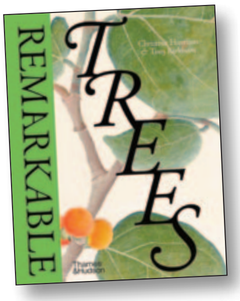


IPSN's key achivements in its first 10 years of existence.



Current locations of IPSN members around the world

Remarkable Trees – Christina Harrison and Tony Kirkham. Publisher Thames & Hudson, 2024



There are a number of books available with 'remarkable trees' in their title but what makes this book stand out is the depth and richness of the storytelling. The subjects of these stories are around 60 different tree species that the authors have selected based on their uses and relationship to humans. The contents are thus separated into chapters focused on trees associated with: building and creating; feasting and celebrating; healers and killers; body and soul; wonders of the world, and; threatened and endangered. What is remarkable about this book is the documentation, artwork and photographs that the authors have been able to draw on from Kew's archives, bringing in unique perspectives from history, and cultures from all over the world. The stories of these remarkable trees are also beautifully told, no easy task with so much information to distil. I learnt something new on every page. I have no hesitation in recommending this book to anyone who loves trees, nature, art of history. There really is something for everyone.

By Paul smith

Partners in the field during last BGCI project management visit (BGCI)

Project Partners visit GrassRoots Ltd in March 2024 (BGCI)

Darwin Initiative Innovation Project: Uganda

In March 2024, BGCI marked the successful conclusion of a two-year Darwin Initiative Innovation-funded project in partnership with Tooro Botanical Gardens, Entebbe Botanical Gardens, Makerere University, and GrassRoots Ltd. This project aimed to explore innovative food opportunities using native plant species and assess their impact on productivity and biodiversity in agroforestry systems, with baseline data collected from field trials.

Markets were assessed, communities engaged, and nutritional analysis completed to pull together information on 34 target species important in Mpigi, Kagadi, Mbale, Kabarole and Wakiso districts. This information, combined with biological and availability information, led to the selection of 13 species with high potential in new value chain developments and sustainable use strategies. From these, 7 new viable products were produced, including 3 fruit juices and 4 dried powdered food additives, proof that African native plant species have a role to play in the future.

The benefits of agroforestry and native plants for the environment and people's health was shared with over 700 rural and urban community members, in open days at Tooro Botanical Gardens, and in Kagadi and Mpigi districts.

Expanding these results is the next step to reach more people, policy makers and development and/or conservation organisations to drive positive change in Uganda, addressing the challenges of degradation and climate change.

A Conservation Action Plan for Threatened Trees in Colombia

A recent project funded by Fondation Franklinia and the Indianapolis Zoo Conservation Grant, has allowed BGCI and CPSG to design a conservation action plan for the threatened trees of Colombia. It involved a conservation gap analysis (including species and actors), a prioritisation scheme related to needs of conservation and feasibility of conservation actions and meeting with key stakeholders in February 2024.

Samanea saman, one of the species assessed by the IUCN Colombian Plant Specialist Group in collaboration wit the Global Tree Assessment (BGCI)

Colombian Tree Conservation Action Planning Group (David Taborda)

All these inputs have resulted in a conservation action plan for the Colombian threatened trees, with a vision for 2030 to improve the conservation status of the most threatened trees, through the implementation of *in situ* and *ex situ* conservation actions by collaboration with key actors, supported by adequate and publicly-available information and by adaptive management during its implementation.

The GlobalTree Portal reveals that Colombia, with its 6,010 tree species, has the world's second highest tree diversity after Brazil. Since 2018, the IUCN Colombian Plant Specialist Group (CPSG) has been a key collaborator in the Global Tree Assessment assessing the extinction risk of Colombian trees. Over 600 trees have been assessed as threatened with extinction.

BGCI Accreditation scheme: more than 100 botanic gardens accredited!

BGCI's accreditation scheme was launched in 2018, with the aim of motivating and empowering gardens to enhance their plant conservation efforts and increase their impact through recognition of their unique skills and collections.

In 2024 we accredited the 100th garden Jardim Botânico Municipal de Bauru in Brazil. Viviane C. de Oliveira Head of Horticulture explains to us the importance of the accreditation to them:

"Following the association of the Jardim Botânico Municipal de Bauru with BGCI, through the Brazilian Alliance of Botanical Gardens, we became aware of the benefits offered to those associated with this network. We began to participate in training courses and activities, share data and information, we had the opportunity to work with other botanical gardens, we submitted projects together, creating dialogues of common interest within the universe of plant conservation.

From the point of view of accreditation itself, we realized that our experiences and structures achieved throughout our work history allowed us to aim for such accreditation. Even so, many experiences existed but were not yet in the form of policies and protocols and the experience of requesting accreditation made us commit to writing them, thus improving the fulfilment of our institutional mission of plant conservation.

The accreditation request process was a great motivator for the Jardim Botânico Municipal de Bauru to expand its standards of excellence."

Accreditations in 2024:

- Betty Ford Alpine Gardens (USA)
- Coastal Maine Botanical Gardens
- Instituto Inhotim (Brazil)
- Jardín Botánico de Medellín (Colombia)
- Jardim Botânico Municipal de Bauru (Brazil)
- Jardín Botánico Universitario de la Benemérita Universidad Autónoma de Puebla (JBU-BUAP) (Mexico)
- Ljubljana University Botanical Garden (Slovenia)
- Oklahoma City Zoo (USA)
- Plantentuin Universiteit Gent (Belgium)
- Qur'anic Botanic Garden (Qatar)
- Spring Grove Cemetery and Arboretum (USA)

School group at Jardim Botânico Municipal de Bauru (BGCI)

Authors: Charles Lane and Chris Malumphy

Japanese beetle

INTERNATIONAL PLANT SENTINEL NETWORK

INTERNATIONAL PLANT SENTINEL NETWORK – NEW GLOBAL PEST AND DISEASE THREATS

IPSN

The International Plant Sentinel Network (IPSN) was established in 2013 to respond to the escalating threat from invasive plant pests and diseases. This new global network brought together Botanic Gardens and Arboreta with plant health scientists and plant protection organisations to work collaboratively against this challenge. It has successfully built capability and capacity in plant health and biosecurity by developing bespoke resources to support skills development. It has been instrumental in raising international awareness about important plant health concerns such as the Polyphagous shot hole borer (PSHB) and enabling gardens to survey their collections. PSHB (*Euwallacea fornicatus*) is of international concern as although native to Southeast Asia it has been accidently introduced to North America, South Africa, Australia, and Israel in the past 20 years. It can attack a wide range of plants killing them as the beetle has a symbiotic relationship with a fungus (*Fusarium sp.*) that kills vascular tissue causing dieback and death.

This article highlights four new and emerging pests and pathogens of concern to Botanic Gardens and Arboreta.

Introduction

Botanic Gardens and Arboreta are under continual threat from a wide range of damaging and invasive plant pests and diseases. In the past 50 years, we have seen an ever-increasing number of organisms being introduced and becoming established in new regions and countries. The Plant Biosecurity Strategy for Great Britain (2023 to 2028) clearly articulates these threats listing a wide range of organisms in the UK – for example – arrival of Dutch elm disease in 1971, *Phytophthora ramorum* in 2002, Ash dieback and the Asian longhorn beetle in 2012 and most recently the expansion of pests such as oak processionary moth, the eight toothed spruce bark beetle and new species such as *Phytophthora pluvialis*. Looking at these organisms, most are well known to science and have been present in their countries of origin for many years, but have accidentally been introduced, most commonly, on infected/infested plant material, to new regions. However, with increasing diagnostic and identification capabilities by national plant protection organisations and research organisations, new species are being discovered and described.

With Botanic Gardens and Arboreta providing an extensive collection of host plant species across the world, the International Plant Sentinel Network provides the mechanism for plant protection organisations to tap into this expertise to establish both distribution of known organisms but also help identify new pests and pathogens of concern. Since establishment of a network by BGCI and Fera Science Limited in 2013, we have learned some valuable lessons in how to engage and access these botanical collections. This has been built on experience gained in other stakeholder and citizen science led projects such as OPAL (Tree Health Survey | Research groups | Imperial College London) and Observatree (An early warning system for tree health and tree disease - Observatree). We should not underestimate the complexity of the task and the skills required to survey for harmful organisms. We have learnt the importance of building capability and capacity within surveyors, for example, they not only need skills to identify pests and diseases but an ability to identify host plants, record the geographical location, work safely with good biosecurity, and finally know how and when to report their suspicions.

At the onset of the network, we implemented a 'triage' approach so that only organisms of statutory plant health concern would be escalated to the appropriate National Plant Protection Organisation (NPPO). Therefore, surveillance targets need to be 'characteristic' showing reliable diagnostic features (typical symptoms/damage or physical features of the pest) and do not overlap with other pests, pathogens, disorders, rare or red listed organisms. They should also be visible from ground level without invasive sampling (no requirement to expose roots through digging, removing healthy bark and creating wounds etc.) or specialist equipment (elevated platform or 'cherry picker'). As Botanic Gardens and Arboreta develop their skills and build their confidence looking for, recording, and reporting named pests; they have also started building a collection of 'sentinel' trees suitable for general surveillance work for the presence of new and unusual pests and diseases. In collaboration with both national and regional plant protection organisations, plant health scientists, and Botanic Gardens and Arboreta, the IPSN Research and Development committee review potential harmful organisms and their suitability for surveillance by Botanic Gardens and Arboreta.

In this article, we will describe some of the latest harmful organisms of global concern to Botanic Gardens and Arboreta and prioritised for action with IPSN partner Gardens.

Emerging Pest and Diseases Threats

Japanese beetle - *Popillia japonica*

The Japanese beetle (Fig. 1) is native to Japan and has been introduced to the neighbouring Kunashir Island, Russia. In 1911, it was accidentally introduced to North America, where it spread and became invasive in most of eastern North America, as well as parts of Canada. In 1970 the beetle arrived in the Azores islands, Portugal, but it was not until 2014 that it was first found in mainland Europe, in Italy, and subsequently spread to Switzerland in 2017 [see distribution on the IPSN factsheet]. Adult beetles are known as defoliators, but they can also feed on fruits. In Japan, the damage caused by this beetle on plants is not severe, however, in North America it is considered a major pest, affecting many crops and fruit trees, as well as ornamental and environmentally important plants. The larvae live underground feeding mainly on plant roots and are pests of lawn and turf. Adult beetles are very active and move within and between plants. They can also fly more than 4 km, but they need warm temperatures (optimum temperature ranges between 29-35°C) to take flight. The beetles can disperse over long distances as larvae or adults in plant trade and adults can also hitchhike in non-host commodities or vehicles. The adult Japanese beetle is highly polyphagous, with over 700 plant species recorded as hosts, from 79 different families. In North America, they cause damage to important crops such as maize, soybean, and pasture. They also cause defoliation on apple, birch, lime and rose. IPSN FACTSHEETS 2024 (bgci.org)

Figure 1. Japanese beetle

Golden root mealybug – *Chryseococcus arecae*

The golden root mealybug (Fig. 2) is a root-feeding insect native to New Zealand. It has been introduced to Eastern and South Australia, including Tasmania, where it was found to impact ornamental plants of high economic value. The first record outside Australasia and in Europe was in a private garden in Perthshire, Scotland, in 2012. Here it caused severe damage to the UK National Collection of *Meconopsis* spp., commonly known as Himalayan blue poppies. The golden root mealybug is considered a pest of ornamental plants and has spread across the UK. Since 2015, It has been found in private and public gardens at several locations in Scotland and England, and in 2019, it was reported in Northern Ireland for the first time. The dissemination of this pest is facilitated by the transportation of infested plants in trade and the exchange of plants between private and public collections, leading to its dispersal over significant distances. Additionally, rapid dispersal can occur within nurseries and Botanic Gardens by the mealybugs being carried with the watering run-off, as these insects can float on water.

Figure 2. Golden root mealybug (David Crossley FERA)

This mealybug is polyphagous, as this bug has been recorded feeding on the roots of plants assigned to at least 65 genera in 30 families. Many new hosts have been recorded in the UK. Its hosts include many ornamental plant genera commonly grown in Britain, crop species (aubergine, raspberry, and tomato), grasses, and herbaceous weeds. IPSN FACTSHEETS 2024 (bgci.org)

Myrtle rust – *Austropuccinai psidii*

The rust fungus (Fig. 3) is native to South America. It was first described on guava from Brazil in the late 19th century, and its presence was subsequently noted across countries in South and Central America and the Caribbean. Since then, the pathogen has been steadily spreading around the world. Significant introduction milestones include North America in the 1970s, Hawaii in 2005, Japan in 2007, China in 2009, and most significantly reaching Australia in 2010 where it is now widespread along the East coast. In 2013, the fungus was found in South Africa for the first time, followed by its detection in mainland New Zealand in 2017. Currently, they are no records of its presence in Europe and its distribution is provided on an IPSN factsheet [IPSN FACTSHEETS 2024 (bgci.org)]. Introductions of the fungus are commonly associated with imported live plant material and plant products, such as young fruit buds, fruits, cut flowers, and foliage. Additionally, the fungal spores can be dispersed over long distances via air currents, as well as through contaminated clothing and luggage.

The hosts include: important timber, amenity, and indigenous plants from a diversity of ecosystems from the Myrtaceae family – nearly 500 species recorded to date, but the number of host species keeps expanding.

Figure 3. Myrtle rust (myrtlerust.org.nz)

Sooty bark disease (SBD) - *Cryptostroma corticale*

Sooty bark disease (SBD) (Fig. 4) is caused by the fungus *Cryptostroma corticale*. The fungus was first described in North America; but was then introduced into Europe, with the first documented case in the UK in 1945. Further observations have been recorded in Central and Western Europe since the 2000s [see distribution on IPSN Factsheet]. The disease leads to dieback and ultimately to the death of maples (*Acer* spp.), primarily affecting sycamores (*Acer pseudoplatanus*). Damage caused by the disease is associated with raised summer temperatures and drought and therefore, there are increasing concerns due recent hot dry summers and future climate change impacts. In addition to the plant health problems, spores of *C. corticale* can also cause significant human health problems in some individuals. Although uncommon, exposure to large number of spores can cause maple bark stripper's disease, a form of hypersensitivity pneumonitis. SBD should not be confused with 'sooty mould', which is caused by saprotrophic (non-pathogenic) growth of fungi colonising sticky exudates or 'honeydew' due to insect feeding on plant sap on foliage.

Hosts affected include *Acer* spp. - with *Acer pseudoplatanus* and *Acer macrophyllum* listed by European Plant Protection Organization (EPPO) as major hosts. The fungus has been isolated from several other living broadleaf tree species as well as dead wood. However, pathogenicity of these isolates and their ability to cause disease has not been found. Further information can be found here: IPSN FACTSHEETS 2024 (bgci.org)

Discussion

Since its establishment in 2013, the IPSN has significantly increased capability and capacity in plant health and biosecurity in

Figure 4. Sooty bark disease

Botanic Gardens and Arboretum around the world. It has developed a wide range of resources to empower staff and volunteers within these gardens to help them understand the distribution of harmful organisms and identify future threats as part of horizon scanning. This includes posters and fact sheets on a high-profile pests and diseases of global concern, IPSN's plant health checker and surveillance guidance. The IPSN has been instrumental in raising international awareness about damaging organisms such as rose rosette virus (RRV) and the polyphagous shot hole borer (PSHB); we are confident of future successes with the new and emerging pests described in this article. As gardens have engaged with the IPSN activities, they have raised their awareness, understanding and skills in plant health and biosecurity to survey for named pests such as RRV and PSHB. In turn, this has led them to identify individual plants as part of an international 'standing army' or sentinels to help detect future threats.

So as we reflect on the first 10 years, there is no doubt that the IPSN is living up to its acronym, it is truly global or international, with a focus on plants and biosecurity, it has established and is utilising sentinel plants, and finally, has actively developed a network amongst Botanic Gardens and Arboreta, plant health scientists and National Plant Protection Organisation.

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FEATURED GARDEN

PLANT BIOSECURITY AT BOTANIC GARDENS OF SYDNEY

Staff from the Australian Botanic Garden Mount Annan collecting cuttings of *Lenwebbia* 'Main Range' in northern New South Wales. This species is critically endangered and threatened with extinction by myrtle rust.

Plant pests and diseases can have a major impact on the operation of botanic gardens and the conservation of plants more broadly. Botanic Gardens of Sydney have a wide range of strategic initiatives to manage biosecurity to ensure existing problems are managed, new incursions prevented, and that pests and diseases do not spread from our gardens. Action on the conservation of plant species threatened by exotic pests and diseases also requires integrated inter-disciplinary science to manage these threats that includes conservation horticulture, seed banking and cryopreservation, genomics and disease detection and management.

Introduction

Over the past decade we have seen a greater recognition of the importance of plant diseases and pests negatively impacting the conservation of plants. Diseases like sudden oak death in North America (Hansen *et al.*, 2012; Parke & Rizzo 2011), Kauri dieback in New Zealand (Weir *et al.*, 2015) and Phytophthora root rot and myrtle rust (*Austropuccinia psidii*) in Australia (Carnegie & Pegg 2018; McDougall & Liew 2024), to name just a few have had a huge impact on the survival of many plant species.

Botanic Gardens of Sydney – comprising three distinct gardens, The Royal Botanic Garden Sydney (RBGS), Australian Botanic Garden Mount Annan (ABGMA) and the Blue Mountains Botanic Garden Mount Tomah (BMBGMT) – have had a focus on prevention and research on plant diseases since 1989. The ever-present issue of biosecurity is brought into sharper focus given the responsibility of managing significant areas of critically endangered ecological communities, including a large area of Cumberland Plain Woodland at ABGMA, and the BMBGMT which is located in the World Heritage listed Blue Mountains National Park. On-site management of pests and diseases in the Gardens is critically important to prevent incursions in these ecosystems.

Symptoms of *Phytophthora* root rot in a *Xanthorrhoea* species in northern New South Wales caused by *Phytophthora cinnamomi*.

Detection and Surveillance

Botanic Gardens of Sydney is uniquely placed among botanic gardens in having an in-house research and diagnostic capacity as part of its core functions. The PlantClinic at RBGS provides a fee-for-service plant disease diagnostic service for other agencies (including national parks), consultants, and the broader horticultural community. PlantClinic also provides diagnostic services, support and advice for pest and disease outbreaks amongst the more than 11,800 species across the three gardens living collections (BGoS 2023). This unique capability has provided incentive to continuously enhance diagnostic techniques to ensure accuracy and speed of diagnosis. Most tests are built on a variety of DNA-based diagnostic tools that are definitive and rapid, facilitating speedy management decisions (e.g. Laurence *et al.*, 2024).

Botanic Gardens of Sydney has been a member of BGCI's International Plant Sentinel Network since its inception, and has contributed to surveillance projects to record pest and disease issues on species originating from the United Kingdom, now growing in Australia. These contributions led to the recent detection of a new pathogen report of *Phytophthora pluvivora* on *Quercus robur* at BMBGMT (Laurence *et al.*, 2023). The location of the RBGS on Sydney Harbour, combined with the substantial number of international visitors, has positioned the gardens as a highly likely location for new incursions of pests and disease. As part of Australia's strict biosecurity programs and protocols, the RBGS is regularly surveyed and monitored by the NSW Department of Primary Industry (NSWDPI) for pest and disease outbreaks.

On the ground management and procedures

Botanic Gardens of Sydney is committed to protecting and enhancing its living collections, which are of national and international significance, and represent a valuable asset for scientific research, conservation, and engagement. In 2023 we developed a comprehensive Living Collections Strategy to fully document the diverse collections and provide a vision for future management. However, due to the complexity of operations across our three gardens, the organisation faces a multitude of biosecurity challenges that pose a threat to the health and diversity of its living collections, as well as to the natural environment and non-accessioned living landscapes within, and immediately adjacent to each garden.

These challenges include the introduction and spread of pests, disease, weeds, and invasive species that can affect plants and soil, and therefore potentially compromise the integrity and resilience of Botanic Gardens of Sydney's living collections. Current practices across the organisation follow best practice approaches, with some having evolved independently based on the context and location of each site. These differences are influenced by the physical location of the gardens, the internal horticultural requirements, and the provision of services to external clients.

Nursery and Horticulture

Botanic Gardens of Sydney has dedicated procedures for nursery hygiene and plant quarantine to ensure staff and visitors do not introduce unwanted biosecurity risks. Those entering clean areas must use footbaths, and new accessions must undertake specific procedures, such as pasteurisation and quarantine periods, to prevent the introduction of potentially compromised growing media or plant material. Hygiene protocols extend to propagation surfaces and the tools and equipment used in each location, including the movement of plants from an infected site to an uninfected site, ensuring no cross contamination both within and across facilities and sites.

Non-accessioned living landscapes

When working throughout the non-garden areas, such as the non-accessioned living landscapes adjacent to the Blue Mountains World Heritage Area, horticultural teams follow strict sterilisation protocols, carrying methylated spirits for decontaminating work boots on entry into these areas, as well as at designated check points throughout. This risk management approach ensures that any pathogens already introduced by other parties using these areas, are less likely to spread further throughout these critical ecosystems.

Biosecurity in botanic gardens is not just about what may enter the garden. While many species held across our three locations are Australian native species, the majority of species, including Australian natives, are being grown outside of their native range. Many of these have the potential to become pest species across Australia and national precautions are taken to identify high risk plants and prevent gardens escapees infiltrating neighbouring areas of conservation value (Australian Government 2010). Botanic Gardens of Sydney works closely with the Australian and NSW governments to ensure any high-risk species are promptly identified, catalogued with a reference collection in the National Herbarium of New South Wales for future identification and research, and quarantined or destroyed to prevent their spread from the gardens to Australia's sensitive native ecosystems.

Symptoms of myrtle rust on *Rhodamnia maideniana*, a critically endangered species in cultivation at the Australian Botanic Garden Mount Annan.

Research

Our science programs have included a component of research on plant diseases. This has focused on diseases of conservation importance (e.g. Phytophthora root rot) in the natural ecosystem and on diseases that have been problematic in managing the living collection in the Gardens (e.g. Armillaria root rot; Fusarium wilt). This research has focussed on mapping the extent of disease in the conservation estate in NSW (McDougall & Liew 2023), developing and validating management techniques (Summerell & Liew, 2020; Liew et al., 2023; McDougall & Liew 2023), enhancing diagnostic capability and capacity and determining the susceptibility of different species (especially threatened species) to pathogens (McDougall & Liew 2024). The incursion of myrtle rust into Australia in April 2010, and its impact on our most important plant family, has broadened our research into better understanding the interaction between this pathogen and the many hosts it attacks.

Metacollections and *Ex situ* conservation

The detection of Phytophthora root rot at the only site where the Wollemi Pine grows in 2004 (Bullock et al., 2000; Puno et al., 20; Summerell & Liew 2020), as well as the recognition that this iconic species is highly susceptible, was a turning point in how we started to think about managing plant diseases impacting critically endangered plant species. It was recognised that control of the pathogen at the site was not possible, and alongside the increased risk of bushfires as a result of climate change, there would be a need to create translocated populations. We are now at the point where we have genomic information about most of the individuals to guide the establishment of the translocated population and the establishment of a metacollection across continents. The recent plantings of Wollemi Pines in collaboration with BGCI and Forestry England across the UK and Europe is a wonderful example of the power of botanic gardens to achieve great conservation outcomes. Botanic Gardens of Sydney is appreciative of BGCI and Bedgebury National Pinetum and Forest, for facilitating the distribution of genetically diverse six-packs of Wollemi Pines throughout the UK and Europe and Atlanta Botanical Gardens for its assistance in receiving Wollemi Pines in the United States.

A similar exercise is now underway with those species that are susceptible to myrtle rust – it is clear there are many species under critical risk of extinction as a result of this disease (Fenshem *et al.*, 2021). Many species in the Myrtaceae are well suited to seed banking but some of the very susceptible species are not seed bankable so options involving tissue culture, cryopreservation and glasshouse collections are being used (Hardstaff et *al.*, 2022). The importance of genomic information is critical as it allows us to only grow and maintain the minimum number of plants that contain the full diversity of the species.

Future Biosecurity Priorities

While current approaches to the understanding and management of biosecurity have served Botanic Gardens of Sydney well, the organisation recognises that this issue carries increasing complexity in a highly globalised world. Over the next two years, Botanic Gardens of Sydney will undertake a comprehensive biosecurity risk assessment across our living collections, facilities, and operations, using a tested and robust methodology. The risk assessment will aim to identify and evaluate the sources, pathways, and consequences of biosecurity threats to the organisation's operations and living collections, as well as the existing and potential mitigation strategies. The risk assessment will be undertaken in close collaboration with our in-house capacity for plant health diagnostics at the PlantClinic, which has extensive experience and expertise associated with our disease history, past procedures and current diagnostic capacity.

A spore sampler to detect incursions of new strains of myrtle rust at the Royal Botanic Garden Sydney.

Genetically diverse cuttings of *Rhodomyrtus psidioides* – the native guava – forming part of a metacollection for this species.

This will result in the development of a biosecurity strategy that defines the vision, goals, and principles of biosecurity management for Botanic Gardens of Sydney, aligning with the organisation's strategic priorities, and the relevant biosecurity frameworks of the Australian and NSW governments. The strategy will identify the key stakeholders, roles, and responsibilities for biosecurity within and outside Botanic Gardens of Sydney, and the mechanisms for communication, collaboration, and coordination throughout its implementation.

We will also implement an operational plan that outlines the specific actions, timelines, resources, and indicators for delivering against the biosecurity strategy. The operational plan will enhance all aspects of our biosecurity management, such as prevention, surveillance, detection, diagnosis, response, recovery, reporting, and review. The operational plan will have a dedicated approach to monitoring and evaluating its implementation to ensure realisation of a comprehensive and effective approach to biosecurity across three unique botanic gardens.

In committing to the development of a new biosecurity strategy and operational plan, Botanic Gardens of Sydney aims to contribute meaningfully to the complementary actions of the forthcoming Global Strategy for Plant Conservation and provide leadership to other botanic gardens and plant-focussed organisations. We strongly believe that our collective operations can lead to better plant health outcomes both within botanic gardens, and throughout the biodiverse ecosystems on which we all rely.

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INTERVIEW

TRUDY PAAP

Dr. Trudy Paap is a distinguished forest pathologist and research fellow at the Forestry and Agricultural Biotechnology Institute (FABI) at the University of Pretoria, South Africa. With a robust background in plant pathology, her research focuses on the detection, identification, and management of tree pests and diseases, particularly in the context of climate change and invasive species. Dr. Paap is actively involved in the Tree Protection Co-operative Programme (TPCP), where she collaborates with industry partners to develop practical strategies for safeguarding forest resources.

Can you describe the most significant plant and pest disease challenges you have encountered in your research in South Africa and Australia, and how you have addressed them?

Dealing with the detection of the *Polyphagous* Shot Hole Borer (*Euwallacea fornicatus*) in South Africa was a particularly challenging experience. Its broad host range, spans agriculture, commercial forestry, natural forests and urban trees. Its cryptic behaviour and resilience to traditional chemical control measures aided its ability to evade detection and escape control. Consequently, it was able to establish across the country relatively quickly. We established a PSHB Research Network, to coordinate research and foster collaboration among researchers, stakeholders and government, but despite this, managing PSHB remains a formidable task that is likely to stay with us for the foreseeable future.

I spent some years working on *Phytophthora cinnamomi* in the southwest of Australia. More recently, I've been investigating the threat it poses to the Cape Floristic Region of South Africa. These two regions share many similarities: importantly, they're both incredibly beautiful biodiversity hotspots! But unfortunately, they're threatened by habitat loss and degradation, including the impacts of invasive alien species. Dieback caused by *P. cinnamomi* is recognised as a key threat to the biodiversity of southwest of Australia.

Biosecurity best practice workshop at Kirstenbosch National Botanical Garden in October 25-26th 2022 with representatives of FABI, SANBI and Prof Brett Summerell from RBG Sydney.

However, our knowledge of the impact of *P. cinnamomi* in the CFR is limited. One of the challenges of managing *P. cinnamomi* is how easily it can be spread – with humans being the most common vector. Once established in an area, eradication is usually not feasible, so raising awareness among stakeholders is key. This has been a huge focus of campaigns in Australia, like the "Arrive Clean – Leave Clean" messaging and Green Card Training of the Dieback Working Group. I hope to establish similar dieback awareness training tailored to the South African context.

In the current global context of climate change and global trade could you tell us what you think the key impacts are for forestry and botanic gardens in terms of pest and disease management?

The impacts of climate change and the movement of pests to new environments through global trade will continue to present us with significant challenges. We're already seeing an increase in the impact of native pests and pathogens due to human-induced changes causing greater plant stress. In addition to the unintentional movement of pests through trade, climate change is also presenting opportunities for pests to spread beyond their traditional range, where they can encounter naïve hosts lacking coevolved resistance. One of the challenges is that we're often dealing with unknowns. There's many examples of devastating pest and disease outbreaks caused by species that weren't previously known to be problematic or weren't even known to science. To be able to address this, we need strong biosecurity measures, robust monitoring and collaborative research efforts, which is where networks like the IPSN play a really important role.

Ganoderma enigmaticum on *Combretum* sp.

What proactive measures have you found most effective in preventing the introduction and spread of invasive pests and pathogens in forestry and botanic gardens?

Simple but essential practices like cleaning footwear and tools can significantly reduce the risk of inadvertently transporting pests and pathogens between locations. Also, getting nursery stock raised off the ground can reduce the risk of pathogen spread. Early detection of new pest and pathogen issues relies on routine visual inspections, so having trained staff who can identify when there's a problem that needs to be escalated and having systems in place to facilitate submission of samples for diagnostics is crucial. Ultimately, fostering a strong culture of plant health awareness and biosecurity best practice among staff is key. When staff feel connected to plant health procedures and understand their importance, they are more likely to consistently adhere to best practices and not take shortcuts that could compromise biosecurity measures.

What are the key steps involved in diagnosing plant diseases in forestry and botanic gardens, and what technologies or methodologies do you rely on?

Some diseases are easy to diagnose as the causal agent produces signs, like the mushrooms and mycelial mats of *Armillaria*. But some are much harder to tease out, and sometimes even determining whether the cause is biotic or abiotic (e.g., temperature extremes, water deficit or excess etc) can be the first hurdle. Getting as much information as possible on the plant and site history is always a good starting point. Collection of samples for analysis – this is guided by the specific symptoms being observed, which usually provides clues as to what kind of pathogen may be involved. For well-studied pathogens, we usually have a good idea of their host range and the kinds of symptoms they induce, as well as robust diagnostics protocols. But if the diagnostics job doesn't fall into this category, then it becomes a bit like detective work. I rely a lot on traditional techniques liked culturing on specific media, rhizosphere soil baiting if I suspect *Phytophthora* is involved, and microscopy. Once I have a suspect, confirming species identity by DNA sequencing.

Are there any new research developments or technologies in the field of plant and pest disease management that you are excited about?

Yes, there's a few new developments that I'm excited about. Advances in molecular technologies are really helping us increase the 'visibility' of microbes. Big data approaches are helping us understand and predict pest and pathogen traits. We can use big data analytics and predictive modelling to better inform our understanding of invasion processes and to forecast pest or disease outbreaks, as well as assess potential impacts under changing environmental conditions. I think this sort of proactive approach can significantly improve our decision-making and resource allocation.


Water filtering

Can you discuss the significance of biosecurity and pest and disease monitoring in the conservation of plant biodiversity, particularly in the context of your work in South Africa?

Historically, much of the focus in plant health has been on agriculture and commercial forestry, but it's essential that we recognise the broader implications for natural ecosystems. Even though invasive species are widely recognised as significant drivers of environmental change, microbial threats have often been overlooked. This is the case in South Africa too, despite leading the way in many aspects of invasive species management, the impact of invasive pests and pathogens on natural ecosystems remains poorly understood. Botanical gardens under the stewardship of the South Africa Biodiversity Institute (SANBI) have a strong focus on cultivating native plants, so these gardens serve not only as valuable *ex situ* collections, but also as sentinel sites for detecting and understanding potential threats to natural ecosystems. By monitoring pests and diseases in these gardens we can enhance our ability to detect and mitigate emerging plant health threats, which contributes to broader biodiversity conservation efforts across South Africa's rich landscapes.

As a key partner in the International Plant Sentinel Network, can you explain the impact of the network in your work, particularly in South Africa?

Among the highlights of my work with the SANBI National Botanical Gardens has been the plant health training workshops that we've run. The IPSN provided organisational support and facilitated connections with international plant health experts, and their assistance in bringing Chris Malumphy and Brett Summerell over for these workshops was just brilliant. They both have years of experience and come from different backgrounds with different expertise, so being able to have them visit has greatly benefited both myself and the gardens.

How do you collaborate with other research institutions and botanic gardens to share knowledge and resources on pest and disease management?

I'm engaged in partnerships with research institutions both in South Africa and globally. These collaborations allow us to combine our expertise and share data, which can help us anticipate future plant health threats and develop effective management strategies, particularly for challenging pests like the polyphagous shot hole borer. I supervise postgraduate students across multiple institutions, which further supports collaborative research efforts. Additionally, I participate in SANBI's Horticultural Enrichment Forum, a forum established to promote knowledge sharing among SANBI gardens and facilitate capacity building. I've also conducted training workshops on biosecurity best practice, surveillance methods, sampling and diagnostic techniques and pest management strategies. My goal with these activities is to empower others to play an active role in safeguarding plant health.

How do you engage with the public and educate stakeholders about the importance of plant health and biosecurity in forestry and botanic gardens?

I've done this through various traditional communication methods like writing articles for popular science publications, radio interviews and podcasts, and conducting presentations and workshops with stakeholders. But I've also had the opportunity to be involved in a couple of SciArt projects, which has been a very rewarding experience. I think the fusion of art and science is a wonderful way for us to communicate important scientific messages, and it also presents us with novel ways to explore the world.

What advice would you give to other forestry researchers or botanic garden managers looking to enhance their pest and disease management practices?

My advice would be to invest in staff education and capacity building, and prioritise early detection through robust monitoring systems. Make the most of platforms like the IPSN to build collaborations and foster partnerships for knowledge sharing.

ARTICLES

Authors: Ricardo C. Miguez, Marcus Nascimento Santos, Maria Lucia F. Teixeira Moscatelli and Cecilia Armesto

INTEGRATED PEST AND DISEASE MANAGEMENT AT THE BOTANIC GARDEN OF RIO DE JANEIRO: CURRENT AND FUTURE PERSPECTIVES

The framework of Integrated Pest and Disease Management (IPDM) adopted by the Phytosanitary Laboratory of the Botanic Garden of Rio de Janeiro (JBRJ) protects plant collections and promotes sustainable practices through ecologically responsible strategies. This multi-level approach ranges from on-site monitoring of pests and diseases to minimally invasive treatments designed to safeguard the thriving ecosystem within the arboretum.

Above and top: Botanic Garden of Rio de Janeiro (JBRJ) (Alexandre Machado)

Introduction to the JBRJ

Established in 1808, the Botanic Garden of Rio de Janeiro (JBRJ) has significantly contributed to advancing plant and agricultural sciences in Brazil. It opened as an acclimatization garden for commercial species in the then-capital of the Portuguese empire. However, by 1822, the garden already showcased the diversity of the tropical flora, attracting renowned naturalists and scientists like Charles Darwin and Albert Einstein (Bediaga *et al.*, 2008; Oliveira, 2008).

In the late 19th century, the garden hosted the National School of Agriculture, which aimed to modernize Brazilian rural production and disseminate studies on soil fertility and plant nutrition. The school introduced new cultivation tools and machinery, promoting a more scientific and professional approach to agriculture in the country (Bediaga, 2010).

In the present-day, JBRJ displays a vast collection of plant species from around the world, growing in a tropical climate that offers ideal conditions for the proliferation of plant pathogens and pests all year round.

This work presents the management strategies employed by the institution's Phytosanitary Laboratory and discusses future directions for pest and disease management.

Integrated Pest and Disease Management (IPDM) at JBRJ

In addition to species conservation and research, JBRJ is a popular site for leisure activities and environmental education. Such diverse roles lead phytosanitary practices towards Integrated Pest and Disease Management (IPDM), which ensures the protection of the ecosystem and the well-being of the people who visit and work in the arboretum.

1. **Monitoring** is the first stage of IPDM. Technicians of the Phytosanitary Laboratory conduct weekly inspections of leaves and trunks for signs of biotic diseases and look out for pests, such as termites, beetles, palm weevils, and leafcutter ants. If any symptoms or unusual signs are detected, material is collected for further analysis.

2. The collected samples move on to the second stage: **identification**. Accurate laboratory identification supports informed management decisions, preventing harm to beneficial insects and avoiding unnecessary costs associated with treating issues that do not pose a phytosanitary concern, like end-of-cycle fungal leaf spots.

3. The next stage is the establishment of what we named the "**Tolerable Damage Level**" (TDL), which encompasses two agronomic concepts: "Economic Damage Level" and "Control Level". The "Economic Damage Level" is the threshold where the cost of not controlling a disease or pest becomes greater than implementing control measures. The "Control Level" indicates the pest population density that should trigger control actions (Riley, 2008). In arboreta, where collections are not regarded in economic terms, the TDL helps determine the urgency to start phytosanitary measures and the best treatment options based on the importance of the affected specimen and the nature of the pest or disease.

4. The fourth stage in IPDM is **prevention**, which focuses on avoiding the introduction of pests and diseases. For this a period of phytosanitary quarantine is mandatory, during which seedlings and saplings should be kept in isolated and screened greenhouses for a few weeks. A careful inspection for pests and eggs must be conducted on the plants and in the potting mix, while any leaves or branches showing signs of disease should be further investigated and destroyed. During isolation, chemical treatments, which are not permitted inside the arboretum, may be employed. As the specimen is cleared for planting, its roots should be examined when removed from the container. If technicians suspect the presence of nematodes, a root sample should be taken to the laboratory for analysis before proceeding.

5. When phytosanitary intervention is necessary, we move on to the **control** stage. According to IPDM, control methods must be the least disruptive and the most sustainable available, balancing the need to treat the affected plant and the obligation to preserve the surrounding ecosystem.

6. The final stage involves **evaluating results** and refining the management plan to ensure its effectiveness and adaptability to changing environmental conditions and pest behavior.

In the next sections, we will discuss the practical applications of IPDM, providing tables that outline key information regarding organisms of interest, affected plant parts, and the measures adopted for impact mitigation.

Botanic Garden of Rio de Janeiro (JBRJ) (Alexandre Machado)

Integrated Pest Management (IPM) at JBRJ

Pest categories and control methods

Insects	Blattodea (suborder Isoptera: termites), Coleoptera (beetles, weevils), Hemiptera (aphids, scales, whiteflies and pentatomids), Lepidoptera (caterpillars), Hymenoptera (leafcutter ants), Orthoptera (grasshoppers and crickets), Thysanoptera (thrips).
Arachnids	Eriophyidae, Tetranychidae, Tarsonemidae, Tenuipalpidae.
Nematodes	Not a present concern.
Affected plant parts	Galls or damage to leaves, roots, bark, trunks, flowers, fruits, and seeds (feeding on the tissues or piercing/ boring holes to lay eggs). Borers introduce pathogens, which can develop into vascular diseases. Pest termites affect the structural integrity of trees and disrupt the flow of water and nutrients, leading to decline in tree health.
Management measures	Neem oil; entomopathogenic fungi and bacteria Pruning to remove resistant infestations or gall midges in susceptible plants Judicious use of selective pesticides.

Our most recurrent issues from the table above are leafcutter ants and pest termites. Both must be correctly identified to protect their beneficial counterparts, which play a key role in nutrient recycling and improving soil health. Hills or mounds of beneficial species are sometimes signaled to educate visitors about their benefits.

The control of pest termites and leafcutter ants with biological agents remains a challenge, but research on potential solutions is ongoing (Teixeira *et al.*, 2010; Santos, 2016 & 2020).

The use of traps to capture pest insects is often crucial to identify the specific pest responsible for damage, particularly in the case of beetles and palm weevils. However, the widespread application of this technique is avoided at JBRJ to prevent inadvertently trapping beneficial insects (Teixeira 2009).

Botanic Garden of Rio de Janeiro (JBRJ) (Alexandre Machado)

Integrated Disease Management (IDM) at JBRJ and McNew's Disease Classification

Identifying all diseases affecting the thousands of specimens in the collection through laboratory analysis is economically unfeasible. Instead, an adapted version of McNew's (1960) disease classification system is used to estimate pathogen identities. This approach is often effective to understand the origin and evolution of a particular pathogen and helps guide control methods.

Diseases are categorized into six groups, exemplified in the tables below with pathogens identified in our arboretum:

Group I: Diseases Destroying Storage Organs

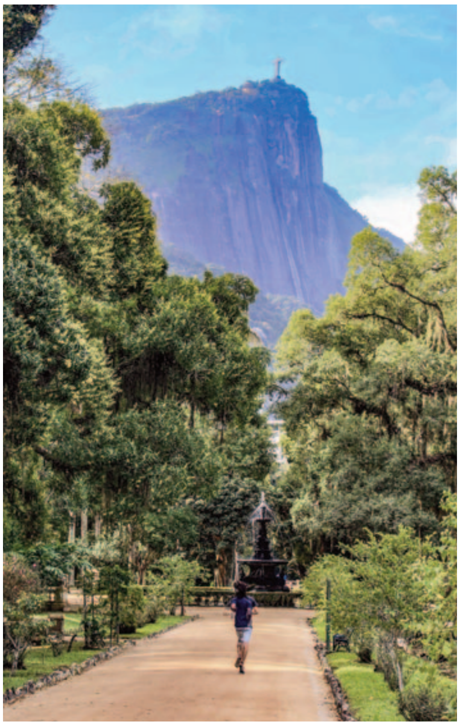
Aspect	Details
Focus	Pathogens that cause soft or dry roots.
Affected plant parts	Seeds, fruits, roots, rhizomes, and tubers.
Common pathogens	*Penicillium* (blue/green molds), *Sclerotinia* (cottony rot, watery soft rot), *Botrytis* (gray mold), *Phytophthora*, *Armillaria*, *Fusarium*, *Rhizoctonia*, and *Erwinia* (bacterial soft rot).
Management measures	Reduce inoculum in the environment: control soil moisture, ensure adequate sunlight and good air circulation. Dispose of contaminated or dead plants. Avoid injuries to plant tissues.
Additional measures	Use of antifungal biological agents. Promote soil colonization by mycorrhizae. Employ compost and organic matter to improve soil health.

Group II: Diseases Affecting Young Tissues

Aspect	Details
Focus	Young tissues, when resistance to pathogens is lower.
Affected plant parts	Young tissues
Common pathogens	*Rhizoctonia* (damping-off), *Pythium* (root rot), *Fusarium* (wilt), and *Phytophthora*.
Management measures	Reduce inoculum in the environment: control soil moisture, ensure adequate sunlight and good air circulation. Dispose of contaminated or dead plants.
Additional measures	Employ antifungal biological agents. Promote soil colonization by mycorrhizae. Use resistant plant varieties where available.

Group III: Diseases Affecting Roots

Aspect	Details
Focus	Affecting roots and the absorption of water and nutrients
Affected plant parts	Roots
Common pathogens	*Fusarium*, *Phytophthora*, *Rhizoctonia*, *Thielaviopsis*.
Management measures	Reduce inoculum in the environment: control soil moisture, ensure adequate sunlight and good air circulation. Dispose of contaminated dead plants.
Additional measures	Employ antifungal biological agents. Promote soil colonization by mycorrhizae. Enhance soil health with organic amendments.



Botanic Garden of Rio de Janeiro (JBRJ) (Alexandre Machado)

Group IV: Vascular System Diseases

Aspect	Details
Focus	Diseases affecting the vascular system, compromising the transport of water and nutrients.
Symptoms	Wilting, yellowing, plant death.
Common pathogens	*Botryosphaeria*, *Fusarium*. (vascular wilt), *Ceratocystis*, *Lasiodiplodia*, *Schizophyllum*, *Verticillium*, *Phytophthora*, *Ralstonia* (bacterial wilt), *Xylella* (leaf scorch), *Erwinia*, *Pantoea*, and *Pseudomonas*.
Transmission	Insects, animals, tools, plant debris, soil, water, wind.
Management measures	Insect control (difficult if not visible on the plant). Resistance inducers: salicylic acid, methyl jasmonate, harpin proteins, benzothiadiazole, potassium phosphite.

Botanic Garden of Rio de Janeiro (JBRJ) (Ricardo Miguez)

Botanic Garden of Rio de Janeiro (JBRJ) (Ricardo Miguez)

Botanic Garden of Rio de Janeiro (JBRJ) (Ricardo Miguez)

Group V: Leaf Surface Diseases

Aspect	Details
Focus	Leaf surface cover or damage, interfering with respiration/transpiration and photosynthetic area.
Symptoms	Leaf spots, discoloration.
Common Causes	Lichens (symbiotic association between algae/cyanobacteria and fungi). *Cephaleuros* (algal leaf spot). Fungi: *Alternaria*, *Austropuccinia psidii* (sin. *Puccinia psidii*), *Bipolaris*, *Botrytis*, *Capnodium* (sooty mold), *Cercospora*, *Cladosporium*, *Corynespora*, *Curvularia*, *Diplocarpon rosae*, *Diplodia*, *Elsinoë*, *Erysiphe*, *Gloeosporium*, *Guignardia*, *Hemileia*, *Lecanosticta*, *Lasiodiplodia*, *Melanconiella* (previously *Meliola*), *Moniliophthora*, *Mycosphaerella*, *Oidium*, *Pestalotia*, *Pestalotiopsis*, *Phoma*, *Ramularia*, *Rhizopus*, *Septoria*, and *Stigmina*. *Oomycetes: Bremia*, *Peronospora*, *Phytophthora*, and *Pseudoperonospora*.
Impact	Lichens: interfere with photosynthetic area but contribute to carbon and nitrogen fixation, bioaccumulation, and biodegradation of minerals. Algae: form thalli between the cuticle and epidermis of hosts, causing chlorosis and branch death when their growth is intercellular. Fungi/ Oomycetes/ bacteria: interfere with photosynthetic area and tissue damage.
Management measures	Control moisture levels by promoting air circulation and adequate sunlight through pruning. Disposal of affected leaves and branches. Algae: use of bacteria from the genus Streptomyces, which acts on algae and some phytopathogenic fungi, representing an alternative with dual function. Fungi/ Oomycetes: resistance inducers (potassium phosphite), Bordeaux mixture, 3% hydrogen peroxide (H_2O_2), lime sulfur; . *Capnodium*: 3% hydrogen peroxide (H_2O_2) and control of piercing-sucking insects/ acari with neem oil or pheromone traps.

Group VI: Diseases Altering Physiological and Metabolic Processes

Aspect	Details
Focus	Plant physiology and metabolism, affecting growth and development
Symptoms	Wilting, chlorosis, necrosis, cankers on trunks and branches, nutrient diversion.
Common pathogens	*Agrobacterium* (crown gall), *Xanthomonas*, *Pseudomonas*, *Pantoea*, *Pectobacterium*, *Xylella* (leaf scorch), *Erwinia* (fire blight), and viruses.
Transmission	Insects, tools, plant debris, soil, water, wind
Management measures	Biological control: beneficial microbes (*Bacillus* spp., *Pseudomonas* spp., *Streptomyces* spp.). Destruction of infected plant material; Quarantine measures. Regular monitoring and early detection through molecular tests.
Additional measures	Resistance inducers: salicylic acid, methyl jasmonate, harpin proteins, benzothiadiazole, potassium phosphite. Promote plant health with adequate nutrition and proper cultural practices. Control of piercing- sucking insect/ acari populations with neem oil or pheromone traps.

Future perspectives

The use of insects and mites for the biological control of plant pests is an emerging trend, but its implementation should be carefully studied for potential environmental impacts on collections. Insects introduced accidentally can have a devastating effect on their beneficial counterparts and damage untargeted plants (Miguez *et al*., 2023).

Similarly, the use of bacteria and fungi to control plant diseases has been widely studied in agriculture globally. However, there is a considerable risk that these agents could turn phytopathogenic themselves when applied to plants that have not been extensively studied (Elad, 2000; Elad & Freeman, 2002; Lahlali, 2022; Santos *et al*., 2022).

In recent years, the field of resistance inducers, designed to bolster plants' natural defense mechanisms, has seen significant advances. The next generation of resistance inducers, such as those derived from algae extracts or chitin and chitosan (sourced from fungal cell walls and insect exoskeletons), promises to enhance plant responses to numerous biotic threats (Browse, 2009; Hadwiger, 2013; Miguez, 2024). If successful in the context of arboreta, these could become invaluable tools for the palliative care of untreatable plant diseases, especially for species with high conservation importance and for those that cannot be replaced in our collections.

Botanic Garden of Rio de Janeiro (JBRJ) (Alexandre Machado)

Furthermore, as climate change increases pest and disease pressure on botanic garden collections, we must prepare our arboreta to face these challenges and their impacts on the nature of pests, pathogens, and plant health. Warmer temperatures can extend the growing season of harmful organisms, leading to more pest generations per year, and can also facilitate their spread into new areas. Extreme heat and drought conditions weaken plants, making them more vulnerable to infections and pest attacks. By increasingly integrating phytosanitary management with strategies to replace aging and disease-prone specimens, we can help ensure the continuity and representativeness of our collections.

Ultimately, adopting sustainable pest and disease management practices in botanic gardens not only protects collections but also sets a broader model for eco-friendly agricultural methods. Through their commitment to research and environmental education, botanic gardens can showcase the effectiveness of Integrated Pest and Disease Management (IPDM) across various contexts, from food production to habitat conservation. As a result, our institutions can play a pivotal role in advancing towards sustainable relationships with nature, inspiring the widespread adoption of environmentally conscious practices and fostering a deeper appreciation for environmental stewardship.

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CASE STUDY 1

PRESERVING BIODIVERSITY: COMPREHENSIVE PEST AND DISEASE MANAGEMENT AT GHENT UNIVERSITY BOTANICAL GARDEN

Ghent University Botanical Garden Victoria greenhouse

The Ghent University Botanical Garden, encompassing 2.75 hectares and featuring 4000m² of greenhouses, is home to a diverse array of over 10,000 taxa. This rich collection fosters an environment conducive to both beneficial and harmful organisms. Maintaining these collections in optimal condition necessitates preemptive measures, continuous monitoring, and meticulous management of diseases and pests. A profound understanding of diseases and damage patterns is essential, and gardeners and staff are regularly trained to identify beneficial and harmful insects and promptly report any damage.

Optimal Growing Conditions

Optimal growing conditions are crucial as weakened plants are more susceptible to pests. Understanding each plant's natural habitat helps in determining the appropriate location, soil composition, irrigation schedule, and climatic zone, fostering an environment where plants can thrive. Changes in environmental factors often precede damage patterns. Variations like colder temperatures, inadequate or excessive light exposure, or imbalanced fertilizer application can significantly affect plant populations. Thus, vigilance in monitoring environmental variables as well as damage patterns is necessary.

Prevention

Diseases and pests can infiltrate the Ghent University Botanical Garden through various pathways, including visitors or natural dissemination into the garden's ecosystem. A recent example is the box tree moth infestation, which caused significant harm to the boxwood collection. Vigilance is also crucial during the exchange of living plant specimens with other botanical entities.

Notably, about 23% of the plants in the garden's living collections originate from wild specimens, posing a risk for introducing harmful organisms.
Dugardin et al., 2023

Annually, the garden receives a substantial influx of new plant material, mainly from seed exchanges with other botanical institutions through the index seminum. Unfortunately, this material is typically not screened for harmful organisms nor accompanied by a plant passport. Moreover, plants or cuttings from these exchanges often evade scrutiny.

Ghent University Botanical Garden view of the pond

Therefore, new plant material should be quarantined and monitored for several weeks to detect any diseases or pests. Although incoming seeds are not currently disinfected before integration, seedlings are rigorously monitored upon germination.

Inside the Greenhouses: Integrated Pest Control

Integrated Pest Management (IPM) was introduced in the Ghent University Botanical Garden 23 years ago to establish an ecological balance, preventing major outbreaks of harmful organisms. IPM aims to foster a healthy environment for both horticulturists and visitors. Given that living plants are not for commercial sale, a degree of damage tolerance is accepted (Ehler, 2006). Beneficial and harmful insects coexist, with harmful insects peaking in spring followed by beneficial insects. By summer's end, both populations stabilize. If necessary, additional beneficial insects are introduced during spring and early summer.

The success of IPM relies on understanding the life cycles of both pests and beneficial organisms (Flint & Dreistadt, 1998). Effective monitoring, conducted from May to September, deploys the correct organisms at the right times to minimize costs and achieve optimal outcomes. Biological control agents are deployed once damage thresholds are surpassed. This strategy has effectively curtailed pest damage in the greenhouses, reducing pest populations to acceptable levels. Remedial actions include enhancing greenhouse climate conditions, mechanical control through pruning or hosing, and introducing beneficial insects. Occasionally, localized chemical interventions are necessary, using methods that minimally disrupt the biological balance (Dugardin & Goetghebeur, 2018).

Outdoor Collections

Chemical interventions are prohibited in the outdoor collections area, which is open to the public, in compliance with Flemish legislation (Belgisch Staatsblad, 2013). Here, disease and pest management rely on preventive measures and vigilant monitoring. Mechanical interventions, such as selective pruning or removal of individual plants, remain viable options.

Regular surveillance prevents significant disease and pest outbreaks. The Ghent University Botanical Garden participates in a regional early warning network for nursery plants, using pheromone traps to monitor population sizes and intervene with targeted strategies when necessary.

New Emerging Pests and Diseases: International Plant Sentinel Network

Climate change has led to increasingly hot, dry summers and relatively damp, warm winters, stressing many plant species and making them more susceptible to diseases and pests. The proliferation of novel pathogens from neighboring countries necessitates heightened vigilance. Collaborative efforts with National Plant Protection Organizations (NPPOs) and experts are crucial for early threat detection and mitigation.

The International Plant Sentinel Network (IPSN) supports these efforts by providing tailored information, deploying plant health checkers, facilitating workshops, and offering guidance. The Ghent University Botanical Garden, a member of IPSN, conducts semi-annual surveys targeting organisms on *Rosa*, *Pinus*, *Quercus*, and *Fagus*. Leading efforts within the Belgian network (Association of Botanical Gardens and Arboreta-VBTA), the garden coordinates activities and encourages partner gardens to participate. Currently, nine gardens actively engage in these initiatives.

> *Systematic monitoring, even without detecting targeted organisms in recent years, provides valuable insights into the health of trees and shrubs.*

Standard protocol uses the ISPN Plant Health Checker. Participation in IPSN enhances vigilance for harmful organisms, empowering staff to maintain thriving plant collections.

Conclusion

The Ghent University Botanical Garden is a bastion of biodiversity, meticulously tending to approximately 10,000 taxa. Through proactive measures, continuous monitoring, and comprehensive management strategies, the garden maintains its collections in optimal condition, fostering an environment where both beneficial and harmful organisms coexist.

Environmental variables are crucial in the garden's ecosystem, emphasizing the importance of optimal growing conditions and vigilance in monitoring changes. Preventive measures mitigate the introduction of diseases and pests, safeguarding the garden's diverse collections. Active participation in regional and international networks enhances the detection and mitigation of emerging threats. Through collaboration and rigorous surveillance, the garden upholds its mission of preserving biodiversity and empowering staff to maintain thriving living plant collections for future generations.

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CASE STUDY 2

PRÁTICAS DE BIOSSEGURANÇA NO INSTITUTO INHOTIM, BRASIL

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Figura 1. Cateter inserido em estipe de *Phoenix canariense* (Bárbara Sales)

O Instituto Inhotim, um museu de arte contemporânea e jardim botânico, prioriza a gestão sustentável de suas coleções botânicas, adotando práticas de biossegurança e otimização de processos para salvaguardar a saúde das plantas. O Instituto segue um conjunto de estratégias para otimizar os processos de tratamentos fitossanitário, incluindo o Manejo Integrado de Pragas, o Controle Biológico e a Endoterapia. Tais atividades demonstram o compromisso do Instituto com práticas sustentáveis e inovadoras na gestão de suas coleções botânicas.

Introdução

Localizado na cidade de Brumadinho em Minas Gerais – Brasil, o Instituto adota uma abordagem científica, técnica e inovadora na gestão de suas coleções botânicas. Como consequência, as práticas de biossegurança têm sido aprimoradas ao longo do tempo junto ao investimento em capacitação e conhecimento da equipe técnica, o que leva à redução dos recursos gastos e, principalmente, à melhoria da saúde do ambiente, das pessoas e das plantas.

Para gerenciar pragas e doenças no cultivo de plantas, existem várias estratégias com diferentes graus de eficácia. As principais abordagens para o controle fitossanitário incluem o manejo cultural, o manejo preventivo, o melhoramento genético, e o controle mecânico, físico, biológico e químico. Sendo este último o mais comum na agricultura brasileira (Bortoloti & Sampaio, 2022).

Quando esses métodos são aplicados com base no Manejo Integrado de Pragas (MIP), que é baseado nos níveis de tolerância e monitoramento das populações infestantes para tomada de decisão, tem em consideração a biologia e ecologia da cultura e de suas pragas, caracterizando um conjunto de estratégias mais sustentáveis. Essa diversificação de estratégias de manejo é importante para a maior eficiência e controle, sendo, portanto, crucial a sua integração no MIP (De Oliveira & Brighenti, 2018).

O cuidado com as coleções botânicas é realizado pelas equipes de áreas verdes e curadoria botânica, diagnosticando especialmente pragas e doenças, e fazendo as complementações nutricionais anualmente. Para tanto, há uma equipe de fitossanitarismo especializada e capacitada para realizar o diagnóstico das pragas e doenças que acometem as coleções. Os tratamentos são propostos conforme com dosagem e procedimentos direcionados pelo encarregado da equipe e o agrônomo responsável pelas coleções.

Figura 2. Injeção aplicada em estipe de Acrocomia aculeata (Bárbara Sales)

Práticas de biossegurança

Como forma de criar modelos e padrões que possam ser úteis para os jardins botânicos brasileiros, o Instituto possui estruturas adequadas para o armazenamento, procedimentos de limpeza e descarte e quaisquer outros procedimentos necessários.

A casa de fitossanitarismo é uma edificação construída especificamente para abrigar os agroquímicos utilizados, equipamentos de aplicação e os principais adubos líquidos que são aplicados no Instituto, de acordo com o proposto pela legislação brasileira. Dentro dessa edificação também temos área para lavagem de Equipamentos de Proteção Individual (EPIs), tanque de reutilização de água de lavagem dos EPIs e tanque de pulverização.

Ressalta-se que todas as embalagens de produtos fitossanitários são descartadas e enviadas anualmente ao Instituto Nacional de Processamento de Embalagens Vazias (INPEV), em conformidade com a legislação.

Além disso, está prevista a construção de uma biofábrica para produção de bioinsumos de fungos e bactérias. Estes produtos serão utilizados para o controle de pragas e doenças, reduzindo o uso de químicos, o volume de aplicação, contaminação ambiental e custo.

Os procedimentos estabelecidos em Inhotim para diagnóstico e tratamento de doenças são: i) reconhecimento; ii) identificação da praga e doença; iii) escolha do produto a ser utilizado; iv) definição da dosagem, tratamento e modo de aplicação. Após determinação, a aplicação é realizada por bomba manual em pequenas áreas ou por bomba pressurizada com grande alcance em áreas maiores. As aplicações são sempre realizadas por duplas para garantir tanto a segurança do processo quanto a dos colaboradores envolvidos.

Antes de iniciar os tratamentos com agroquímico, seguimos um procedimento de escalonamento dos tipos de controle, são utilizado químicos apenas após esgotar todas as demais possibilidades. Iniciamos os controles, quando possível, com: i) limpeza manual da parte afetada e/ou dos insetos presentes; ii) remoção de partes afetadas; iii) utilização de caldas biológicas ou extratos vegetais; iv) uso de domissanitário; v) em último caso, uso de agroquímicos de produção agrícola.

Controle biológico e manejo integrado de pragas

O controle biológico, parte crucial do manejo integrado de pragas e doenças, utiliza seres vivos como predadores, parasitoides e microrganismos para controlar pragas e doenças. Esses organismos benéficos podem ser introduzidos ou já podem existir naturalmente no agroecossistema. O manejo integrado visa reduzir o uso de agroquímicos nocivos, promovendo o equilíbrio e a saúde do agroecossistema através de uma estratégia que combina medidas preventivas, culturais, biológicas e químicas. Este método reduz a dependência de pesticidas e proporciona uma alternativa mais sustentável.

É possível encontrar bioprodutos comerciais licenciados que auxiliam no controle de algumas pragas e doenças. Por exemplo, optamos por trabalhar com cepas do fungo *Trichoderma*, que ajuda no tratamento de infecções causadas por outros fungos. Para o controle de larvas, utilizamos a bactéria *Bacillus thuringiensis*. Para algumas pragas, especialmente o *Rhynchophorus palmarum*, conhecido popularmente como bicudo ou broca-de-coqueiro, adotamos o manejo integrado, combinando diferentes técnicas como ainstalação de armadilhas com feromônios, aplicação do fungo entomoparasita *Beauveria bassiana*, aplicação de óleo vegetal repelente a base de Neem (*Azadirachta indica*), e, em último caso, aplicação de inseticida na copa do vegetal.

Endoterapia

A endoterapia representa uma estratégia alternativa de manejo fitossanitário, caracterizada por seu baixo impacto ecológico (Moura et *al*., 2023). Este método envolve a administração ou infusão de um agente fitossanitário diretamente no caule de uma árvore ou palmeira. Posteriormente, este agente é transportado através dos tecidos vasculares internos da planta, alcançando até as partes mais elevadas da copa. O objetivo deste procedimento é superar as limitações encontradas nas aplicações convencionais de produtos fitossanitários, especialmente em situações em que os equipamentos disponíveis são inadequados ou ineficazes (Moura et *al*., 2023).

Em meados de 2023, a equipe técnica de fitossanitarismo recebeu treinamentos especializados em técnicas de endoterapia. As técnicas de infusão podem ser empregadas de diversas formas, como por exemplo utilizando um cateter (Fig. 1) ou infusão de baixa pressão por injeção (Fig. 2). Ambas as técnicas têm sido aplicadas conforme a estrutura morfológica das plantas. Para plantas de maior diâmetro que necessitam de aplicaçõesfrequentes, bem como para aquelas de menor diâmetro com alto valor ornamental, utilizamos técnicas de infusão de baixa pressão, ou seja, a injeção. Esta técnica permite que o composto seja aspirado e translocado na planta. O sucesso de qualquer método de infusão está intrinsecamente atrelado à taxa de transpiração da planta

Considerações finais

O Instituto Inhotim demonstra um compromisso com a gestão sustentável e inovadora de suas coleções botânicas, priorizando a saúde das plantas e a otimização dos procedimentos operacionais. Além de estar desenvolvendo processos que visam estabelecer práticas que podem ser referências para outros jardins botânicos do Brasil. Suas práticas de biossegurança abrangem uma gama de métodos de controle de pragas e doenças, que incluem o descarte responsável de embalagens de agrotóxicos de acordo com a legislação brasileira e à adoção de técnicas inovadoras como a endoterapia, enfatizando uma abordagem integrada que minimiza o impacto ambiental. Através desses esforços multifacetados, o Inhotim visa garantir a saúde e a vitalidade a longo prazo de suas renomadas coleções botânicas.

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CASE STUDY 3

THE ROLE OF BIOSECURITY IN PROTECTING IMPORTANT PLANT COLLECTIONS IN BOTANIC GARDENS

Figure 1. *Juniperus communis* infected by *Phytophthora austrocedri* in a botanic garden.

Plant collections within botanic gardens are the reason for their existence, therefore it is extremely important that plant collections are protected through biosecurity development, this should be at the top of a botanic gardens' management priorities. Botanic gardens are uniquely placed to show biosecurity best practice and talk to their visitors and wider audience about plant health. This case study explains how the Royal Botanic Garden Edinburgh has made plant health a priority through applying evidence-based solutions to their garden management.

The impacts of plant pests and pathogens (henceforth pests) have become a significant aspect of garden management in recent years (Brace et *al*., 2020) (Fig. 1). These impacts are not only on plant health, but also on visitor health and safety, and on the important conservation work underway in many botanic gardens. The situation is further exacerbated by the stress of climate change on plants, making them more vulnerable to pests (Gautam et *al*., 2013).

In almost all cases, pests are introduced into new areas by people, e.g., on or in plants, growing media, etc. (Brasier, 2008; Spence et *al*., 2020). It therefore stands to reason that the work of botanic gardens can pose a biosecurity risk (Wondafrash et *al*., 2021). As a result, they need to follow and demonstrate best practice to protect important plant collections, both in gardens and the wider environment.

Once introduced, pests often become a permanent feature, therefore 'prevention is better than cure'. This brings biosecurity up the list of management priorities for botanic gardens. Yet, knowing where to start can be challenging, biosecurity information is often diffuse and technical which makes the subject intimidating to non-specialists (Elliot et *al*., 2023a).

However, there is help available to garden managers. For example, the Royal Botanic Garden Edinburgh (RBGE) were the first large garden in the UK to go through the process of becoming Plant Healthy Certified. This externally audited certification scheme allows a business or organisation to examine their biosecurity processes and improve them over time. Scheme applicants are audited against the requirements of the scheme's Plant Health Management Standard (PHMS) on an annual basis (Plant Healthy, 2022). This has helped RBGE formalise their processes to improve biosecurity.

Figure 2. A well-managed compost heap in a botanic garden nursery.

The PHMS is publicly available and can be used as a reference document for those wishing to examine their biosecurity processes, whether they become Plant Healthy Certified or not. Plant Healthy takes the “systems approach”, examining nine areas which contain 31 requirements, covering all aspects of biosecurity (Plant Healthy, 2022).

The PHMS builds on a number of previous international examples of the systems approach. This approach was initially developed for food safety where it is known as HACCP (Hazard Analysis Critical Control Point). Over the last 20 years HACCP has been both proposed and adopted in various locations around the world to address biosecurity concerns (e.g., Parke & Grünwald, 2012). The Nursery and Garden Industry of Australia (NIASA) have adopted a HACCP systems approach for plant production and management organisations (Prince, 2008).

As a result of this work, specific, evidence-based information is available to garden managers from international research which can help to improve their biosecurity processes. Such as, managing the plant waste generated by gardening activities which can be a challenge. Waste is often piled up somewhere on site in the hope that it will eventually rot down. However, this material could contain plant pests and therefore its disposal and onward use should be carefully considered. Elliot *et al*., (2023b) produced a plant waste management guide which managers can use to ensure that plant waste is managed effectively. It describes how to store and manage waste as well as the specific conditions required for successful composting (Fig. 2).

Other elements of biosecurity for botanic garden managers to consider include water management, workspace hygiene, isolation and quarantine, record keeping, and surveillance (Kline et *al*., 2022; Parke & Grünwald, 2012). Consideration should be given to each of these elements in a systematic way so that improvements to processes can be made to protect plant collections. To help with this, botanic gardens have shared their biosecurity experiences for others to learn from, for example, Aukland Botanic Garden’s Nursery Biosecurity Project (Stanley & Dymond, 2020).

As well as managing plants within their collections, botanic gardens frequently carry out conservation work, both nationally and internationally. Habitat restoration and creation are an essential part of conservation work; however, such activities are potentially fraught with plant health risks which are rarely considered before the work is carried out (Mitchell, 2023).

Fortunately, biosecurity best practice advice has been produced to help those carrying out conservation work (Mitchell et *al*., 2023) which provides a risk framework to help practitioners develop a biosecurity risk assessment before work starts.

Botanic gardens are in a privileged position as demonstrators of horticultural and environmental best practice. They have a major role to play in the education of the public on plant health issues via engaging with their visitors and working with others on wider communications. It is essential that biosecurity is seen as a priority by botanic gardens to prevent pest introduction and spread, thereby protecting important plant collections.

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RELEVAMIENTO DE LA ENTOMOFAUNA Y ENFERMEDADES FÚNGICAS EN LA COLECCIÓN VIVA DE *QUERCUS* SPP. DEL JARDÍN BOTÁNICO ARTURO RAGONESE, ARGENTINA: LA IMPORTANCIA DEL MONITOREO Y SU CONEXIÓN CON EL PROGRAMA DEL IPSN

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Figura 1. Registro del estado sanitario de los ejemplares de Quercus spp., muestreos a través de la observación directa, trampas cromáticas pegajosas y trampas de intercepción de adultos de insectos xilófagos (Marcela Sánchez y Vanesa Mema).

Las especies del género Quercus se encuentran en una amplia variedad de hábitats. Son resistentes y de bajos requerimientos agroecológicos; sin embargo, condiciones climáticas adversas o tratamientos silvícolas inapropiados pueden predisponerlas a plagas y enfermedades. En Argentina existe escasa información sobre estas especies, siendo este trabajo una primera contribución para profundizar su conocimiento y establecer acciones de manejo que garanticen el bienestar de los ejemplares. Además, se busca generar un compromiso con el BGCI y el programa IPSN para dar aviso de alertas sobre la aparición de plagas y enfermedades, formando parte del sistema de centinela a nivel global.

Descripción del área de estudio

El estudio se realizó en el Jardín Botánico Arturo E. Ragonese (JBAER), ubicado en el Centro Nacional de Investigaciones Agropecuarias - Instituto Nacional de Tecnología Agropecuaria (INTA), localizado en 34°40'S 58°39'O y situado dentro del conglomerado urbano bonaerense, a 30 km de la Ciudad Autónoma de Buenos Aires, Argentina.

El clima de este sitio se clasifica como subtropical sin estación seca. La temperatura media anual es de 16.2°C y las precipitaciones promedio alcanzan 1.020 mm. Los suelos pertenecen a la Serie Castelar (Ca), principalmente Molisoles, con clasificación taxonómica: Argiudol Vértico, Fina, illítica, térmica. El escurrimiento es medio (grado 3) y la permeabilidad moderada (grado 4), por lo tanto, es un suelo bien drenado (clase 4). No posee salinidad ni alcalinidad sódica. El relieve presenta una pendiente media (clase 1) correspondiente a áreas suavemente onduladas, con un gradiente de 0,5 a 1%, sin piedras ni afloramientos rocosos.

La Colección Viva del JBAER está compuesta mayoritariamente por especies leñosas conservadas *ex situ*, por lo que pueden mostrarse sensibles a estreses bióticos, como el ataque de plagas, patógenos y plantas epífitas en relación con su zona de origen. La sanidad de esta colección viva es fundamental para la preservación de los recursos genéticos, ya que sustentan la mayoría de las actividades de investigación, conservación, educación ambiental y recreación.

La población cuenta con 45 ejemplares del género *Quercus* de las siguientes especies: *Q. variabilis, Q. ilex, Q. suber, Q. robur, Q. rubra, Q. palustris, Q. imbricaria, Q. cerris, Q. bicolor, Q. macrocarpa* y *Q. nigra*. Estos árboles se disponen en doble fila a lo largo de una de las calles principales del jardín botánico denominada "avenida de los robles".

Colecta de muestras

Para la evaluación de la entomofauna asociada a *Quercus* spp., se realizaron relevamientos mensuales que consistieron en: observaciones directas del material vegetal (hojas, frutos, ramas y corteza); extracción de una rama de 60 cm de longitud aproximadamente, tomada de cada uno de los árboles; y utilización de trampas cromáticas pegajosas, trampas Lindgren y trampas de intercepción de adultos para insectos xilófagos (Fig. 1). En el laboratorio se registraron el número de hojas por rama, la cantidad de insectos observados y el tipo de daño. Los individuos con signos de parasitismo fueron colocados en cajas de Petri o tubos de vidrio con tapa de algodón, mantenidos vivos sobre sus plantas hospederas con suministro adicional de agua-miel hasta la emergencia de los adultos.

Además, se registraron síntomas o lesiones foliares y signos o estructuras fúngicas. Se efectuó el censo de todos los ejemplares y se seleccionaron algunos individuos para la extracción de muestras vegetales para su análisis en laboratorio e identificación morfológica a nivel de género. Para la determinación del estado fitosanitario de cada ejemplar, se realizaron observaciones visuales buscando principalmente defectos estructurales, ya que son condicionantes del buen crecimiento, desarrollo y sanidad. Se registró la presencia de heridas, lesiones, descortezado, muerte apical, caída de ramas, cancros y cuerpos fructíferos de hongos superiores en tronco. Además, se identificaron árboles suprimidos, inclinados o con copas desbalanceadas, defectos que generan una disminución en la estabilidad. Técnicas fitopatológicas de rutina fueron utilizadas para el procesamiento del material vegetal, realizando preparados microscópicos para el estudio del tamaño y forma de las estructuras reproductivas. La identificación taxonómica a nivel de género se realizó utilizando claves citadas en la bibliografía y revisando bases de datos micológicas.

Figura 3. *Tuberculatus* sp. (Hemiptera: Aphididae) (Pilar Nuñez)

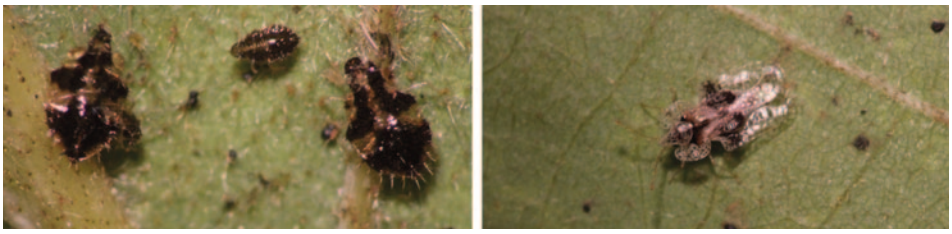

Figura 2. *Corythucha bonaerensis* (Hemiptera: Tingidae). Izquierda: Ninfas. Derecha: Adulto. (Pilar Núñez)

Los insectos plaga y sus interacciones tróficas en la colección viva de Quercus del jardín botánico

Los insectos identificados a nivel específico y hallados con las mayores abundancias fueron: *Corythucha bonariensis* (Hemiptera: Tingidae) (Fig. 2); *Tuberculatus annulatus* y *T. quercicola* (Hemiptera: Aphididae) (Fig. 3); *Megaplatypus mutatus* (Coleoptera: Platypodidae). Áfidos y tíngidos se encontraron asociados a *Quercus robur, Q. rubra, Q. macrocarpa, Q. imbricaria, Q. variabilis, Q. suber* y *Q. cerris*.

En la trama tritrófica (Fig. 4) se muestra en el primer nivel trófico (planta hospedera), las especies de *Quercus* representadas en el JBAER, seguido en el segundo nivel trófico, por las principales especies de fitófagos, y por último en el tercer nivel trófico (enemigos naturales), las familias con representantes de insectos parasitoides y predadores. Las interacciones fitófago-enemigo natural señaladas con línea punteada indican una relación potencial, que no implica haber hallado a ambos insectos en interacción concreta (ej. predador consumiendo a su presa).

En cuanto a los insectos xilófagos, mediante las capturas por trampas de intercepción se hallaron 1098 adultos de *M. mutatus*. Las capturas de adultos de *M. mutatus* se realizaron entre los meses de octubre y diciembre en cuatro trampas colocadas en las especies *Q. nigra* y *Q. rubra*.

¿Qué enfermedades fúngicas encontramos en la colección viva de Quercus del Jardín Botánico?

El 78% de los ejemplares observados mostraron lesiones foliares, pudrición seca, cancros y/o esporocarpos (cuerpos fructíferos de hongos superiores) en hojas, ramas y troncos. A partir de los caracteres morfológicos estudiados se logró identificar a los siguientes géneros: *Alternaria, Capnodium, Oidium, Pestalotiopsis* y *Phoma*.

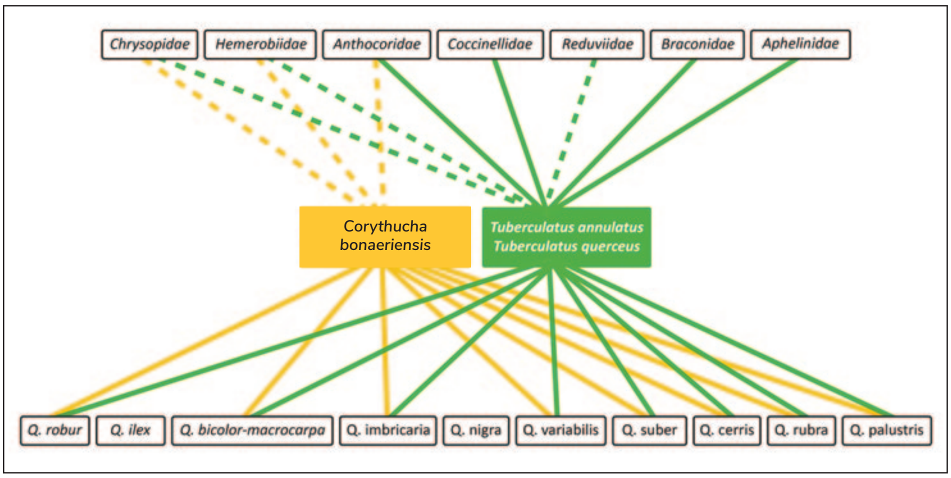

Figura 4. Trama trófica de conectancia correspondiente al "sistema Quercus" estudiado. (Lorena LaFuente)

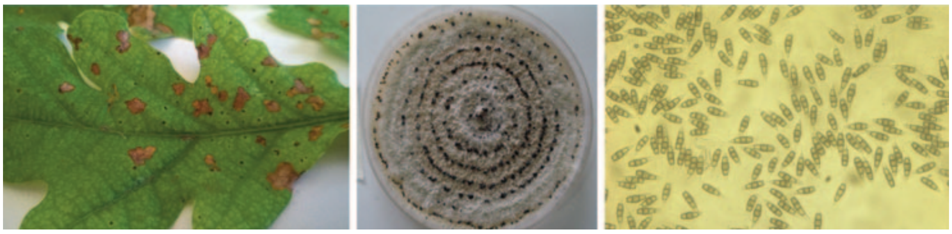

Figura 5. De izquierda a derecha: 1) Mancha foliar en hoja de *Quercus robur*. 2) Colonia del aislamiento de *Pestalotiopsis* sp. creciendo en medio de cultivo APG a los 14 días. 3) Conidios de *Pestalotiopsis* con 5 células, 3 centrales más anchas y oscuras y 2 extremas hialinas y aguzadas (40X) (Vanesa Mema)

El género fúngico más frecuente fue *Alternaria*, presente en *Q. bicolor*, *Q. cerris*, *Q. imbricaria*, *Q. nigra*, *Q. robur*, *Q. rubra* y *Q. palustris*. Su sintomatología puede observarse por la aparición de manchas puntiformes, circulares e irregulares, en promedio de 2 mm de diámetro y color castaño claro a negro dispersas aleatoriamente sobre la hoja. En el ejemplar de *Q. nigra* se observaron síntomas severos de deficiencia de nutrientes que se manifiestan por la clorosis de las hojas adultas y juveniles.

En el caso del género *Pestalotiopsis* (Fig. 5), sólo se aisló de ejemplares de *Q. rubra* y *Q. robur*. Los síntomas observados inicialmente corresponden a pequeñas manchas foliares circulares-irregulares, de color castaño rojizo con borde definido oscuro, que luego se extiende con necrosis de los tejidos. La morfología de la colonia del aislamiento de *Pestalotiopsis sp*. creciendo en medio APG (agar papa glucosado) se caracterizó por presentar ondulaciones en los bordes, con micelio blanco algodonoso y la formación de acérvulas en zonas concéntricas. Los caracteres micromorfológicos, conidios se describen con 5 células, 3 centrales más anchas y oscuras y 2 extremas hialinas y aguzadas.

Se identificaron también aislamientos con estructuras morfológicas típicas del género *Phoma* (Fig. 6), presentando una alta frecuencia en *Q. robur* (80% de los individuos afectados), además de las especies *Q. cerris* y *Q. rubra*. Los síntomas se asocian a la presencia de manchas de tamaño indefinido, con forma circular a irregular, de color pardo, las cuales se manifiestan como quemaduras o quebrado del follaje. La colonia presentó márgenes lobulados con escaso micelio aéreo radial, de color castaño-oliváceo a negro y con formación de picnidios globosos, comprimidos, de color castaño oscuro a negro, ostiolados conteniendo abundantes conidios unicelulares de forma ovalada y hialinos.

El programa IPSN en el contexto de los jardines botánicos de la Argentina

La Red Internacional de Plantas Centinela (IPSN en sus siglas en inglés) es una red mundial de jardines botánicos, institutos de sanidad vegetal y Organizaciones Nacionales de Protección Fitosanitaria (ONPF) que trabajan juntos para proporcionar un sistema de alerta temprana contra plagas y patógenos vegetales nuevos y/o emergentes.

La red IPSN lleva a cabo diferentes actividades: monitoreo enfocado de plagas y patógenos específicos en plantas huéspedes de interés; monitoreo general de especies clave para detectar plagas y patógenos que puedan estar presentes y no sean conocidas en esas especies; desarrollo y capacitación a través de talleres/cursos de identificación; creación y circulación de pósteres y otros materiales que proporcionan información sobre plagas y patógenos emergentes, sobre cuestiones generales de bioseguridad y riesgos específicos de ciertas plagas y patógenos.

En este contexto, la información obtenida a través de los estudios desarrollados desde el JBAER y dirigida por profesionales del Instituto de Microbiología y Zoología Agrícola del INTA, sirve de sustento para enriquecer al programa IPSN y capacitar al personal de los jardines botánicos participantes de la red de América del Sur. Este estudio es de importancia para actuales y futuras investigaciones, ya que, en la actualidad, existe escasa información acerca de plagas y patógenos fúngicos que afectan especies del género *Quercus* en la Argentina.

El equipo de trabajo que participó en este estudio está conformado por:

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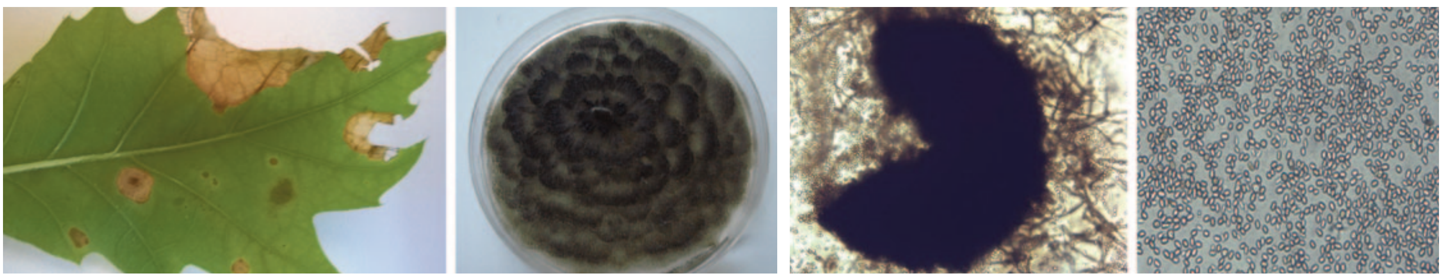

Figura 6. De izquierda a derecha: 1) Mancha foliar en hoja de *Quercus robur*. 2) Colonia del aislamiento de *Phoma sp*. creciendo en medio de cultivo APG a los 14 días. 3) Picnidio con ostiolo y 4)conidios unicelulares de *Phoma sp*. (microscopía 40X) (Vanesa Mema).

Authors: Jenni García Quiceno, José Soto and Gabriela Doria

MONITORING PLANT PATHOGENS IN THE BUTTERFLY HOUSE AT THE BOTANICAL GARDEN OF MEDELLIN, COLOMBIA

Above: Figure 1. *Siproeta epaphus* visiting *Tithonia rotundifolia*

In this article we highlight research and monitoring efforts focused on pests and diseases impacting nectariferous plants in the butterfly house at the Botanical Garden of Medellin, Colombia. The study involved the identification of phytopathogens affecting two native species (*Hamelia patens* and *Stachytarpheta cayennensis*) and one introduced species (*Tithonia rotundifolia*). We recorded symptoms and sampled affected plant parts to isolate and identify symptom-associated microorganisms, detecting pathogenic fungi and oomycetes. These findings are crucial as they represent the first step in developing biological management strategies for plant diseases in the butterfly house.

Project Context

The study of plants in a butterfly house is essential not only to ensure the health and well-being of butterflies, but also to maintain biodiversity and ecological balance at the site. The Botanical Garden of Medellin (BGM) butterfly house serves as an educational setting highlighting the vital role that butterflies play in the reproduction of flowering plants. It houses a living collection of 14 host and seven nectariferous plant species, which are crucial to the life cycle of butterflies, providing food, shelter, egg-laying sites, and other resources.

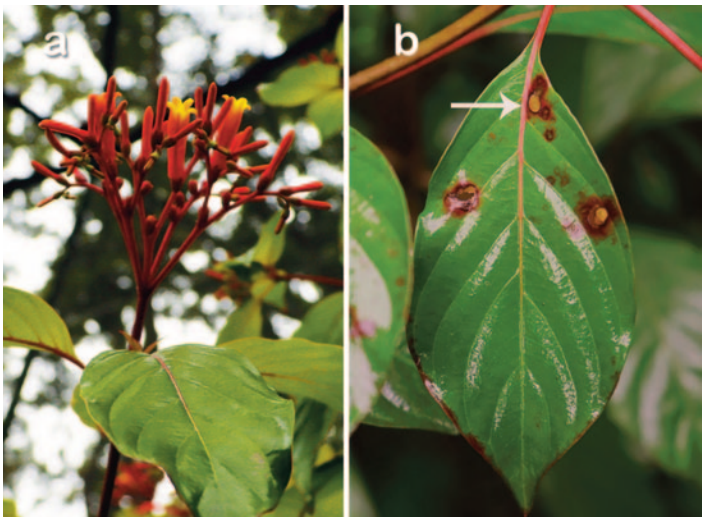

Figure 2. *Hamelia patens* (a) without and (b) with symptoms (white arrow).

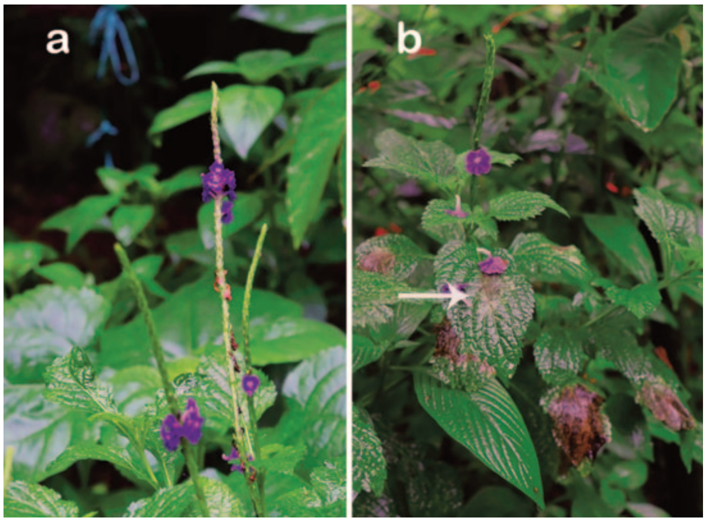

Figure 4. Stachytarpheta cayannensis leaves (a) without and (b) with symptoms (white arrow).

The host and nectariferous plants in the butterfly house are part of the approximately 1,300 species that comprise the botanical garden's living plant collection. These plants face constant threats from pests and diseases which can compromise their health, leading to plant collection losses and negative impacts on the butterfly population.

We identified plant disease symptoms in two native Colombian species, *Hamelia patens* (Rubiaceae) and *Stachytarpheta cayennensis* (Verbenaceae), and one introduced species *Tithonia rotundifolia* (Asteraceae) growing in the butterfly house at BGM. *H. patens* and *S. cayennensis* are native to tropical America, including Colombia, while *T. rotundifolia* is native from Mexico to Central America, but has been introduced and is now widely distributed in Colombia. These species have varied environmental and social uses, such as medicine and food (ColPlantA, 2024). They grow in the dry tropical biome and provide resources such as pollen and nectar to the butterflies, which are important sources of energy.

At the BGM butterfly house, butterflies such as *Siproeta epaphus* (Nymphalidae) (Fig. 1), *Heraclides anchisiades* (Papilionidae), *Heliconius charithonia* (Nymphalidae), and *Heliconius doris* (Nymphalidae), have been recorded feeding on nectar from these plant species, especially *H. patens.*

Therefore, identifying and monitoring plant pathogens is essential to develop management strategies to ensure the conservation and sustainability of the butterfly house and the BGM.

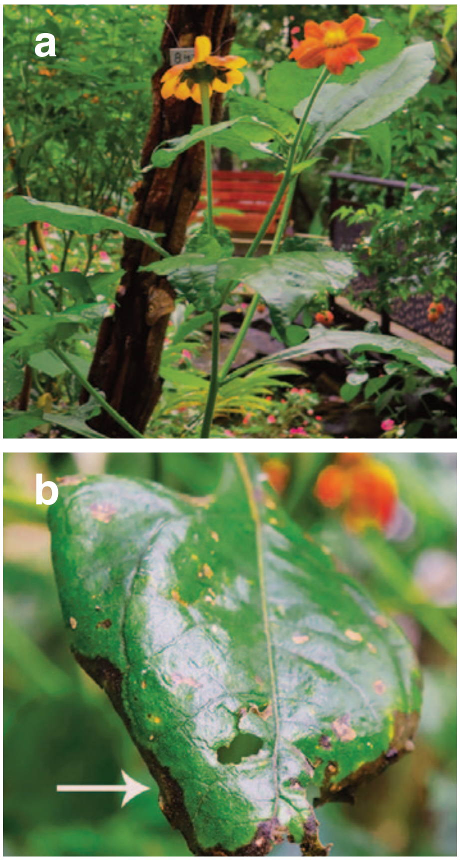

Figure 3. *Tithonia rotundifolia* (a) without and (b) with symptoms (white arrow).

Monitoring and identifying plant diseases in the butterfly house at BGM

Monitoring is one the initial strategies for preventing and controlling plant diseases. Fifteen to twenty samples of leaf tissue were collected from symptomatic plants showing spots and blight across the three species: *H. patens*, *S. cayennensis*, and *T. rotundifolia.*

To isolate fungal and oomycete pathogens, sporulation was induced on the leaf samples using the moist chamber method (García-León *et al.*, 2013). First, pieces of each leaf were disinfected using a 3% sodium hypochlorite solution and then rinsed with distilled water for one minute. Five leaf pieces were then placed in a sterile container with filter paper damped with sterile distilled water. The samples were incubated in the containers at room temperature (approximately 24 °C) for 24 to 72 hours.

When reproductive structures of fungi and oomycetes were formed, samples were taken by making imprints with adhesive tape. The spore samples were stained with a drop of lactophenol blue and mounted on a microscope slide using the same piece of tape. The samples were observed under a B-383PL OPTIKA light microscope. For identification of the pathogens, the taxonomic guide 'Illustrated Genera of Imperfect Fungi' (Barnett & Hunter, 1998) was used.

The identification results suggested the following:

- Symptoms found in the leaves of *H. patens*; such as irregular reddish-purple to brown margins and bull's eye light brown spot, were linked to *Cladosporium sp.* (Davidiellaceae) and *Peronospora sp.* (Peronosporaceae) (Fig. 2).
- For *T. rotundifolia*, which primarily showed necrotic leaf edges, the symptoms were associated with *Cladosporium sp.* and *Peronospora sp.* (Fig. 3).

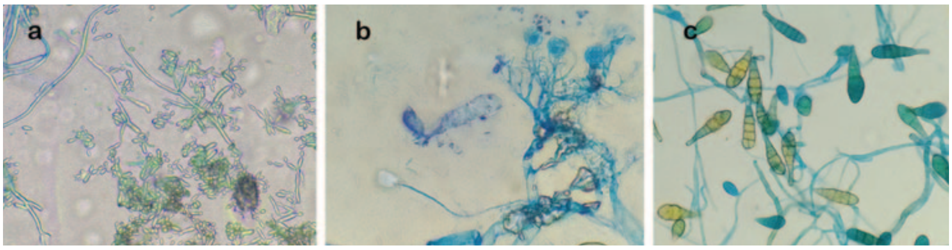

Figure 5. Microscopic view of reproductive structures of (a) *Cladosporium sp.*, (b) *Peronospora sp.* and (c) *Alternaria sp.*

- *S. cayennensis* exhibited leaves with light brown to grey spots, which could also be found on the flower buds. These symptoms were associated with *Cladosporium* sp., *Peronospora* sp., and *Alternaria* sp. (Pleosporaceae) (Fig. 4).

The identification of *Cladosporium* sp. and *Alternaria* sp. was possible by observing their asexual reproductive structures: spores, conidia, conidiophores, and hyphae, in the fresh preparations mounted with lactophenol blue (Fig. 5 a & c). In the case of *Peronospora* sp., sporangiophores and sporangia were observed (Fig. 5b).

Cladosporium sp. is an ascomycetous fungus whose spores can be found in air, soil and water bodies, making it a cosmopolitan organism. It is a dematiaceous fungus, characterized by its dark pigmentation. On the other hand, *Peronospora* sp. is a pathogenic oomycete, a mycelial organism similar to fungi that requires high humid conditions to grow. The presence of *Peronospora* sp. on plants can facilitate the secondary entry of other pathogens into affected tissues, such as *Botrytis* sp.. Lastly, *Alternaria* sp. is an ascomycete, this genus is common and has a wide distribution.

In our experience, phytopathogenic diseases in nectariferous plants can significantly impact butterfly populations at BGM's butterfly house. Butterflies are highly selective in their choice of food plants, both in the larval and adult stages, and affected plants become less attractive to them. This reduces the availability of nectar, compromising the feeding and ultimately the survival of the butterflies.

Implemented disease management strategies

Monitoring and accurate identification are key for developing strategies to reduce the impact of phytopathogen agents (Hohn, 2022), sanitation of the plant is also equally important. Pathogen characterization and identification provide the BGM additional tools to implement effective management strategies to prevent the spread of plant diseases. These strategies include increased monitoring through frequent visual inspections of the plants to detect disease symptoms or conditions conducive to pathogen growth. Complementary to monitoring, infected plants are removed and destroyed to prevent disease spread. Moreover, gardening tools such as pruners, hedge shears, and pruning saws are disinfected by spraying them with an iodine solution (2.1% active iodine at a concentration of 15 ml per liter).

We propose additional actions to strengthen current measures for preventing disease spread, including the implementation of biological strategies. These involve the use of induced systemic resistance (ISR) and biocontrol agents such as *Bacillus* sp., *Pseudomonas* sp., *Trichoderma* sp., *Burkholderia phytofirmans*, as well as treatments with jasmonic and salicylic acid, and phosphites combined with amino acids. Recent research has shown their potential in controlling and inducing defense responses against different phytopathogens (Yu et al., 2022). For instance, *Trichoderma* employs mechanisms such as antibiosis, mycoparasitism, endophytic capabilities, and the production of secondary metabolites (Hernández-Melchor et al., 2019). We suggest adding these microorganisms into the plants at the butterfly house through soil application. For this, the solution containing the microorganism should be prepared according to the manufacturer's instructions and applied around the roots of the plants once the soil has reached field capacity, the point at which the soil retains the maximum amount of water after excess has drained. Field capacity favors higher absorption of nutrients.

With this approach, we aim to ensure the vitality of native and introduced plant species, which support research and educational activities, and maintain the ecological balance within the butterfly house and the botanical garden.

The Botanical Garden of Medellin joins a global network

Since 2024, the BGM has been a member of BGCI's (Botanic Gardens Conservation International) International Plant Sentinel Network (IPSN). This network unites botanical gardens to provide an early warning system for new and emerging pest and pathogen risks by monitoring sentinel plants. It also aims to improve biosecurity best practices across botanic gardens and arboreta. Through this research project, we strive to reinforce our commitment to plant pathogen research by generating valuable data on pathogens affecting native and introduced species at the BGM's butterfly house. By monitoring and analyzing pathogen presence, the project provides a vital early warning system for diseases potentially affecting wild populations, enabling prompt action to mitigate risks and address global pathogen threats.

Acknowledgments
We would like to express our gratitude to the communications and living plant collections teams at BGM for their support in the completion of this project.

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NATURAL FUNGAL CONTROL IN MEDICINAL PLANTS: A CASE STUDY OF RIO DE JANEIRO BOTANICAL GARDEN, BRAZIL

Figure 1. Partial view of the cultivation area of the JBRJ Medicinal Plants Collection. (Patricia C. Fagundes)

Despite the efforts to keep the thematic collection of medicinal plants at the Rio de Janeiro Botanical Garden free from pesticides, plants encounter challenges from fungi and herbivores, particularly during winter and wet periods. A study conducted between July and October 2023 identified 15 medicinal plant species most affected by fungi through *in situ* observations and queries to the 'Fungi Reported on Plants in Brazil' database (Embrapa). We reviewed the literature for natural alternatives to manage fungal problems, focusing on extracts such as chamomile, nettle, horsetail, chives, and neem. The review aims to offer insights into sustainable strategies to control fungal diseases in small-scale ex *situ* medicinal plant collections.

Introduction

The study aimed to evaluate and compile data on natural alternatives for controlling and preventing fungal diseases in medicinal plants within the Medicinal Plants Collection at the Rio de Janeiro Botanical Garden (JBRJ). These alternatives aim to enhance plant health, conserve biodiversity and provide safer products to consumers, by principles of sustainable agriculture.

Established in 1986, the Medicinal Plants Collection is situated within the Arboretum of JBRJ (Fig. 1), making it one of the institution's oldest sections. This collection aims to raise awareness about the importance of knowing and preserving medicinal plants, combining scientific and traditional knowledge.

Figure 2. Examples of plants from the Medicinal Plant Collection (JBRJ) showing symptoms possibly caused by fungal diseases. (A) cercosporiosis, (B) rust, (C) white mold. (Patricia C. Fagundes)

It supports conservation, public engagement, and education, and cultivates around 170 medicinal species (more than 340 individuals), including herbs and shrubs native and non-native to Brazil.

Medicinal plants: Their role in health and benefits of pesticide-free cultivation

Medicinal plants produce bioactive substances with therapeutic properties and are widely used in health practices, rituals, culinary, and phytotherapy (Carvalho, 2015; Britto et *al*., 2018). The World Health Organization (WHO) recommends their use due to their cost-effectiveness and potential advantages over synthetic drugs, encouraging further research (Rodrigues, 2004). The growing interest in natural plant products has led to a significant increase in the use and study of these plants.

The commercialization of medicinal plant products is vital for many families in developing countries, where these products often serve as the primary therapeutic option (Tupiassú & Cardoso, 2010). Ensuring these products are free from pesticide residues is essential for maintaining quality and protecting health, as pesticide residues can pose risks like chronic toxicity and fertility issues. Recognizing the value of medicinal plants, the WHO and the Brazilian Unified Health System (SUS) have promoted their use in primary health care since the 1980s. Since 2006, the SUS National Policy on Medicinal Plants and Phytotherapeutics has supported their safe use of these plants, encouraging natural and sustainable agricultural practices. The policy also values and integrates traditional and scientific knowledge about medicinal plants (Brazil, 2006).

Cultivating medicinal plants requires attention to environmental factors, agricultural practices, planting timing and spacing, soil management, and technical supervision to ensure healthy development and prevent diseases (Poutaraud & Girardin, 2005). Integrated pest management, which includes crop rotation, organic fertilization, and biological, mechanical, and natural controls, is a sustainable strategy that benefits both producers and consumers.

Challenges and strategies in the control of fungal diseases in medicinal plants

Fungal diseases in medicinal plants can impact various parts of the plant, leading to symptoms such as defoliation, wilting, and rot. If not properly managed, these diseases can cause significant losses (Töfoli & Domingues, 2018). In Brazil, common fungal diseases affecting medicinal plants include leaf spots, rusts, powdery mildews, and downy mildews (Russomanno & Kruppa, 2010) (Fig. 2).

Effective control of fungal diseases requires producers to identify the causative agents, understand their mode of action, and implement specific preventive measures.

Nutrient-rich soils free of and contaminants are important to promote healthy plants, more resilient to pests and diseases (Blanco, 2022). Phytosanitary measures, including cultural and biological management and the use of low-toxicity natural products, play a fundamental role in controlling fungal diseases, thus increasing the productivity of medicinal plants (Herbarium, 2011; Carvalho, 2015).

Selection and cataloging of medicinal plants affected by fungal diseases in the JBRJ Medicinal Plant Collection

Between July 25 to October 4, 2023, medicinal species with aerial parts affected by fungi were selected during weekly visits to the JBRJ Medicinal Plantas Collection. During these visits, the plants were documented through weekly photographic records. A total of 15 most affected species were selected for the study (Fig. 3). The selection criteria were based on the the identification of typical symptoms of fungal infections, such as:

- Spots and scorching on the leaves (indicative of leaf spots)
- Yellowish lesions with a rusty appearance and covered by a powdery layer (indicative of rust)
- Presence of white or slightly grey mold on the upper side of the leaf (indicative of powdery mildew)
- Whitish powdery mold, which turns grey, usually on the underside of the leaf (indicative of downy mildew).

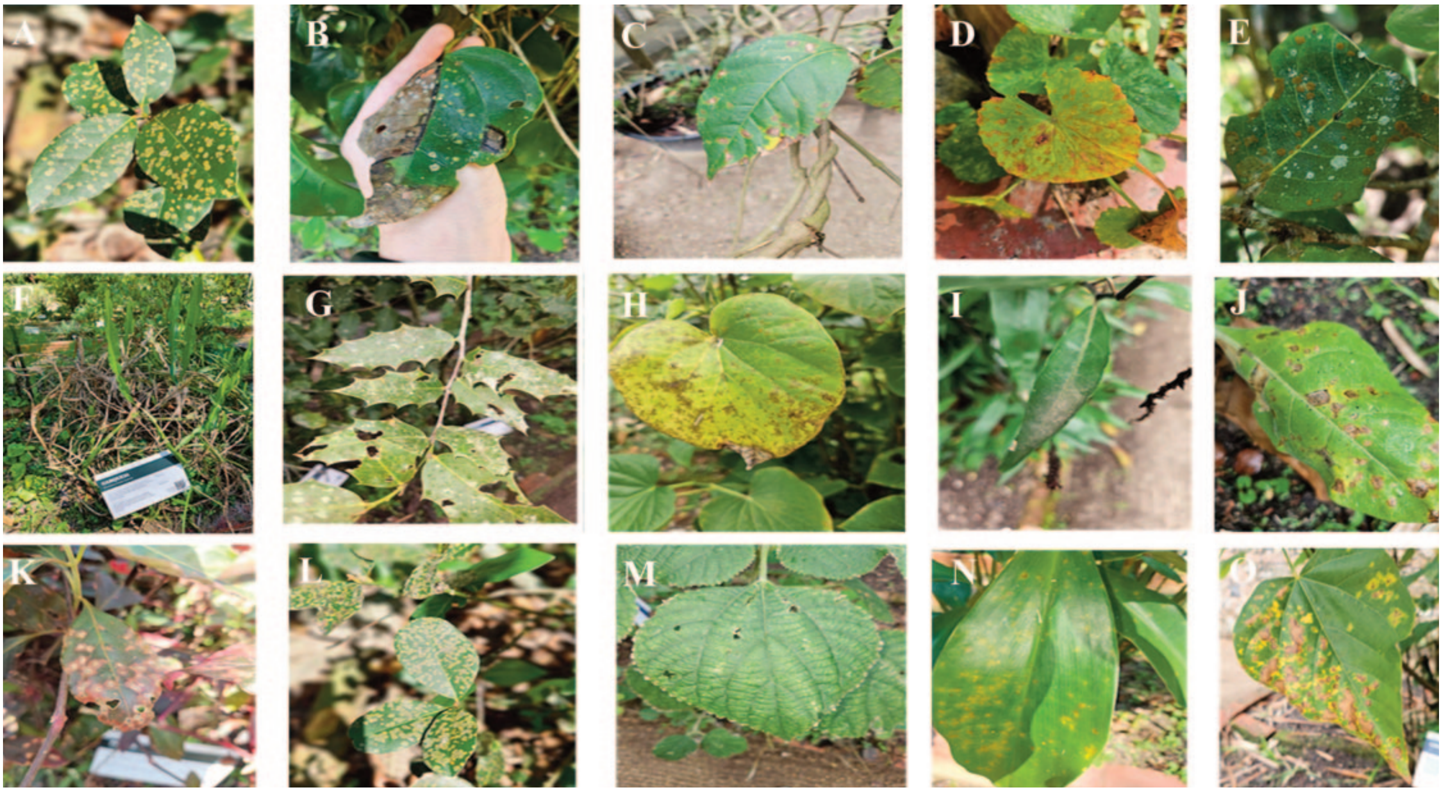

Figure 3. The 15 medicinal plants selected for the study from the Medicinal Plant Collection (JBRJ) affected by fungi. (A) *Laurus nobilis* L., (B) *Mikania glomerata* Spreng., (C) *Banisteriopsis caapi* (Spruce ex Griseb., (D) *Centella asiatica* (L.) Urb., (E) *Chrysobalanus icaco* L., (F) *Baccharis crispa* Spreng., (G) *Maytenus ilicifolia* (Mart. ex Reissek) Biral, (H) *Piper regnellii* (Miq.) C.DC., (I) *Justicia gendarussa* Burm.f., (J) *Nicotina tabacum* L., (K) *Alternanthera brasiliana* (L.) Kuntze, (L) *Eugenia uniflora* L., (M) *Boehmeria nivea* Gaudich, (N) *Costus spiralis* (Jacq.) Roscoe, (O) *Bixa orellana* L. (Patricia C. Fagundes)

During the study, the following fungal symptoms were observed on the selected medical species:

A. Leaves of *Laurus nobilis* exhibited white and brownish spots along their entire length, possibly indicating the presence of mildew alongside symptoms suggestive of rust. These symptoms persisted from July to mid-September, coinciding with leaf renewal (Fig. 4).

B. Leaves of *Eugenia uniflora* displayed symptoms like those observed in *Laurus nobilis*, including signs of rust, mildew, and a whitish substance. Leaf renewal occurred in mid-September.

C. *Mikania glomerata* exhibited dark and light spots, along with whitish dots and signs of damage possibly caused by caterpillars or beetles.

D. *Bixa orellana* presented dark and yellowish spots on the leaves throughout the study, followed by insect attacks that significantly reduced the number of leaves.

E. *Centella asiatica* showed widespread dark spots suggesting rust, with leaf renewal after mid-August.

F. *Chrysobalanus icaco* exhibited white and brown spots indicative of rust and lichen.

G. *Baccharis crispa* appeared dry, with desiccated stems, branches, and leaves, likely due to nutrient deficiency or phytopathogens. Inflorescences were observed in early October.

H. *Maytenus ilicifolia* was attacked by several microorganisms including lichens and displayed spots of different shapes and colors. The plant flowered after the rainy season, in July-August).

I. *Piper regnellii* showed yellowish and whitish spots with necrosis from the beginning of the study.

J. *Justicia gendarussa* remained asymptomatic until August, when brown and whitish patches appeared.

K. *Nicotina tabacum* exhibited dark spots surrounded by yellowing from July, with flowering observed in late August (Fig. 5).

L. *Alternanthera brasiliana* exhibited powdery whitish material on both sides of the leaves, with continuous leaf renewal throughout the study.

M. *Banisteriopsis caapi* displayed brownish and yellowish spots suggestive of fungal infestation. However, the plant later underwent leaf renewal, and no further fungal presence was observed.

N. *Boehmeria nivea* showed brown spots from July and developed lesions and showed signs of insect attacks from September.

O. *Costus spiralis* presented yellowish spots and necrotic areas from the start of observations period, with white powdery residue appearing beginning in August.

Out of the 15 species studied, 11 were affected by rust, and nine showed symptoms

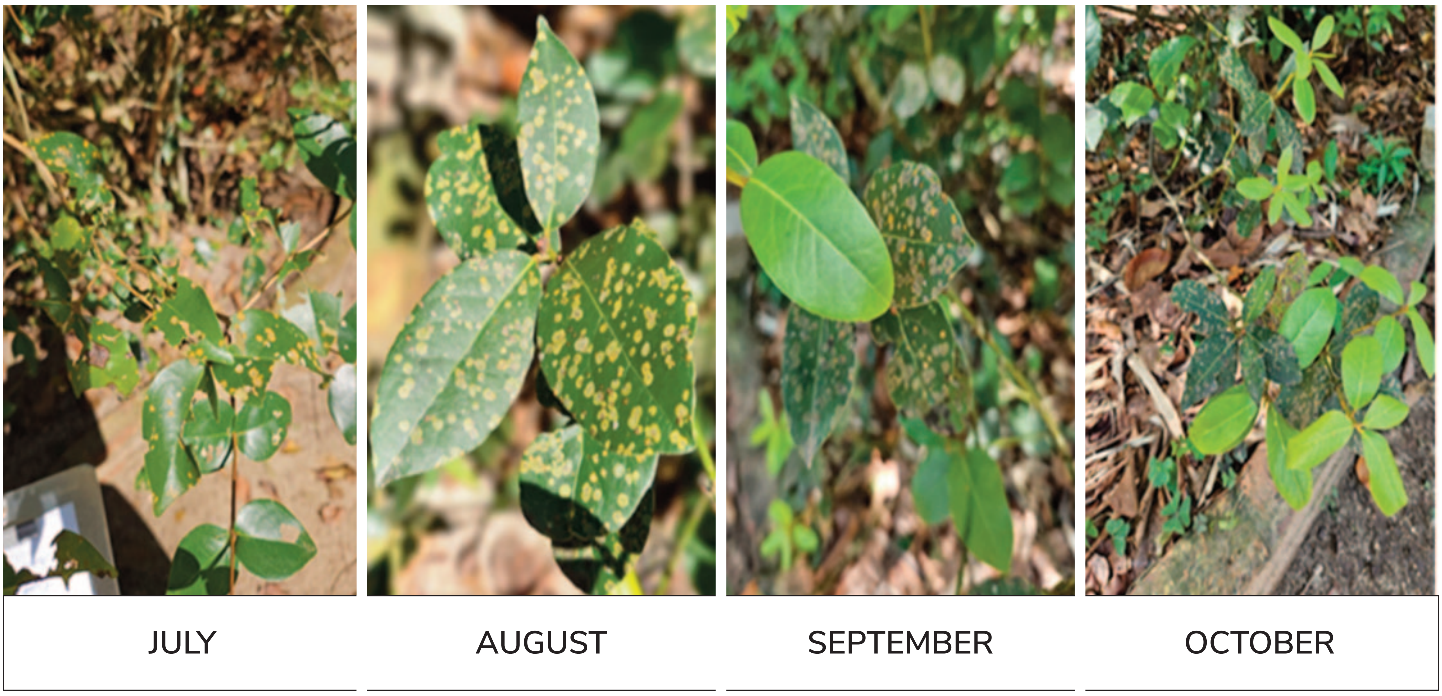

Figure 4. Leaves of *Laurus nobilis* L. observed from July to October 2023. (Patricia C. Fagundes)

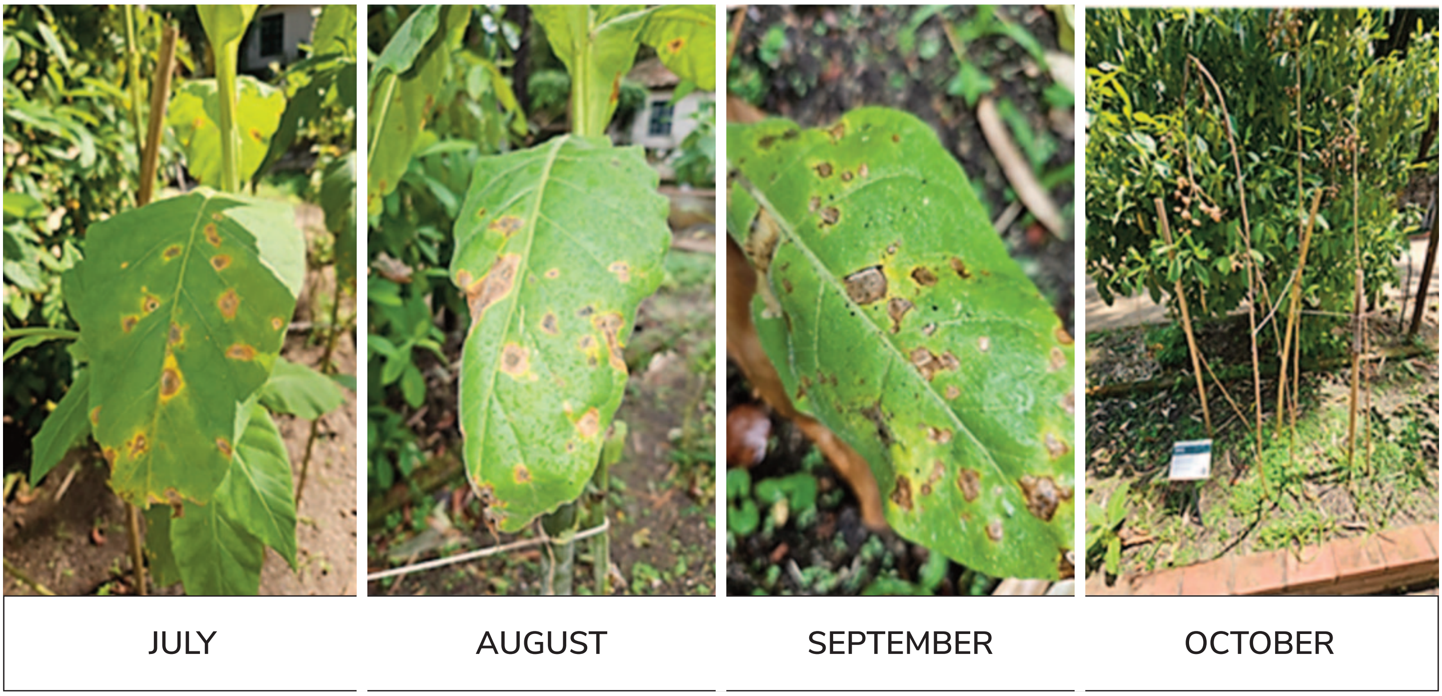

Figure 5. Tobacco leaves (*Nicotiana tabacum* L.) were observed from July to October 2023 in the Medicinal Plants Collection (JBRJ). (Patricia C. Fagundes)

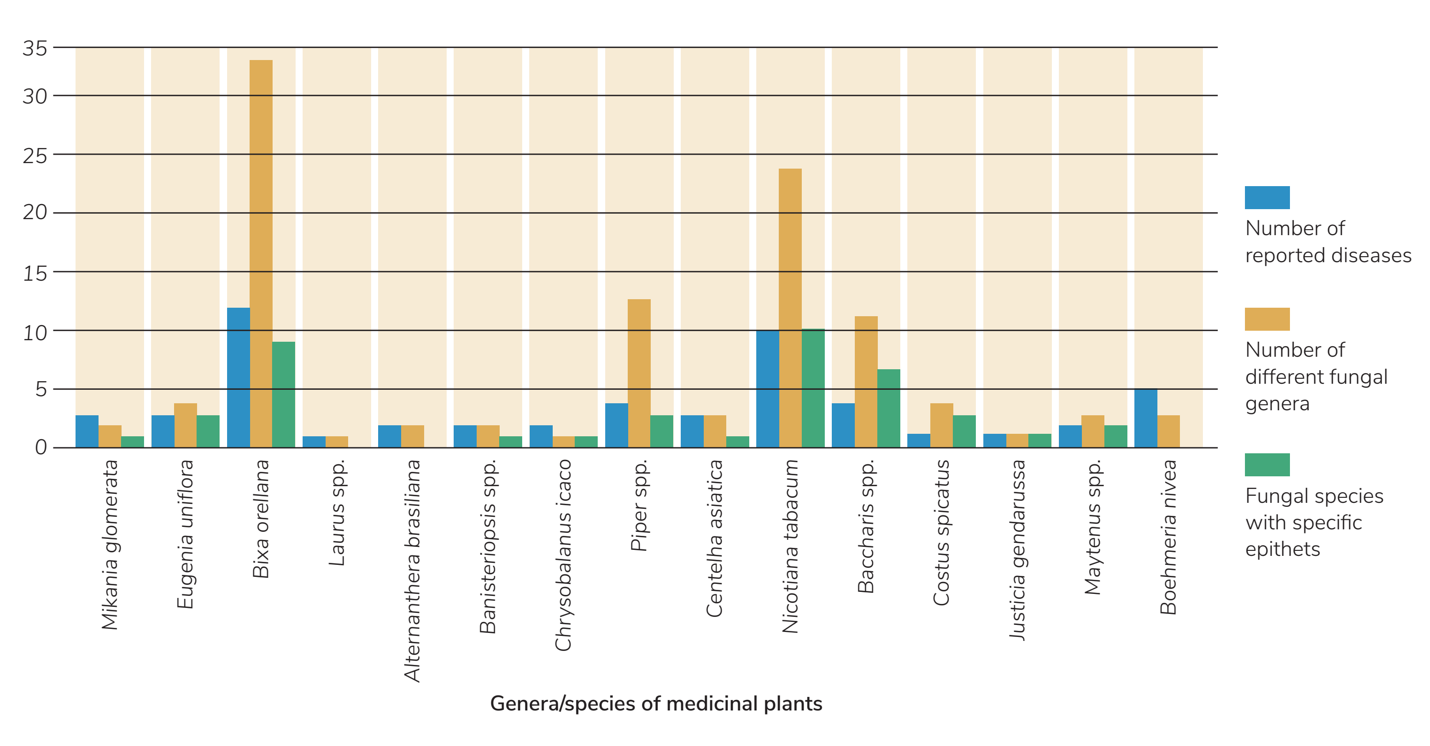

Figure 6. Incidence of fungal diseases, distinct fungal genera, and fungal species with specific epithets found in the selected medicinal plants. When specific data for the medicinal species were unavailable, the plant genus was used for the survey. Data sourced from the Database of Fungi Reported on Plants in Brazil (Mendes & Urben, 2009).

After selecting the medicinal plant species, queries were made to the Embrapa database 'Fungi Reported on Plants in Brazil' (Mendes & Urben, 2009) and to the fungi specialist Dr. Aníbal Carvalho from JBRJ. This database includes 6,903 fungal species associated with 3,682 plant species, with records from 1933 to 2009, sourced from technical books, national and international journals, and specialized websites. Queries in the database are based on the scientific names of host plant species, providing detailed information on the associated fungi, including the type of relationship (endophytic or parasitic), names of diseases or symptoms, potential occurrence in seeds, geographic distribution by state or region, and relevant bibliographic references.

By consulting the 'Fungi Reported on Plants in Brazil', potential pathogens affecting the health of the selected medicinal plants were identified. The highest number of fungal disease reports were found in economically significant species like *Bixa orellana* and *Nicotiana tabacum* (Fig. 6). For *Baccharis* spp., fifteen species of the genus *Puccinia* were reported, including *P. baccharidicola* Henn. and *P. baccharidis* Dietel & Holw. Additionally, cercospora leaf spot, seed-related fungi, anthracnose, and other diseases varied across the studied species.

Non-toxic alternatives for controlling fungi

Biological control of fungal diseases involves the use of live microorganisms, such as viruses, mites, bacteria, and fungi, to reduce or eradicate pathogen populations in plants (Halfeld-Vieira et al., 2016). In addition, there are several commercially available natural alternatives, each with specific agents to combat fungal diseases. To identify effective options for the control of fungal diseases in medicinal plants from the JBRJ collection, we conducted a literature review (see Table 1).

We found in the literature that extracts of *Azadirachta indica*, *Matricaria chamomilla*, *Equisetum* spp. and *Urtica dioica* can be natural and affordable solutions to combat various fungi. These extracts can be tested and used for the prevention and control of fungal infections within the collection.

Conclusions

The 'Fungi Reported on Plants in Brazil' database, is an important tool for researchers and farmers. It provides detailed reports on fungal species that could potentially affect specific plants, the diseases they cause, and their geographical distribution, facilitating the analysis needed for effective treatment and prevention against phytopathogens. However, it is important to note that the database is outdated, containing information only up to 2009. Therefore, monitoring of plants and timely application of preventive or curative treatments are essential for effectively managing fungal diseases.

Diversifying control strategies to include natural methods and cultural practices can significantly improve the health of plants in the collection. Using plant extracts with proven antifungal properties, the research promotes sustainable practices that protect plant health and reduce negative impacts on the environment and human health, while contributing to the conservation of medicinal plants.

Table 1: Some natural alternatives in combating fungal infections in medicinal plants

Natural alternatives	Composition	Application	Reference
Bordeaux mixture ('calda bordalesa')	lime, copper sulfate, water	late blight, black spot, anthracnose, leaf spot, purple spot, damping-off and downy mildew	Embrapa (2007)
Lime and sulphur mixture	powdered sulfur, lime and water	spot, damping-off, downy mildew, rust, powdery mildew, anthracnose and leaf spot	EMATER (2012)
'Calda viçosa'	copper sulfate, zinc sulfate, magnesium sulfate, boric acid and lime	rust	Embrapa (2007)
White Syrup ('calda branca')	sifted ash, dolomite limestone, quicklime and soap and water	black spot and late blight	EMATER (2012)
Mint (*Mentha piperita*) extract and garlic (*Allium sativum*) extract	crush mint leaves and garlic bulbs, add water and let sit for an hour; strain the mixture and soak the seeds for 24 hours before sowing	prevent fungal diseases in the seeds and promotes healthy plant development	EMATER (2012)
Neem (*Azadirachta indica*) leaf, seed and oil extract	macerate the leaves in water for 12 hours to extract the active ingredients; once crushed, the seeds should also be left in water for 12 hours before spraying	neem oil can be used if diluted in water, showing action against fungi in general	EMATER (2012)
Milk ans ash solution	mixture of milk with wood ash, fresh cow manure and sugar	combating fungi in vegetables	EMATER (2012)
Chamomile (*Matricaria chamomilla*) extract	chamomile flowers should be immersed in hot water and left to soak for three days to extract the antifungal active ingredients	fungi in general	CODERSE (2016)
Garlic (*Allium sativum*) extract	grate the garlic and soak it for 24 hours in mineral oil. Then prepare a solution of melted coconut soap in hot water, add it to the garlic and oil, and strain the mixture	combating mildew, rust, black rot, stalk rot and alternaria leaf spot	CATI (2013)
Horsetail (*Equisetum* spp,) extract	boil the horsetail extract for 10 min	fungi in general	UNESP (2002)
Nettle (*Urtica dioica*) extract	dilute the nettle extract in water for about eight hours and then stain the preparation	fungi in general	UNESP (2002)
Papaya (*Caricas* spp.) leaf extract	dilute the papaya extract in water with added coconut soap	rust on coffee plants	UNESP (2002)

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Figure 1. *Chryseococcus arecae* ventral surface (Cattlin)

GOLDEN ROOT MEALYBUG (*CHRYSEOCOCCUS ARECAE* (MASKELL)): A NOVEL CHALLENGE FOR BOTANIC GARDENS AND PUBLIC LANDSCAPES

This article aims to provide the information required to identify C. arecae and the potential impacts of infestation in conservation collections. Outlined are species introduction, rate of spread, host range and effects on plant growth, as well as suggested actions in the event of live infestation and measures for preventing entry and establishment. Being an emergent pest, published research and accounts are limited; this article pulls together the available sources to build a clearer, yet ultimately incomplete picture. Transparency amongst conservation collection holders is key to addressing knowledge gaps, facilitating continuation of their vital work whilst effectively mitigating risk.

Introduction

Currently archived on the UK Plant Health Risk Register, *Chryseococcus arecae* (Maskell) is not a notifiable pest as it is already established and widespread in the UK and considered a low risk to plant health (Department for Environment, Food & Rural Affairs, 2020). Nevertheless, the list of recorded hosts for *C. arecae* is rapidly expanding, and it is probable that it will become widespread, with the possibility of occurrences in glasshouses as well as in outdoor cultivated and natural areas (Malumphy *et al*., 2014).

Evidence suggests that the most severe damage will occur on preferred hosts, including widely planted ornamentals *Meconopsis* (R.Vig) and *Primula* (L.) spp., and host plants experiencing stress, which is thought to increase vulnerability to serious infestation (Malumphy *et al*., 2017). Two significant *Meconopsis* collections in Scotland have incurred severe damage from *C. arecae*, resulting in the abandonment of a National Collection and the removal of all open ground cultivated plants at a National Trust property (Frediani, 2020; Malumphy *et al*., 2017).

Infested plants were intercepted in quarantine at Royal Botanic Garden Edinburgh (RBGE) and its regional garden, Logan Botanic Garden, in March 2024, with further infestations discovered in the potted alpine collection at RBGE later in the same month (Iris BG, 2024).

Botanic gardens are integral to the fulfilment of the conservation targets set out in the Kunming-Montreal Global Biodiversity Framework (GBF) (Convention on Biological Diversity, 2022). The species recovery, habitat restoration and rebuilding of genetic diversity outlined in these targets necessitates the movement of live plant material into or through *ex situ* collections, which carries an inherent risk of pest introduction (Hayden, 2020), rendering living collections in botanic gardens vulnerable to infestation by species such as *C. arecae*.

Chryseococcus arecae: An overview

A root-feeding species native to New Zealand (Cox, 1987), *Chryseococcus arecae* (Hemiptera: Coccomorpha, Pseudococcidae) has acquired the common name Golden root mealybug in the UK on account of its granular, sulphur-yellow coating (Malumphy *et al*., 2014) (Fig. 1 & 2), a characteristic not found on other hypogeal species recorded in the country (Williams & Malumphy, 2012).

Detailed morphological accounts of adult females are given by Cox (1987), Williams (1985) and Williams & de Boer (1973), larviform and wingless, they are oval to rotund, up to 3.1mm long and 2.7mm wide, beneath the waxy coating, the body surface is deep purple-red in colour. The genus *Chryseococcus* and species *C. arecae* are readily distinguishable (golden wax aside) from all recorded mealybugs in the UK, displaying a set of diagnostic characteristics outlined by Cox (1987) and Malumphy *et al*., (2014).

Figure 2. *Chryseococcus arecae* ventral surface (Cattlin)

Figure 3. *Chryseococcus arecae* feeding on *Haberlea sp.* (Marshall)

Comprehensive biological studies have not been undertaken, but observations suggest that *C. arecae* reproduces sexually, giving rise to multiple generations across a season (Malumphy *et al*., 2014). A polyphagous species, it has been found feeding on the roots of ornamentals, (Fig. 3) wild species and crops (Allen & Malumphy, 2018) and also occurs in soil, leaf litter and under moss (Cox, 1987), populations have also been found amongst basal rosettes and behind old leaf sheaths (Fig. 4).

Introduction and rate of spread

Chryseococcus arecae spread within the Australian faunal region from New Zealand (Brittin, 1915; Cox, 1987; Maskell, 1890; 1893; Williams & de Boer, 1973), having been introduced into Southern Australia and Tasmania (Ben-Dov, 1994; Williams, 1985). The first confirmed case in the Palearctic region was recorded in 2012 in central Scotland, where it was found on the roots of *Meconopsis grandis* (Prain) and *Primula chungensis* (Balf.f. & Kingdon-Ward) (Malumphy *et al*., 2014), populations were confirmed at a National Trust property in Northern England in 2015 on the roots of *Achillea* spp. (Malumphy *et al*., 2017). There is no record of infestations occurring elsewhere internationally.

Table 1: Documented hosts plant for the Golden root mealybug (Brittin, 1915, Frediani, 2020, Iris BG, 2024, Malumphy et al., 2017, Maskell, 1890; Williams & de Boer, 1973)

Apiaceae *Astrantia sp.* *Eryngium sp.* **Araliaceae** *Hedera sp.* **Arecaceae** *Rhopalostylis sapida* H. Wendl. & Drude **Asparagaceae** *Cordyline indivisa* Endl. **Asteraceae** *Achillea ptarmica* L. *Aster sp.* *Brachyglottis sp.* *Cirsium sp.* *Inula sp.* *Ozothamnus sp.* *Raoulia sp.* *Rudbeckia sp.* **Boraginaceae** *Pulmonaria sp.* **Brassicaceae** *Aethionema sp.* *Barbarea vulgaris* R.Br.	**Campanulaceae** *Edraianthus dalmaticus* DC. *Lobelia tupa* L. *Caryophyllaceae* *Dianthus deltoides* L. *Lychnis sp.* **Cunoniaceae** *Eucryphia sp.* **Cyatheaceae** *Cyathea dealbata* Sw. **Ericaceae** *Erica sp.* *Rhododendron sp.* **Fabaceae** *Thermopsis sp.* **Gentianaceae** *Gentiana septemfida* Pall. **Geraniaceae** *Geranium phaeum* L. **Gesneriaceae** *Haberlea rhodopensis* Friv. *Haberlea rhodopensis* 'Virginalis' *Rhabdothamnus solandri* A.Cunn.	**Hydrangeaceae** *Philadelphus sp.* **Iridaceae** *Sisyrinchium sp.* **Lamiaceae** *Lavandula sp.* *Prunella sp.* *Rostrincula dependens* Kudô *Salvia sp.* **Malvaceae** *Sidalcea sp.* **Onagraceae** *Epilobium sp.* **Orchidaceae** *Dendrobium sp.* **Papaveraceae** *Corydalis kokiana* Hand.-Mazz. *Corydalis wilsonii* R.Br. *Meconopsis baileyi* Prain (syn. *M. betonicifolia Franchet)* *Meconopsis grandis* Prain	**Plantaginaceae** *Veronica sp.* *Veronicastrum virginicum* (L.) Farw. **Poaceae** *Agropyron repens* Gould *Anthoxanthum odoratum* L. *Cortaderia sp.* *Poa annua* L. *Stipa sp.* **Primulaceae** *Androsace sarmentosa* Wall. *Auricula sp.* *Cyclamen sp.* *Primula alpicola* (W.W.Sm.) Stapf *Primula capitata* Hook. *Primula chungensis* I. Balfour & Kingdon-Ward *Primula* 'Inverewe' *Primula polyantha* Mill.	**Ranunculaceae** *Aquilegia sp.* *Clematis sp.* *Hepatica nobilis* Mill. *Pulsatilla vulgaris* Mill. *Ranunculus kochii* Ledeb. *Ranunculus seguieri* Vill. **Rosaceae** *Alchemilla sp.* *Filipendula kamtschatica* (Pall.) Maxim. *Geum sp.* *Potentilla sp.* *Rubus sp.* **Saxifragaceae** *Astilbe sp.* *Heuchera* 'Beauty Colour' **Solanaceae** *Solanum sp.*

The pathway of entry to the UK remains undetermined. The infested plants had been acquired over two decades from growers in Scotland and the north of England. The possibility of introduction via material collected from the Sino-Himalayan region was discounted following analysis of European and Asian faunas (Malumphy et *al*., 2014). It is suspected that *C. arecae* was brought into the UK through trade with New Zealand (C. Malumphy, pers. comm. 25th June, 2024) The species' Subterranean habit and cryptic behaviour render it easily missed, to date it has not been identified on imported material (Malumphy et *al*., 2017). Anecdotal accounts suggest that *C. arecae* favours, but is not restricted to, fleshy-rooted, herbaceous species (Malumphy et *al*., 2017).

The extent of spread in the UK is at present unquantified. *C. arecae* is reported to have been found in Northern Ireland in 2019 (Royal Horticultural Society, 2024) and several recent anecdotal accounts throughout central Scotland are yet to be confirmed. A factsheet and poster published online by the International Plant Sentinel Network (IPSN) in March 2024 (IPSN, 2024a and 2024b) may, together with this article, raise the profile of *C. arecae*, resulting in increased reports and allowing a more accurate picture of distribution to be formed.

Trade and inter-collection exchange, including amateur club plant swaps and gifted plants, is predicted to expedite the rate of spread, which would be low under natural circumstances (Malumphy et *al*., 2014). Run-off from irrigation in nursery settings may facilitate the spread of root-feeding mealybugs, which could float between pots (Malumphy et *al*., 2017). Additionally, damp surfaces may aid juveniles in walking between plants (Jansen, 1994).

Host range and economic impact

Malumphy et *al*. (2014) listed 19 genera across 14 families, with a follow-up paper increasing this to 54 genera across 29 families (Malumphy et *al*., 2017), recent records augment the total to 65 genera across 30 families (Frediani, 2020; Iris BG, 2024) (Table 1). Cox (1987) states that *C. arecae* is among the most prevalent mealybugs in New Zealand yet is not considered a threat. Presumably it is checked in its native habitat by the pathogens and pests with which it coexists, although no natural enemies have been reported, since its presence appears to be maintained below economic injury level (Ennos, 2015). It has not become a major concern in Australia but has damaged ornamental plants in Tasmania (Williams, 1985).

The monetary impact in the UK is currently predicted to be minimal, though there exists some uncertainty on this (Malumphy et *al*., 2017). The vigour of favoured ornamental host plants is significantly diminished by infestation, which may result in decreased market value of commercially grown species. It has been demonstrated under laboratory conditions that the roots of tomato can sustain a population of *C. arecae*, but the probability of spread to a commercially grown crop of this type is thought to be low (Malumphy et *al*., 2014).

Figure 4. *Chryseococcus arecae* on leafy material (Marshall)

- Assess infested plants based on conservation and collection status.
- If adequately represented elsewhere within collection or a widely available cultivar then discard.
- Check plant records to ensure all plants of the same accession are inspected and dealt with.
- If infested plants are traceable to a single source (e.g. donor), ensure all plants of this origin are inspected.
- Inspect neighbouring plants.
- Notify relevant plant health authority.

- If accession must be saved, remove and discard as much growing media as possible through root washing; removal of spent basal leaves is also recommended.
- Roots and basal leaves may be treated with bioinsecticide at this point (efficacy not verified).
- Dispose of any porous pots; non-porous pots should be disinfected.
- Vegetative propagation should be carried out if an option, or seed collected.
- Repot into uncontaminated growing media.

- Isolate mother plants and propagules in separate quarantine facility.
- Individual plants may be bagged.

- Inspect plants on regular basis; little known about egg hatching periods so suggest minimum weekly inspection.
- If reinfestation occurs, repeat washing and treatment with bioinsecticide.
- If vegetative/seed propagation has been successful, original infested plants should be discarded.

Figure 5. Dealing with infestation: container-grown plants

Vulnerability of conservation collections to infestation

The species diversity and relatively small plantings in *ex situ* collections ought to prove advantageous in dealing with a pest specialised on a particular host (Antonovics & Hayden, 2020); *C. arecae* has a broad and expanding host range (Malumphy *et al.*, 2017), rendering plants in this novel environment vulnerable.

Common practices in the curation of plantings in conservation collections might well influence the rate of spread and population size of *C. arecae*. Displays that group together varying accessions of the same species may be at risk, should *C. arecae* prove able to feed on that plant (Hayden, 2020). Conversely, mixed plantings that bring together plants not linked by geography or taxonomic relationship could facilitate rapid infestation of new hosts (Antonovics & Hayden, 2020).

A particular risk of inter-collection spread of *C. arecae* exists for organisations that manage sister sites, particularly where propagation is undertaken at a central location (Royal Botanic Garden Edinburgh, 2024). The potential for spread from regional gardens into the natural environment is also increased, since these sites are typically in rural settings with relatively permeable boundaries into the surrounding vegetation (Gossa *et al.*, 2021). It is predicted that control of *C. arecae* in natural landscapes will be incredibly challenging (Malumphy *et al.*, 2014).

Impact on growth of a favoured host

Reports suggest that *Meconopsis* spp., particularly the perennial 'big blues', are a preferred food source for *C. arecae* in the UK and are more significantly affected than many other hosts (Frediani, 2020). Plants from which sap has been removed through heavy infestation exhibit diminished vigour and flowering capacity (Malumphy *et al.*, 2017), with leaf growth stunted and clumps not increasing in size as expected. It is thought that the fleshy, relatively shallow-rooted nature of *Meconopsis* spp. results in easy feeding. Observations suggest that populations may occur outside the root zone (Frediani, 2020).

Elevated stress resulting from anthropogenic climate change may render host plants more susceptible to infestation (Malumphy *et al.*, 2017). Higher average temperatures may decrease the intervals between generation emergence of *C. arecae*, as well as facilitating more efficient reproduction over winter months; increased nutrient concentrations in plant sap, resulting from heightened drought stress, may accelerate prolificacy (Bisgrove & Hadley, 2002).

Reactive measures for dealing with infestation

There are currently no known controls for open ground infestations of *C. arecae* (Royal Horticultural Society, 2024). Measures for container-cultivated plants are currently experimental and their effectiveness assessable only from anecdotal evidence; an in-depth analysis of these measures exceeds the scope of this article.

The steps that may be taken in event of live infestation are outlined in Fig. 5 for potted plants and Fig. 6 for open ground plantings. These are based on the actions of previously affected organisations (Malumphy *et al.*, 2017), as well as recommendations from specialist growers of known favoured host plants (Meconopsis Group, 2024). It should be noted that suggested measures for dealing with infestation in open ground are based on reasonable judgement, rather than a solid evidence base (which does not yet exist). Uncertainty regarding the biology of *C. arecae* renders it difficult to state definitive timescales for periods of isolation and fallowing (Malumphy *et al.*, 2017)

- Assess infested plants based on conservation and collection status.
- If adequately represented or a widely available cultivar then discard.
- Check plant records to ensure all plants of the same accession are inspected and dealt with.
- If infested plants are traceable to a single source (e.g. donor), ensure all plants of this origin are inspected.
- Inspect neighbouring plants.
- Notify relevant plant health authority.

- Lift all infested plants from the ground and discard those not required for conservation/ collection purposes; this may not be possible for all plants, dependent on size.
- Assess time to setting seed, if imminent and seed required then may be prudent to leave in ground until seed is collected (unless adequate amount in seed bank).
- Do not remove spp. based on current host list as this is incomplete, err on side of caution and remove anything showing signs of infestation. .

- Wash roots of any plants that must be kept for propagation purposes, discarding soil and spent basal leaves.
- Treatment with bioinsecticide may be trialled at this point.
- Repot plants into uncontaminated growing media; isolate mother plants and propagules in separate quarantine facility.
- Once propagation is confirmed as successful, original plants should be destroyed.
- Vegetative material of plants too big to be lifted from affected site should be cleaned and treated in the same way; once propagation is confirmed, original plant can be removed.

- Where reasonably practicable, remove soil to depth of c.30cm from infested site and sterilise using steam. Replace and fallow for minimum 2 seasons.
- Where sterilising is not possible, suggest fallow period of 4-5 years.

Figure 6. Dealing with infestation: open ground

Measures for preventing infestation: Biosecurity

The primary course of action for conservation organisations seeking to minimise the probability of entry and establishment of pests such as *C. arecae* ought to be investment of resources in a scrupulous biosecurity programme. This includes staff training, implementation of inspection and monitoring systems, as well as collaboration with science and horticultural divisions and appropriate public engagement (Hayden, 2020). At a basic level, checking the root systems of all incoming plants is critical in protecting conservation collections.

Record keeping and transparency

Affected organisations have a duty to keep accurate accounts of infestation. Individual plant records should be updated to reflect a change in plant health status and detailed notes made on the extent of infestation and the course of action taken. In the absence of specific capabilities for the recording of pest occurrences within plant records databases, 'task lists' (or similar) can be valuable as a means of providing an overall picture across an organisation.

Honest and open information sharing with other collection holders and plant health authorities is integral to understanding the biology and host range of *C. arecae* and will expedite the development of effective controls. Perceived reputational damage might act as a deterrent to some managers (Hayden, 2020), nevertheless, data recorded and shared by conservation organisations is a vital resource which may inform future pest risk analysis (PRA) or prompt review of quarantine status (Gossa et *al.*, 2021).

Curatorial decisions and horticultural practice

Careful consideration should be given to living collection layout in organisations for which *C. arecae* poses an imminent threat or is already present. The avoidance of expansive single-species plantings of known hosts is advised, as is the planting of preferred hosts close to threatened plant species. Rapid action should be taken when infestation is discovered to limit spread and subsequent damage.

With sustainability in mind, a 'right plant, right place' approach should be applied to the arrangement of conservation collections, for which the knowledge of horticultural staff on the ground is essential. Targeted irrigation infrastructure catering to plants' specific needs may be a prudent investment (Smart & Elliot, 2015).

Conclusions

The true impact of *C. arecae* is yet to be realised. It is conceivable that spread into natural vegetation will occur and damage to ornamental plantings has already been sustained. Though it is expected (albeit not certain) to be economically insignificant, the impact on conservation collections may be considerably higher. It is likely that host plants will become more susceptible to infestation as a result of increasingly challenging environmental conditions. The rare and endangered plant species in conservation collections are vulnerable to infestation, particularly those held in small numbers. Knowledge sharing amongst organisations, informed and decisive curatorial decisions and rigorous biosecurity practices will safeguard these genetic resources.

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OCCURRENCE OF ALIEN INSECT AND MITE PESTS IN THE BOTANICAL GARDEN IN NITRA IN THE NEW MILLENNIUM – A REVIEW

Figure 1. Nymph of *Nezara viridula*

The Botanical Garden (BG) in Nitra was established in 1982 in the Campus of the Slovakian University of Agriculture in Nitra. The area of the BG is 7.5 hectares, but together with the adjacent Demonstration Garden the total area is 21 hectares. The average annual temperature is 8.7° C and the average annual precipitation is 767 mm. The climate is dry continental, and it is one of the warmest and driest locations in Slovakia. The number of plant taxa in the collection is 3,765. The ongoing trend of climate change and commercial plant trade gives alien insect pests opportunities to spread. The BG is not an exception, as it is a part of the green infrastructure of the city of Nitra, the garden is well connected to the urban environment. This connectivity facilitates the accidental introduction and spread of alien insect pests and diseases, as they can easily migrate from other green spaces, gardens, and urban areas into the BG. Allochthonous insect and mite pests found in Slovakia and monitored by the BG are listed below following taxonomic orders.

Suborder *Prostigmata*

- *Aceria granati* (Nalepa, 1890) was recorded for the first time in 2017 on a plant imported from Hungary (Kollár *et al.*, 2021). The mite was later found in the dendrological collections of the BG on Punica granatum and its cultivars.
- *Aceria kuko* (Kishida, 1927) is a mite creating galls on *Lycium chinense* and *L. barbarum*. The first record comes from Suvák (2020), but since it is well distributed in remote areas, we believe it was present earlier in Slovakia.

Figure 2. Nymphs of *Nezara viridula*

- *Aceria pyracanthi* galls were detected in the BG in 2011 on *Pyracantha coccinea* (Kollár, 2011). This was the first case in Slovakia. In the next years it was present in the whole region.

Galls of these mites can lead to earlier senescence of leaves and reduce the assimilation area. However, the damage is not significant.

Order *Hemiptera*

- The southern green stink bug (*Nezara viridula*) (Fig. 1, 2 & 3) was spreading gradually from Hungary northwards and was discovered in Slovakia in 2014 (Vétek & Rédei, 2014). As a polyphagous lace bug, it can affect the health of ornamental plants and serve as a vector for bacterial diseases and viral infections. It has become increasingly abundant in recent years.
- The brown marmorated sting bug (*Halyomorpha halys*) (Fig. 4 & 5) is spreading gradually from Hungary northwards, similarly to *Nezara viridula*, and was discovered in Slovakia in 2016 (Hemala & Kment, 2017). Because it is considered an important pest affecting a large number of crops and ornamental species, it can be considered, together with *Nezara viridula*, as problematic pest.
- The oriental grass root aphid (*Tetraneura nigriabdominalis*) is creating galls on leaves of different elm species. The first record comes from 2009, with the damage to elm trees being minor. The pest does not have a big impact on the overall health of trees growing in urban environments. We consider it a naturalised invasive pest (Kollár, 2021).
- The white peach scale or mulberry scale (*Pseudaulacaspis pentagona*) was recorded for the first time in 2005 on *Catalpa speciosa* on urban trees (Fig. 6 & 7). When abundant, the peach scale can cause severe damage and can lead to crown dieback (Kollár & Hrubík, 2007).
- The citrus flatid planthopper (*Metcalfa pruinosa*) arrived in Slovakia in 2010 (Jánsky & Semelbauer, 2010) and has been spreading with enormous speed. It is polyphagous and can cause necrosis on ornamental plants.
- The arrival of the oak lace bug (*Corythuca arcuata*) in 2018 in Slovakia (Zúbrik *et al*., 2019) and its rapid spreading northwards have raised significant concern among foresters and horticulturalists. This pest causes significant damage to oak species, often reducing leaf area as early as August. The first visible damage to oaks in Nitra was observed in 2020.
- The western conifer seed bug (*Leptoglossus occidentalis*) was found in Nitra in 2006 (Kollár *et al*., 2009) and has since become a widespread insect pest. It causes significant damage to the seeds of different conifers, primarily pines.


Figure 3. Mating adults of *Nezara viridula*


Figure 4. Adult form of *Halymomorpha*


Figure 5. Nymph of *Halyomorpha halys*

- Euonymus scale (*Unaspis euonymi*) is a tiny, sap-sucking insect that infests the stems and foliage of *Euonymus* spp. It arrived in Slovakia around 2000, probably with infested plant material (Galko & Zúbrik, 2018). While it can cause substantial damage to *Euonymus* plants, it is very well controlled by the ladybird *Exochomus quadripustulatus*.
- The Tulip tree aphid (*Illinoia liriodendra*) was found in 2014 in the city park of Nitra (Kollár & Barta, 2016). The damage of this insect pest is minor.
- Black-bordered oak aphid (*Myzocallis walshii*) was recorded for the first time in Nitra in 2007 (Barta, 2009) on *Quercus rubra*. The damage of this insect pest is minor.
- Bow-legged fir aphid (*Cinara curvipes*) arrived in Slovakia in 2007 (Nakládal et al., 2007). Although they can appear in large numbers, their damage to fir trees is minor.
- The plane tree bug (*Arocatus longiceps*) was first found in 2000 in Štúrovo (Kment & Bryja, 2001), and was later found in Bratislava and Nitra on plane trees. The damage of this insect pest is minor.
- Hydrangea scale (*Pulvinaria hydrangea*) is a polyphagous, sap-sucking pest. It was discovered in Bratislava in 2011 and later on in Nitra (Kollár, 2014). This scale occurs scarcely and the damage to plants is minor.
- In the last years, new planthoppers *Agalmatium flavescens* (Janský & Strmisková 2017), *Acanalonia conica* (Jánsky et al., 2021) and leafhoppers *Scaphoideus titanus* (Tóthová et al., 2015), *Orientus ishidae* were found in Nitra. Leafhoppers and planthoppers are important vectors for bacterial diseases and viral infections.

Figure 6. *Pseudaulacaspis pentagona* on *Catalpa bigonioides* 'Nana'

Figure 7. Males and females of *Pseudaulacaspis pentagona* on *Catalpa bignonioides* 'Nana'

Order Coleoptera

Seed beetles *Bruchidius siliquastri*, *B. terrenus*, *Megabruchidius dorsalis* and *M. tonkineus* are all present in Nitra and are causing damage on seeds of different tree species (Majzlan & Vidlička, 2022).

- *Bruchidius siliquastri* is present in Nitra since 2009 (Kollár et al., 2009) and causes significant damage on seeds of *Cercis* species. *Bruchidius terrenus* was found recently in Nitra in 2022 on *Albizia julibrissin*.
- *Megabruchidius tonkineus* was first found in 2011 in Bratislava and 5 years later in Nitra. However, it has now been replaced by *Megabruchidius dorsalis*, which was found in Slovakia 3 years later (Majzlan & Vidlička, 2022).
- The arrival of the cypress jewel beetle (Fig. 8) (*Lamprodilla festiva*) in Bratislava was in 2017 (Jendek et al., 2018) and three years later in Nitra. This insect pest caused significant mortality among *Thuja* and *Juniperus* species.
- The velvet long-horned beetle (*Trichoferus campestris*) was first recorded in Slovakia in 2007 (Sabol, 2009) and has since spread to all regions with a milder climate. It has been documented causing damage to 40 tree species, conifers included. This insect pest can cause crown dieback or even lead to tree death.

Figure 8. Emerged imago of *Lamprodila sp.* next to the exit hole

Order *Diptera*

- The spotted wing drosophila (*Drosophila suzukii*) was reported in Slovakia in 2014 in the European and Mediterranean Plant Protection Organization (EPPO) database (EPPO, 2024). Over the next five years it spread significantly in the fruit growing regions of Slovakia. The damaging effect on fruits is significant.
- The walnut husk fly (*Rhagoletis completa*) (Fig. 9) was recorded for the first time near Bratislava in 2017 (Kozánek et *al.*, 2018). In the next four years it was present in all regions where the walnut is present. It can cause significant damage to nut yields.
- The locust gall midge (*Obolodiplosis robiniae*) was recorded for the first time in the southwestern part of Slovakia in 2006 (Zúbrik et *al.*, 2007). In the next decade it spread massively. However, recently the population decreased, and we have rarely seen galls.
- *Amauromyza elaeagni* is a leaf miner on *Eleagnus* species. It was recorded for the first time in Nitra in 2006 (Kollár et *al.*, 2009). It is a pest of low importance.

Order Lepidoptera

- The box tree moth (*Cydalima perspectalis*) (Fig. 10 & 11) appeared in 2012 in Bratislava (Pastoralis et *al.*, 2013) and subsequently spread rapidly in regions where the host plant, *Buxus sempervirens*, is commonly planted (Bakay & Kollár, 2018). The damage caused by the box tree moth was significant, and a lot of old box tree hedges had to be replaced by different ornamentals.

Figure 10. Larval stage of *Cydalima perspectalis*

Figure 9. *Rhagoletis completa*

- The lime leaf miner (*Phyllonorycter issikii*) invaded Slovakia from the east in 2000 (Tokár et *al.*, 2002) and in the next years it became a common species on linden trees. The damaging effect is minor.
- *Phyllocnistis vitegenella*, a relatively new leaf miner for the fauna of Slovakia, appeared in 2019 and can be found abundantly on *Vitis* and *Parthenocissus* species (Kollár, 2021). Damage by this insect is still being determined.
- The juniper ermine moth (*Argyresthia trifasciata*), which creates leaf mines on *Juniperus* and x *Cupressocyparis* species, was recorded in Slovakia in 2006 (Tokár et *al.*, 2010). In the following years, it could be found in many regions. The damage is minor.
- The fig-tree skeletonizer moth (*Choreutis nemorana*) appeared in 2015 in several localities (Lendel, 2017) and has since become very abundant. The damage is usually not lethal for the plant.

Figure 11. Melanic form of *Cydalima perspectalis*

Order Hymenoptera

Several insects from the order Hymenoptera can be found in Slovakia, although most have minor impact on the plant species they infect, these are a few the BG monitors.

- The almond seed wasp (*Eurytoma amygdali*) appeared in Nitra around 2009 (Kollár, 2014) and can make significant damage to the almond yield. We have found that the distribution is uneven and locally specific.

It is clear from the above the phase a wide range of pests to be found on ornamental and crop plant species in Slovakia. The original introductions of many unknown, however but implementing correct plant health practices for the spreading of current pests and new introductions can be prevented. The BG will continue to monitor pests with both severe impact and minor impact, in light of climate change these impacts could also change and we need to be ready to provide solutions.

Acknowledgement
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PATHOGEN IDENTIFICATION IN KEY PALM SPECIES: CASE STUDY TO IMPROVE MANAGEMENT IN AN URBAN AREA

Este artículo tiene una versión en español. Para leer la versión en español, haga clic aquí.

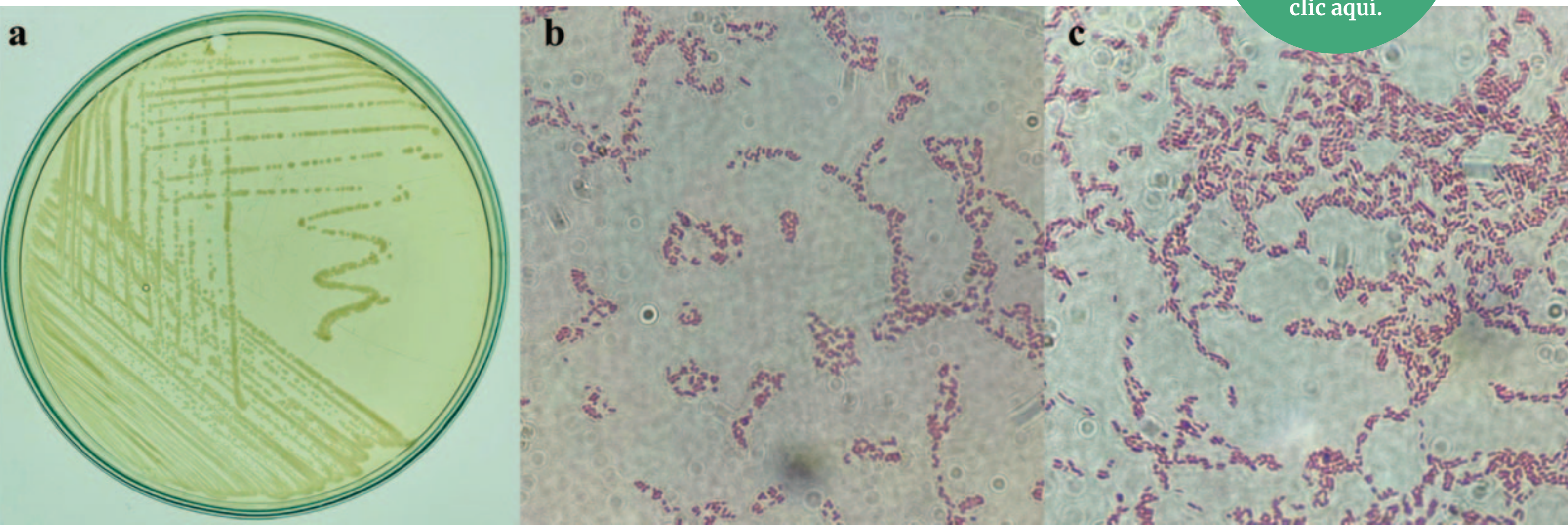

Figure 1. Gram negative bacteria, potentially phytopathogenic, found in palm samples. (a) Soil dilutions in petri dish. b) Bacteria found in rhizosphere of *Roystonea regia* (40x) and (c) bacteria found in rhizosphere of *Archontophoenix cunninghamiana* (40x).

Medellín is renowned for its diverse palm species, contributing significantly to its landscape and heritage. The Botanical Garden of Medellin (BGM) has a crucial role in maintaining urban flora. However, palm health is threatened by diseases that cause significant mortality. This study focuses on preserving Medellín's palms by identifying and managing pathogens affecting five key palm species. Laboratory analyses identified gram-negative bacteria, as well as the pathogenic fungi *Fusarium*, *Phytophthora*, *Lasiodiplodia*, *Pestalotiopsis*, and *Curvularia*. This research aims to provide essential insights and preliminary solutions to enhance the resilience and longevity of Medellín's urban palms.

Introduction

Medellín, located in the Andean region of South America, has an urban area covering 105 km^2 characterized by extensive green spaces and diverse plant life, with palms being a significant feature of the city's landscape. According to the Urban Tree System (SAU), Medellín is home to 71 species and 23,682 palm individuals (Alcaldía de Medellín, 2024), making them a substantial part of the city's natural and cultural heritage. Palms are commonly found in public parks, streets, and private gardens, playing an essential role in the urban environment (Varon & Morales, 2016).

The Botanical Garden of Medellin (BGM) has been central to transition on the city's urban tree composition (Hoyos-Estrada, 2007). Historically dominated by non-native plants, Medellín's urban flora has notably shifted towards native tree species that reflect the biodiversity of Antioquia and Colombia. BGM also collaborates with public entities, such as the Major Office, to maintain, monitor and apply phytosanitary treatments to the urban forest of Medellín. These efforts ensure that Medellín's green spaces are sustainable and representative of the region's ecological heritage.

Recently, observations made by the Interdisciplinary Committee of Urban Forestry (CISU) of Medellin have alerted about several diseases affecting palm species in the city leading to sudden death.

Between 2006 and 2024, there were 3,796 palm tree removals across 29 species, with the most affected including the Royal palm (*Roystonea regia*), Payanesa palm (*Archontophoenix cunninghamiana*), Wahingtonia palm (*Washingtonia robusta*), Canary palm (*Phoenix canariensis*) and Sancona palm (*Syagrus sancona*) (Alcaldía de Medellín, 2024). In coordination with the Secretary of the Environment of Medellín, the CISU and the BGM, these five species were prioritized based on their abundance, emblematic status, and susceptibility, to study pathogens associated with palm diseases.

Roystonea regia (Kunth) O.F. Cook, native to Cuba, accounts for 2,377 individuals planted in Medellín, of which 232 (9.7%) were removed due to diseases or sudden death between 2006 and 2023 (Alcaldía de Medellín, 2024). *Archontophoenix cunninghamiana* (H.Wendl.) H.Wendl. & Drude, native to East Australia, has 4,052 individuals in Medellín, with 226 (5.6%) removed. *Washingtonia robusta* H.Wendl., native to Mexico, has 1,135 individuals in Medellín, with 58 (5.1%) removed. *Phoenix canariensis* Chabaud, originally from the Canary Islands, has 308 individuals registered in Medellín, with 30 (9.7%) removed. Finally, *Syagrus sancona* (Kunth) H.Karst. is a native palm, has 308 individuals in Medellín, with 30 (9.7%) removed (Alcaldía de Medellín, 2024).

Fieldwork

The city of Medellín, Colombia, is located at 6°13'55"N, 75°34'05"W, at an elevation of 1479 meters above sea level, with an average temperature of 24°C. The SAU platform allows individual monitoring of each plant in the city. Technicians regularly record plant conditions, respond to citizen reports, and document diseased plants or those needing removal due to death or advanced disease stages. For this study, we located individuals marked for removal and those listed as diseased in Medellín. Additional field surveys identified palms from the five species prioritized for this study. We selected 16 diseased or dead palms, 2-4 individuals per species, and took samples from the stipe and rhizosphere (root with soil). Sampling of dead individuals followed national (ICA & Minagricultura, 2020) and regional (CIB, 2016) protocols. Samples from live symptomatic individuals followed the guidelines for detecting lethal yellowing in palms (Bahder & Helmick, 2018). We recorded each individual's location, affected plant organs, symptoms and took photographs. In total we collected 28 samples, which were sealed in resealable bags and transported in cooler boxes to the laboratory on the same day.

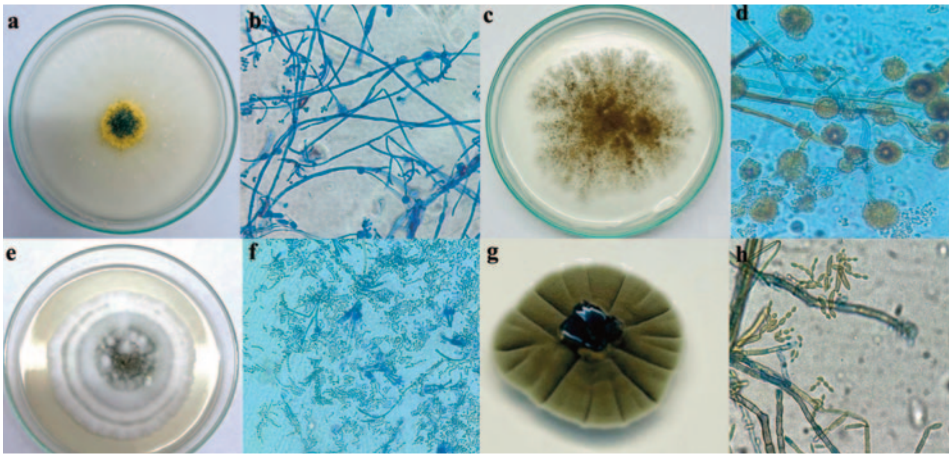

Figure 2. Micellium and 40x microscopic magnification of some of the non-phytopathogenic fungi found in palm samples. (a,b) *Trichoderma* in rhizosphere of *Archontophoenix cunninghamiana*. (c,d) *Aspergillus* in stipe of *Syagrus sancona*, (e,f) *Penicillium* in dead tissue of *Washingtonia robusta* and (g,h) *Cladosporium* in stipe of *Phoenix canariensis.*

Laboratory methods

Plant tissues were examined under the microscope to identify any bacterial, fungal or nematode infection. For the stipe and root collected from the diseased and dead palm trees, tissues were thoroughly washed with running tap water, and then washed with sterile distilled water. Infected tissues were sterilized by soaking them in 1.0 % NaOCl for 1, 1.5, 2 and 2.5 minutes, followed by rinsing with distilled water and sterilization in 70 % alcohol. Sterilized tissue was plated on PDA 100µL for pathogen isolation.

For soil samples, we made serial dilutions up to 10^{-3} and plated 100 µL of each dilution in trypticase soy agar (TSA) for bacteria and potato dextrose agar (PDA) for fungi, with each medium tested in triplicate.

After four days of incubation of the fungal samples, the hyphal tip of each fungus was transferred onto the PDA medium. Single isolates were then transferred onto different media, namely, V8 (vegetable juice), oat agar, potato carrot agar and PDA. Each fungal isolate was identified based on morphological (color of the fungal colony in different media, pattern of growth, sporulation, presence of secretion or exudates, and the number of days needed for growth on different media) and microscopic (evaluation of hyphal and spore structures) characteristics.

Results

The sampled palms presented sudden death or disease symptoms such as yellowing, browning, bud collapse, wilting and fruit rot. The stipe of one Sancona palm tree had a bad smell.

From the soil samples dilutions, we obtained more than 300 colony-forming units of bacteria. We selected ten dominant morphotypes: eight gram-positive and two gram-negative, with the latter presumably being phytopathogenic (Fig. 1).

For fungi, 30 isolates were successfully obtained. Nine genera were identified, and eleven cryptic fungi were found in the samples. Four potentially non-dangerous fungi were found (*Aspergillus*, *Penicillium*, *Cladosporium*, and *Trichoderma*) (Fig. 2) and five reported as phytopathogenic (*Fusarium*, *Lasiodiploida*, *Pestalotiopsis*, *Curvularia*, and *Phytophthora*) (Fig. 3 & 4).

All palm species exhibited phytopathogenic fungi, although not all individual palms were affected (Table 1). *Phoenix canariensis* and *Washingtonia robusta* each presented eight fungal morphotypes, followed by *Archontophoenix cunninghamiana* and *Roystonea regia* with seven morphotypes each. In the native palm species, *Syagrus sancona* five morphotypes were found. The most common genera of fungi in the rhizosphere were *Trichoderma*, pathogenic *Fusarium* and *Lasiodiplodia* were also found. In the stipe, Trichoderma was also the most common fungus, and pathogenic *Curvularia, Fusarium, Lasiodiplodia*, and *Phytophthora* were found in the samples.

Table 1 Presence of microorganism found on the stipe and rhizosphere samples of the five key palm species.

Plant section	Microorganism species	Palm tree individuals					
		Archontophoenix cunninghamiana	*Phoenix canariensis*	*Roystonea regia*	*Syagrus sancona*	*Washingtonia robusta*	Total
Stipe	*Aspergillus* sp. 1				1		1
	Cladosporium sp.		1				1
	Curvularia sp.	1					1
	Fusarium sp.					1	1
	Lasiodiplodia sp.			1			1
	Penicilliium sp. 1					1	1
	Pestalotiopsis sp.		1			1	2
	Trichoderma sp. 1	1					1
	Trichoderma sp. 6			1			1
	Trichoderma sp. 8				1		1
	Trichoderma sp. 9					1	1
	Phythophthora sp.		1			1	2
	Indet. 1	1					1
	Indet. 2	1					1
	Indet. 3	1					1
	Indet. 4		1				1
	Indet. 6			1			1
	Indet. 7			1			1
	Indet. 8			1			1
	Indet. 10					1	1
Rhizosphere (Soil+root)	*Aspergillus* sp. 2				1		1
	Fusarium sp.	2			1		3
	Lasiodiplodia sp.				1		1
	Penicilliium sp. 2					1	1
	Trichoderma sp. 2	1					1
	Trichoderma sp. 3		1				1
	Trichoderma sp. 4		1				1
	Trichoderma sp. 5		1				1
	Trichoderma sp. 7			1			1
	Indet. 5		1				1
	Indet. 9			1			1
	Indet. 11					1	1

Among the non-pathogenic fungi, *Trichoderma*, with an incidence of 32 % in the samples, is known for its beneficial role as an antagonist of other phytopathogenic fungi. While *Aspergillus* (with an incidence of 7.2 %), *Penicillium* (3.5 %) and *Cladosporium* (3.5 %) do not represent a serious threat to ornamental palms, but their presence may indicate the need to adjust environmental and health management practices to maintain optimal plant health.

In the case of phytopathogens, *Fusarium* had an incidence of 14.3 % in the samples. This fungus can cause symptoms of wilting and general deterioration in ornamental palms by invading the plant's vascular system and interrupting the flow of water and nutrients. In palms, *Fusarium oxisporum* is related to Vascular Wilting disease (VW) (Acosta-García, 2001; Elliott, 2010; Flood & Mepsted, 1991).

Phythopthora species had a 7.2 % of incidence. *Phytophthora palmivora* specifically is associated with Bud Rot (BR) disease, which is fatal to more than 30 palm species in the Caribbean region and is also present in Northern Andes region (ANCUPA, 2013; Hung et al., 2015).

Lasiodiplodia, with a 7.2 % of incidence, is associated with Leaf blight disease in coconut palms (LBC), specifically caused by *Lasiodiplodia theobromae* and *L. pseudotheobromae*. This disease can lead to several symptoms in the palms, including progressive wilting of leaves and branches, tissue necrosis, leaf spots, and eventual death of the affected plant (Santos et al., 2020).

Pestalotiopsis, with an incidence of 7.2 %, can cause leaf spots, necrosis on leaves and branches, as well as premature defoliation in affected palms (Betancourt-Ortiz *et al.*, 2023). Additionally, lepidoptera species have been associated as vectors in Colombia (Martínez & Plata-Rueda, 2013).

Finally, *Curvularia* species, showing a 3.5 % of incidence, can cause curvulariosis, generating symptoms in ornamental and oil palms, such as leaf spots ranging from brown to black, necrosis of leaf tissues, and even rotting of leaves and stems in severe situations. These symptoms can result in defoliation and general weakening of the plant (Febriani & Kasiamdari, 2024).

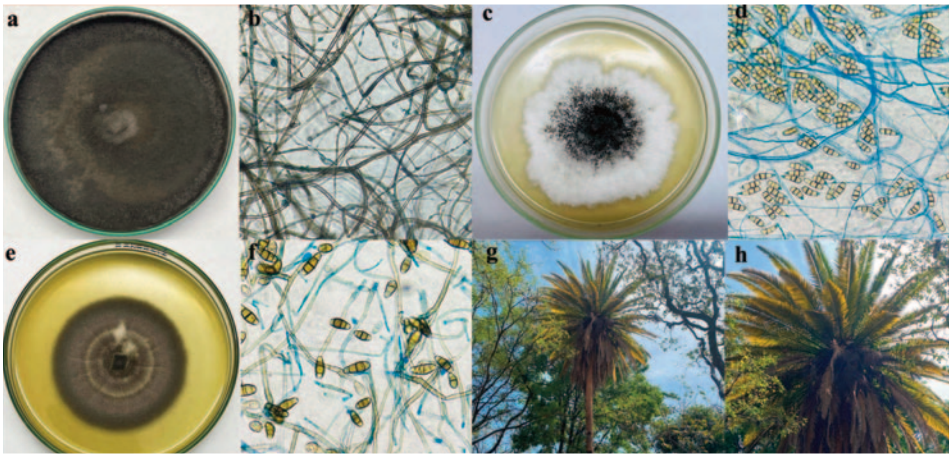

Figure 3. Micellium and 40x microscopic magnification of some of the phytopathogenic fungi found in palm samples. (a) *Lasiodiplodia* in stipe of *Roystonea regia*, (b) *Pestalotiopsis* in stipe of *Phoenix canariensis*, (c) *Curvularia* in stipe of *Archontophoenix cunninghamiana*, (d) symptomatic palm tree of *P. canariensis* affected by *Pestalotiopsis*.

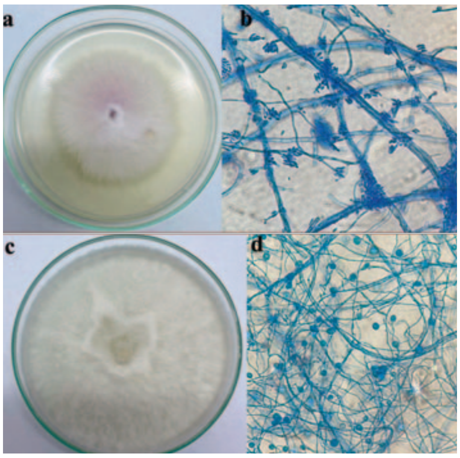

Figure 4. Micellium and 40x microscopic magnification of some of the phytopathogenic fungi found in palm samples. (a, b) *Fusarium* in rhizosphere of *Archontophoenix cunninghamiana* and (c, d) *Phytophthora* in dead tissue of *Washingtonia robusta*.

Strategies to mitigate diseases

Currently, there are no known effective treatments for some of the diseases caused by *Phytophthora*, such as Bud Rot, one of the most prevalent tropical diseases caused by *P. palmivora* (Cenipalma, 2014; SADER & SENASAICA, 2019). Therefore, when *Phytophthora* presence is confirmed, the removal of the palm in a maximum of three days lapse is recommended (ANCUPA, 2013; Silva-Carreño & Martínez-López, 2019).

On the contrary, several treatments are available for diseases caused by *Fusarium oxysporum*, including biological control, fumigants and preventive treatments. These have proven to be effective, despite the existence of several subspecies that can cause diseases to palms (Acosta-García, 2001; Dihazi et al., 2011; El Hassni et *al*., 2004; Vásquez-Ramírez & Castaño-Zapata, 2017).

Some fungal diseases require the testing of the mycelium sensitivity to biological or chemical molecules under laboratory conditions. This is the case of LBC caused by *L. theobromae*, for whic the sensitivity evaluations have shown that methyl benzimidazole type fungicides (such as benomyl and thiabendazole) are effective for treatment, whereas demethylation inhibition type fungicides (such as imazalil, prochloraz, tebuconazole) are less effective. However, these studies have been only conducted on fruit crops (Ablormeti *et al*., 2021; Da Silva Pereira *et al*., 2012). Similarly, curvulariosis caused by *Curvularia* spp., has been treated through biological control in sensitivity tests for oil palm (Febriani & Kasiamdari, 2024; Sunpapao *et al*., 2018), with benomyl proving effective in oil palm nurseries, showing over 70% effectiveness (Brahima et *al*., 2023). Diseases caused by *Pestalotiopsis* spp. have also been treated with biological control in fruit crops (Widyaningsih & Triasih, 2021). Nevertheless, research on chemical fungicides for treating palm diseases remains preliminary and requires further investigation (Obeng et *al*., 2023).

Conclusion

This article presents survey findings on endophytic and pathogenic fungi on both the rhizosphere and stipe in the urban palms of Medellín, and includes descriptions of potentially pathogenic bacteria found in the rhizosphere. Identified fungal pathogens include *Fusarium*, *Phytophthora*, *Lasiodiplodia*, *Pestalotiopsis*, and *Curvularia*, which are known to cause severe palm diseases. These findings highlight the urgent need for targeted disease management in Medellín, with potential implications for nearby regions with similar climates.

Proposed strategies for managing the identified pathogens include removing and destroying infected plants and using proven biological and chemical treatments from the literature. Regular monitoring, pathogen sensitivity testing, and adhering to effective treatment protocols is essential. The BGM plans to conduct molecular identifications and sensitivity tests on pathogens to enhance palm health knowledge. Ongoing research will focus on developing innovative strategies to protect palms from emerging diseases, thereby maintaining the ecological balance, ensuring the long-term sustainability of Medellín's green spaces, and preserving the city's biodiversity and natural heritage.

Acknowledgments

This article is part of the study conducted by the Botanical Garden of Medellín for the District of Medellín, titled "Evaluation of Microorganisms Associated with the Mortality of Some Species of Medellín Palms." This clause is included as a requirement of the District of Medellín: "The document and its contents are protected by copyright laws (Law 23 of 1982, Decision 486 of 2000 of the Andean Community, and other applicable Colombian regulations). The copyright holder retains all intellectual property rights, including reproduction, distribution, public communication, and transformation, while respecting the author's moral rights. Use, reproduction, or publication without prior written permission is prohibited and may result in legal action.

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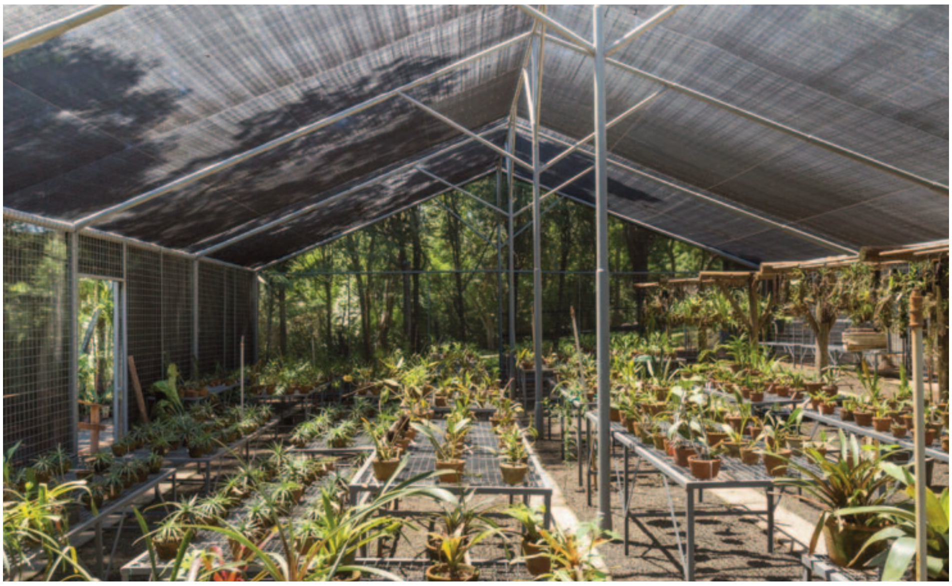
A staff member recording the evolution of symptoms in plants in the quarantine facilities of the Bauru Botanic Garden. (Viviane C. de Oliveira - Archives of the Bauru Botanic Garden).

THE ONGOING CHALLENGE OF PHYTOSANITARY MANAGEMENT IN *EX SITU* COLLECTIONS: A CASE STUDY FROM THE BAURU BOTANIC GARDEN

Cattleya witigiana orchids. On the right healthy plants and on the left plants showing visual symptoms of *Phytophthora nicotianae* pathogen infection. (Viviane C. de Oliveira, Archives of the Bauru Botanic Garden).



Technical Reserve Nursery of the Bauru Botanic Garden: Managing a large number of species with varied morphological characteristics and different cultural requirements is one of the difficulties in maintaining ex *situ* collections for conservation. (Fátima Sandrin).

Botanic gardens can pose biosecurity risks due to potential pathogen invasions and spread. Botanic gardens involved in conservation and ecological restoration have a crucial responsibility in phytosanitary control, ensuring the health of their plants and preventing them from becoming a threat for the regional flora. Additionally, the large number of visitors and the proximity to urban areas and environmental reserves can pose risks to the health of their collections. The Bauru Botanic Garden is working to address this issue in its daily routines, by implementing and improving its biosafety practices.

Introduction

The Bauru Botanic Garden (JBMB) is located on the edge of the urban area of the municipality of Bauru, in the state of São Paulo, Brazil. More than just a space for coexistence, leisure, and tourism, JBMB is dedicated to the conservation of regional flora, integrating education and research into its mission. With 30 years of existence, the garden has several plant collections for *ex situ* conservation, some potted and kept in different nurseries (e.g., Orchids, Bromeliads, Pteridophytes) and others in open beds (e.g., Arboretum, Ethnobotanical Collection, Aquatic Plants, Lianas, Cerrado Plants, and Medicinal Sensory Garden). Each of these collections requires different cultural treatments according to their characteristics and growing environment needs. These treatments include watering, fertilization, pruning, light exposure, and, for potted plants, periodic changes of substrate and cleaning of pots and nurseries. In addition to its *ex situ* plant collections, JBMB manages its 321-hectare environmental reserve, which is one of the last large Cerrado reserves in São Paulo maintained for *in situ* conservation.

Maintaining botanical collections for *ex situ* conservation in botanical gardens or arboreta is a major challenge. Specimens must be provided with an artificial environment tailored to their needs, with conditions conducive to their development. Adding to this complexity is the vast number of species with varied morphological characteristics, each requiring specific cultural treatments such as diverse watering and fertilization routines, and developing on different types of substrates (sometimes even without substrate at all), among many other important characteristics for collection management. Additionally, plants are threatened by a large number of insects, fungi, bacteria, and viruses, commonly referred to as pests and diseases. In tropical countries, where climatic conditions are more favorable for the life cycle of these pathogenic microorganisms, rigorous phytosanitary control is essential to avoid damaging the health of plant collections and, ultimately, the regional flora.

In recent years, with the expansion of its collections, JBMB has increasingly felt the need to improve its biosecurity practices by monitoring pests and diseases within its collections, with the aim of creating strategies to mitigate their impact. As discussed by Wondafrash *et al.* (2021), botanical gardens play an important role in conservation, but they can also pose biosecurity risks to their collections and natural environments if pests and pathogens are introduced and spread without effective management. These biosecurity risks in botanical gardens can arise from routine activities, such as the movement of plants and plant materials within the garden, the collection of specimens from native areas, and the reintroduction of plants in ecological restoration projects. Additionally, the large number of visitors and the garden's location, on the edge of the urban area and within an environmental reserve, can contribute to biosecurity risks.

Staff of the Bauru Botanic Garden carrying out physical pest control in the ex *situ* collection for conservation. (Fátima Sandrin).

Staff of the Bauru Botanic Garden in charge of managing the Medicinal Sensory Garden plant collection. (Viviane C. de Oliveira. - Archives of the Bauru Botanic Garden).

Developing Best Biosecurity Practices

Over the last few years, JBMB has made a series of strategic decisions to improve its biosafety practices. One of the first steps was to create additional structures to accommodate both the existing and future plant collections. A quarantine facility and a holding nursery were built in addition to the existing nurseries. This ensures that newly arrived plants—from field collections, donations, seizures, or plants showing symptoms of pests and diseases—are isolated from others, preventing the transmission of harmful organisms. While both installations have served their purpose, it has become apparent that their dimensions need to be expanded to accommodate the increasing volume of plants.

The staff responsible for managing ex *situ* collections for conservation play a fundamental role in phytosanitary control. They undergo internal training and receive periodic instructions to ensure best practices are followed. To ensure that plants remain healthy, staff implement preventive measures through appropriate management practices, such as adequate watering and fertilization, disinfection of pruning instruments, maintenance of substrate quality, asepsis of nurseries and beds, and manual control of insects when present at tolerable levels.

Phytosanitary control should always be carried out preventively. A set of management strategies and systematic care, including detailed documentation, can significantly contribute to the health of collections. Symptoms of pests and diseases can often be observed on the leaves, stems, or roots of plants, or the pathogen may be present on the plant or in the soil. Even an untrained member of the management team can unintentionally spread pests or diseases, for example, by using infected pruning instruments. Therefore, it is essential that the entire team responsible for the collections is well-informed, encouraged, and trained to support effective biosafety practices (Stanley & Dymond, 2020). The development of protocols, investments in appropriate infrastructure, and ongoing training are critical. Even after a pest or disease has been detected, these practices can be decisive in preventing the spread of infestation to other plants.

Partnership Between Institutions

When preventive practices alone are not sufficient to contain pests and diseases at tolerable levels, implementing emergency measures is recommended. As soon as symptoms of a pest or disease are observed, or the causative agent is identified, the plant must be isolated for diagnosis and appropriate phytosanitary treatment, followed by a decision on whether to return the plant to the collection or discard it. A successful partnership between JBMB and the São Paulo Agribusiness Technology Agency (APTA) has yielded good results. When the in-house team is unable to diagnose a phytosanitary problem, a part of the affected plant or the entire plant is sent to APTA for a correct diagnosis and the most effective treatment.

Partnerships like the one described above enable effective diagnosis and management of phytosanitary problems and can prevent, in some cases, the loss of entire batches of plants. For example, at the beginning of 2023, JBMB received a batch of *Cattleya witigiana* orchids, a species listed as endangered according to the List of Brazilian Flora Threatened with Extinction (Martinelli & Moraes, 2013). These orchids were confiscated by enforcement agencies on suspicion of being illegally collected from the wild, which is prohibited in Brazil. Upon arrival, the entire batch was placed into quarantine, and a few days later, staff noticed symptoms of rot in the pseudobulbs and leaves of some of the orchids. The symptomatic plants were isolated, affected parts were removed, sprinkler irrigation was stopped, and some plants were sent to the Bauru regional APTA for diagnosis. APTA identified the pathogen as *Phytophthora nicotianae* and recommended a treatment regime for the entire batch. Although many plants were lost to the disease, the majority could be treated and preserved.

When the Problem is Already Established

When a pest or disease is detected in a plant or collection, control measures must be implemented according to the specific needs of the situation. These measures can include:

- Physical Control: Adjusting environmental conditions to deter pests.
- Mechanical Control: Removing or destroying infected plant parts.
- Chemical Control: Applying pesticides or fungicides with caution to minimize environmental impact and avoid resistance.

The waiting nursery that receives plants and plant material from field collections, donations or seizures.
(Viviane C. de Oliveira, Archives of the Bauru Botanic Garden).

The use of pesticides is undeniably useful, but they must be used with caution. Environmental impacts, the protection and health of employees and visitors, the possibility of phytotoxicity, and the need to alternate products to avoid resistance must all be considered. Therefore, pesticide use should be guided by agricultural engineers to ensure effectiveness and responsibility.

Over the years, JBMB has documented the main pests and diseases that affect its collections, with the aim of creating a database. The database records frequent problems, symptoms caused, and management measures adopted. Although it is still under development, this database has already helped to quickly identify problems and make informed decisions about plant health. Additionally, lists of essential chemical products and detailed protocols for their safe application have been created. A pesticide use record book and a specialized storage area for these chemicals, meeting technical safety standards, have also been established. JBMB is also developing a Biosafety Policy, a comprehensive internal regulatory document outlining procedures for phytosanitary management, including monitoring, evaluation, prevention, control, and mitigation of pests and diseases.

Planning for the Future

Another crucial aspect JBMB is working on is raising awareness among its visitors about the importance of adopting effective biosecurity practices. Botanical gardens receive millions of visitors from around the world, making it challenging to fully control the risk of pest and disease entry. Visitors may inadvertently introduce or spread pests and diseases via their vehicles or clothing. Similarly, pests and diseases can escape from botanical gardens to other environments, such as public parks and urban forests. Raising awareness through information boards, lectures, and other strategies is essential to address these risks (Hayden, 2020).

Staff of the Bauru Botanic Garden in charge if the chemical pest control in the orchid collection. Picture: (Viviane C. de Oliveira - Archives of the Bauru Botanic Garden).

Staff of the Bauru Botanic Garden preparing for image registration of *Cattleya witigiana* orchids for the Database. (Viviane C. de Oliveira, Archives of the Botanic Garden of Bauru).

For botanical gardens involved in ecological conservation and restoration, it is vital to understand their responsibility in phytosanitary control for plants used in restoration projects. This not only preserves plant health but also prevents these plants from becoming a threat to regional flora.

The development and implementation of biosecurity strategies must be seen as a continuous process. Challenges include team training, securing financial support, and raising awareness about the importance of these initiatives. Support networks between botanical gardens and similar institutions can be powerful tools in developing and refining these practices. Sharing knowledge and observations about plant health and biosecurity globally can enhance monitoring and control methods (Clements & Brockerhoff, 2016). We hope this experience report from JBMB inspires other botanical gardens to be aware of their responsibilities and motivates them to establish robust biosafety and phytosanitary control practices.

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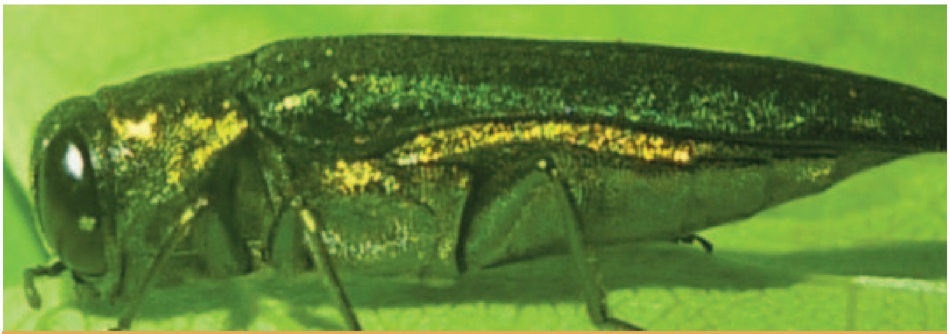
THE WELSH PLANT HEALTH SURVEILLANCE NETWORK



Agrilus planipennis (Emerald ash borer)

Agrilus biguttatus (Two-spotted oak bupresid)

Ips typographus (Larger eight-toothed European spruce bark beetle)

Thaumetopoea processionea (Oak processionary moth)

Figure 1. Four of the insect pests under surveillance by the WPHSN

The Welsh Plant Health Surveillance Network (WPHSN) is a Welsh Government funded plant health initiative. Launched in 2022 by Forest Research (FR) its primary aim is to monitor the presence and absence of native and invasive pests and pathogens that can pose a threat to the health of plants and trees across Wales, acting as an early warning system and monitoring tool.

The WPHSN collaborates with the Wales Plant Health Sentinel Site Network, the Welsh Government Woodland Estate, and private landowners to gather data which is used to inform the development of priority goals and policies relating to woodland management in Wales.

Welsh woodland surveillance

The Welsh Plant Health Surveillance Network (WPHSN) primarily consists of a network of pheromone insect traps and mechanical spore traps strategically situated in woodlands, parks and gardens around Wales to detect organisms which have historically been detected in the region, and to detect new arrivals which have the potential to thrive in Wales as the climate changes. Biological samples are collected from the traps on a fortnightly cycle between April and December each year. The insect samples are typically analysed by FR staff in Wales, while spore samples are sent to our state-of-the-art plant health facilities at Alice Holt for in-depth laboratory testing. This allows for the recording of the presence and absence of specific pests and pathogens, such as, non-native bark beetles and fungal diseases (Fig. 1).

Additionally, tree health visual surveys are conducted where disease is suspected. For example, oak trees are examined for symptoms of Acute Oak Decline - a disease caused by an aggregation of bacteria - where crowns are showing signs of thinning, where resin-like bleeds are observed on tree stems, and/or where *Agrilus bigutattus*: a jewel beetle associated with the causal bacteria of the disease (Reed et *al*., 2018).

Where diseases affecting conifers are suspected, such as *Phytophthora pluvialis* – a fungal pathogen of Douglas fir and western hemlock - potentially susceptible stands within a 5 km radius of an identified fungal pathogen outbreak undergo visual surveys for signs and symptoms of disease. These visual surveys are undertaken in conjunction with the Natural Resources Wales (NRW) tree health team.

Secondary aims of the WPHSN are to raise awareness of plant and tree health issues, educate stakeholders and the public of the species likely to cause stress and disease to trees, to share advice and information to support "citizen scientist" observations and identification, as well as to promote good biosecurity practices to minimise the future spread of disease.

Engagement with landowners and land managers at public events, like the Royal Welsh Show, highlighted that the narrative around tree disease is typically focused narrowly on ash dieback disease and Dutch elm disease. This has caused us to accelerate the collaboration with external agencies to broaden the public perception of tree disease to incorporate other pathogenic diseases, such as those caused by *Phytophthora* species as well as expanding the knowledge sphere around woodland pests, such as *Ips typographus* and oak processionary moth.

The need to widen the knowledge sphere in the public domain around woodland pests and pathogens [from ash dieback and Dutch elm disease] became apparent at networking events, like the Royal Welsh Show.

Established as a unique venture between Forest Research and Welsh Government in 2022, the WPHSN is a new initiative for Wales. The project lead, Racheal Lee, was keen to ensure the pilot phase (2022 – 2025) of the surveillance network incorporated sites that were deemed 'at higher risk of invasion'; subsequent phases will observe the network to spread across the country. Higher risk sites were determined from research published by Professor Hugh Evans in his research report (Evans, 2021), in which he proposed the likelihood of the distribution of *Ips* species

Figure 2. Infographic illustrating public access sites collaborating with the WPHSN (Lee & Olivieri, 2024).

(bark beetles) specifically to be from the East of England (where these have colonised and been detected) in a westward direction as climatic suitability for colonisation improves across the UK, i.e., higher summer temperatures and more frequent windstorms. These variables provide conditions for multiple generations of the insect to occur in a single 12-month period and assist with its migration (Evans, 2021). This distribution model has been adopted in the WPHSN to monitor potential colonisation of *Ips typographus* in Wales, together with other insect pests with the potential to cause disease and tree mortality in Welsh woodlands. Examples include *Ips cembrae* (large larch bark beetle), *Thaumetopoea processionea* (oak processionary moth), *Agrilus* species (jewel beetles), *Monochamus alternatus* (Japanese pine sawyer beetle), and *Lymantria dispar* (Gypsy moth) and this work has informed the location of site selection for inclusion in the trapping network.

Change in climatic conditions in Wales can improve colonisation opportunities for invasive pests, such as Ips typographus and Oak processionary moth, which can be detrimental to commercial spruce plantations and oak parklands respectively.

Ips typographus is an important insect pest as it poses a significant health risk to spruce stands when established (Blake et al., 2024). With the commercial forestry industry in Wales worth an approximate £499.3 million per year (NRW, 2024), collaboration with NRW for access to the Welsh Government Woodland Estate was of paramount importance for the surveillance of spruce. Similarly, oak processionary moth (OPM) and *Agrilus* beetle colonisations pose a serious threat to the health of oak and ash trees (Fig. 2), thus collaboration with the Sentinel Site Network and private landowners provides access for surveillance to broadleaf trees in parks and gardens.

Fungal pathogens being monitored by the WPHSN include:

- *Hymenoscyphus fraxineus* - responsible for ash dieback disease
- *Neonectria neomacrospora* - responsible for causing cankers in fir trees
- *Heterobasidion* and *Phytophthora* species – parasitic pathogens of conifer trees, e.g., *Picea* species (spruce trees) and *Tsuga heterophylla* (western hemlock) respectively, which are important because of their value to the commercial forestry industry.

Sentinel site collaboration

Within the WPHSN, the term 'Sentinel Site' not only applies to the 22 sites (one in each local authority region in Wales) which make up the Wales Plant Health Sentinel Site Network (Welsh Government, 2022), but refers also to sites with public access and private landowners which are collaborating with the WPHSN for the purposes of monitoring for invasive pest and disease species (Fig. 2).

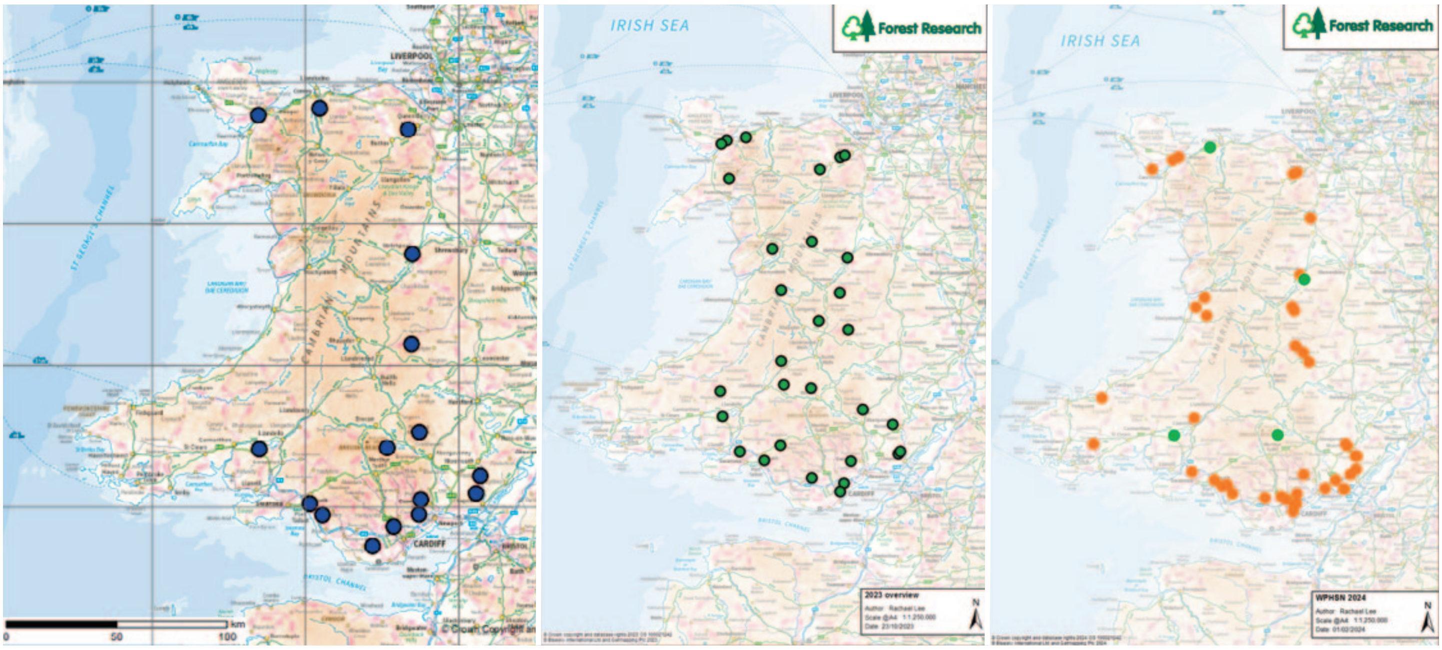


Figure 3. Map of Wales illustrating the trapping network 'J' formation which established following guidance from the report by Professor Evans (2021) and the development of the network through the pilot phase: Year 1 - 2022 (left), Year 2 - 2023 (centre), Year 3 - 2024 (right).

Working with external agencies has facilitated the growth of the WPHSN by affording access to a range of woodlands, maximising the range of organisms we can survey for, and allowing the sharing of information and advice. Moreover, active and ongoing collaboration delivers mutual operational support in the event of a suspected interception.

Collaboration with sentinel sites is a multifaceted enterprise that supports the WPHSN in the ongoing monitoring for damaging, species and the sharing of plant health information.

Project achievements

In Year 1 of the pilot project, the higher risk sites formed a 'J' formation across Wales – starting at Swansea in the south, moving eastwards along the M4 corridor to southeast Wales, incorporating Cardiff and Chepstow, up the Wales/England border to Denbighshire, and then westward along the A55 corridor towards Bangor, ending on Anglesey. A total of 33 insect traps and 2 spore traps were deployed across 23 sites.

To expand the network for a greater coverage of Wales, years 2 and 3 continued to use the 'J' formation network with the addition of traps through the centre of Wales in a south to north trajectory (Fig. 3). A total of 66 insect traps and two spore traps were deployed across 32 sites in year 2, and 84 insect traps and five spore traps were deployed across 40 sites in year 3.

Sites are a combination of conifer plantations managed by NRW, sentinel sites consisting of parks and gardens with public access, and privately owned mixed woodlands.

Data collected from the traps has been used to build a distribution map of pests and pathogens. It is important to note, recording a negative in this pilot project is as equally important as recording a positive as it illustrates the absence on non-native invasive species. Furthermore, incorporating an abundance record from a positive result will allow for the monitoring of the disease to establish whether it is increasing and/or spreading, or indeed, decreasing in abundance and geographical distribution.

Conclusions

During the pilot phase (2022 – 2025), the WPHSN expanded its surveillance network geographically, forged working relationships with sentinel sites and external agencies to support data collection, and built a 'real time' map detailing the detection of insect and fungal pathogens. It has been well received by the sentinel site network as a tool for them to use to protect their trees, parks and gardens. Public engagement at events, such as the Royal Welsh Show, has flown the flag for this initiative and has helped to broaden the discussion around tree diseases.

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https://www.forestresearch.gov.uk/research/monitoring-tree-pests-and-diseases-in-wales/

Author: Erin Buchholtz

COHERENT TERMINOLOGY FOR COMMUNICATING METHODS OF MAINTAINING PLANT HEALTH

Pesticide application signage is often small to maintain garden aesthetics. Visitors may ask staff questions the signs do not address. (Erin Buchholtz)

Pests and diseases have major impacts on the health of plant collections in public gardens. Visitors to these spaces influence how we address these challenges, through their understanding of the rationale and approval of best management practices. Language regarding plant protectants is not standardized and often leads to misunderstandings about the use of pesticides and other integrated pest management practices. This article will explore terminology like organic, natural, and chemical and how educating stakeholders reduces the stigma of plant health management efforts in public gardens.

Introduction

Public gardens exist to showcase beauty, educate visitors, and connect people to plants and wildlife. These spaces also furnish ways to conserve threatened and endangered plant species, allowing for the protection and sharing of germplasm with partner organizations worldwide. It is therefore vital for staff to ensure optimal plant health. Integrated pest management (IPM) offers multiple ways to address plant health concerns: cultural, mechanical, biological, and chemical are the most commonly listed in IPM.

Unless visitors to these spaces understand the terminology regarding the methods used, personal interpretation could lead to false or dangerous assumptions.

Pesticides

Worldwide, efforts to ban or heavily restrict pesticide use limit management options for maintaining or improving plant health. Misconceptions about pesticides affect both extremes - those seeking to use what they want to eradicate a pest or those insisting all pesticides pose unacceptable risks. Exploring the definition of the word pesticide is a good place to start.

While municipalities and regional governments each offer definitions, key differences must be addressed. They can be simple, yet restrictive: "Pesticides are chemical compounds that are used to kill pests, including insects, rodents, fungi, and unwanted plants," (World Health Organization, 2020). In this instance, the suffix "-cide" means literally as something that kills.

Other organizations and agencies offer looser definitions. In the United States, a pesticide may kill the intended target. However, it may only repel the damaging pest from the valued crop (United States Environmental Protection Agency, 2024). In this instance, the pest's death is not the intent of the applicator. Rather, a product that helps to keep the harmful organism from damaging the plant is considered a pesticide. No harm comes to the pest directly, though it may not be able to complete its lifecycle due to reduced food availability or forced relocation.

Pesticides are used to manage a pest. The goal is to protect a desirable organism or object. If the word causes misconceptions about the outcome, public garden staff can specify and differentiate pesticides from repellents, prophylactics, and other nonlethal solutions. While legal definitions of the products may limit manufacturers' marketing efforts, we can offer clarifying language about the modes of action or intended outcomes.

> *"The desired outcome of pesticide use is to protect a desirable object or organism from pest damage"*

No matter the strength of the chemical or how safe it is for visitors, public gardens must also look for wildlife when applying pesticides to protect plant collections. (Erin Buchholz)

Chemical

Another ambiguous term, a chemical is something that has a constant and defined composition (United States Nuclear Regulatory Commission, 2020). The process used to prepare a chemical can be natural or artificial. In gardening, the word is often used interchangeably with pesticide. Therefore, it's seen as something negative. But water is a chemical.

When practicing IPM in a public garden, the use of plant protectants depends on the area's audience. In formal settings where the bulk of weddings or other large events occur, plants must look flawless, and pesticide use is forgiven or encouraged. In areas meant for children and families, we may tolerate pest damage if no poisonous materials are used. Research may focus on how plants perform without chemical interventions. Conservation or restoration work relies on herbicide use for excellent results in a limited amount of time.

In IPM, chemicals are often mentioned as "a last resort," (Food and Agricultural Organization of the United Nations, 2024). This often refers to pesticides that are not biologically derived. Therefore, it is reasonable to assume when a public garden visitor asks if chemicals are used, they are referring to registered pesticides.

In some instances, gardens don't specify what pesticide is used or the safety considerations. In that case, closure of areas is necessary to ensure safety. (Erin Buchholz)

A coworker once told me that no chemicals could be used in his work environment. Seeking clarification, I asked if bicarbonate, or baking soda, could be used to manage foliar diseases. He said that would be acceptable. I asked if coffee grounds could be added to the soil to repel slugs. He said that was a great idea. I asked if soap could be used on aphids. He agreed. Those substances count as chemicals, but they are not always registered pesticides.

Taking time to clarify what people mean when they use words like chemicals or pesticides can alleviate conflict or resentment and give staff and visitors the chance to share concerns rather than miss an opportunity for collaboration or improvement. In that instance, I better understood that the coworker did not want registered pesticides used because of public perceptions. Once I clarified that many of our pesticides have active ingredients that are the same as household ingredients, we began to explore which would be appropriate for use in that garden space.

Pesticides used in organic production are not always safe. Applicators often wear a respirator when working with biological controls to prevent illness. (Erin Buchholz)

Natural

"Is it natural?" Seeing a sprayer in a public garden is unnerving for many visitors. While application signage offers excellent information about what is sprayed and why, we must be prepared to stop and answer questions immediately. Another vague term heard concerning plant protectants is natural.

When speaking to garden clubs and volunteer groups or tour guides, it is my experience that the word natural conveys a feeling of safety. If the chemical I apply was derived from something we can eat or at least something we can easily pronounce, there is less concern.

Arsenic and uranium are natural, but they are not considered safe by most people. When plant protectants are marketed as natural, it can create a false sense of safety. Pesticide labels in many geographical areas contain information necessary to protect the eyes, skin, lungs, and other vital organs of people exposed to them. Even natural products can cause harm if proper protective equipment is neglected.

In the public garden, we can model the proper use of naturally or biologically derived pesticides by letting visitors see the use of coveralls, gloves, boots, and eye protection. A respirator may cause apprehension, but educating people about possible allergic reactions that living plant protectants pose could save lives.

Organic

Similarly, visitors feel that organically grown plants are safer. But that term has different meanings depending on legalities, geography, and production. In the United States, the Department of Agriculture legally defines and identifies what food qualifies as organic (United States Department of Agriculture, 2012). As the United States legally only considers food products to qualify as certified organic, it does not apply to ornamental gardening.

That does not stop ornamental landscaping companies from claiming to be organic. More likely, the company in question means that they don't use registered chemical pesticides. A public garden can help clarify by sharing its pesticide use policy, and why it does not qualify as organic.

Worldwide, the definition of organic varies. The European Union, India, Japan, and other entities have each defined standards in recent years. A compilation of organic standards can be found in the International Organic Standards document (OneCert International, 2018). Again, this refers to agronomic crops, fruits, vegetables, meat, dairy, and other food products. There is no mention of ornamental horticulture or arboriculture.

Visitors to public gardens may ask about organic practices. While many public gardens embrace and may have food growing and production spaces, they may not follow legal organic practices. There is ample opportunity for us to help people understand these standards.

Organic can also refer to chemistry, fertilizers, or originating from living material. Determining the intent behind the language can clarify the legal ramifications behind common claims of how plants are grown.

Even "organic" or "natural" pesticides require personal protective equipment (PPE). This may not make visitors to public gardens feel welcome. (Andrea Rodriguez)

Conclusion

Public gardens are repositories of incredible knowledge. We showcase and share connections between plants and people. We are in a unique position to help standardize terminology that is often misunderstood or misused by modeling behavior and collaborating with our visitors. Learning about their curiosities regarding pesticides, what a chemical is, how natural the products we use are, and whether or not we follow organic standards will help us deliver reliable and trusted messaging. Furthermore, it will remove misconceptions about our practices and remove the stigma associated with keeping our collections safe and healthy.

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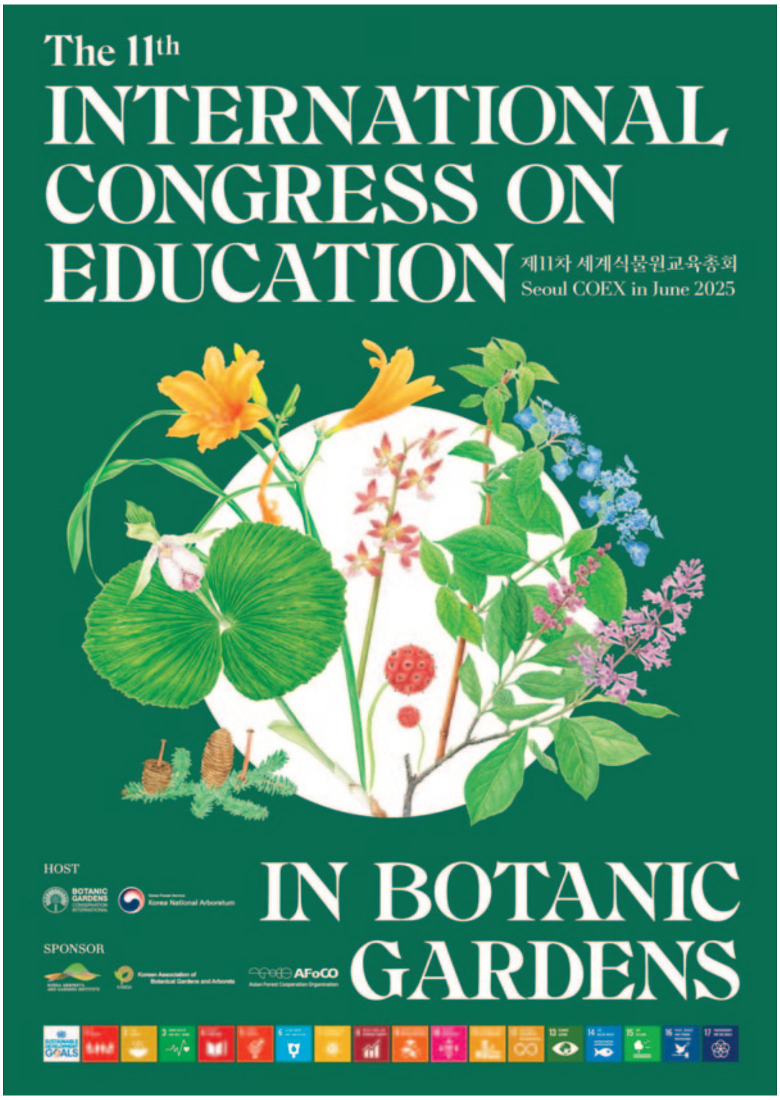
ACCESS THE REFERENCES SECTION HERE

11TH INTERNATIONAL CONGRESS ON EDUCATION IN BOTANIC GARDENS (ICEBG)

Education for change: botanic garden's role in addressing global challenges



Since its start in 1991, the **International Congress on Education** has gathered educators, practitioners, researchers, and academics to explore advancements, exchange ideas, discuss future priorities and foster collaborative efforts in botanic garden education. Held every 3-4 years, these events have focused on themes like sustainability, global awareness, biodiversity conservation, and community outreach.

The upcoming **11th ICEBG, hosted by the Korea National Arboretum**, will carry its legacy forward, placing a strong emphasis on transforming botanic garden education to meet the pressing challenges of biodiversity loss and climate change. It will be a unique opportunity to collaborate with international education experts, gain insights from diverse perspectives, and contribute to a collective effort in addressing environmental challenges. To ensure global accessibility, this Congress will be a hybrid event, allowing participation either in person or online.

We look forward to welcoming as many of you as possible at the 11th ICEBG in South Korea! Stay tuned for more details!

Save the date!

When	9-13th of June 2025 (with a Welcome Day on the 8th of June).
Where	Seoul, South Korea. COEX Exhibition Hall.
Host	Korea National Arboretum (KNA).
Theme	'Education for change: Botanic Garden's role in global transformation'

GLOBAL LEARNING AND OUTREACH NETWORK FOR BOTANIC EDUCATORS (GLOBE)

GLOBE

Are you a botanic educator? We're excited to announce the launch of the Global Learning and Outreach network for Botanic Educators (GLOBE) on LinkedIn!

GLOBE network is designed to encourage collaboration, exchange best practices, and inspire innovation in botanic garden education and public engagement. Whether you have a new toolkit or resource to share, an interesting article you have read, an upcoming webinar to promote, or a successful educational activity from your garden to highlight, please feel free to post it here. This is the perfect space to connect and share with fellow professionals.

You can also simply join as a member to access useful information others are sharing!

Join us today! Click here to join GLOBE on LinkedIn

or search for "Global Learning and Outreach network for Botanic Educators" directly on the search function.

Let's grow together—invite your colleagues and network to join GLOBE and be part of this vibrant community!

BIOSECURITY BEST PRACTICE GUIDANCE LEAFLETS

The Plant Health Centre of Scotland has developed biosecurity best practice guidance leaflets, that hope will be of great use to improve biosecurity practices:


Plant Health Centre

Scottish Government
gov.scot

Biosecurity best practice for safe disposal of plant waste and spent growing media

Research has shown that plant waste and spent growing media can harbour pests and pathogens, including quarantine-regulated species such as *Phytophthora ramorum*. These organisms have the potential to spread from untreated waste piles to cultivated plants and the wider environment. This guidance aims to help the horticultural sector understand and mitigate these risks by providing some practical advice on waste management.

*Waste and environmental legislation is a devolved issue so please note that if you are using this guidance outside Scotland, the relevant national licencing authorities will need to be contacted.**

Minimise waste and risk of infected waste material by growing clean plants

The best way to limit waste volumes and to minimise the risk of pests and pathogens proliferating in waste is to ensure that plant stock is sourced and grown to high standards of biosecurity and is monitored frequently to ensure that plants remain visibly healthy/symptom-free. Various types of growing media ingredients and mulches (e.g. pot tops) can also harbour and be sources of pests/pathogens.

Biosecurity best practice for safe disposal of plant waste and spent growing media:

Click here to access the leaflet


Plant Health Centre

Scottish Government
gov.scot

Biosecurity best practice for conservation

Ruth Mitchell (Hutton), Matt Elliot (RBGE), Henry Creissen (SRUC) and Lisa Ward (Forest Research)

Key principles to promote plant health in the natural environment:

1. **Risk assessment** – a thorough assessment should be made before an activity is carried out to identify and assess the potential impacts and risks of that activity. The boxes below can be used to help develop the risk assessment.
2. **Bio-security protocols:** should be developed to mitigate or reduce the risks identified in the risk assessment.
3. **Responsible person for biosecurity:** Organisations involved in habitat creation/restoration should have a named individual responsible for biosecurity. This person should be trained in biosecurity and have overall responsibility for the development of a risk assessment and protocols that address biosecurity risk.
4. **Check protocols followed:** Regular checks should be made by the responsible person throughout the project to ensure biosecurity protocols are followed by staff and contractors.
5. **Monitoring:** Assessing plant health should be part of regular monitoring, such as habitat condition surveys or the monitoring of restoration/creation success.

Carrying out plant conservation work (e.g. relocations, translocations, habitat creation, habitat restoration) carries a risk of the inadvertent introduction of pests and pathogens into sensitive habitats. Thereby negating the objectives of the work. For example, there are several species of *Phytophthora* (fungal-like plant pathogens) which are ideally suited to surviving and spreading within plant production facilities. If measures are not taken, pathogens can be introduced from the nursery or from soil on machinery/tools into the wider environment on plants during conservation activities.

Every phase of the process from the production of the plants, to planting at the restoration site, to movement of machinery and soil needs to be considered. The framework below describes actions that could be taken to reduce the risks of, and increase resilience to, plant pests without identification of specific plant pests.

1

Biosecurity best practice for conservation:

Click here to access the leaflet

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EXPLORE THE TREE HEALTH CENTRE RESOURCE HUB!

The Tree Health Centre Resource Hub, created and managed by the Yorkshire Arboretum, aims to make the wealth of tree health and biosecurity information across the internet more easily accessible.

Discover a comprehensive collection of tree health and biosecurity resources all in one place. Tge Hub is designed to streamline your access to credible information, with new resources added regularly.

What's Inside:

- **Courses and Events:** Find training opportunities and events for all skill levels.
- **Templates and Downloads:** Access ready-made templates and tools to save you time.
- **Guidance and Factsheets:** Quickly find essential, easy-to-understand information.
- **Careers:** Explore links for career development and continuing professional development.
- **STEM:** Dive into resources related to Science, Technology, Engineering, and Maths.
- **Pests and Diseases:** Stay updated on the latest information about pests and diseases in the UK.
- **Rules and Regulations:** Navigate relevant rules and regulations with ease.
- **Videos, Webinars, and Online Training:** Access quality online courses and webinars.
- **Citizen Science:** Discover ways to get involved and bring your family and friends along!

Explore, learn, and stay ahead with the Tree Health Centre Resource Hub! Access the hub here

THE TREE HEALTH CENTRE
AT THE YORKSHIRE ARBORETUM