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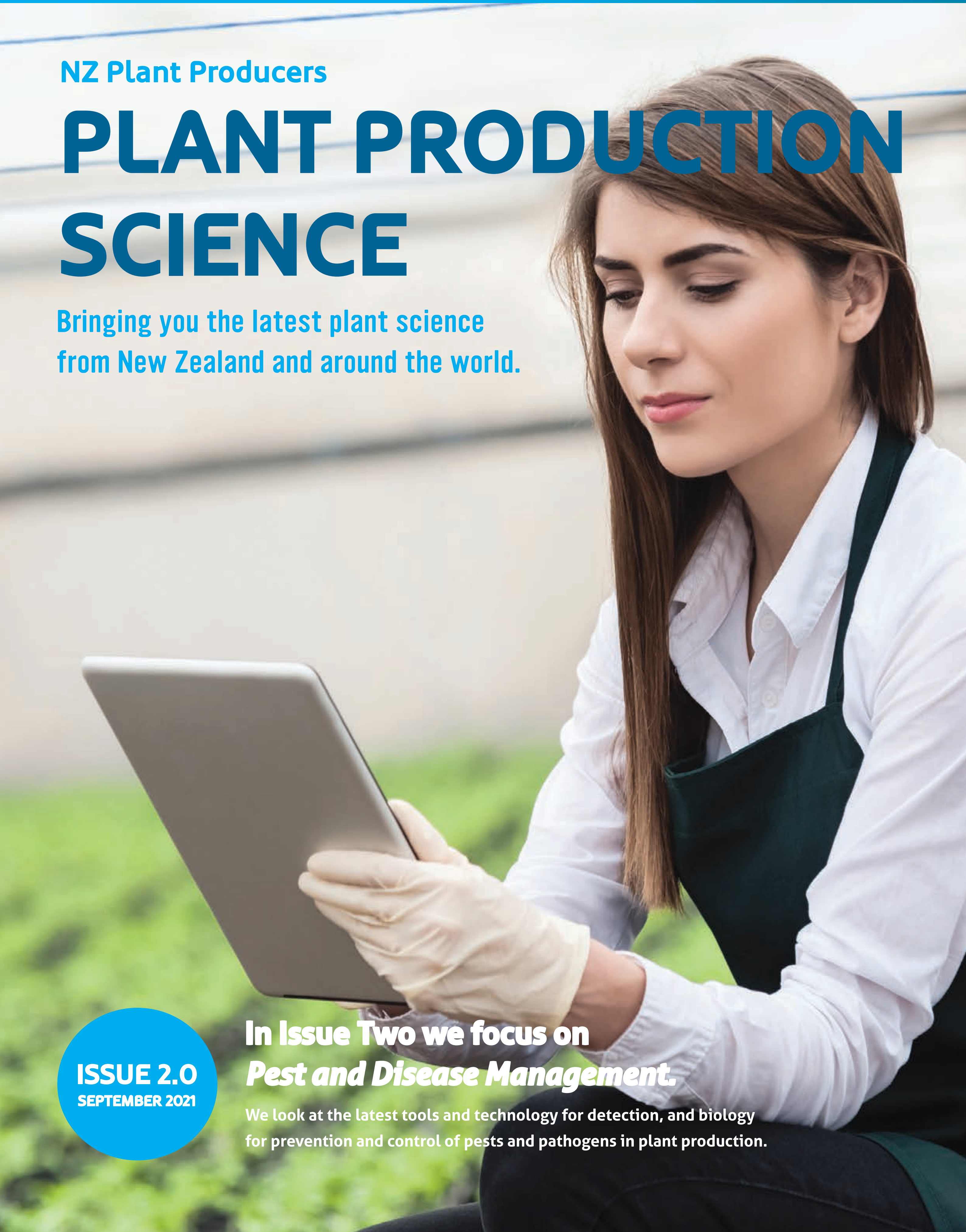

NZ Plant Producers

PLANT PRODUCTION SCIENCE

Bringing you the latest plant science
from New Zealand and around the world.

ISSUE 2.0
SEPTEMBER 2021

In Issue Two we focus on *Pest and Disease Management.*

We look at the latest tools and technology for detection, and biology for prevention and control of pests and pathogens in plant production.

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Using science and innovation in your plant production? Tell us about it! *kathryn@nzppi.co.nz*

Welcome to Plant Production Science, *in this issue we look at the latest science and technology for managing pests and diseases in plant production.*

From phone apps to robotics and genetic technologies, we could be forgiven for thinking biosecurity and pest management has become a game of technology. But it is an interplay. Technology provides the tools and biology the problems, and both are integral to finding new solutions.

This is nowhere more evident than the field of molecular biology and genetics, where cutting edge technologies continue to drive our understanding of biology which in turn drives innovative new technologies. The same breakthroughs which are helping us manage SARS CoV-2 Covid-19 virus in our communities are being developed to manage plant diseases in our productive and natural environments. In this issue we look at the use of RNA vaccines to protect plants against myrtle rust and the potential application of wastewater testing for detecting viruses in greenhouse environments.

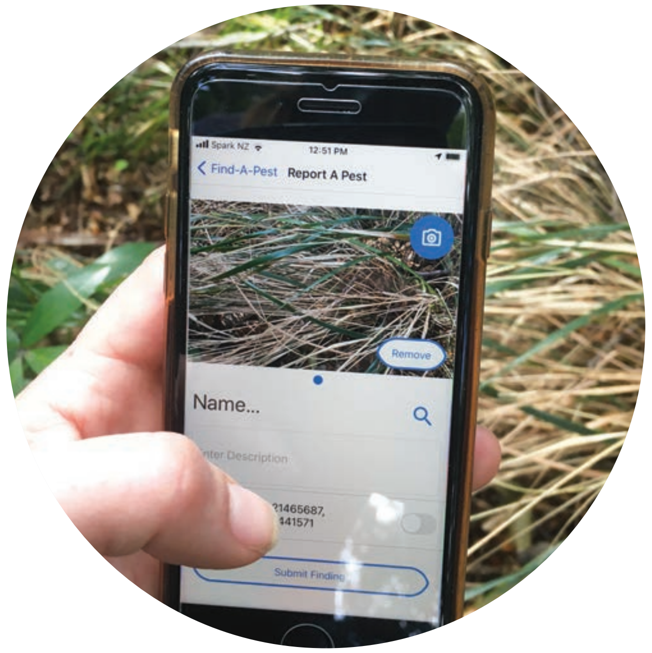
We look at the latest apps for predicting and reporting pests, and smart robotics applications to detect pests and diseases. And we also take a look at non-chemical and biological methods for disease management including Integrated Pest Management that seek to reduce the adverse impacts of pest control on human health, the environment and non-target organisms.

Finally I would like to thank our advertisers Hill Laboratories and GoodtoGrow NZ for their generous support which funds the printing costs for this publication. Please support these businesses with your business.

Ngā mihi

Kathryn Hurr, Biosecurity & Technical Manager
NZ Plant Producers Inc.

Find-A-Pest



Find-A-Pest is a free to download app for iPhone and Android that makes identifying and reporting pests and weeds easy.

It's been developed to help grow the community of kiwis helping to protect New Zealand from new pests and diseases. People with boots on the ground are a natural line of defence against unwanted pests for New Zealand. The Find-A-Pest app has been created with exactly this kind of primary industry expertise in mind. It harnesses the collective power of thousands of workers 'keeping an eye out' in our orchards, nurseries and natural environments.

Users can submit photos and any additional information (i.e., where pests were found, damage, size) straight from their phones. The app includes a list of pests specific to various industries and up-to-date factsheets on 'new to New Zealand' unwanted pests, such as the Brown Marmorated Stink Bug (BMSB), as well as pests that are already established in New Zealand.

When a user submits an image through Find-A-Pest, it is triaged by an industry representative. Low-risk pests are sent on to iNaturalist NZ (a web-based science platform) for full identification. iNaturalist has built an amazing machine learning system using "computer vision" which is based on millions of identified photos. It matches the species in photos and identifies them with great accuracy. Photos which show unusual or suspected new threats are sent through to the MPI Hotline.

It is functional for those working in remote areas or out in the field, with offline reporting automatically uploaded when Wifi or mobile phone services are back in range. The app automatically stores the date, time, and GPS location of each observation, and users can choose to obscure their location from public view, if wished.

A general news function is included where information can be directly relayed, including details about upcoming events and other awareness campaigns. It is also equipped with a push notification system for biosecurity alerts to help users keep up to date with urgent biosecurity news, such as a new incursion in your area.

The app has been a huge collaborative effort across a wide range of stakeholders, including forestry & horticulture industries, Regional Councils, the Department of Conservation and the Ministry for Primary Industries. The extensive co-design process underpinned the choice of app functionality to ensure that it was fit for purpose across a range of industries and users.

NZPPI is working with the Find-a-Pest co-design team to build a library of relevant pest fact sheets for the plant production environment.

Erin Lane, Biosecurity Advisor
Kiwifruit Vine Health Inc.

Robotics and sensor technologies

Key advances in computer stereo vision and Machine Learning are poised to revolutionise field and container nurseries.

Technological advances in the last two decades have moved robotics from the factory floor into the horticultural industries. In New Zealand, companies like Compac and BBC Technologies became global leaders in scanning, grading and sorting fruits of different size, shape, colour, weight and defects using sensor technologies. The forestry sector now makes use of computer vision to grade tree seedlings, measuring the overall size, shape, stem straightness and root structure against a given quality specification. The robotic grading output was measured against three expert seedling graders and performed as well as all of them. In this way, robots can be 'trained' using the knowledge of the best nursery staff and this learning can be embedded through computer algorithms into the computer system.

Modern greenhouses offer a good environment to implement precision technologies, with availability of infrastructure (i.e., wires, pipes, roof, concrete floors) to support the implementation and mobility of smart machinery. Pilot projects have been developed using optical sensors mounted on various platforms for pest and disease scouting and detection. Robots 'look' for pests and diseases and send messages and pictures to operators to show the location of specific pests or anomalies.

Photo: Fully mobile, machine-vision robot sprayer

Both supervised and unsupervised image analysis approaches have been used to develop deep learning techniques to improve the performance of robots performing these tasks. These precision technologies could identify pests and diseases before they become outbreaks, replacing the practice of calendar spraying with localised and deliberate intervention, reducing costs and avoidable plant losses. While promising, they need to be practically feasible, as well as cost-effective, reliable and accurate before they are widely adopted across the industry.

Different sensors are used for different applications. For example, multispectral cameras have been used to 'flag' citrus trees with fungal diseases.

Spider mites are not obvious until they have built up large populations and stippling becomes noticeable on leaves or webbing becomes visible. The detection of symptoms at an early stage using RGB (Red, Green, Blue) and multispectral sensor applications greatly enhance the ability to 'see' these types of pests before they cause widespread damage.

Hyperspectral sensors cover a spectral range of up to 350-2500nm and can give a continuous spectral resolution less than 10nm. This makes it suitable for disease differentiation based on slight variances and can help detect diseases during the latency period, before symptoms are even visible to the human eye.

Specific pathogens affect their hosts differently, resulting in a suite of damage symptoms which can be difficult to discriminate from abiotic stresses.

A recent study using hyperspectral imaging successfully distinguished between root-knot nematodes (biotic stress) and water deficiency (abiotic) stress in tomato plants with up to 90% accuracy.

These technologies are still at the pioneering stage and there are several challenges to overcome. NZ Plant Producers are keen to encourage and promote the exploration of these technologies in plant production systems, partnering with applied researchers. We would like to hear from our members what specific applications you would be interested in seeing developed.

Professor Mike Duke,
Waikato University – Te Whare Wananga o Waikato
& Kathryn Hurr

Lining up for plant vaccines

RNAi vaccines

University of Queensland scientists have developed a vaccine to protect plants from Myrtle rust.

BioClay™ is a new approach to plant protection that makes use of a natural process called RNA interference (or RNAi for short) that occurs inside the cells of all plants and most animals. Small pieces of double stranded RNA (dsRNA) are sprayed onto the plant and can be absorbed by rust spores present on the leaf surfaces. These dsRNA sequences interfere with the normal protein coding processes in the rust fungi. Cellular processes cut up and then separate the RNA into single strands. These single strands then bind to the messenger RNAs with matching sequences in the fungal spores, which shuts down production of the proteins they encode.

The technique does not involve genetic modification, as the RNA is not integrated into the plant genome. Lead Researcher Dr. Anne Sawyer says there are several advantages of this treatment over current chemical fungicides to control rusts. "We use bioinformatics to design dsRNA that is highly specific to myrtle rust and targets essential myrtle rust proteins.

Photo: Spraying BioClay™ dsRNA on a plant. Credit: Dr. Anne Sawyer

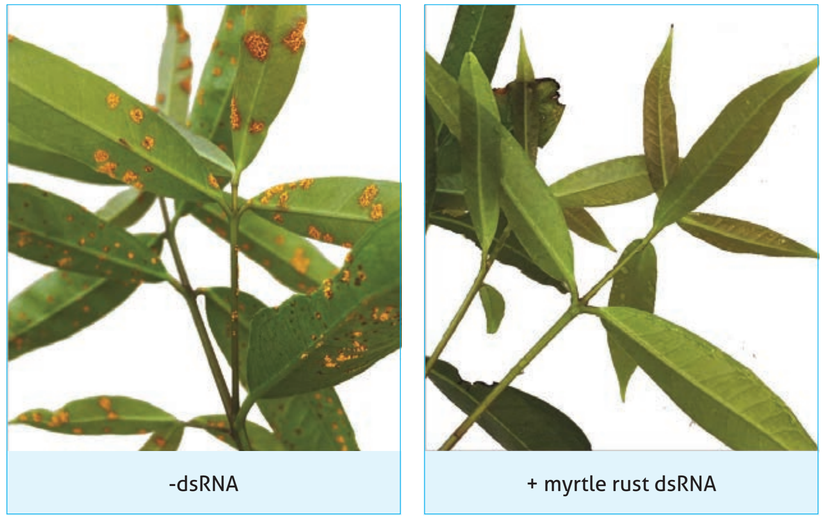


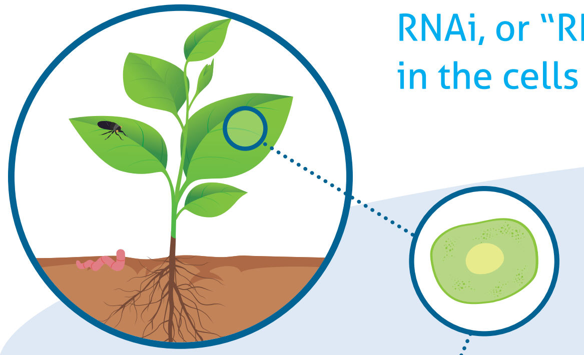
Photo: Myrtaceae leaves without dsRNA treatment and with treatment. Credit: Dr. Anne Sawyer

Current fungicides lack specificity and kill or suppress lots of different types of fungi, which can lead to resistance. New chemistries are expensive to develop. It can cost over $250 million and take up to 10 years to bring a new fungicide to market. Fungicide runoff is also a problem and consumers don't want fungicide residues on their food crops."

RNA is very short-lived in the environment, as natural enzymes present in the environment break it down and it's easily washed off by rain. UQ researchers have found a way to bind the dsRNA to clay sheets which allow for sustained protection, lasting up to 30 days. They are working on testing the BioClay™ for extended disease protection against myrtle rust in the environment.

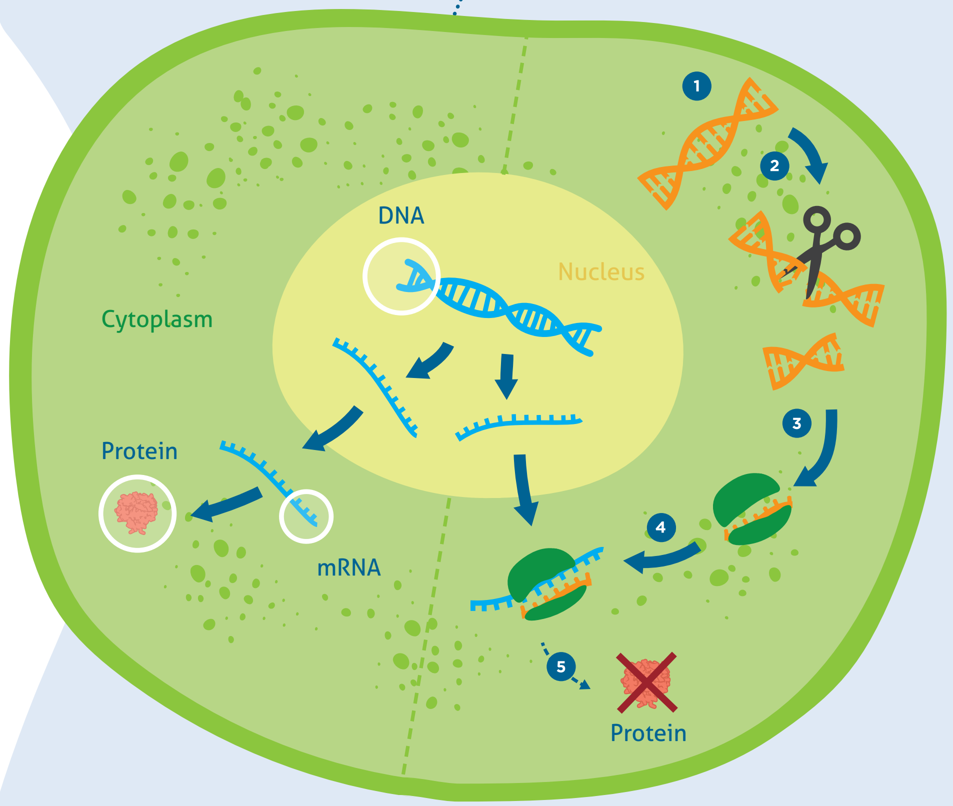
Dr. Anne Sawyer
University of Queensland, Australia

Understanding RNAi



RNAi, or "RNA Interference," is a natural process that occurs in the cells of plants, animals, and people.

All living things – like this plant – are made up of **cells**, the basic units of life.



How does RNAi work?

1. It begins when a form of RNA made of two strands (**double-stranded RNA, or dsRNA**) is introduced into the cell, for example by a virus, or produced in the cell.
2. When a cell "sees" dsRNA, it activates structures that work like scissors to **cut it up.**
3. Next, **other structures attach** to these small pieces of RNA and turn them back into single-stranded RNA.
4. These structures then bind to **mRNA with a matching code.**
5. As a result, **production of the protein** encoded by that mRNA is prevented.

Protein production

A. Inside the nucleus of each cell is a detailed genetic blueprint, encoded in **DNA...**

B. ... which is transcribed (copied) into **messenger RNA (mRNA) ...**

C. ...which gets translated by the cell's machinery to make a specific **protein.**

RNAi is a natural process that works like a "dimmer switch" to dial down the level of a protein. It is thought to have evolved to protect cells from viruses.

Infographic credit: adapted from CropLife International.

Detecting eRNA

Wastewater testing is now an important surveillance for detecting Covid-19 in our communities and the same methology is being applied to look for viruses in plant production.

This year we saw eRNA testing being used for the first time in our industry as MPI tested wastewater from greenhouses producing tomatoes to track the presence of a new virus called *Pepino mosaic virus* (PepMV). It proved itself to be an incredibly useful tool in managing this biosecurity incursion and it looks like the use of eRNA will become more common in our industry. So how does it work?

Every living organism sheds DNA (or RNA) into the environment and even in trace amounts, with the right environmental DNA/RNA sampling and testing methods, it is possible to recover and read this genetic code.

The techniques have been around for a while and found a new purpose in 2020 for detecting the SARS-CoV-2 virus. Coronavirus genomes consist of RNA rather than DNA, so researchers optimized eRNA methods to find the virus in air and human wastewater. Wastewater sampling is now routine in New Zealand's regional Covid-19 monitoring.

Plant viral genomes mostly consist of single stranded RNA (~75% of all plant viruses) and there are plenty of potential applications for eRNA testing in plant production. The ability to detect viruses in waste irrigation water is a far more cost-effective strategy for monitoring for presence of pathogens than sampling and testing leaf material from individual plants in the greenhouse. In time, these techniques could be expanded to include surveillance for a wider range of plant pathogens, including bacteria, fungi and oomycetes. While the science behind eRNA techniques is complex, the actual process of collecting and testing a sample is relatively simple. Samples are filtered through very fine paper or concentrated using chromatography or ultracentrifugation.

The techniques used to read the DNA or RNA that might be present are the same as those used for tissue or blood samples, usually quantitative polymerase chain reaction (PCR) or whole genome sequencing. Scientists can either read all the sequence present in the sample – or target a specific sequence of interest.

Research has demonstrated that plant viruses can also be found in human wastewater facilities e.g., pepper mild mottle virus (PMMoV) can survive the transit through the human digestive tract and is released into wastewater after consumption of chilli pepper products. PMMoV is globally distributed and has found to be more abundant in various water sources than human pathogenic viruses. Its presence has no seasonal fluctuation, so PMMoV testing has even been proposed as an indicator for water pollution.

A new tool for Myrtle rust

Myrtle rust is difficult to control but the severity of infection in the nursery and its spread in nursery stock pathways can be reduced using fungicides and cultural management.

Myrtle rust requires seasonally warm temperatures and humidity for development of the disease. Up until now, plant producers would start applying fungicides in late spring/early summer as temperatures start warming, with no real way of knowing whether this was too early or late to start managing the disease. To better manage the disease in the nursery environment, NZ Plant Producers has partnered with Dr. Rob Beresford and HortPlus, a New Zealand agritech company, to develop an online decision support tool. The tool makes use of the myrtle rust climate model developed by Rob, paired with local weather station information to predict the risk in a particular area. It allows producers to predict risk events for myrtle rust infection and identify optimal dates to apply preventative fungicides and other control methods to minimise the disease.

Photo: Climate forecasting and the myrtle rust climate model, helping producers predict risk events for myrtle rust.

The tool can be accessed via smartphone or computer and will be available through NZPPI's website in late 2021. The tool and supporting information will be compulsory for certified nurseries signed up to the Myrtle Rust Module under the Plant Pass scheme. Access through NZPPI's portal to the HortPlus weather & disease platform will be freely accessible for all nurseries for two years, generously funded through a grant from the Ministry for Primary Industries.

Management of myrtle rust in the nursery

Climatic modelling suggests that myrtle rust will continue to spread in much of the North Island, and in the north and west of the South Island.

Myrtle rust (*Austropuccinia psidii*) was first detected in New Zealand in 2017, believed to be wind-blown from Australia. All producers of Myrtaceae nursery stock must help to prevent further spread of myrtle rust into all parts of New Zealand.

The most vulnerable native Myrtaceae species are *Lophomyrtus* spp., pohutukawa (*Metrosideros excelsa*) and swamp maire (*Syzygium maire*). Several exotic species are also severely impacted. As myrtle rust continues to spread in the natural environment, infections will start to become more common in some of the less susceptible species, such as rātā (*Metrosideros* spp.), mānuka (*Leptospermum scoparium*) and kānuka (*Kunzea spp.*).

The myrtle rust pathogen is able to rapidly colonise new areas and disperse from them because it produces large numbers of urediniospores. These spores have thick walls that resist desiccation and contain pigments that reduce the effects of UV radiation.

Although large numbers of spores are produced yearly, the size of rust epidemics can vary from year to year because of the availability of susceptible host material and weather conditions. Several conditions must be satisfied before infection can occur. The latent period (time from infection to new spores) becomes very long (>60 days) at average daily temperatures below 10°C.

Photo: Myrtle rust symptoms on young growth. Rust spores need warm conditions and leaf wetness to germinate.
Credit: © jacqui-nz / CC BY-SA 4.0

The fungus can survive symptomless inside the plant during the extended latent phase and can subsequently form uredinia and spores when temperatures rise again. This means that overwintering can occur as a latent infection and uredinial reinfection during winter is not necessary for survival between seasons.

Rusts can have complicated lifecycles. Myrtle rust (*Austropuccinia psidii*) is believed to be capable of completing a sexual cycle on myrtaceous hosts, via teliospore production and basidiospore infection. However, the importance of the sexual cycle in seasonal epidemic development is not yet understood and teliospores have only infrequently been found in New Zealand.

Myrtle rust is difficult to control but the severity of infection and its spread can be reduced via fungicide application.

Photo: Myrtle rust is difficult to control but the severity of infection and its spread can be reduced via fungicide application.

Overseas results have shown that triazole and strobilurin fungicides are highly effective against myrtle rust. These fungicide groups are available in New Zealand in products containing triadimenol, azoxystrobin or trifloxystrobin. Field trials using these fungicides are being conducted in New Zealand during the 2021-22 season.

Contact fungicides remain on the surface of plants but can be easily disintegrated by sunlight or washed off by rain or irrigation, so there is always a need to repeat applications to protect the vulnerable new growth (young leaves and shoot-tips). The efficacy of contact fungicides is based on their being present before the pathogen arrives and before infection occurs. Systemic fungicides are absorbed into the plant tissue and may be distributed to some degree within the plant and offer some after-infection activity.

Non-chemical control in the nursery

Plant producers can minimise the severity of rust in the nursery using cultural controls. Spores need only 4-6 hours of leaf wetness to germinate and infect young, new growth during warm temperatures. Place susceptible species in the windiest part of the nursery to minimise humidity and leaf wetness. Time irrigation early in the day to help wash overnight spores away and allow foliage to dry before humidity increases again in the evening. If possible, irrigate using drippers rather than overhead sprinklers to reduce both wetness duration and infection risk.

Young Myrtaceae plants are especially vulnerable. Producers should avoid trimming, fertilising or potting susceptible species during warmer spring and summer periods to avoid a flush of new growth during risky periods.

The preventative fungicides (mainly contact) are applied on the plant to act as a protective barrier before the pathogen arrives or begins to grow, to prevent infection from occurring. "Curative" fungicides penetrate the plant tissues and help stop the early-infection of the pathogen if they are sprayed on within 24 to 72 hrs of infection. Such fungicides are extremely important to control disease, however, there are very few of these available for myrtle rust control.

Most fungicides that have protective and curative properties with systemic action (such as tebuconazole, triadimenol, propiconazole, and flusilazol) serve as flexible windows for users when required and have become a mainstay for a variety of pathogens. It is important to alternate between different classes of fungicide so that resistance doesn't build up.

Dr. Rob Beresford, Principal Scientist
Plant & Food Research,
Rangahau Ahumāra Kai

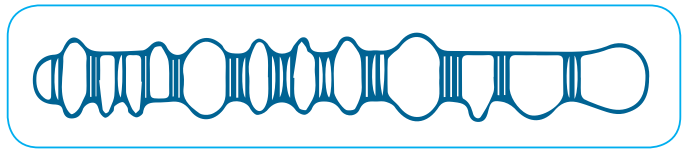
Source: "MPI 18607 Project Report Chemical control – review of control methods and fungicides"

Viroids: small, naked and infectious

Viroids are a bit like viruses, only smaller and they don't have a protein coat. Here we explore what they are and why plant producers should care about them.

The first viroid was identified in 1971, nearly 100 years after viruses were discovered. It was found to be the causal agent of a disease of potato and named *Potato spindle tuber viroid* (abbreviated PSTVd). Soon afterwards, *Citrus exocortis viroid* (CEVd) was discovered and together they shaped our understanding of this new order of "subviral agents". They are exclusive to the plant kingdom and they belong to one of two families: Pospiviroidae (type species *Potato spindle tuber viroid*) and Avsunviroidae (type species *Avocado sunblotch viroid*) (ASBVd). Viroid hosts include both herbaceous and woody species — agronomic as well as ornamental.

They are tiny, only 1/80th the size of a virus and unlike viruses, they don't have a protein-coat: they are naked infectious molecules comprising only a circular piece of single-stranded RNA (ribonucleic acid) about 300 bases long (the smallest is only 220 bases). They are one of the simplest plant parasites conceivable, being entirely dependent on enzymes in the plant host to survive and replicate.



Structure of a viroid - circular single-stranded RNA with some pairing between complementary bases and loops where no such pairing occurs

Photo: *Avocado sunblotch viroid* (ASBVd) symptoms on fruits and leaves of avocado, *Persea americana*.
Photo credit: SAG, Chile

Viroids replicate autonomously when inoculated into their host plants and incite, in most of them, economically important diseases. Typical symptoms include yellowing, stunting, leaf distortion, fruit distortion and colour break, and stem and leaf necrosis.

Scientists do not fully understand how they are able to resist plant defence responses and produce symptoms in their hosts when they do not code for any proteins. There is some evidence that RNA silencing is involved in producing symptoms, similar to RNA interference (RNAi) which 'silences' or shuts down the production of specific proteins in the host plant (see page 6).

They are incredibly infectious, spreading very easily from plant to plant by sap-sucking aphids, through contaminated mechanical damage to plants (e.g. contaminated secateurs), or by plant to plant leaf contact.

Breeding for disease resistance

New approaches to traditional breeding are accelerating the production of disease resistant varieties of plants.

Janette Barnett of Amoré Roses has been importing rose varieties for the past ten years. She says that to avoid the need for fungicides, breeding companies are now selecting varieties with natural resistance to common diseases like black spot and powdery mildew. Janette tests their performance in New Zealand conditions by growing the resistant varieties for three to five years in test beds under a no-spray programme. In general, roses bred in hotter, drier climates do not cope as well with New Zealand's damp climate, although there are some lovely exceptions.

Plants have evolved to obtain resistance against pathogens by preventing them from gaining access to the cell. These physiological barriers and surface-recognition features are part of a natural "immune system" against pathogenic microorganisms. Most cell types have inbuilt antimicrobial defences that can identify pathogens, send signals that activate response pathways, and respond. These defences involve numerous genes and recent advances in genomics is helping breeders to incorporate these traits in economically important species.

Photo: Sweet Romanza® is a disease-resistant rose bred in the Netherlands.

Breeding for disease resistance in plants is still comparatively limited due to the complexity involved in finding and mapping the resistance mechanisms. Once identified, the genes that provide natural resistance can be bred into varieties using traditional breeding approaches with DNA-based marker-assisted selection. It may require several cycles of breeding to combine the disease-resistant trait and desirable ornamental characteristics into a single plant genotype.

Most plant diseases are caused by fungi. Leaf spots, blights, rusts, smuts, powdery mildew and downy mildew are all pathogens that cannot grow without a living plant host. Effective control of these diseases is currently achieved through regular fungicide application but there is an increasing availability of disease-resistant cultivars of roses, chrysanthemum, gerbera, lily, carnation, and petunia. Eventually, mutations in strains of mildew and fungi will gradually overwhelm the plants defence mechanisms. More advanced technologies, such as CRISPR hold the promise of a faster turnaround in keeping plants several steps ahead of their pathogens. However, plants produced using these techniques are regulated under the Hazardous Substances and New Organisms Act 1996 and none are currently approved for release in New Zealand.

A Fresh Look at Integrated Pest Management

For the past 30 years New Zealand has led the world in integrated pest management (IPM) techniques but we are still very much at the beginning of the journey. Learning from experience and a pipeline of new research is creating opportunities for a step change in effective and sustainable IPM programmes.

Modern plant production facilities include high tech greenhouses and managed growing areas that can provide a perfect mix of environmental controls and plant diversity to support successful biological pest control. The nursery environment offers unique opportunities to manage pests and diseases minimising the health and environmental risks of pesticides.

One example where IPM has been successfully applied in controlling thrips and mites is at the **Wellington Botanic Gardens.** The display houses are open to the public 364 days of the year and spraying toxic pesticides became increasingly problematic. A review in 1996 saw a change of tack. Plant Collection Manager Clare Shearman says the initial focus was on reducing toxic pesticides and utilising low toxicity pesticides, but they soon realised pesticides are quite unnecessary. "We didn't need to eliminate pests, we needed to learn how to better manage them."

The Garden's Integrated Pest Management programme combines cultural, physical, and biological controls to minimise pesticide use. Specialist Garden Team Leader Cindy Telford says the key is to monitor plants regularly and keeping a close eye on what is happening within the crop.

"We do plant checks and clean-over our plants daily as we water. Regular monitoring ensures we find potential pest problems before significant damage has occurred. We're looking at our plants every day and so we even know when they have new leaf."

Cindy says they buy-in predatory mites every month from November to March, and fresh nematodes twice a year. The mites arrive packaged with food in bran and are divided into little envelopes and tied around vulnerable plants. Cindy also keeps 'banker plants' in the glasshouses to create a food source for the predators.

Photo: Cindy Telford ties packages of predatory mites into plants in the greenhouse.

Integrated Pest Management (IPM) emphasizes the sustainable control of pests rather than the 'boom & bust' pest outbreaks which are induced by pesticides. IPM strategies are usually multi-faceted and include careful sanitation practices, cultural techniques, the best crop genetics, as well as biological and chemical management tools. Calendar spraying is replaced by 'justified' chemical use, minimising pesticide damage to natural enemies. But how easy is it to adopt IPM in greenhouse plant production and floriculture?

It's more labour intensive than calendar spray regimes, but Clare and Cindy agree it has just become a part of every-day practice at the Gardens. "We now get lots of enquiries from other gardens asking how we do it when they're stuck using chemicals. It just getting over the initial change and putting up with a pest population explosion, but then it comes back and just becomes a part of your work everyday."

Cindy Telford,
Wellington Botanic Garden, Me Hehe Ki Pōneke

Photo: Robotic application of spray treatments.

Technology will drive IPM practice?

The practices used at the Wellington Botanic Gardens can be adapted through technology to meet the need for scale in a commercial nursery. The future of monitoring indoor plant production will definitely include automation: Remote sensing with multi-spectral cameras and machine learning is now able to detect differences between plants due to production practices, pathogen infection or pest feeding and this technology is being successfully integrated into different aspects of biological control, including scouting for pests and diseases. Further automation of Integrated Pest Management processes such as the use of drones or robotics to collect scouting data and to apply a treatment will be available in the near future.

Research targets new IPM tools

"A Lighter Touch' is a significant new research project that has been launched in the New Zealand horticulture industry. This programme will trial new Biopesticides and Biological Control Agents (BCA's) that can be used in IPM programmes. Integrating a new generation of softer agrichemicals that are compatible with biopesticides and BCA's will enable them to be used safely. Research into resistance management will ensure that these IPM tools will be effective for decades to come.

The skinny on biological controls

Biological control agents suppress pest populations by consuming them, but they can also reduce pest fecundity or survival by reducing the amount of time spent feeding just by their presence. Failed attacks by predators can also injure potential prey, leading to their death. For example, the thrips predatory mite *Neoseiulus cucumeris* (formerly *Amblyseius cucumeris*) does not prey on second instar western flower thrips, but its 'harassment' led to reduced feeding and less survival to adulthood of thrips, resulting in less plant damage. Aphids have been seen to interrupt feeding and exhibit costly defensive behaviours, including dropping off the plant, in reaction to the presence of a non-enemy parasitoid wasp.

The season is important when selecting biological control agents, because some predators, like *Orius sp.* or *Aphidoletes aphidimyza*, will diapause at low light and low temperature conditions found in winter. The thrips predatory mite *Amblyseius swirskii* performs better than *Neoseiulus cucumeris* under warm conditions, but both predators have similar performance under cooler conditions.

The host plant is also important: some of the generalist phytoseiid predators prefer smooth, glabrous plants, while others benefit from leaf hairs or trichomes.

Finally, there are many studies that show that biological control agents can feed on, parasitize or infect each other (i.e. intra-guild and hyperpredation), which potentially affects the efficacy of biological control programs. For example, the parasitoid *Pauesia nigrovaria* was released in New Zealand as a biological control agent for the **giant willow aphid,** but a significant proportion of field-collected aphid mummies have yielded hyperparasitoids, predominantly *Dendrocerus carpenteri*, a generalist hyperparasitoid known to be present in NZ for some time. [1]

[1] You can read more about biological control of the giant willow aphid at the link https://www.giantwillowaphid.co.nz/__data/assets/pdf_file/0009/78723/GWA_newsletter_2021.pdf

Fungus gnat control

Earlier this year we were notified of uncontrolled outbreaks of fungus gnats in greenhouse production. Here we review the IPM solutions available for their control.

Fungus gnats primarily affect indoor houseplants. They are not strong fliers, and their flight is erratic, more like a mosquito. Annoyingly, they tend to fly into people's faces and drinks which makes them a nuisance for office workers and plant hire companies.

Photo: Close up of an adult fungus gnat (*Bradysia* sp.)

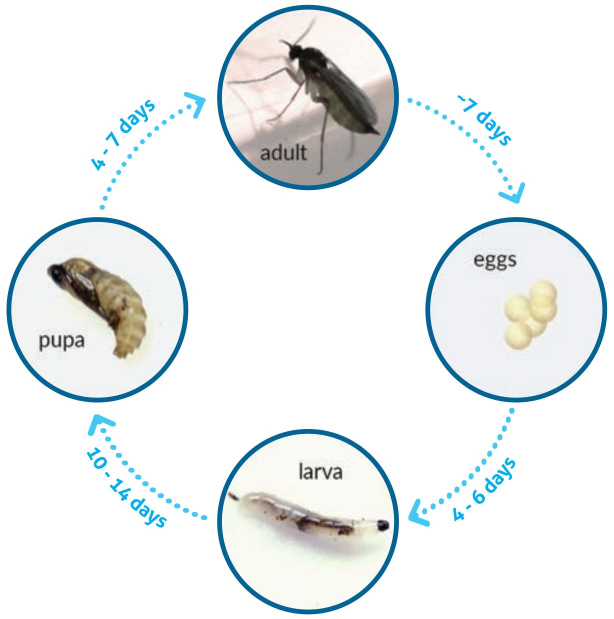


Photo: Life-cycle of fungus gnats

They are a fruit fly–sized insect pest which are attracted to moisture in the potting soil. Adult fungus gnats represent the visible "tip of the iceberg." The rest of the life cycle takes place in the media, where adults lay eggs in the cracks and crevices. The larvae are most plentiful in the top layer of soil but can be found throughout the pot down to the drainage holes. They are clear to white in colour with a distinctive black head capsule, about 7mm in length. Adult gnats lay their eggs (up to about 200) on organic matter near the soil surface. After about three days, the eggs hatch into larvae, which burrow into the soil to feed on fungi and decaying plant material. Two weeks later, adult gnats emerge from the soil to repeat the process. Adults live for about one week.

Signs and symptoms of fungus gnats include:

- Plants lack vigour and leaves may turn yellow
- Small brown scars are evident on roots, and root hairs are eaten off
- With heavy larval infestations, plants can be weakened severely and die

Scouting

Yellow sticky cards are highly attractive to adult fungus gnats. Mount at least one sticky card per $90m^2$, taking care to check and change the cards often.

The larval stages can be monitored with potato wedges pressed into the surface of the soil. Check back in 24 to 36 hours to inspect the wedges for fungus gnat larvae, which will be visible as tiny translucent larvae crawling (use a torch if needed).

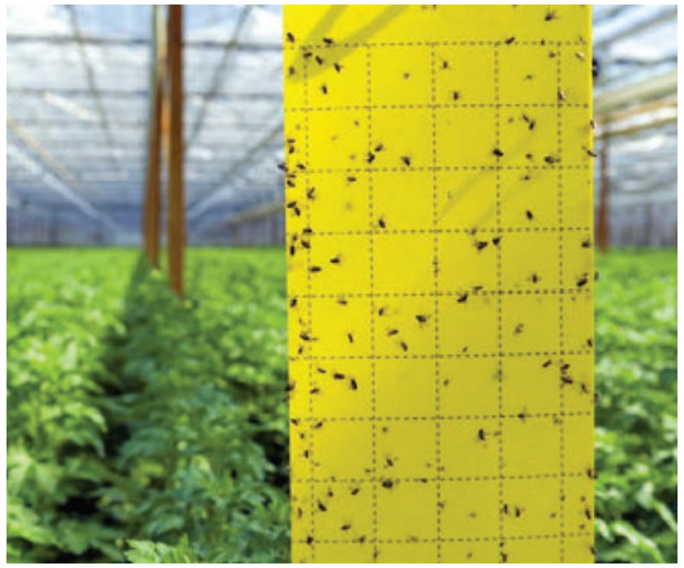


Photo: Yellow sticky traps for fungus gnats and other flying insect pests.

Cultural controls

The best solution is preventative. Ideal conditions for fungus gnat outbreaks are high humidity, high soil or growing media organic matter, water-saturated soil or growing media, presence of moss and algae and decaying plant material.

Biological controls

Biological control of fungus gnats can be highly successful. Utilizing a combination of biological control agents (BCAs) such as beneficial nematodes, specifically *Steinernema feltiae* and predatory mites, such as *Stratiolaelaps scimitus* (formerly known as *Hypoaspis miles*). Both are available for sale in New Zealand.

Applied properly to the soil, the nematodes enter the fungus gnat larvae through various body openings. Once inside, they release a bacterium that kills the host. The nematodes reproduce within the fungus gnat larvae and later return to the soil to look for more prey.

The predatory mite *Stratiolaelaps scimitus* is a soil-dwelling predatory mite that feeds on fungus gnats (mycetophilids, sciarid flies) and other insects, mites and nematodes in soil and growing media.

Adult mites are 0.5-1.0 mm long and are usually found in the top few centimetres of soil or compost. Both adult and immature mites are predatory. They prefer feeding on younger fungus gnat larvae, and adults can consume 1-5 prey per day.

These predatory mites will survive in most potting mixes, rockwool and perlite. They handle most greenhouse conditions and is not harmed by regular watering, although flooded or waterlogged areas are not tolerated.

Biological and chemical treatments

There are various treatments available. VectoBac is a bacterial larvicide which is used against mosquito larvae in standing water. It consists of the bacterium, *Bacillus thurigiensis subsp. israelensis* (strain AM65-52), and is effective against a wide range of larvae. As a soil treatment (liquid form) it can be watered in and is also available as a topical spray. Bt is commonly used in Permaculture and Organic production as a general larvicide.

However the short life cycle means that eggs will keep hatching out and treatment needs to be done every four to six days for several months until the problem is remedied.

Microbial disease protection

New research has provided insights into how the vast communities of microbes living with plants can affect their health.

Like the human gut microflora, these microbes have a profound influence on growth and development in plants, their function and resilience to different environmental and biotic stresses.

Recent work by Plant & Food Research has identified microbial endophytes in mānuka (*Leptospermum scoparium*) that promote plant growth, influence biochemistry (including DHA production in nectar), and still others that help the plant defend itself or confer resistance to diseases. Some microbes even have the potential to inhibit germination of rust spores in mānuka and pōhutukawa, offering the potential to inoculate myrtaceous species against myrtle rust.

Microbes are normally acquired from the environment and soil, and sometimes passed through generations in seed. They can be manually inoculated onto other plants and confer similar functions to the new host. For example, the mānuka microbiome has been shown to inhibit grapevine trunk diseases and impart disease resistance to PSA in kiwifruit vines.

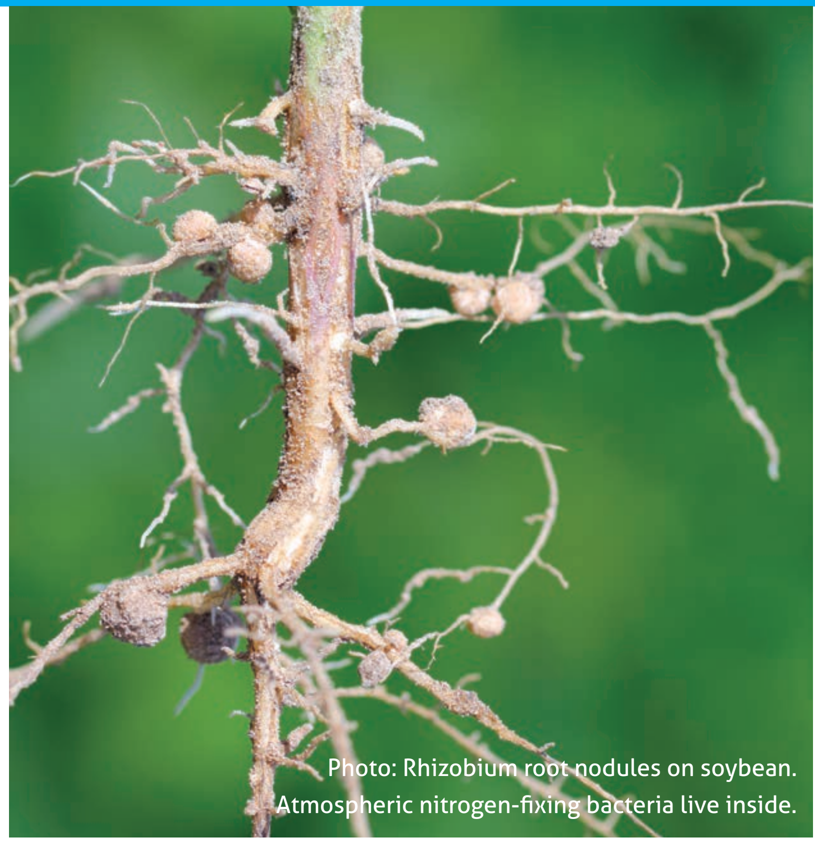


Photo: Rhizobium root nodules on soybean. Atmospheric nitrogen-fixing bacteria live inside.

Soil microbes also have a well-recognised role in plant growth and development. Leguminous plants use *Rhizobium* bacteria to fix nitrogen and the native species of *Rhizobium* are important for growth and development in kowhai (*Sophora sp.*) and *Clianthus* (kakabeak) in the natural environment.

In the fungal world, mycorrhizal fungi have symbiotic (mutually beneficial) relationships with the root systems of living plants. Filament networks envelop the seedlings root structure, extending the root systems so they can explore a larger volume of soil than plant roots alone.

This symbiotic relationship dates back several hundred million years, and approximately 95% of terrestrial plant species rely on mycorrhizal symbioses to thrive. The majority use arbuscular mycorrhizal (AM) fungi but ectomycorrhizal fungi (EM) are important in several tree species including pine, douglas fir, oaks and New Zealand species of beech (*Fuscospora and Lophozonia*) and mānuka. EM fungi envelop the trees underground roots with sheaths of fungal tissue. Many of these types of fungi produce spore-bearing fruit bodies in summer and autumn, some of which are delicious! These tree species can all be inoculated with edible EM fungi, such as truffles (*Tuber* sp.) and Porcini (*Boletus edulis*), enhancing growth of the trees and potentially providing a crop of fungi. Both AM and EM mycorrhizal types increase the uptake of Phosphorus, of other poorly mobile elements, and of water, and can increase resistance to some root pathogens.

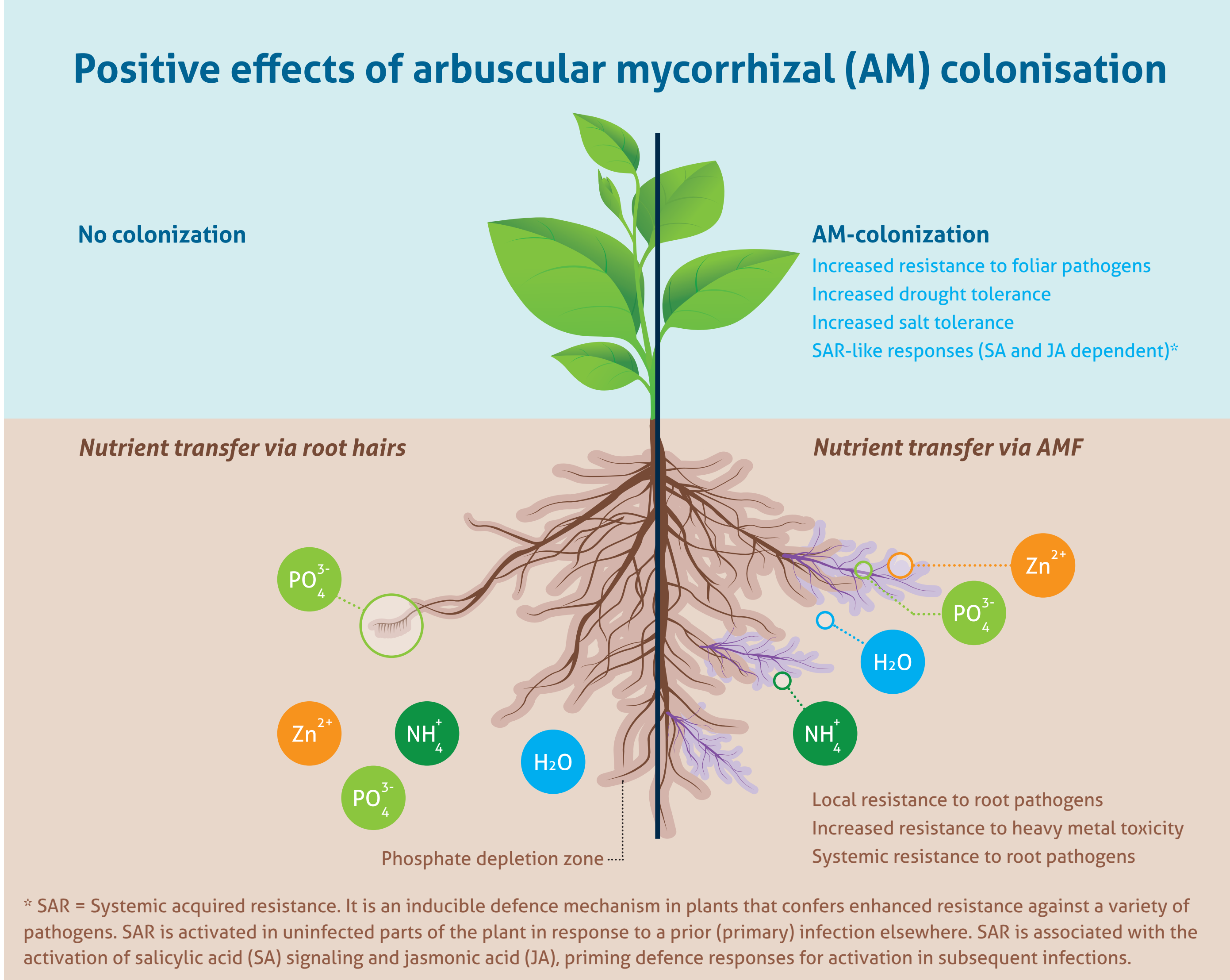


Diagram: Systemic acquired resistance (SAR) is an inducible defense mechanism in plants that confers enhanced resistance against a variety of pathogens.

Nowadays beneficial microorganisms (PGPB: plant growth promoting bacteria, PGPR: plant growth promoting rhizobacteria, AMF: arbuscular mycorrhizal fungi) are used not only to improve plant growth but also protect against soilborne pathogens. Although it's an emerging strategy that needs more research, promising results are expected.

Modern techniques for clearing and developing land tend to destroy mycorrhizal fungi, necessitating the use of fertilizers to promote plant growth and fungicides to control fungal phytopathogens. In turn, these chemicals can be detrimental to beneficial soil microorganisms.

Containerised plant production is dependent on potting media where beneficial microorganisms may be limited or absent.

Adding mycorrhizae is expected to benefit growth and disease resistance in the potted plant and continue to assist plant growth and survival when it is planted in the landscape.

A New Zealand developed product - MycoGro Hort® - has been developed from a range of New Zealand native species of arbuscular mycorrhizae - *Claroideoglomus lamellosum, Funneliformis mosseae, Rhizosphagus intraradices, R. irregularis, R. fasciculatus, Diversispora sp.* and *Paraglomus sp.* The mixed microbial community is beneficial to growth in a wide range of grass and shrub species, promoting growth and biomass of roots and shoots. In avocado nurseries, it helps protect plants from root-rot pathogens.

Biodisinfestation

Reducing soil borne pathogens and nematodes is common-place in horticultural crop production and is also important in field-grown nursery crops.

Root-knot nematodes (*Meloidogyne spp.*) are a serious parasite of a wide variety of crop and ornamental plants and can cause substantial economic losses. They are common in soil and feed on the epidermal cells of roots, penetrating a plants root tissue to lay their eggs. This activity causes galls, or knot-like swellings, to form on the root. This damage negatively impacts root development and means the crop can't take up nutrients efficiently, slowing plant growth and ultimately, leading to reduced yields for producers

Traditional methods of control use applications of nematicides and fumigation, both of which create environmental hazards. Host-plant resistance for nematode especially *Meloidogyne spp.* has been reported in many crop species.

New promising biodisinfestation treatments based on natural products are being trialled as an alternative to chemical applications. In a Spanish study, agricultural by-products were used to disinfest the soil and reduce nematode populations. Beer bagasse and rapeseed cake were incorporated into the soil with fresh cow manure. After the first crop post-treatment, researchers found a significant reduction in galling on plant roots. Lead author Maite Gandariasbeitia notes that "the high nitrogen content of these by-products promotes the activity of beneficial microorganisms in the soil, which helps to break down organic matter like manure and kill off nematodes and other parasites which damage crops." Plots also demonstrated increased yields by around 15% compared to the control plots after one year. Additionally, the organic matter treatment boosted populations of beneficial microorganisms in the soils, which was demonstrated by a significantly higher soil respiration rate.

Maite Gandariasbeitia López
Plant Production & Protection Dpt., Neiker, Spain

Photo: Root galling caused by root-knot nematode infestation. Credit: Maite Gandariasbeitia et al.

Phytophthora disease management in nurseries

Phytophthora organisms are among the most destructive plant pathogens globally. Greater awareness of the conditions that encourage *Phytophthora* and knowing the signs for early detection are important in reducing the risk of spreading the disease.

Outbreaks of *Phytopthora* originating from infected nursery stock has had catastrophic impacts on crops, forests and ecosystems. In New Zealand, species of *Phytophthora* affect native trees (e.g. *P. agathidicida*, kauri dieback), forestry plantations (e.g. *P. pluvialis*), as well as orchards (e.g. *P. cinnamomi* in avocado). Research is underway to characterise the populations of *Phytophthora* in plant production nurseries, and to update best practice in the Plant Production Biosecurity Scheme (Plant Pass) to prevent the spread of these pathogens.

Phytophthora cause crop losses and reduce the quality of greenhouse and nursery plants. They can be moved long distances in plant trade, potentially spreading diseases to new hosts and habitats. It is important for plant production facilities to identify potential sources of contamination and to take corrective measures to prevent disease.

The two main factors to look for are the pattern of diseased plants and water drainage. *Phytophthora* thrive, grow, reproduce, and infect plant roots in water, saturated soil, and along riverbanks and ponds. Excess water or poor drainage allows roots to become flooded for extended periods. During such events, swimming spores (zoospores) are attracted to the roots and begin the infection process.

Phytophthora root rots generally start below ground and work up the plant, but there are exceptions. Some species attack only aboveground parts of the plant, causing leaf spot and blight, sunken cankers, necrotic leaf or stem blotches, defoliation and a dieback starting at branch tips. Symptoms below the ground will present as few feeder roots, with dark and decaying roots at the root tips and least severe near the root crown.

Strict hygiene in the nursery environment provides confidence when plants are destined for planting into important ecological locations. A wide variety of cultural and chemical controls can be implemented. Management practices which are useful include gravelling pathways and roads to prevent water-borne splash, maintaining stock off the ground on benches, or on gravel or concrete flooring, removal of weed species (potential hosts), using clean water sources for irrigation, and cleaning and sterilisation of containers. Regulating the amount, frequency, and duration of water coming to plants and the way water is conducted away from plants is key. Good nursery procedures for inspection for pest and diseases, and traceability of plant batches are also paramount.

The purpose-built greenhouse at Scion in Rotorua has been designed for hygienic production of plants free from *Phytophthora*. Other Scion research in pine nurseries has demonstrated the usefulness of high-throughput DNA sequencing technology to understand communities of *Phytophthora* and related organisms. This data provides a baseline describing the diversity of these pathogen communities currently present and it is hoped that this research will enable scientists to track the improvements that can be made using hygienic practises and treatments such as fumigation.

Dr. Rebecca McDougal, Craig Ford and Julia Soewarto, Scion

Photo: The *Phytophthora* ImmunoStrip®
Credit: Permission from Agdia, Inc. Elkhart, IN, USA

Diagnostic testing

The first step in managing any of the several diseases caused by *Phytophthora spp.* is to obtain an accurate diagnosis. Traditional methods require laboratory procedures to culture onto agar petri dishes, or molecular testing using a Polymerase Chain Reaction (PCR) machine. A useful diagnostic tool that can be used in-house by the nursery operator are *Phytophthora* Immunostrips® (Agdia). These are simple to use and can detect the presence of *Phytophthora* in plant material and water samples. They are not suitable for soil.

The *Phytophthora* ImmunoStrip® is designed for on-site testing of plant tissues suspected of infection with *Phytophthora* species. The test is also suitable for detection of *Phytophthora* species that affect other important crops such as *P. fragariae* in strawberry or *P. infestans* in potato.

New Zealand Plant Producers is the industry body for plant nurseries and related businesses.

Our members produce the plants growing the food that Kiwis eat and export, regenerating New Zealand's forests, beautifying our urban landscapes and being planted by millions of Kiwis in their backyards.

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