Reducing risk to wild ecosystems in nursery production: the Nursery Biosecurity Project at Auckland Botanic Gardens, Aotearoa (New Zealand)

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Abstract

The implication of the nursery trade in the historic movement of the pathogen that causes kauri dieback (*Phytophthora agathidicida*) instigated a review of nursery biosecurity procedures at Auckland Botanic Gardens. The nursery grows 65,000 native plants a year which are planted at restoration sites throughout Auckland. Threatened plants are also grown in the nursery and returned to the wild. The biosecurity project resulted in a manual of protocols, supported by infrastructure upgrades, to enable the nursery to take all practicable steps to ensure there is as little risk as possible to natural ecosystems through nursery practices. This work also demonstrates the important role of botanic gardens in providing education and advocacy for such schemes in all nurseries.

Introduction

Potted nursery-raised plants are a potential vector for moving pathogens to new locations, and botanic garden nurseries are no exception when plants are grown for conservation and restoration purposes, i.e. relocation to the wild. Plants can also harbour pathogens within their tissues, and pathogens can be present in soils or the media of potted plants. *Phytophthora* present at restoration sites with failing trees has been connected to plant nurseries that have produced stock for these projects (Garbelotto *et al*., 2018). Conditions ideal for pathogens may be created in nurseries by the arrangement of plants closely spaced and in single-species blocks, the presence of windbreaks to reduce airflow, regular (often overhead) irrigation and the occurrence of accumulated materials (such as reused pots and stacks of trays) and machinery. Nurseries are novel ecosystems that may provide pathogens with new opportunities to infect a range of susceptible hosts that they may not normally encounter in a wild setting. A nursery situation could also potentially create the opportunity for interspecific hybridisation, leading to the emergence of new pathogens where the hybrid has many potential new hosts. Pathways for pathogens and pests in and out of a nursery, including programmes to reduce habitat and suitable conditions for pathogen survival and spread at the nursery, need to be managed for all botanic gardens involved in return to the wild and habitat restoration projects.

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Auckland Botanic Gardens nursery

The nursery is part of Auckland Botanic Gardens (ABG). It produces plants to maintain the collections at ABG, but also grows 65,000 native plants each year for habitat restoration outside ABG and propagates threatened plants for conservation projects (ultimately also returned to wild habitats) (Fig. 1). Conservation and restoration are important roles that botanic gardens can play worldwide and, despite the implication of the nursery trade in spreading invasive non-native plants, pests and pathogens in the past, the role of nurseries in preventing plant extinction is likely to become more important.

In 2006 the death of large kauri (*Agathis australis*) trees in parks in Auckland was observed, and *Phytophthora agathidicida* was subsequently identified (Weir *et al*., 2015) as the cause of these deaths. The symptoms are known as kauri dieback. Pathogens such as *Phytophthora* species are becoming more apparent in wild ecosystems with devastating irreversible effects worldwide (Hansen, 2015), for example sudden oak death in the US, caused by *P. ramorum*. *Phytophthora* are soil-borne pathogens, and the movement of soil is identified as a risk pathway for the movement of the pathogen and therefore potentially the disease. *P. agathidicida* has a resting life stage propagule – an oospore – that can remain dormant for many years, and it is possible that it may be moved in potted plants irrespective of the species of plant in that pot. A review of the historic movement of

Fig. 1 Auckland Botanic Garden grows 65,000 plants a year for restoration of forests throughout the Auckland region. Photo: Rebecca Stanley.

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this pathogen (Beachman, 2017) concluded that *P. agathidicida* was 'almost certainly' introduced to four kauri forest sites via contaminated potted seedlings raised at a forestry nursery in the 1950s. The realisation that a nursery could unwittingly spread such a pathogen, were one to arrive (the effects of which may not be known for decades), led to the initiation of the Nursery Biosecurity Project at ABG in 2014.

The Nursery Biosecurity Project

By current standards the design of the ABG nursery is outdated, and the process of clean plant production and pathway management is impeded in some ways by this. Any new nursery facility should have biosecurity standards at the forefront of its design. Despite the age and layout we have endeavoured to ensure plants that leave ABG are as clean as possible so that pests, weeds and diseases are not spread by our plant production processes or transport. The initial focus on nursery biosecurity was to ensure that no native plants grown for revegetation could be a vector for kauri dieback; however, our goals broadened during the review to include any nursery-borne micro-organisms that may adversely affect the wild natural sites that plants are dispatched to. The primary goal of the review was to identify risk pathways for such pathogens and pests into the nursery and within it, including processes and infrastructure which might support habitats or spread, and to put management procedures in place to minimise these risks.

An unexpected outcome was the realisation that the most critical part of a nursery hygiene system for biosecurity is management support and staff involvement in order to achieve acceptance of, and adherence to, new systems and processes. It only takes one incursion of a pest, if it is a new pest to the country or a legally unwanted organism, for conservation and restoration work to cease or be compromised. It is crucial that nursery staff receive training and education opportunities to stay motivated and informed of industry best practice for biosecurity. Our staff are advocates for nursery biosecurity and are encouraged to continually suggest improvements to hygiene practices; their willingness to share their knowledge makes a valuable contribution to our industry's biosecurity awareness. In a botanic garden setting all horticulturists, not only nursery staff, must be involved and understand the biosecurity processes. A collaborative approach to designing new systems and processes at the ABG nursery has resulted in a highly motivated team of advocates who promote nursery hygiene and have an active role supporting this journey in community nurseries.

Biosecurity auditing schemes

In 2015 ABG enrolled in the (Australian) Nursery Industry Accreditation Scheme (Greenlife Industry Australia, 2020) which promotes industry best practice. This enabled us to evaluate nursery processes through an environmental and biosecurity lens that was independently audited. In 2019 the ABG nursery was part of a pilot group for a New Zealand nursery biosecurity standards scheme, developed and run by New Zealand Plant Producers Incorporated (2020). Both schemes provided an invaluable opportunity for critical analysis of each step of nursery production, development and documentation of best practice. They also provided access to external experts for mentoring and formulating customised solutions.

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Risk pathways

The review identified three pathways to focus on:

- arrival of infected plant material or soil/media (e.g. in purchased potted plants, on machinery, tyres or boots, or in bulk mixes for bagging up plants);
- improvements in hygiene within the nursery;
- documentation of best practice to record, maintain, communicate and improve biosecurity systems.

Arrival of media and plant material

Only commercial growing media supplied by reputable companies who undertake regular testing of their products is permitted on site. Preferred suppliers are those that are also accredited under a biosecurity scheme. This ensures suppliers are aware of the potential for their product to contain pathogens or weed propagules and are minimising that potential before their product is shipped.

Threatened plants or rare cultivars can usually be collected as seed or cuttings without the risk of soil being brought to ABG. This protocol does restrict the acquisition of salvaged plants which may arise if a very threatened plant site is about to be destroyed by a development. If the risks of that site are assessed carefully these acquisitions may be permitted depending on the threat level of the species and knowledge of pathogens at the home site. This method of acquisition may be considered under exceptional circumstances and with the deployment of mitigation methods such as washing off as much soil as possible and ensuring the plant is quarantined.

The development of cost-effective, field-based detection methods, such as molecular high-throughput detection tools, in nurseries and gardens would be very beneficial to assess soil contamination status. Present methods rely on visual inspections for symptoms of known pests and pathogens.

Seed of any species may not be acquired if it is collected off the ground in order to minimise the chance of any soil being present on seed brought to ABG. All plants purchased must first enter a quarantine area and remain there for one month before being accepted into the main standout area. While in the quarantine area, the plants are closely monitored for pests and diseases. Assays which can rapidly detect the presence of *Phytophthora*, such as lateral flow technology (Lane *et al*., 2007), are diagnostic tools that we have not deployed due to budget constraints but should be used if possible, particularly if plants are arriving from high-risk areas or those with known *Phytophthora* infestations. Once infected material has entered the nursery, in media or soil outside the quarantine area, it is unlikely to be reversible. Prior to the review, plant material was acquired, sometimes from specialist collections and wild sites, either in pots or as divisions which may have included native soils from those locations. Because of the risk of introducing pathogens in soil, no plants are purchased or acquired from any garden with natural soils attached. Nor are plants purchased from any nursery that has kauri dieback or from a nursery in catchment where kauri dieback is known to be present. We will continually seek to improve plant acquisition by preferring to purchase plants from other nurseries that have been through a biosecurity scheme, hygiene audit system or similar accreditation scheme. Soil movement from the garden is also minimised.

Unlike the nursery, it is not possible to control the entry of particles of soil which

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may enter parts of the garden accessible to visitors. Entry to ABG is free and visitors can come in at any of five public entrances as well as multiple private accessways. These many entry points prevent the use of footbaths as a practical barrier to pathogen incursion. Gardens with single entry points for visitors can consider disinfectant footbaths (Hayden, 2020). We use signage to endeavour to deter people from entering garden beds (Fig. 2). Botanic gardens worldwide share the concern of pathogen spread via soil on visitors' footwear because visitors do sometimes enter garden beds, partly encouraged by the opportunity for taking selfies. The biosecurity risks of garden tourism should also be considered as a pathway for pathogens entering botanic gardens, as a visitor may target multiple gardens on one trip and visit several consecutively in a day or week. Minimising soil movement from the garden to the nursery is one way to lessen the risk of a pathogen brought to ABG by visitors to the garden entering the nursery.

Communication and education

In contrast to commercial nurseries, botanic garden nurseries are usually off limits to general garden visitors, but they often host visiting groups and volunteers. Nursery-based staff in a botanic garden are the core workers in that location, and other garden staff (generally horticulturists but also education and visitor services staff as well as garden managers) come and go from the nursery facility throughout their working day or week. Biosecurity protocols and training

Fig. 2 Signage informing visitors not to step on the garden beds to minimise the opportunity for soil particles on their footwear to make contact with the soil in the garden beds. Photo: Rebecca Stanley.

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must recognise these levels of use and that not all staff will be completely familiar with all protocols as the nursery is not their core workplace. In addition, garden staff who are not nursery-based may pose additional risk pathways as they may be more likely to be travelling from wild sites or from other gardens.

Volunteers may also come from numerous places in the region, some from areas where kauri dieback is known. No boots or equipment with soil attached from outside the garden is permitted to enter the nursery. Boot-washing stations are located at the entrance to the nursery area (Fig. 3). Staff are inducted in nursery biosecurity when they start work at ABG, and all are expected to support new staff to understand the biosecurity systems. Visitors must be signed in at the nursery by staff.

Fig. 3 Boot-washing stations in the nursery are used to ensure staff and visitors have clean footwear before entering. Water washes into the stormwater drain. A footbath with disinfectant is used after washing. Photo: Rebecca Stanley.

No visitor, volunteer or contractor vehicle is permitted to drive through the nursery area, and cars are restricted to the quarantine area at the nursery entrance. If a vehicle must access the nursery (e.g. at dispatch time when a transporter is contracted to move 65,000 native trees for replanting), it and its tyres must be clean. An inspection is carried out on entry. No washdown area is provided as we do not want the water run-off to remain in the nursery area. Ideally, plant transporters are also required to be certified in plant biosecurity schemes. Our current provider is certified under another New Zealand plant health scheme for kiwi fruit nurseries (Kiwifruit Vine Health, 2020) which has strict biosecurity standards legally regulated under a National Pest Management Plan under the New Zealand Biosecurity Act (1993).

Signs state that entry to the nursery is restricted to permitted persons only (with no public access). Other signs are used to show expected nursery visitors (such as contractors) where to park vehicles and directing all visitors to the office. A nursery biosecurity poster welcomes visitors and staff and sets the tone for their visit. Signage highlights the importance of biosecurity within the nursery to people who do not usually work there.

Botanic gardens are well-placed, with our education role, to promote nursery biosecurity for conservation purposes. Our nursery has become a centre of excellence for this work in our community, with ABG staff sharing practical methods of nursery hygiene with community and volunteer-run nurseries outside the gardens. It is also a place where we advocate this approach through tours given to volunteers, contractors and nursery industry professionals (Fig. 4).

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Fig. 4 Tours of the nursery biosecurity improvements are an effective way to engage and educate volunteers and other industry professionals in the programme. Photo: Julia Watson.

Hygiene protocols

Hygiene protocols can reduce the transmission of infected material through the nursery, and general improvements to nursery conditions can reduce the number of suitable habitats for pathogens and in turn decrease the proliferation of pathogens under nursery conditions.

Process improvements

New processes to improve hygiene have been introduced for ensuring that reusable pots are cleaned, sterilised and dried. The use of new pots would guarantee sterility; however, a balance between high standards of hygiene and environmental sustainability is important. Sterilising pots using disinfectant, heat or steam should be considered to enable their reuse. Purpose-built steamers are available; however, ABG staff have built a steam cleaner using a high-pressure hot-water device which feeds into an industrial aluminium chamber. Scale and budget will need to be considered at each nursery to ensure a workable steam-cleaning system. Other hygiene measures to minimise cross-contamination include:

- the use of sterilising sprays containing isopropyl alcohol or other disinfectant on tools and work surfaces at the end of every day and between batches of plants;
- restricting the use of tools to specific areas; for example, the propagating secateurs are not used anywhere other than the propagation bench.

Environmental weeds are controlled in and around the nursery to prevent weed

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seeds entering the potted plants. Plants are surveyed and weeded throughout their time in the nursery. Standard Operating Procedures (SOPs) include inspections of plants before dispatch and require that obviously infested or unhealthy plants are not transported to wild sites.

Infrastructure

The ABG nursery was built in 1976 on a north-facing slope. The slope is a desirable feature; it ensures water does not naturally pool in the standout area for plants. However, this also means the outward flow of water from the nursery must be managed via entry into an underground water tank, with overflow entering a vegetated swale. The tank captures excess water for reuse in the nursery; however this will not be operational until we have more information on the most effective filters to remove pathogens before water is reused. Research into the survival of the *Phytophthora agathidicida* oospores in water is required to inform this.

All plants in standout areas have been raised off the ground by spreading a 6 cm layer of scoria gravel and laying weed matting over the top. The matting is replaced every other year. This ensures no potted plants are in contact with soil, nor do they sit in water. This minimises the chance of pathogens at the site moving from soil into potted plants. It also minimises the habitat available for water- and soil-borne pathogens as the site is often dry, even when irrigated in summer.

All wooden propagating benches have been replaced with stainless steel or galvanised steel benches. This ensures that no pathogens survive on the benches and provides an easy-to-clean and sterile surface. Unused old equipment and stacks of disused products have been removed as they could provide habitats for exotic skinks and other pests such as garden snails.

Future projects to improve infrastructure will consider capillary watering systems which might reduce microclimates for rusts such as myrtle rust (*Austropuccinia psidii*) which requires water to sit on leaves for germination.

A new, contained green-waste holding area has been constructed on a concrete pad within the nursery. Green waste is transported from the nursery to the main ABG depot area periodically for composting. The area is covered. No green waste generated in the garden is permitted to enter the nursery or be placed in the holding area, to eliminate the risk of diseases from the garden being brought directly into the nursery. No diseased material is placed here; this is bagged and placed in the landfill waste bin.

Documented processes

Documenting biosecurity best practice has several benefits, including communicating the work to other nurseries and biosecurity scheme auditors, ensuring continuity when staff change, streamlining the induction of new staff, and allowing continual reviews and improvements.

As highlighted by the decades-long lag time between suspected historic infection of plants with *Phytophthora agathidicida* in the nursery and its current impacts in wild ecosystems, it is critical to ensure traceability. The locations of transfers from nurseries to wild sites are documented and records kept. Provenance and acquisition information of plants is recorded as a routine practice, and this doubles as an excellent biosecurity measure to ensure traceability, so if an infected plant is detected its source can quickly be identified and traced. Every plant

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received at ABG is given an accession number which is recorded in an accession book and added to the Iris-BG database (Rustan & Ostgaard, 2012–2016).

Additional recording systems were put in place for inspections of all deliveries: dockets are signed as goods are inspected and held in the nursery office, and books are available to record all health monitoring. All accessions that are destroyed in quarantine due to the presence of pests or disease are recorded in Iris-BG in the comments field for that accession. All other recording books and diaries are stored together in a central location to ensure they are easy to find. All best-practice manuals and reference books (such as pest identification books) are easily accessible in one place on a biosecurity resources shelf.

The nursery manual is a compilation of SOPs which forms the core written output of the Nursery Biosecurity Project. Current SOPs include: Incursion Response; Sanitising and Cleaning; Vehicle Movement; Plant Dispatch; Propagation; Potting Mix; Plant and Seed Sourcing; Accessions; Quarantine; Disposing of Vegetation and Mixes; Pest, Weed and Disease Control; Lining Out; Stock Management; Pesticide and Herbicide Use; Fertiliser Use; Surveillance; Biosecurity Induction and Training; and Biosecurity Internal Audit.

Testing the system

A pre-emptive fungicide regime was instigated in the nursery in 2017 with the aim of reducing the chances of the recently arrived (to New Zealand) invasive plant pathogen myrtle rust establishing at the nursery. In 2018 myrtle rust was detected at ABG, although only in the garden, not the nursery. Despite the use of fungicides in March 2019 myrtle rust was detected in the nursery on *Lophomyrtus bullata* which seems to be the most susceptible New Zealand native plant to date. The incursion response SOP was deployed. When detected, the rust was restricted to one block of the nursery. Diagnosis was confirmed immediately by staff, and all affected plants were documented and bagged so the rust would not spread and were then disposed of. No subsequent infections in the nursery have been detected. The experience reinforced the concept that the restriction of wind-borne pathogens to any open nursery site is not possible, but that systems and processes to deal with documented incursions enable a quick and measured response which is familiar and understood by all staff.

The presence of documented incursion responses reassures site managers of parks (where the native trees will be planted) that our nursery has well-thought-out and robust processes, helping to build trusted relationships and encourage open conversations prior to any potential incursion. Plants in the vicinity of an incursion will be monitored, and no plants will be dispatched until there have been no detections in the nursery, on any stock, for at least one month after the last symptom is detected.

Holding known susceptible species to a newly arrived pathogen is a vexing issue. *Lophomyrtus bullata* will require active conservation management to prevent extinction but commercial nurseries are reluctant to grow this species as they are justifiably cautious of restrictions on trade if their nursery is infected with a pathogen such as myrtle rust. This species was being held in the ABG nursery for conservation purposes due to its new threat status. It is imperative that methods are established to ensure this

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work can continue without endangering wild ecosystems.

Conclusion

The ABG nursery is committed to the conservation of threatened plants and restoration of natural habitats of Auckland. Despite the age and design constraints of the nursery we have endeavoured to ensure plants that leave ABG are as clean as possible, minimising the chances that pests, weeds and diseases are spread to wild ecosystems by our plant production processes or transport. The manual produced from the Nursery Biosecurity Project supports this work and ensures an ongoing commitment to review and improve practices. It has also offered an opportunity for ABG to provide education and support on biosecurity practices to the plant production and nursery industry.

One caveat remains: that methods described here rely on visual inspections for symptoms of pests and pathogens, and all pathway management is based on the principle of hygiene. Evidence-based pathway management and the development of cost-effective field-based detection methods, such as molecular high-throughput detection tools, in nurseries would be beneficial to reduce the risk that nursery-grown plants pose to wild ecosystems.

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