Nursery levy at work: **Nursery Production Plant Health & Biosecurity Project**

Downy mildew

Early management is critical

Introduction

Downy mildews are obligate plant parasites that attack a wide range of plants and are responsible for some of the world's most destructive plant diseases, e.g. downy mildew of grapes and blue mould of tobacco. They also cause considerable losses to the nursery production of ornamental and vegetable seedlings. Downy mildew organisms are distinctly different from the powdery mildew fungi. Some common downy mildew hosts include Cissus, lisianthus, poppy, ranunculus, rose, snapdragon, stock, pansy, alyssum, impatiens, sweet pea, cucurbits, helichrysum and brassica seedlings.

Downy Mildew

Downy mildews are classified in the class Oomycetes and order Peronosporales and are distantly related to the "water mould" organisms *Phytophthora* and *Pythium.* There are many different downy mildew pathogens. Most downy mildews found in nurseries belong to the genus *Peronospora,* however *Plasmopara* and *Bremia* are sometimes present. Downy mildews are host specific and will not transfer from one host genus to another. For example, the downy mildew pathogen that infects roses (*Peronospora sparsa*) is only found on roses. Downy mildew caused by *Peronospora parasitica* occurs on stocks and brassicas, but it is a different race on each host, and neither race will cross infect the other host.

Fig. 1. Damage to impatiens caused by downy mildew

They are all obligate parasites that can only grow in living host tissue. They cannot be cultured on artificial media in the laboratory.

Downy mildews produce sporangia of determinate growth. Sporangia are not produced until the sporangiophore completes its growth and matures. The sporangia are then produced at the same time. After the sporangia fall off, the sporangiophore withers and dies. It is the type of branching of the sporangiophore that determines which genus the downy mildew belongs to. Some species are a complex of races, where each race is specific to particular host plant species.

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Symptoms

On seedlings, symptoms occur on cotyledons, true leaves, hypocotyl and stems. In some plants when seedlings are infected, downy mildew becomes systemic and growth is stunted, malformed and discoloured. Leaf symptoms are remarkably variable and it is difficult to make generalizations.

A common symptom is the downy growth (sporangiophores and sporangia) mostly on the lower leaf surface. Spores are usually white, lavender or grey. On some plants pale yellow to necrotic spots or black speckles appear on the upper leaf surface. Some spots are angular and delimited by veins. Severe infection can result in the death of large parts of the leaf. In perennial hosts, such as roses, it affects the young apical shoots causing distortion, stunting and stem cracking.

Disease Cycle

All downy mildews produce sporangia which germinate directly by forming a germ tube that penetrates the plant. In some species (*Plasmopara*) sporangia can germinate 'indirectly' by forming zoospores. *Peronospora* and *Bremia* rarely form zoospores.

Spores germinate on wet leaf surfaces, penetrate the host and grow for five to seven days absorbing nutrients from plant cells by haustoria. Sporangiophores with sporangia then emerge through the stomata on the undersurface of the leaf during the night. They resemble bunches of grapes with each grape being a sporangium. As the air dries out in the morning sporangia (spores) are released and dispersed by air currents or water splash. As the host tissue dies the pathogen produces oospores which allows the downy mildew to survive from one season to the next. Germinating oospores form sporangiophores and sporangia. Downy mildew can also survive the death of plant tissue by going systemic in the plant.

Oospores are usually not a problem in the nursery because plants are grown in sterilized potting mix.

Downy Mildew – A Disease of Historical Significance

In 1878 grape rootstocks with resistance to the root aphid, *Phylloxera*, were introduced into Europe from America. Unknown to the importing country these rootstocks carried oospores of downy mildew (*Plasmopara viticola*). This downy mildew had coevolved with native grape species in north America. Downy mildew is a deadly pathogen of grapes and all but destroyed the wine industry in Europe. There was no known control for the disease. One day, a notable scientist from Bordeaux, Professor Millardet, noticed grape vines growing near the road had little mildew whereas the rest of the vineyard was devastated. On enquiring he found that the grower had sprinkled the vines near the road with a mixture of copper sulphate and lime to deter pilfering by schoolboys. Professor Millardet then prepared a compound of water, bluestone and slaked lime which became known as Bordeaux mixture. This was the first manufactured fungicide to be used around the world on a large scale. It was as important to agriculture as penicillin was to medicine. It started a new era of technology in agriculture and provided a great stimulus to the new science of plant pathology around the world.

Fig. 2. Lisianthus leaves infected with downy mildew.

Fig. 3. Plant collapse caused by downy mildew in impatiens.

Conditions Favouring Disease

Temperature and humidity are vital factors in the disease cycle. Downy mildew diseases thrive under cool (15-23°C), moist conditions with a high relative humidity (85% or higher) at the leaf surface. Free water on the leaf surface is essential for infection and high humidity (> 90%) is needed for sporulation.

Spread

Spores can become airborne and travel long distances in moist air currents. They can spread short distances by water splash. Some downy mildews can be seedborne and produce systemically infected seedlings. They can be spread a long distance with contaminated cuttings and plants before symptoms become visible.

In nurseries they are disseminated by fans, air circulation and overhead irrigation.

Disease Management

Downy mildews 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. If you cannot see typical downy mildew sporulation on the lower leaf surface with a hand lens you may be treating the wrong disease. Sporulation can be encouraged by incubating leaves under high humidity in a plastic bag. If in doubt send suspect plants to a reputable diagnostic laboratory.

An integrated control strategy is required for downy mildew including the following points:

- Use seed and planting material from a reputable source.

Downy vs. Powdery Mildew – How Do They Differ?

The two pathogens share the name "mildew"; both are obligate parasites and rely on living plants for nutrients; they both absorb nutrients from plant cells by haustoria - but they are very different.

The organisms causing downy mildew are Oomycetes and are not closely related to true fungi. They are "water moulds" and are distantly related to *Phytophthora* and *Pythium*. Powdery mildews are caused by true fungi.

White, flour-like powdery mildew colonies appear on the upper leaf surface but can also be present on both sides of the leaf surface. Downy mildew is primarily on the underside of leaves. Leaves affected with powdery mildew yellow but do not fall prematurely. When downy mildew is the causal agent infected leaves may fall prematurely.

Downy mildew hyphae live internally in the host. Powdery mildew hyphae occur mostly on the surface of the host.

Downy mildews are favoured by cool, humid, wet conditions. They require a film of water on the leaf surface for spore germination and infection. Powdery mildews prefer warm, humid conditions and a dry surface for spore germination. Germination is actually inhibited by free water.

Chemicals used to control downy mildews are similar to those used for diseases caused by *Phytophthora* and *Pythium* and differ from those used for true fungi such as the powdery mildews. For more detailed information on powdery mildew refer to the factsheet on this disease.

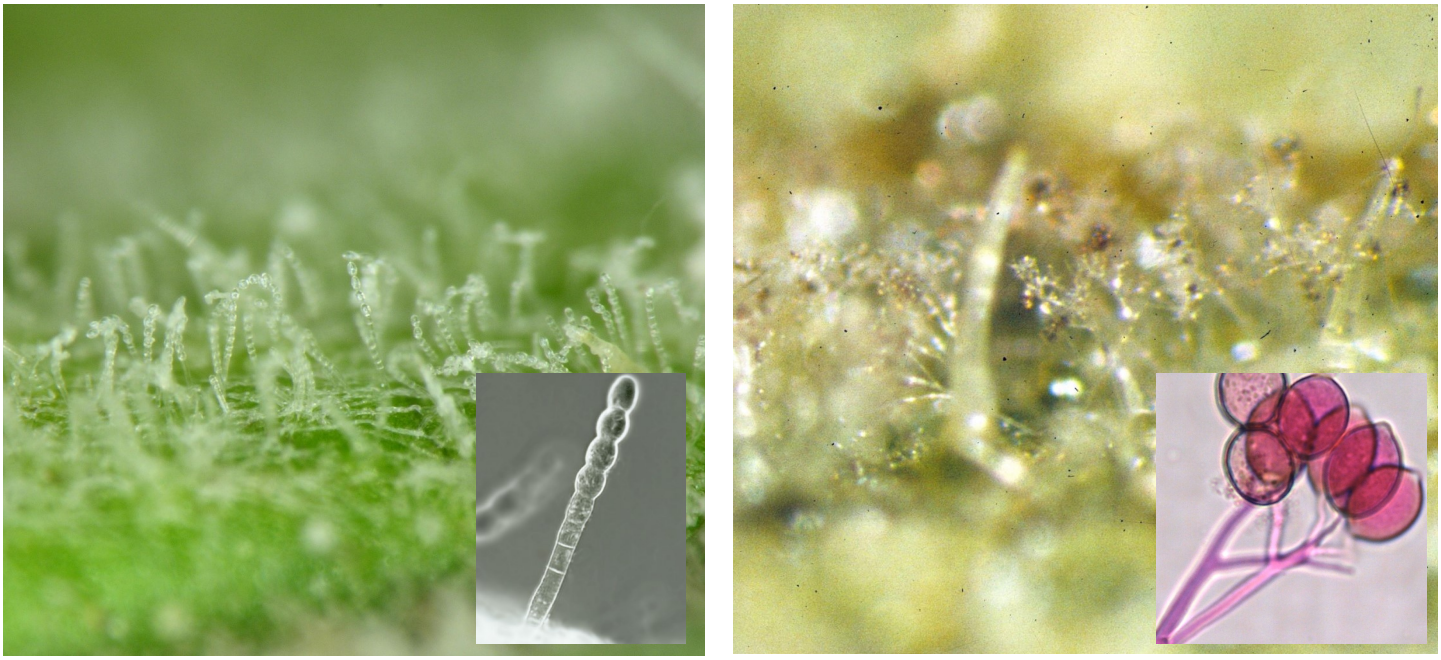

Fig. 4. Spores of powdery mildew occur in chains; they do not branch (left – photo by P. Bachi, University of Kentucky, bugwood.org) and chains at high magnification (left insert) . Downy mildew spores (right) occur at the ends of branched hyphae and do not occur in chains (main photo by C. Averre, NCSU, Bugwood.org; close up insert by DAF). Downy mildew under high magnification

- Monitor highly susceptible plants. Early detection of the disease is essential.
- Downy mildew needs some six hours of leaf wetness for spores to germinate and infect leaves and at least four hours of wetness to produce sporangia. Therefore, water plants at the time of day when leaf surfaces dry quickly. Use protective cropping to avoid contact with rain. Capillary watering systems that do not wet the foliage can be very effective.
- Use fans to vent the growing area so as to reduce humidity and leaf wetness.
- Space plants to allow good air circulation around foliage.
- As a plant with a nutrient deficiency is more susceptible, maintain a balanced nutritional program.
- Remove and destroy all infected plants.
- Destroy any alternative hosts around the nursery which may be providing a source of spores.
- Apply appropriate fungicides (see below).

Fungicides for use Against Downy Mildew

There are a number of fungicide products available against downy mildew in production nurseries including those with pre-infection (protectant) and post -infection (systemic or penetrant) modes of action. Protectant fungicides must be applied before infection occurs, and should be used in a regular spray schedule to ensure that the chemical is present on the plant surface during high risk periods. Systemic fungicides have the ability to kill downy mildew after infection has occurred. They should be applied as soon as possible after an infection event. Obviously, any damage to leaves caused by downy mildew will remain, but new growth should be healthy. Table 2 lists most products available for use against downy mildew in production nurseries. However, other products may also be available for specific crops that may be grown in certain nurseries. As with the use of all pesticides, it is best to rotate between three or more active ingredients from different mode of action groups to limit the occurrence of pesticide resistance. For information on product registration, refer to infopest or the APVMA and always follow best practice guidelines for pesticide use.

Downy Mildew Biosecurity Threat

Plant diseases caused by downy mildew remain an ever increasing threat to the nursery industry. Some species and their variants are not known to occur in Australia. International trade in nursery plants and ornamentals is increasing and this increases the risk of these pathogens being introduced. A notable incursion in recent years is downy mildew (*Plasmopara obducens*) of *Impatiens.*

Table 1. Host plant and downy mildew species primarily associated with each plant species.

Host Plant	Downy mildew
Allium (onion)	*Peronospora destructo*
Brassica	*Peronospora parasitica*
Cucurbits	*Pseudoperonospora cu-*
Lactuca (lettuce)	*Bremia lactucae*
Pisum (pea)	*Peronospora viciae*
Rheum (rhubarb)	*Peronospora jaapiana*
Spinacia (spinach)	*Peronospora farinosa* f.sp. *spinaciae*
Beta (silver beet)	*Peronospora farinosa*
Vitis (grape)	*Plasmopara viticola*
Antirrhinum	*Peronospora antiirrrhini*
Cissus (grape ivy)	*Plasmopara viticola*
Eustoma	*Peronospora chlorae*
Papaver (poppy)	*Peronospora arborescens*
Ranunculus	*Peronospora anemonse*
Rosa (rose)	*Peronospora sparsa*
Matthiola (stock)	*Peronospora parasitica*
Lobularia	*Peronospora parasitica*
Helichrysum	*Bremia lactucae*
Impatiens	*Plasmopara obducens*
Primula	*Peronospora oerteliana*
Helianthus	*Peronospora halstedii*

Fig. 5. Damage to *Salvia* caused by downy mildew.

Overseas, downy mildew causes a leaf blight of coleus, which is not currently in Australia. Cultivars vary in their susceptibility to the disease, however leaves generally become necrotic and drop prematurely.

Should any new downy mildew enter Australia, early detection will be essential for its eradication. For this reason, regular monitoring is essential in production nurseries. If unusual symptoms are found contact the nearest department of agriculture or call the Exotic Plant Hotline on 1800 084 081.

This document was prepared by Ken Pegg and Andrew Manners (Agri-science Queensland, Department of Agriculture, Fisheries (DAF), Ecosciences Precinct, GPO Box 267, Brisbane QLD 4001) as part of NY11001 Plant health biosecurity, risk management and capacity building for the nursery industry in 2015. Thanks go to Lindy Coates, John Duff and Tony Cooke for helpful comments on previous versions of this factsheet. Unless otherwise stated, photographs can be attributed to DAF (particularly Leif Forsberg).

Fig. 6. Downy mildew symptoms on coleus (caused by *Peronospora belbahrii*) (Top right - photo by Jay Pscheidt, Oregon State University). Leaf and stem symptoms on rose caused by downy mildew (bottom photos).

Table 2. Products registered for use against downy mildew relevant to production nurseries as at December 2015. It is recommended to read current labels for more up to date information. Mode of action P = protectant (and/or preventative), C = curative (and/or eradicant); Mobility in plant S = systemic, T = translaminar, CT = contact.

MoA group	Active ingredient	Example product	Registration details	Mode of action	Mobility in plant
D + M1	Metalaxyl + copper	Ridomil Gold	Brassicas, cucumber, grape, leek, spring onion and ornamentals, PER13673 silverbeet and spinach	P, C	S, CT
D + M3	Metalaxyl + mancozeb	Zeemil	Grape, cucurbits, lettuce, onion, poppy, rhubarb, PER14008 garlic, PER12399 snow peas and sugar snap peas, PER14045 brassicas, rocket, chicory, endive, radicchio and beetroot,	P, C	S, CT
M	Hydrogen peroxide + peroxy acetic acid	Peratec plus	Grape, brassicas, alliums	P, C	CT
M1	Copper products	Copperguard	Brassicas, lettuce, red beet, rhubarb, silverbeet, spinach, onions, vines PER81491 Non-food nursery stock	P	CT
M3	Mancozeb	Mancozeb	Grape, beetroot, silverbeet, spinach, cole and cucurbit crops, PER81491, PER14768 and PER14880 Non-food nursery stock, PER14470 snow peas, PER 14473 spring onions and leeks, PER14958 brassica leafy vegetables, silverbeet, spinach, lettuce, beetroot, chicory, endive, parsley, radish, rocket, PER13790 various culinary herbs	P	CT
M3 + 1	Mancozeb and thiophanate-methyl	Zyban	Ornamentals	P, C	CT, S
M3	Metiram	Polyram	Grape, selected brassicas, cucurbits, bulb onions and garlic and poppies	P	CT
M5	Chlorothalonil	Bravo	Cucurbits, onions (not spring onions), peas, grapes, PER81285 Parsley, PER14034 spinach, silverbeet and spring onions, PER 13036 fennel, PER11990 brassica leafy vegetables, PER11451 eggplant and radish	P	CT
4 (+ M3)	Propineb (sometimes with oxadixyl)	Rebound	Cucurbits, lettuce, onion and grape, labels vary	P[1]	CT[1]
11	Azoxystrobin	Amistar	Non-food nursery stock, ornamentals, cucurbits, grapes, leeks and poppies	P, C	S, T
33	Phosphorous acid	Phospot	Grape and cucurbits, labels vary. PER 14493 rhubarb, PER14184 selected brassicas, PER13791 various culinary herbs, PER13698 Fennel and alliums, PER11951 broccoli, Brussels sprouts, cauliflower, spinach, silverbeet, endive, chicory and radicchio	P, C	S
40	Dimethomorph	Acrobat	Cucurbits, grape, lettuce, oilseed poppies, onion, PER81491 and PER14768 Non-food nursery stock, PER14470 snow peas, PER 14473 spring onions and leeks, PER14958 brassica leafy vegetables, silverbeet, spinach, lettuce, beetroot, chicory, endive, parsley, radish, rocket	P, C	S
40	Mandipropamid	Revus	PER14837 Various leafy vegetables	P, C	S

[1] oxadixyl is protective and curative and systemically mobile in plants