Factsheet 09/14 (a revision of 04/04)
(HDC projects HNS 186, HNS 150, HNS 135, HNS 79 and HNS 53)

Hardy Nursery Stock

Control of downy mildew diseases on hardy nursery stock and perennial herbaceous plants

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Downy mildew diseases, although sporadic, can seriously damage hebe, rose and several other major nursery stock and herbaceous perennial species. This factsheet provides guidance on how to minimise losses by the use of clean stock plants, good nursery hygiene, avoiding favourable environmental conditions for disease development and by appropriate fungicide treatment.

Action points

- Where the market allows, consider growing more resistant species and varieties.
- Be aware of which plant species and varieties are most susceptible to downy mildew. Check these regularly for any initial disease symptoms and to assess the efficacy of control measures.
- Take care not to confuse symptoms – rose downy mildew for example, can sometimes be confused with black spot and buddleia downy mildew can appear similar to leaf and bud nematode damage.
- Ensure stock plants are, and remain free of downy mildew.
- Manage the crop so as to minimise prolonged leaf wetness: do not use overhead irrigation in the late evening, use drip or sub-irrigation where possible, grow high-value susceptible crops in well-ventilated structures, use as wide a plant spacing as economically possible and use circulation fans to improve air movement.
- Act promptly when downy mildew is found. The disease cycle can be as short as five days under favourable conditions.
- Where practicable, trim off diseased shoots from lightly affected plants and treat with a suitable fungicide; promptly remove and dispose of severely affected plants.

1. Hebe downy mildew (*Peronospora grisea*) is often found on young shoots where it causes leaf yellowing, distortion and leaf necrosis

2. Digitalis downy mildew (*Peronospora digitalidis*) sporulating on the leaf underside

- Treat susceptible species and varieties with a suitable protectant fungicide during conditions conducive to disease development.
- Use products from at least two different fungicide groups in a spray programme and alternate these to minimise the risk of selecting resistant fungal strains.
- Reduce the spray interval (for example, to seven days) when conditions are very favourable for disease development.
- Make sure that good spray coverage is achieved throughout the plant canopy, especially on the lower surface of leaves.

Background

Downy mildews on hardy nursery stock and herbaceous perennial species are most common on crops grown in poorly ventilated structures and on plants grown in densely packed beds with overhead irrigation. Infection results in leaf spots (often angular), leaf disfigurement, premature leaf fall and stunted growth. Although generally less damaging than 10-15 years ago, probably due to the adoption of new fungicides and improved management practices, downy mildew diseases still occur each year and have the potential to cause serious plant losses.

Symptoms

Crops commonly affected by downy mildew are listed in Table 1. It should be noted that many of the downy mildews are host-specific. For example, there is no risk of the downy mildew from rose affecting hebe, or vice versa. However, if conditions are favourable for the development of downy mildew on one crop on a nursery, they may be equally favourable for the development of a different downy mildew on another crop. Symptoms of the more common downy mildew diseases are described below.

Buddleia downy mildew (*Peronospora hariotii*)

Varieties of *Buddleia davidii* are particularly susceptible to downy mildew. The fungus causes angular, pale-yellow lesions on the upper surface of leaves that subsequently turn brown and can be mistaken for the symptoms of leaf and bud nematode (*Aphelenchoides ritzemabosi*). Leaves become distorted. Sporulation of the fungus occurs on the leaf underside, but it can be difficult to see because of the presence of leaf hairs.

3. Buddleia downy mildew (*Peronospora hariotii*) results in angular, yellow-green spots on the upper leaf surface

Digitalis downy mildew (*Peronospora digitalidis*)

The angular necrotic spots produced by this fungus can be confused with those caused by the leaf and bud nematode. Under favourable conditions dense brown sporulation can result on the lower leaf surface.

4. Necrotic spots on the upper leaf surface caused by *Peronospora digitalidis*

Geum downy mildew (*Peronospora potentillae*)

Geum downy mildew is a common disease of the crop and affects many varieties; *G.* x 'Borisii' is particularly susceptible. Disease symptoms take the form of light-coloured angular leaf blotches, bounded by the veins, with sporulation visible on the undersides of leaves. Infection occurs on the older leaves first. There is no growth distortion.

5. Geum downy mildew gives rise to angular yellow blotches, becoming pale brown

Hebe downy mildew *(Peronospora grisea)*

Hebe downy mildew is a common disease affecting many varieties. Distorted leaves are usually the first sign of infection, especially on large leaf varieties (such as 'Midsummer Beauty'). Irregular shaped chlorotic areas may eventually develop within leaves which may fall prematurely. On small leaf varieties leaf necrosis in the shoot tips is a common symptom. In humid weather, a purple-grey matt of fungal growth develops on the underside of affected leaves.

6. Sporulation of hebe downy mildew on the lower leaf surface

Hellebore downy mildew (*Peronospora pulveracea*)

Affected leaves initially turn pale, lose colour and curl downwards slightly at the margins making them appear distorted. The upper surfaces of leaves develop grey water-soaked areas which eventually becoming necrotic. A grey sporulation of the causal fungus develops on the lower surface. The disease can be severe and completely destroy plants.

7. Grey water-soaked areas on the upper leaf surface as a result of hellebore downy mildew

Laurel downy mildew (*Peronospora sparsa*)

This mildew is an occasional disease on cherry laurel and Portugal laurel, caused by the same fungus that infects rose. Typically the disease appears as irregular necrotic blotches. The edges of blotches are often light green in colour. Sporulation is not commonly seen. As with some other foliar diseases of *Prunus* species, affected areas may eventually drop out leaving a 'shot-hole'.

8. Necrotic blotches are a symptom of laurel downy mildew

Rose downy mildew (*Peronospora sparsa*)

Rose downy mildew is a common disease of both outdoor and protected grown susceptible varieties at certain times of the year. This fungus produces irregular, rounded, yellow-green or purplish spots on the upper side of leaves and occasionally on the calyx, petals and stems. Sometimes flowers or flower buds are malformed. Sporulation is often sparse but a whitish-grey, downy, fungal growth is sometimes seen on the undersides of leaves. Affected leaves may become necrotic and fall prematurely. If left uncontrolled, growth of plants (both height and stem diameter) is significantly reduced and plants may fail to reach marketable grade. Young shoots can become so heavily diseased that they die back.

9. Rose downy mildew causing plant defoliation

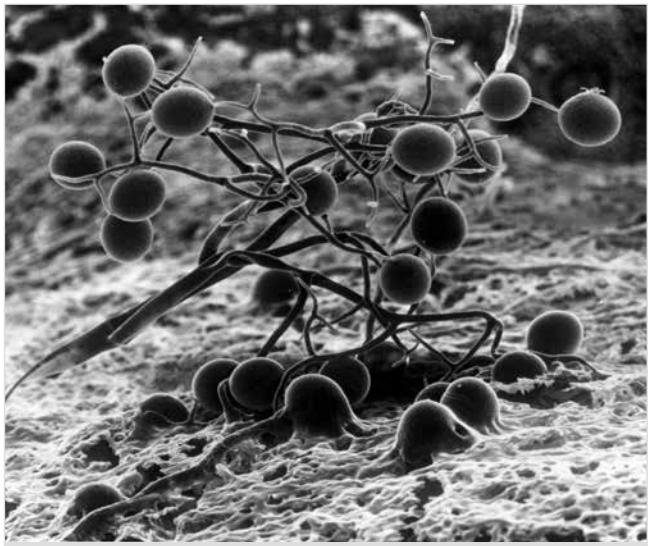
Table 1. Downy mildew diseases of nursery stock and herbaceous perennial plants

Crop	Downy mildew fungus	Symptoms and comments
Agastache	*Peronospora belbahrii*	Chlorotic leaf spots eventually turning brown, brown sporulation on leaf underside
Anemone	*Peronospora ficariae*	Soil-borne, leaves dull, grey-yellow, down-curled
Aquilegia	Not currently named	An uncommon problem; foliage turns very pale, light brown downy sporulation seen over the entire underside of the leaf
Buddleia	*Peronospora hariotii*	Angular, pale-yellow lesions, later turning brown; distorted leaves; common on varieties of *B. davidii*
Coreopsis	*Plasmopara halstedil*	Black spots on upper leaf surface, white felt-like growth below
Digitalis	*Peronospora digitalidis*	Angular, necrotic spots with brown sporulation on the lower leaf surface
Gaillardia	*Bremia lactucae*	Leaf chlorosis with a fluffy white sporulation on lower leaf surface
Geranium	*Peronospora geranii*	Especially on variety 'Johnson's Blue'; brown blotches on upper surface that coalesce causing leaves to shrivel
Geum	*Peronospora potentillae*	Angular yellow leaf blotches, becoming pale brown
Hebe	*Peronospora grisea*	Distorted leaves; purple-grey mat of sporulation on underside of leaves
Helleborus	*Peronospora pulveracea*	Leaves appear grey, watersoaked and may be down-curled
Helianthemum	*Peronospora leptoclada*	Yellow or brown angular lesions on upper leaf surface
Laburnum	*Peronospora cytisi*	Leaf distortion and localised necrosis on the upper leaf surface
Lamium	*Peronospora lamii*	Purple spots on the upper surface, developing into brown necrotic areas
Meconopsis	*Peronospora arborescens*	Grey sporulation on underside of leaves, flower stalks and seed pods
Potentilla	*Peronospora potentillae*	Angular yellow leaf blotches, becoming pale brown
Prunus (laurel)	*Peronospora sparsa*	Irregular necrotic blotches with light green edges; sporulation rarely seen
Rosa	*Peronospora sparsa*	Irregular, yellow-green/purplish spots on upper side of leaves and sometimes on calyx, petals and stem
Salvia	*Peronospora lamii*	Angular yellow or pale-green leaf spots on the upper leaf surface
Verbena	*Peronospora verbenae*	Yellow to pale green leaves with grey to brownish growth on the lower leaf surface
Veronica	*Peronospora grisea*	Yellow and brown spots on upper leaf surface, grey sporulation on leaf underside

Disease sources and spread

The life cycles of these diseases are not fully understood. Rose downy mildew caused by the fungus *P. sparsa* is the most studied and it is likely that other downy mildews behave in a similar way. Air-borne spores produced on the underside of leaves are the most important means of spread, although it has been suggested that the fungus is occasionally spread in seeds. These spores are short-lived, surviving just a few days. Under moist conditions, they germinate quickly and infect leaves or other plant parts. Many downy mildews infect leaves via stomata, which are most common on the lower leaf surface.

The fungus can survive between seasons in a dormant state as fungal strands, or as resting spores inside infected host tissue (such as leaves). The role of resting spores in disease spread is uncertain; no method of their transmission from leaf debris to fresh leaves resulting in infection has been described. In rose, studies have confirmed the occurrence of *P. sparsa* within the stem cortex, crown and root tissues of plants showing symptoms, supporting the occurrence of persistent infections. Fungal hyphae and resting spores were abundant within the infected stems.



10. Electron micrograph showing the spore bearing structures of rose downy mildew, commonly found on the lower leaf surface

Conditions favouring disease development

Outbreaks of downy mildew generally occur only sporadically, suggesting the diseases are limited by environmental conditions. Various studies have shown a dependence on temperature and leaf wetness, and isolates from different geographic locations may differ slightly in their response to temperature. In the case of *P. sparsa* for example, spore germination and infection occurs over a broad range of temperatures from 5 to 25°C, with occasional isolates germinating at temperatures as low as 2°C. Spores may survive low temperatures even if they do not germinate. The optimum temperature for infection is between 15-20°C. At this temperature, as little as four hours of leaf wetness are sufficient for infection to take place. Whereas, at temperatures around 10°C, at least eight hours of leaf wetness are required for significant levels of infection. A recent study on rose downy mildew in California identified a critical leaf wetness duration of 84 hours accumulated over 10 days, to discriminate between wet periods that are conducive to the development of downy mildew and those that are not.

The latent period between infection and symptom development can be as short as four days (at 20-25°C) with sporulation occurring one day later. When the temperature is in the range 10-20°C, symptoms can still appear in four to seven days. This very rapid disease cycle is not uncommon for downy mildews and helps to explain the difficulty in achieving effective control.

11. Susceptible crops such as buddleia are most at risk from damaging attacks of downy mildew if grown in densely-packed beds with frequent overhead irrigation

Control strategy

Successful control of downy mildew is achieved by adopting a range of control measures throughout the production process.

Use of resistant varieties

Observations suggest varieties of buddleia, hebe and rose can differ significantly in their susceptibility to downy mildew. For example, *Rosa* 'Silver Jubilee' is noted to be very susceptible, as are varieties of *Buddleia davidii*. Many larger leaf hebe varieties are susceptible (such as 'Midsummer Beauty' and x 'Franciscana Variegata') but so also are some of the smaller leaf varieties including *H. albicans, H.* 'Frozen Flame'*, H. rakiensis* and *H. `Youngii`* syn. 'Carl Teschner'. *H. ochracea* 'James Stirling' appears to have some natural tolerance to the disease.

Healthy stock plants

Careful selection of stock plants from which cuttings are to be taken is vital. Plants should be closely examined to ensure freedom from visible downy mildew. Young, actively growing plants are best, as juvenile cuttings are less likely to be infected and also root faster than older cuttings from woody plants. A programme of preventative fungicide sprays together with care in irrigation to avoid leaf wetness (such as using drip- or sub-irrigation) will minimise the risk of downy mildew on stock plants, and consequent latent infections in cuttings.

Crop management: avoidance of conditions that favour downy mildew development

Leaf wetness is the most important factor that encourages downy mildew disease. If the leaf wetness duration can be kept to less than four hours on most days the risk of significant levels of downy mildew occurring is low. Consider adopting the following measures:

- Avoid overhead irrigation during the evening or at night.
- Use capillary sand beds and drained beds, where overhead irrigation will be required less frequently.
- Grow high-value susceptible crops on sand beds under protection; this both avoids rainfall and precludes the need for frequent overhead irrigation, and can provide very effective control of downy mildew.
- Consider using drip-irrigation for stock plants.
- Space plants as much as possible so as to allow good air circulation and rapid drying conditions.
- Ventilate glasshouses and structures to increase airflow across the crop.
- Use fans to move air in areas where natural ventilation is limited and air may be stagnant.
- Avoid placing downy mildew susceptible crops in areas where there is little natural air-movement.

Nursery hygiene

Where practicable, prune out and carefully dispose of affected shoots. If stock plants are affected, dispose of the whole plant. After an attack, rake or vacuum up fallen leaves, to help prevent disease spread; this may also reduce carryover to the following season. If a crop becomes severely affected, dispose of the plants and carefully remove all debris. Consider treating the standing area with a disinfectant (such as Jet 5) after a severe disease outbreak.

Fungicides

Foliar sprays of fungicides remain the cornerstone of downy mildew control for most growers. A wide range of fungicides is available (see Table 2 in the pull out sheet in the pocket at the back of the factsheet). For effective control, it is important that:

- Programmes based on protectant fungicides commence before the disease is noted.
- Fungicides from at least two different fungicide groups are used, where both products are active against downy mildew.

- Products from different fungicide groups are used alternately, or in mixtures (where allowed); some example programmes are shown in Table 3 (see the pull out sheet).
- The spray interval is reduced (for example from 14 to seven days or less) when conditions favour downy mildew (e.g. during periods of persistent leaf wetness).
- The spray application achieves good coverage of leaves throughout the crop canopy (nozzle type and arrangement, spray pressure and water volume should be adjusted as necessary), including the lower surface of leaves where practicable.
- Fungicides are used in combination with other control strategies, especially suitable crop management techniques to avoid prolonged leaf wetness.
- The rapid extension growth that occurs in hot conditions where overhead irrigation is used is protected via fungicide applications.

Once a crop becomes infected, it is difficult to eradicate the disease by fungicide sprays alone; however, it is possible to reduce infection of new extension growth by trimming off affected shoots and following with a fungicide programme.

12. The potential for hebe downy mildew to severely damage plants is clearly seen in this fungicide comparison trial (untreated on left)

Alternative products

Foliar fertilisers based on potassium phosphite (e.g. Hortiphyte) used to improve plant nutrition have been observed to have an incidental beneficial effect in controlling downy mildew. The use of such foliar fertilisers interspersed between fungicide products applied for downy mildew control, may permit an increased spray interval between fungicide treatments.

Further guidance on the use of fungicides

Crop safety

Many of the fungicides listed in Table 2 with potential for the control of downy mildew do not have specific label recommendations for use on an individual nursery stock or perennial herbaceous crop species. Off-label use is permitted, at growers` own risk, via Extension of Authorisation for Minor Use (EAMU) and also via the Long Term Arrangements for Extension of Use (LTAEU). Before use, a copy of the product label and EAMU notice of approval (if relevant) must be obtained and complied with. It is strongly recommended that when a fungicide is used for the first time on a new crop or variety, it is first tested on a small number of plants to ensure there is no phytotoxic risk. Grower experience suggests phytotoxic damage is most likely to occur:

- On young plants.
- On the soft growth of older plants.
- When several pesticides are used on a crop over a short period of time, when several pesticides are used in a mixture, or when additional wetters/spreaders are added.
- During very hot or bright weather; or cold, frosty weather.

Crop damage has been noted on some varieties of hebe following treatment with Amistar (azoxystrobin) and Fubol Gold WG (mancozeb + metalaxyl-M) yet other varieties were unaffected.

Fungicide programmes

There are many potential programmes using fungicides from different fungicide groups for alternate sprays that could be devised based on the information in Table 2. Some have been tested in HDC funded trials on both hebe and geum (HDC project HNS 186) and showed good, though not complete control. A number of examples are provided in Table 3.

A spray interval of 14 days is commonly used in preventative programmes. The spray interval should be reduced in persistent wet weather or at other times when conditions are favourable to the disease, from 14 to seven days for example. Also consider reducing the spray interval to seven days, for two or three applications, after first spotting downy mildew in a very susceptible crop, to prevent the disease becoming established. Conversely, consider increasing the spray interval to 21 or 28 days in warm sunny weather when crops dry quickly.

Fungicide resistance

The development of fungicide resistance is a real risk in downy mildew species, especially when fungicides are used intensively. Although not confirmed in any of the species listed in this factsheet, fungicide resistance has resulted in loss of control in related downy mildew fungi that affect impatiens (*Plasmopara obducens*), lettuce (*Bremia lactucae*) and cucumber (*Pseudoperonospora cubensis*). The phenylamide (e.g. Fubol Gold WG) and strobilurin (e.g. Amistar) groups appear to be most at risk. In order to minimise the risk of selecting resistant strains of the fungus, it is recommended that:

- Fungicides are used according to the programmes shown or similar programmes that have been designed to avoid resistance development.
- No more than two sprays of the same fungicide, or fungicide group, are used in sequence, thereafter a fungicide from a completely different fungicide group is used.
- In the case of strobilurin fungicides, no more than 50% of the total sprays of this type of fungicide are applied per crop.
- The label recommendations are carefully followed especially those concerning the dose rate.
- Fungicides alone are not used for disease control; the cultural control measures detailed in this factsheet, especially those regarding the management of leaf wetness, are also adopted.

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Further information

HDC Factsheets and publications

- HDC Factsheet 03/14. 'Use of chemical disinfectants in protected ornamental plant production'.
- HDC Factsheet 01/13. 'Practical measures to prevent and manage insecticide, fungicide and herbicide resistance for horticultural crops'.
- HDC Factsheet 15/09. 'Control of rose downy mildew'.
- HDC Factsheet 14/06. 'Guidelines and best practice for pesticide spray application in protected ornamental crops'.

HDC Grower summaries and reports

- HNS 186: 'Control of downy mildew on shrub and herbaceous plants'.
- HNS 150: 'Managing downy mildew epidemics in rose production systems by early detection and treatment of infection sources'.
- HNS 135: 'Container-grown rose: Evaluation of natural products for prevention and control of downy mildew and improved shelf-life'.
- HNS 79: 'Hebe: Control of downy mildew on container-grown crops'.
- HNS 53: 'Container-grown rose: Control of downy mildew by manipulation of cultural factors and timely use of fungicides'.
- PO 012: 'Evaluation of the efficacy of non-metalaxyl-M based fungicides/programmes against metalaxyl-M resistant strains of *Plasmopara obducens*'.
- PO 011a: 'Monitoring metalaxyl-M sensitivity in impatiens downy mildew isolates from infections in 2013'.
- PO 11: 'Monitoring metalaxyl-M sensitivity in impatiens downy mildew isolates from 2012 infections'.

Other publications

FRAG-UK technical leaflet: Fungicide Resistance (http://www.pesticides.gov.uk/Resources/CRD/Migrated-Resources/Documents/F/FRAG_UK_General_leaflet_v5_1b_March_12.pdf).

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Table 2. Fungicides with activity against downy mildew diseases which are currently permitted for use on container-grown ornamental crops (April 2014)

Product	Active ingredient(s) and fungicide group	Label approval or EAMU	Approved for use		Maximum number of applications	Comments
			Outdoor (O)	Protected (P)		
Amistar	Azoxystrobin (11)	0443/09	✓	✓	4*	Maximum total dose 4 L/ha/year. Maximum two sprays/year for outdoor forest nursery
Bravo 500	Chlorothalonil (M5)	1130/11	✓	-	2	Expires 3 March 2015
Fenomenal	Fosetyl-aluminium (33) + fenamidone (11)	1990/13	✓	✓	2	Also permitted as a drench up to three applications/year, total dose 30 kg/ha/year
Fongarid Gold	Metalaxyl-M (4)	Label	✓	✓	1	Drench treatment only
Fubol Gold WG	Mancozeb (M3) + metalaxyl-M (4)	2288/13	✓	✓	3*	Maximum total dose 5.7 L/ha/crop
Infinito	Flupicolide (43) + propamocarb hydrochloride (28)	0952/13	✓	-	4*	Maximum total dose 6.4 L/ha/crop. Latest application seven days before harvest
Invader	Dimethomorph (40) + mancozeb (M3)	0109/12	✓	-	3	Note that the two active ingredients are in the same groups as for Valbon
Paraat	Dimethomorph (40)	2585/11	-	✓	2	Minimum spray volume 600 L/ha
Percos	Ametoctradin (45) + dimethomorph (40)	0819/13	✓	✓	4	Use outdoors is restricted to June to September and only on permeable surfaces
Pergado Uni	Mandipropamid (40)	1605/12	✓	✓	4 (O) 1 (P)	Note the limit of one spray only on protected crops
Plant Trust	Fosetyl-aluminium (33)	Label	✓	✓	1	Growing medium incorporation; primarily for *Phytophthora* control
Proplant	Propamocarb hydrochloride (28)	3100/12	✓	✓	3	Note minimum interval of 40 days between sprays
Previcur Energy	Fosetyl-aluminium (33) + propamocarb hydrochloride (28)	1845/13	✓	✓	2*	Maximum total dose 5 L/ha/year. Latest application 23 days before harvest
Revus	Mandipropamid (40)	2867/08 0487/12	✓	✓	4 (O) 1 (P)	Final use 31 January 2015. Final use 31 January 2015
Signum	Boscalid (7) + pyraclostrobin (11)	1842/09	✓	✓	2	
Subdue	Metalaxyl-M (40)	Label	✓	✓	1	Drench treatment only
Valbon	Benthiavalicarb-isopropyl (40) + mancozeb (M3)	1513/10	✓	-	1	Note that the two active ingredients are in the same groups as for Invader

* Based on maximum total dose.

Before using a product for a plant protection purpose, always check that it is currently approved for the intended use and situation. For the latest information, check with a professional supplier or with the Chemicals Directorate (CRD), Tel: 08459 33 55 77; website: www.pesticides.gov.uk. When using a product for the first time, always test treat a small number of plants first, based on maximum total dose, to check for crop safety.

Table 3. Example fungicide programmes for the control of downy mildew

Situation	Spray 1	Spray 2	Spray 3	Spray 4	Spray 5	Spray 6	Spray 7
Protected or outdoor*	Percos	Fubol Gold WG	Signum	Percos	Fubol Gold WG	Signum	Percos
Protected or outdoor with foliar fertiliser	Fubol Gold WG	Hortiphyte†	Signum	Fubol Gold WG	Hortiphyte†	Signum	Fubol Gold WG
Outdoor only*	Infinito	Percos	Infinito	Percos	Infinito	Percos	Infinito

*Note that outdoor use of Percos is restricted to applications between June and September and only on plants grown on permeable surfaces.

†If a spray programme includes a potassium phosphite foliar fertiliser interspersed between specific downy mildew fungicide products, there is evidence that the nutritional treatment provides additional protection against downy mildew.