A Management Plan for a Diversity of Leaf Spot Diseases in Production Nurseries

Grow plants optimally to reduce pressure from leaf spot pathogens

INTRODUCTION

This paper provides information on the management of destructive leaf spot diseases and disorders that can occur in production nurseries. Managing leaf spot will promote the production of healthier plants, improve overall plant growth and ultimately yield greater plant uniformity. It will also minimise biosecurity risks.

Leaf spot symptoms are varied, but all will reduce leaf photosynthesis, plant vigour and may cause plants to be unsaleable. Leaf symptoms can be caused by non-pathogenic factors (e.g. environmental conditions, genetic disorders, nutrient deficiencies etc.) or from plant pathogens (e.g. fungi, bacteria etc). As their treatment varies according to the cause, it is very important to correctly identify the causal agent. Diagnosing the cause of a leaf spot can be difficult because a single plant pathogen may cause more than one symptom and many different pathogens can cause virtually identical symptoms. It is recommended to use the services of a plant disease diagnostic laboratory for reliable identification and management recommendations, e.g. Grow Help Australia, Crop Health Services and other services in each state and territory.

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This management plan covers best practice guidelines that can be applied to reduce the incidence of most leaf spots and improve overall plant health. These are discussed in the general leaf spot management section. Use of pesticides is also discussed but more detailed information on fungicide resistance and resistance management can be found in a companion factsheet. Fungicide active ingredients available for use in nurseries against leaf spot pathogens has been tabulated at the end of this document and possible rotations are discussed for each pathogen group.

Because there are so many pathogens and disorders that can cause leaf spots, this management plan is relatively long. Key points and management strategies for each group are discussed with links to further information where possible.

MANAGEMENT PLAN OUTLINE

GENERAL LEAF SPOT MANAGEMENT

Many leaf diseases and disorders can be managed by modifying cultural practices. The following recommendations apply for the management of many leaf spot pathogens. Apply as many strategies as possible.

- **Avoid introducing diseased plants** into the nursery. Obtain plants from a reputable supplier and quarantine new plants within the nursery until confident they are disease free. Examine leaf/plant health before inclusion in the nursery proper. Take particular care with plants susceptible to certain diseases.
- Only **propagate from disease free plants** (cuttings, transplants and seed).
- **Monitor plant health regularly** for signs of disease and act promptly if found. Be aware, some leaf spots occur as a result of root rot or other factors. Give more monitoring effort to susceptible plants, particularly during high-risk periods.
- **Grow resistant varieties** or provide clients with alternate species that have similar growth habit to susceptible plants.
- Regularly wash hands and **disinfest equipment** that are exposed to plants, e.g. secateurs, gloves, staking equipment etc. Clean benches between consignments.

- **Practice good sanitation** within the nursery. Keep propagation areas clean and free of plant debris. Hygienically remove crop debris from the nursery to reduce inoculum load.
- **Hygienically discard** all plants known to be infected and likely to become unsalable. It is not recommended to stockpile infected plants on-farm (e.g. in a rubbish heap/ compost pile) as this will increase the risk of reinfection.
- **Disinfest growing areas and structures** as needed but particularly after an infestation has occurred. For more information on disinfesting irrigation water and growing areas refer to technical resources available on the nursery production FMS website and NSW DPI.
- **Decrease periods of leaf wetness** as this promotes growth and sporulation of many leaf spot pathogens:
  - If possible, avoid overhead irrigation and exposure to rainfall, at least during high risk periods and on susceptible lines. Water droplets that fall on leaf spots can cause fungal spores and bacterial cells to splash onto nearby plants, potentially infecting nearby plants.
  - If overhead irrigation is used during high-risk periods, watering should be done when leaves will dry relatively quickly.
  - **Increase ventilation** to increase the rate that leaves dry. Even small fans placed strategically in protected cropping structures can have a large impact.
  - **Increase plant spacing** (effectively increases ventilation). Overcrowded plants will encourage infection as this prevents the drying of leaves after rainfall, irrigation, dew or fog.
- **Remove weeds from stock plants and growing areas**. Manage banker and garden plants to reduce spread of disease into stock.

Infected plant material should be removed promptly and hygienically to reduce risk of spreading the disease.

- **Avoid physical damage** that may occur through movement of staff and equipment, wind and other actions. Manage insects and mites to minimise damage. Wounds provide an open pathway for pathogens to infect the plant.
- **Grow plants under optimal conditions** (e.g. nutrient regimes, irrigation, growing media properties etc.) as healthy plants are more resistant to pathogens. This sounds obvious, but can sometimes prove difficult.

Always consider the entire plant when diagnosing leaf spots, sometimes leaf spots can be induced by root rots. Therefore confirm that other plant parts are healthy prior to implementing management actions.

CHEMICAL CONTROL OF LEAF SPOT PATHOGENS

Fungicides are an important tool for the management of some leaf spot pathogens. As the name suggests, they are active against fungi. Some products are also active against water mould pathogens (e.g. *Pythium* and *Phytophthora*) and others may protect against bacterial pathogens. Like all pesticides, they should not be solely relied upon. Once a leaf spot is present on a leaf, the spot will always be present, the plant tissue cannot be repaired. Therefore, management strategies discussed above should be incorporated into normal growing practices such that pathogen pressure is reduced. As a result, the need to apply fungicides is diminished. This is important because fungi are prone to resistance build up and fungicides can cause phytotoxicity. Refer to the fungicides webinar and fungicide resistance and resistance management factsheet for more information.

Fungicides tend to be more effective protecting healthy plants or acting against pathogens that are restricted to leaf tissue only. They cannot eradicate an infestation that has grown into the roots or main stem vascular tissue and become systemic. Similarly pathogens that produce resistant spores in growing media are unlikely to be eradicated.

As fungicides target the biology of specific groups of pathogens, it is important to correctly identify the pathogen responsible. Knowing the pathogen and its unique disease cycle also allows more efficient application of the fungicide in regards to concentration, frequency and timing.

There are currently no true bactericides available for use against bacterial pathogens. Copper products can protect healthy plant tissue but will not eradicate bacterial pathogens. Similarly, there are no chemicals available in Australia for the control of viral plant pathogens and nematicides currently available are not registered for use against nematodes on nursery stock.

It is not recommended to apply fungicides to plants that are infected with a systemic pathogen. Symptoms may be temporarily masked with the treatment, but will not be eradicated. As such, the pathogen will be spread when the plant is sold.

Edema on the underside of a blueberry leaf.

ABIOTIC LEAF SPOTS (NON-PATHOGENIC FACTORS)

Abiotic disorders are caused by non-living factors and can be amongst the most difficult to pinpoint, particularly for production nurseries growing a wide range of hosts with diverse growing requirements. Many species grown in Australia have not been well studied, therefore symptoms induced by nutrient deficiencies and specific growing conditions are largely undocumented. It is therefore important to combine investigative skill with careful observations to deduce what is affecting the plants.

Generally, abiotic factors can be suspected if a very high percentage of the stock line are showing symptoms (e.g. near 100%). This occurs because all of the plants are exposed to the same conditions. Symptoms often suddenly appear, without any further development and subsequent new growth is not affected. They can sometimes appear on one or two varieties within a species, but may also simultaneously occur across unrelated species. There can also be a progressive development of symptoms, depending on the cause.

Common abiotic factors that cause leaf spot symptoms include burn (sun, light, or heat), chemical injury (caused by pesticides), edema (where cells have more water than they can transpire), nutrient toxicity or deficiency (sometimes induced by extremes in pH), mechanical injury (hail, wind or mechanical abrasion) and genetic/varietal disorders.

Effective management of abiotic symptoms relies on effective identification of the cause and either preventing it from happening again or, if not possible, reduce the impact of the factor. Because this is a large topic that often requires a detailed and investigative approach, a management plan specifically on non-pathogen disorders was developed for the production nursery industry.

PATHOGENIC LEAF DISORDERS

Unlike leaf spots caused by non-pathogenic factors, leaf spot pathogens have the potential to persist and spread within a nursery if not effectively managed. The management of a plant disease will vary according to the pathogen and its biology, the particular host it is infecting and the environmental conditions that favour the disease. There are six main groups of pathogens that can cause leaf spot symptoms in production nurseries; fungi, bacteria, virus, water moulds (e.g. downy mildew and Phytophthora), algae and foliar nematodes.

FUNGAL LEAF SPOTS

Fungal leaf spot is a common descriptive term applied to a number of diseases affecting the foliage. The group is extremely varied with some important differences that influence management strategies. Therefore this group is covered in four short sections. 1) spots, blights and blotches, 2) rusts, 3) powdery mildew, and 4) sooty blotch and sooty mould. Note that sooty mould is typically an epiphyte, growing on sugary solutions produced by insects and plant secretions (nectaries). Therefore it is not a true leaf spot pathogen but can still impact saleability and photosynthetic rate.

SPOTS, BLIGHTS AND BLOTCHES

Leaf spots (other names: anthracnose, scab, leaf blotch, shot hole) may vary in size, shape and colour. They usually include a distinctive margin and sometimes have a yellow halo. There may be fungal growth, spores or small black fruiting bodies associated with the spot, particularly in humid weather. It is often necessary to use a hand lens or a microscope to see these structures. If the spots are numerous or close together, diseased areas may join together to form irregular areas called blights or blotches.

Leaf blights and blotches are generally larger diseased areas than leaf spots and more irregularly shaped. Fungi that cause leaf spots, blights and blotches in nurseries include species of the genera; *Botrytis*, *Colletotrichum*, *Fusarium*, *Calonectria*, *Alternaria*, *Pseudocercospora*, *Pestalotiopsis*, *Cercospora*, *Bipolaris*, *Curvularia*, *Septoria*, *Cladosporium*, *Phyllosticta*, *Elsinoe*, *Diplocarpon*, *Phoma* and other minor fungal leaf spot pathogens.

The leaf spot damage will vary from minor to severe depending on the interaction of host plant, fungus and the environment. The general pathogenic leaf symptom management recommendations listed above apply to most fungal leaf spots, blights and blotches. In addition, however, it is recommended to apply protectant fungicides to susceptible lines during high risk periods when plants are healthy (i.e. before symptoms occur). Protectant fungicides may need to be applied at least fortnightly during high-risk periods to protect healthy plants, but should be discontinued once the risk period has subsided. If needed, apply curative or eradicant fungicides registered for the pathogen in your crop during highest-risk periods or upon observing early symptoms (Table 1).

Rotate between products as per recommendations in the fungicide resistance management factsheet. For example, applications against *Botrytis* (grey mould) could include protectant products leading up to and during high-risk periods from the M3 (e.g. mancozeb) and M5 (e.g. chlorothalonil) mode of action groups (Table 1). Then, if required, rotate between the following products at earliest signs of symptoms or during periods of known very high-risk:

- 1+M3 products, e.g. thiophanate methyl + mancozeb
- 2 product, e.g. iprodione
- 7 product (e.g. boscalid) or 7+11 products
- 11 product (e.g. azoxystrobin) or 7+11 products
- 9+12 products, cyprodonil + fludionxonil

Dracaena with anthracnose, leaf spots caused by *Colletotrichum* and a close up of a leaf spot showing small, raised fruiting bodies on necrotic tissue.

RUST

Rust is the common name for disease caused by a particular group of parasitic fungi. Rusts produce small leaf spots that are often raised into pustules embedded in the leaf tissue. Pustules rupture releasing masses of spores that are spread via wind, insects, water splash and people. Spores are typically bright yellow, orange-red, reddish-brown or black in colour; this is what gives the pustules the rust-like appearance. In severe cases, the leaf withers and dies rapidly. Some types of rust also occur on stems, flowers, fruit or on new growth (which can cause deformity or dieback), e.g. myrtle rust.

Rusts can be very damaging to a large number of plants grown by the production nursery industry and are sometimes difficult to manage. Important rust hosts in nurseries include acacia, blueberry, bamboo, carnation, chrysanthemum, daylily, fig, frangipani, fuchsia, geranium, iris, monstera, peach and rose. Rusts are generally quite host-specific, attacking only a small number of closely related plant species, but exceptions occur. For this reason, knowing the host can assist in their identification.

Rust pustules (*Puccinia allii*) on garlic.

Successful management of rust diseases generally involves a range of integrated approaches including cultural practices and pesticides during high-risk periods. In addition to the general strategies for managing pathogenic leaf symptoms, the following options are highlighted for rust:

- Grow resistant varieties if available. This is one of the most important strategies to reduce pest pressure.
- Remove infected plants that are unsalable and destroy fallen leaves with minimal disturbance – spores can be easily dislodged.
- Be aware that clothing and equipment can become contaminated with spores and potentially spread rust. Put in place a signalling system to staff so that they can avoid walking by plants infested with rust, e.g. a sign/flag etc. This will assist in reducing pathogen spread.
- Begin fungicide applications at the first sign of rust or just prior to known high-risk periods.

There are a number of active ingredients with registrations against rust relevant to the production nursery industry, some of which are specific to individual rust species (Table 1). Rotate between products as per recommendations in the fungicide resistance management factsheet. For example one possible rotation includes protectant products from M1 (copper products), M3 (e.g. mancozeb) and M5 (e.g. chlorothalonil) leading up to and during high-risk periods (Table 1). Then, if necessary, rotate between:

- 1+M3 products, e.g. thiophanate methyl + mancozeb
- 11 products, e.g. azoxystrobin
- Additional products available for specific rusts, e.g. myrtle rust

For additional information on rust refer to the nursery paper on rust fungi. The Rust Fungi of Australia also has detailed information on rust identification, in particular listing rust species by their host plant and includes images of symptoms.

POWDERY MILDEW

Powdery mildew is a widespread and important disease of many nursery plants and ornamentals.

Several genera cause the disease, symptoms of which are similar on many hosts. The most common powdery mildew fungi infecting ornamentals and nursery plants are *Erysiphe*, *Leveillula*, *Podosphaera*, *Sphaerotheca*, *Uncincula* and *Oidium*. Most species of these pathogens are host specific often infecting only a few plant species.

Powdery mildew appears as white to light grey, superficial, powdery or mealy fungal growth. It grows mainly on the upper side of leaves, but may also occur on stems and flowers, producing great numbers of spores on the surface of the host plant. Powdery mildew fungi are obligate parasites, which means that they can only obtain nutrients from a living host plant. Powdery mildew rarely kills plants, but can cause severe leaf distortion, defoliation, shoot dieback and reduction in growth. They may have little or no effect on some plants other than to reduce their aesthetic appeal.

Powdery mildew is windborne, but can also be spread mechanically, e.g. by insects, staff and equipment. Spores that land on a susceptible host germinate and grow across the plant surface. Powdery fungi are unique in that they do not require a film of water on the leaf to germinate. They can germinate on dry surfaces when the relative humidity is low (as low as 20%), but higher humidity is favourable. Infection of the host plant occurs within five to seven hours and a new generation of spores may be produced within five days of infection if conditions are favourable.

Dry leaves in warm, humid and cloudy conditions favour disease development; cloudy weather limits damage to the fungus by ultra violet radiation. This means that plants growing in the shade are more prone to mildew than those growing in sunlight. Unlike other leaf fungal pathogens, frequent periods of leaf wetness inhibit formation and dispersal of spores.

Powdery mildew fungi may remain active all year in mild climates. In more temperate climates the fungus may overwinter as inactive fungal growth or specialised fungal structures in buds, or on shoot tips, and resume growth with the return of warmer weather.

Management of powdery mildew relies on regular monitoring; powdery mildew epidemics can develop very quickly from low levels of infection. Implement the general leaf spot management actions and the following practices specific to powdery mildew.

- Adjust nutrition to avoid very succulent growth, which is more likely to be damaged by powdery mildew.
- If possible, adjust irrigation to increase leaf wetness during high-risk periods. Keep in mind that this may increase the risk of infection by other pathogens and may not be possible for some crops.
- Since powdery mildew fungi survive in dormant buds and shoots, prune to remove relatively heavily infected material prior to application of fungicides.
- Reduce relative humidity around foliage by allowing good air circulation.
- For more information refer to the powdery mildew factsheet.

Numerous fungicides are registered against powdery mildew, some of which are protectants that prevent germination of conidia and ascospores. However, since the majority of fungal growth occurs on the leaf surface, protectant products can be very effective. Other products have curative or eradicant activity, which act against existing powdery mildew colonies.

It is recommended to apply protectant products during high-risk periods, before symptoms occur. This could include applications about every 1–2 weeks leading up to the highest risk period rotating between M1 (copper products), M2 (e.g. potassium bicarbonate) and M3 (e.g. mancozeb) products (Table 1). Once symptoms occur it is recommended

to rotate between products that have eradicant or curative mode of actions including (Table 1):

- 1+M3 products, e.g. thiophanate methyl + mancozeb
- 7 (e.g. boscalid) or 7+11 products
- 11 (e.g. azoxystrobin) or 3+11 or 7+11 products
- 8 products, e.g. bupirimate

White fluffy powdery mildew growth (*Podosphaera* sp.) on Zucchini

SOOTY BLOTCHES AND SOOTY MOULDS

Sooty blotch and sooty mould in production nurseries are rare, but do occur, particularly in association with sucking pests. As the names suggest, sooty mould and sooty blotch produce blackening of the leaf surface. The main difference between the two diseases is that growth from sooty mould is easily removed by brushing to reveal healthy tissue beneath, whereas sooty blotch can not be removed by wiping.

Sooty blotch appears as a black superficial blemish on the leaves and fruit radiating out from where a single spore has germinated and infected the plant. Many species can be involved in sooty blotch on any one crop, for example, on apple more than 58 species have been identified associated with sooty blotch symptoms. The fungus colonises both upper and lower surfaces of the leaves causing black, circular spots, up to 5 mm diameter. It infects young leaves and fruit, but growth is slow; spots are generally seen when leaves and fruit mature. Spores are subsequently produced in the black spots, and these are spread by wind during wet, humid weather or when there are heavy dews.

If infection is severe it may block sunlight, reduce photosynthesis, and, in turn, growth and fruit production. It is considered a "cosmetic disease" as the spots on the leaves and fruit are shallow and there are no rots associated with them. Nevertheless, the spots can be unsightly and they reduce the market value of ornamental plants and fruit. It can sometimes be mistaken for sooty mould.

Sooty mould produces a black velvety coating on the leaf surface consisting of mycelium and spores of Ascomycete fungi, commonly *Cladosporium*, *Alternaria* and a range of other species. The symptoms are more severe when 'honeydew' secretions (excreta) from insects are present. Honeydew secretions from insects stick to the leaf surface and provide a sugary solution for fungal growth. Although sooty moulds do not cause disease lesions, their dark, saprophytic growth on the leaf surface restricts photosynthesis, which in turn impedes plant growth. Very occasionally, other fungi can be found on plants growing on sugary secretions, particularly in association with sugary plant secretions, e.g. nectar dropping from flowers or extra-floral nectaries.

Infection is favoured by warm wet weather; spores can be produced in large numbers after rain from infected tissue. In addition to the general recommendations for managing pathogenic leaf symptoms outlined above, the following is recommended to specifically manage sooty blotch and sooty mould diseases in nurseries:

- Manage insect pests as required, management plans and factsheets are available on the Nursery Production FMS website.
- Use of copper and strobilurin fungicides may help where labels are registered against general 'leaf spots' (Table 1).

Sooty blotch on kiwi fruit leaves caused by *Stomiopeltis* sp.

BACTERIAL LEAF SPOT

Bacteria can cause leaf spots and blights that are often difficult to distinguish from that caused by fungal pathogens, and sometimes even viruses. Leaf spots are the most commonly encountered bacterial diseases in production nurseries, though some bacterial infections cause a leaf blight (e.g. bacterial leaf blight in Anthurium) or wilt.

These spots often have a chlorotic (yellow) halo due to toxin production, but not always. They may be circular or irregular, angular when bordered by veins and sometimes longitudinal in plants with strong longitudinal veins. Bacterial leaf spots occur on a wide range of plants including bougainvillea, dieffenbachia, philodendron and geranium.

Necrosis following leaf veins caused by a species of *Burkholderia* on bird of paradise. Note that the newer leaf appears almost healthy except for one small, relatively dark region in the middle of the leaf.

They survive in plant debris on the soil surface, in soil, in and on seed, in or on insects, and as epiphytic populations. Plant pathogenic bacteria are spread by wind, dust, soil and media, rain splash, surface and irrigation water, insects, mites, nursery staff and their equipment. In the nursery, bacteria are spread most often by water splash from the soil to leaves and from leaf to leaf by overhead irrigation.

Nurseries often have ideal conditions for bacterial diseases especially in greenhouses where there is high humidity and temperature, close planting, poor air circulation, mist beds and overhead irrigation. Bacteria cannot directly penetrate plant tissue and must enter through wounds or natural openings, e.g. hydathodes or stomata. They can also enter through lenticels and wounds on leaves, stems and roots.

Plants infected with a bacterial pathogen cannot be cured. Even when symptoms are no longer present, bacteria still persist in the plant at low levels and symptoms are likely to reappear when conditions are favourable. This is termed latent infection.

Only copper products are registered in Australia for controlling plant pathogenic bacteria and only foliage is protected by these. They are not effective against systemic bacterial infections and unlikely to eradicate local bacterial infections on leaves, i.e. bacteria are likely to remain in the local area despite application of copper products. There are currently no systemic chemical treatments registered for the control of bacterial plant pathogens in Australia.

Therefore, focus on preventing infection and enforce the general leaf spot management strategies. In addition, the below recommendations are highlighted for bacterial disease.

- It is recommended to NOT sell plants that have been infected by bacterial pathogens.
- Grow resistant varieties where available. This is a very effective method of managing bacterial diseases.
- Use copper based pesticides to protect healthy plants. Also refer to the factsheet on copper formulations and application.
- Heat treat seed to reduce bacterial infections. In general this involves heating seed in a water bath to 50–60°C for 20–30 minutes. The exact temperature and time is case specific and must be kept strictly to protect seed viability. Where possible locate literature that is seed species specific. If none is available trial and error can be used to find the best conditions.
- Refer to the factsheet on bacterial pathogens for more information.

Bacterial leaf spots (*Xanthomonas campestris*) on capsicum leaf. Note angular spots surrounded by a yellow halo.

VIRAL LEAF SPOT

Viral leaf spot symptoms include mosaic, mottle, ringspots and necrotic spots that can be accompanied by other symptoms, such as dwarfing or deformed growth. Viruses are minute, non-cellular pathogens that multiply within the cells of their hosts; they can only be visualised using an electron microscope. Plant viruses are spread within nurseries by seed and propagation material, insect vectors that feed on the plants, or sap contamination of equipment and staff. Some viruses may be transmitted by leaf rub or mechanical rubbing on equipment and clothing. In general, infected plants cannot be cured. Some viruses do not, however, infect the growing tip of a plant (the meristem) and the unaffected tissue can be tissue-cultured to recover virus-free plants. If you suspect that a plant is being affected by a plant virus, submit a sample (or at least send a photograph of symptoms) to a diagnostic service as accurate identification often determines control measures.

There are no chemical or biological controls for plant viral infections. Cultural methods and prevention are the only effective management tools available:

- Inspect plants regularly and immediately remove plants that are likely to be infected by a plant pathogenic virus. Quarantine plants if necessary until testing can confirm if a virus is present.
- Ensure all propagation material such as seed, cuttings, bulbs, budwood and mother stock are free of plant pathogenic viruses.
- Control sucking insect pests (aphids, whiteflies and thrips) that can vector the viral pathogens.
- Grow resistant varieties whenever possible.
- For more information refer to the production nursery factsheet on viral diseases.

Necrotic spots and necrotic ringspots caused by *Tomato spotted wilt virus* on impatiens.

OOMYCETES (WATER MOULDS)

Downy mildew and *Phytophthora* are classified as Oomycetes (pronounced: oh-oh-my-seat); their biology is significantly different to fungi. However, management strategies in regards to leaf diseases are similar.

Temperature and humidity are vital factors in the disease cycle of Oomycete leaf diseases, which thrive under cool, moist conditions with a high relative humidity at the leaf surface. Free water on the leaf surface is essential for infection and high humidity is needed for sporulation.

Spores can become airborne and travel long distances in moist air currents, e.g. in fog, overhead irrigation and sometimes with normal air circulation. They can spread short distances by water splash. Some can be seed-borne and produce systemically infected seedlings. They can be spread a long distance with contaminated cuttings and plants before symptoms become visible.

DOWNY MILDEW

Symptoms are predominantly on the underside of the leaf and consist of light grey to purplish, mouldy growth. Most downy mildews found in nurseries belong to the genus *Peronospora*, however *Plasmopara* and *Bremia* are sometimes present. They are all obligate parasites that can only grow in living host tissue, which means they cannot be cultured on artificial media in the laboratory. Downy mildews are host specific and will only infect closely related plant species. Spores germinate on wet leaf surfaces, penetrate the host and invade. They grow out through the stomata on the under surface of the leaf during the night, resembling bunches of grapes with each grape being a spore (sporangium). As the air dries out in the morning, spores are released and dispersed by air currents or water splash. All downy mildews produce sporangia, which form a germ tube that penetrates the plant. In some species (*Plasmopara*) sporangia can germinate 'indirectly' by forming multiple zoospores, which are released and can swim short distances. As the host tissue dies the pathogen produces thick walled oospores that allows the downy mildew to survive from one season to the next. Oospores are usually not a problem in the nursery because plants are grown in sterilized potting mix.

Downy mildew from the genus *Peronospora* on blackberry (above) and *Helleborus* (below).

Early infestations of downy mildew may be effectively managed with fungicides, though susceptible species can be challenging, e.g. basil. Like other pathogen groups, protectant products should be used leading up to high-risk periods including copper products (group M1) and group M3 products (mancozeb and thiram) (Table1). During high-risk periods, or perhaps when early symptoms have first appeared, rotate between curative or eradicant products (Table 1):

- 1+M3 (thiophanate methyl + mancozeb)
- 4+M1 (metalaxyl + copper hydroxide)
- Group 11 or 3+11 products (azoxystrobin, sometimes with tebuconazole)
- Group 21 product (cyazofamid)
- 40+M3 (dimethomorph+mancozeb)

PHYTOPHTHORA

Although this pathogen predominantly causes root and crown rots, several species can also cause leaf blight (*P. cactorum*, *P. citricola*, *P. citrophthora*, *P. hibernalis*, *P. infestans*, *P. nicotianae*, and *P. palmivora*). Aerial *Phytophthora* may also infect roots and crown. Therefore, if it is suspected as the cause of leaf blight symptoms, special care must be taken to monitor root and crown health of nearby plants. Where plants have *Phytophthora* leaf blight, *Phytophthora* is likely to be present in growing media, even if roots appear healthy.

Leaf blight symptoms first appear as diffuse brown to dark-brown spots or blotches that rapidly turn black resulting in premature leaf fall. It can spread to neighbouring plants by water splash or fog and may be spread longer distances by wind driven rain, invertebrate vectors, staff and equipment. Contaminated irrigation water can spread this pathogen over the entire nursery. *Phytophthora* requires a wet leaf surface to germinate and will then penetrate the host and invade, killing the leaf tissues and producing blight symptoms. Sporangia are produced at the edge of the lesion, and spread by rain splash and wind. When they land on the surface of a leaf they can germinate in two ways depending on the species of *Phytophthora* involved; 1) germinate directly or 2) release motile zoospores which swim for a short time before encysting, germinating and infecting. *Phytophthora* can also produce thick walled oospores that survive in the soil for many years.

Downy mildews and leaf blight *Phytophthora* species are very destructive pathogens, and it is important to be able to correctly identify early infections of the disease so that the correct remedial treatments can be applied. An integrated control strategy is required for these pathogens that includes the above general leaf pathogen recommendations and the following more specific ones:

- Oomycetes need several hours of leaf wetness for spores to germinate and infect leaves and at least four hours of wetness to produce sporangia. Therefore, irrigate plants at the time of day when leaf surfaces dry quickly. Use protective cropping to avoid contact with rain.
- Do not overwater.

Leaf spots on palms caused by *Phytophthora*.

- Disinfest dam, creek and river water using a system that is endorsed by the production nursery farm management system.
- Hygienically remove plants that are or have been infected with aerial leaf blight caused by *Phytophthora*, even if roots appear healthy. Fungicides will not eradicate *Phytophthora* (though symptoms may be completely suppressed); infected plants should not be sold as this will spread the disease.
  - Fungicides are listed in Table 1 with activity against Phytophthora to protect healthy plants while managing the problem until it has been eradicated from the nursery.
- Hygienically remove plants that have a systemic infection of downy mildew.

For further information on these pathogens refer to the production nursery factsheets on downy mildew and Phytophthora. There is also a factsheet specifically on the *P. ramorum*, a serious pathogen that is not present in Australia. Additional information on *Phytophthora* can also be found in the soilborne root pathogen management plan.

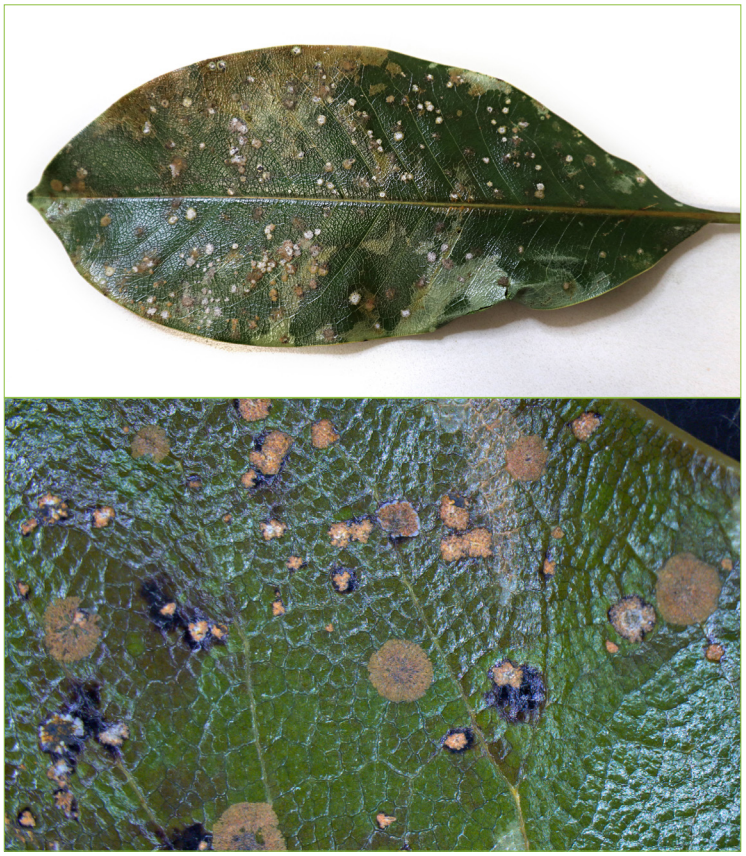
ALGAL LEAF SPOT

Algal leaf spot is a minor disease caused by parasitic algae (one of three *Cephaleuros* sp.). They have a wide host range of more than 200 plant species. Hosts with leathery leaves are particularly susceptible.

Symptoms appear on the leaves as furry green to orange spots that are flat and only slightly raised above the leaf surface. The spots are round, often 2–4 mm diameter, but may merge and appear as larger spots. The furry look is due to the spore bearing sacs that can detach and spread by water splash and wind. They then require free water to release motile spores that swim for a short time before they germinate and infect. In this way, they are similar to *Phytophthora* and downy mildews.

Algal leaf spot damage is mostly cosmetic, though some are minor plant parasites. Some algal leaf spots can become lichenised, which can be slightly more parasitic than algae alone. High temperatures and humidity favour algal leaf spot. General leaf spot management strategies indicated above are usually adequate. In severe cases, the following strategies should be enforced more vigorously:

- Avoid overhead watering and reduce leaf wetness as much as possible. Ensure good media drainage.
- Ensure that plant density allows for good ventilation and air circulation for rapid drying of leaves.
- Discard infected debris hygienically to prevent spread of the disease.
- Change the level of shading of the crop (if shading is too heavy or too little for optimal plant growth, make appropriate alterations, especially if dieback is also occurring).
- Apply copper-based fungicides with general 'leaf spot' registrations if the plant is seriously infected; repeat applications every 1–2 weeks during periods of high pest pressure.



Orange coloured algal leaf spots and lichenised algal leaf spots (white and orange spots) on magnolia.

FOLIAR NEMATODES

Nematodes are a diverse group of microscopic, non-segmented round worms that are tapered at each end. About 10% of nematodes are plant parasites and even fewer are foliar. Foliar nematodes (e.g. *Aphelenchoides fragariae*, *A. ritzemabosi*, and *A. besseyi*) are pathogens of certain nursery production lines and field crops.

They infect leaves by entering the stomata. Feeding within leaves may cause brown to black, or chlorotic, vein-delimited angular lesions that can become necrotic with age. Leaves,

buds and flowers can become malformed or crinkly. They require water to move across the leaf surface therefore infection is favoured by surfaces moistened by dew, rain or overhead irrigation. Foliar nematodes feed primarily within the leaf tissue, but occasionally on exterior plant tissue, depending on the environment and type of plant host.

Foliar nematodes are dispersed by water splash and direct contact with neighbouring plants. Under cool temperature and reduced moisture these nematodes can over-winter and remain dormant until more favourable conditions return. When moisture becomes available, they rehydrate and begin feeding.

Preventing a nematode problem is the best management strategy; no pesticides are available for use on nursery stock against nematodes. If you suspect that foliar nematodes are infecting a crop, quarantine the plants until it is confirmed by a diagnostic laboratory. Consider where the populations may have arisen, e.g. mother stock plants, alternative hosts and plant suppliers. It is not recommended to sell plants that have been infested with foliar nematodes.

- Hygienically dispose of infested plants that become unsaleable.
- Remove crop debris. Clean the growing area thoroughly as nematodes could be present on trace amounts of plant material that could then reinfest susceptible crop lines.
- Space plants to avoid leaves touching.
- Use raised benches where possible to avoid contamination from infested organic material.
- Refer to the production nursery factsheet on nematodes for more information.

Deformed and necrotic new growth of strawberry caused by bud and leaf nematode, *Aphelenchoides fragariae*.

BIOSECURITY

The national and international nursery/plant trade continues to actively move seed, seedlings, cuttings, plants, fruit, vegetables and cut flowers. No nursery is exempt from the threat of an exotic leaf spot pathogen; the risk of such an incursion can never be completely eliminated. Every nursery should make sure that source material is free of disease and routinely submit diagnostic samples for testing, particularly when new symptoms occur. Production nurseries can potentially eradicate pests and diseases from their business; this endeavour is much easier when the infestation is detected early. On a national scale, early detection can facilitate the eradication of certain pests and pathogens. If you observe unusual symptoms and suspect an exotic species, call the Exotic Plant Pest Hotline on 1800 084 881 and or submit a sample to a diagnostic laboratory for identification.

This document was prepared by Sarah Dodd, Ken Pegg and Andrew Manners (Agri-science Queensland, Department of Agriculture and Fisheries, Ecosciences Precinct, GPO Box 267, Brisbane QLD 4001) as part of the nursery levy and Hort Innovation funded project Building the resilience and on-farm biosecurity capacity of the Australian production nursery industry (NY15002) in 2019. All photos by DAF.

Table 1. Pesticides for use against foliar diseases in production nurseries. Note that registration indicated here are for those relevant to non-food nursery stock and ornamental crop lines. Additional products may be available for use against certain pathogens on individual crops. Always read the label carefully to ensure it is suitable. Where two active ingredients are present in the same product they are separated by a '+'. Mobility and activity for each product is presented along the line, e.g. for 1+M3 products, thiophanate methyl is translaminar with curative and protectant properties, mancozeb is a contact, protectant product. Blank cells indicates that a registration is not available.

FRAC CODE	ACTIVE INGREDIENT	MOBILITY (CTS)[1]	ACTIVITY (PCE)[2]	FUNGAL LEAF SPOTS	RUSTS	POWDERY MILDEW	DOWNY MILDEW	PHYTOPHTHORA	BACTERIA	SITUATION AND SELECTED LABEL COMMENTS
M1	Cu as ammonium complex	C	P				Yes		Yes	Ornamental registration only.
M1	Cu as hydroxide	C	P	Alternaria, Colletotrichum	Myrtle rust only		Yes		Yes	Ornamental registration only, labels vary. Use PER81491 for all non-food nursery stock.
M1	Cu as oxychloride	C	P	Fungal+leaf spot label	Yes[3]	Yes[3]	Yes		Yes[3]	Ornamental registration only. Nursery stock – PER81491
M1	Cu as sulfate	C	P						Yes	Ornamental registration only.
M2	Potassium bicarbonate	C	P	Alternaria alternata	Geranium rust only	Yes				Non-food nursery stock PER81290 and PER84952.
M2	Sulphur – various formulations	C	P		Yes	Yes				Ornamental use only; labels vary greatly.
M3	Thiram	C	P	Leaf spot[3]	Yes[3]	Yes[3]	Yes[3]	Yes[3]	Yes[3]	Ornamentals only.
M3	Mancozeb	C	P	Alternaria, Botrytis, Cercospora, Colletotrichum, Mycosphaerella, Phoma, Rhizoctonia , Septoria	Yes		Yes			Product labels have only limited use for nursery stock. Use PER81491 for nursery stock.
M5	Chlorothalonil	C	P	Alternaria, Botrytis, Septoria	Yes					Ornamental registration only. Labels vary — some for Tas only.
1+ M3	Thiophanate methyl + mancozeb	S C	P, C P	Leaf spots and blights, Botrytis, petal blights	Yes	Yes	Yes			Ornamental use only.
2	Iprodione	C, T	P, some E/C	Botrytis						Ornamental use only.
3	Prochloraz	T, S	P, C/E	Colletotrichum						Non-food nursery stock PER 81448.
4+ M3	Metalaxyl + Mancozeb	S, C C	P, C, E P	Alternaria, Colletotrichum, Septoria			Yes	Yes		Non-food nursery stock – PER81491. Label has use against downy mildew on ornamentals only.
4+ M1	Metalaxyl-M + Cu as hydroxide	S, C C	P, C, E P				Yes			Ornamental use only.
11	Azoxystrobin	C, S	(P, some C)	Botrytis, Colletotrichum, Alternaria	Yes	Yes	Yes			Nursery stock and ornamentals. Must be applied at least 6 months prior to first harvest. Do not use curatively. Refer to labels and PER81491.
3+ 11	Tebuconazole + Trifloxystrobin	T, S T	P, C, E P, C	Botrytis, rose black spot, some labels specify 'leaf spots'	Yes, including myrtle rust	Yes	Yes			Ornamentals only.
11+ 3	Azoxystrobin + Tebuconazole	C, S T, S	P (some C) P (some C)	Colletotrichum, Cladosporium, Rhizoctonia	Myrtle rust only	Yes				Non-food nursery stock PER 87173.
7+ 11	Boscalid + Pyraclostrobin	T T	P (some C) P (some C)	Botrytis, Colletotrichum		Yes				Non-food nursery stock – PER81491.
7	Boscalid	T	P (some C)	Botrytis		Yes				Non-food nursery stock PER84952.
7	Oxycarboxin	S	C		Yes, including myrtle rust					Ornamental use only, PER81491.

FRAC CODE	ACTIVE INGREDIENT	MOBILITY (CTS)[1]	ACTIVITY (PCE)[2]	FUNGAL LEAF SPOTS	RUSTS	POWDERY MILDEW	DOWNY MILDEW	PHYTOPHTHORA	BACTERIA	SITUATION AND SELECTED LABEL COMMENTS
8	Bupirimate	T, S	P, C/E			Yes				Non-food nursery stock – PER81491.
9	Pyrimethanil	C, T	P (slightly C)	Botrytis						Ornamental use only.
9 12	Cyprodonil + Fludioxonil	T/S C	P, E/C P	Botrytis, Colletotrichum, Rhizoctonia, Sclerotinia						Non-food nursery stock – PER81491.
21	Cyazofamid	C, T	P, E				Yes	Yes		Non-food nursery stock – PER84707.
28	Propamocarb	S	P, E/C	Preventative during propagation – no specific pathogens listed						Refer to label.
40+ M3	Dimethomorph + Mancozeb	T C	P, C, E P	Alternaria, Colletotrichum Botrytis			Yes	Yes		Non-food nursery stock – PER81491.

[1] C=contact, T=translaminar or locally systemic, S= systemic http://ipm.ucanr.edu/PMG/r302900211.html. Information presented here is based on current research. Knowledge of fungicide movement within plants can change as additional research becomes available. Where mobility descriptors are separated by a comma, products have multiple traits, e.g. C, T indicates the product is both contact and translaminar. T/S indicates that it is not clear if the product is Translaminar or systemic.

[2] P= protectant, C= curative, E = eradicant; refer to the fungicide resistance management factsheet for more information on these terms. Where products have multiple modes of activity separated by a comma, both apply to the product. P, E indicates that it has protectant and eradicant properties. Where products are C/E it indicates that literature is unclear if it is either curative or eradicant or both.

[3] 'Fungal leaf spot' or 'Leaf spot' registrations include rusts, powdery mildew and could include other leaf spots, e.g. algal leaf spot. Efficacy should be tested prior to widespread use.