Factsheet 17/10
HNS and Herbaceous Perennials
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Control of powdery mildew diseases on hardy nursery stock and herbaceous perennials

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Powdery mildews are some of the most common, widespread and easily recognised diseases of hardy nursery stock and herbaceous perennial species. This factsheet provides guidance on how to minimise losses by avoiding environmental conditions favourable for disease development and by applying appropriate fungicide treatments.

Action points

- Be aware of which plant species and varieties are most susceptible to powdery mildew. Check these regularly for first symptoms of the disease and to assess the efficacy of control measures.
- Where the market allows, consider growing more resistant varieties.
- Take care not to confuse symptoms:
  - powdery mildews sometimes result in leaf purpling or other discolouration with no obvious fungal growth
  - they sometimes develop on the lower leaf surface.
- Ensure mother stock remains free of powdery mildew.
- Be prepared as warm, humid days without rain and cool nights with high humidity generally favour disease development.
- Manage the crop so as to minimise prolonged high humidity:
  - do not use overhead irrigation in the late evening or night
  - grow plants in a site with full sun and good air circulation
  - use as wide a spacing as economically possible
  - space container-grown plants before they need it
  - use circulation fans to improve air movement in glasshouses.

1 *Acer* powdery mildew causing distinct powdery white spots

- Act promptly when powdery mildew is found; the disease cycle can be as short as three days under favourable condition.
- Where practical, trim off diseased shoots from lightly affected plants and treat with a suitable fungicide; promptly remove and dispose of severely affected plants.
- Treat susceptible species and varieties with a protectant fungicide before powdery mildew becomes established, normally in the spring. Initiating fungicide sprays at the first sign of disease is only possible if crops are inspected regularly for the advent of powdery mildew.
- Use products from at least two different fungicide groups in a spray programme and alternate these to minimise the risk of selecting resistant strains of the fungus.
- Reduce the spray interval (for example to 7 days) when conditions are very favourable to disease development; make sure that good spray coverage is achieved throughout the plant canopy.
- Where practical, prune and destroy infested shoots at the end of the season; rake up and destroy fallen leaves.

Background

Each year powdery mildews affect many species of hardy nursery stock and herbaceous perennials. The diseases they cause may be slight or, in some situations, if left untreated, may cause severe economic losses. They impair photosynthesis, stunt growth and can cause premature leaf fall. They generally do not kill their hosts but extensive white fungal growth on leaf, stem and flower surfaces make plants unsightly, and thus either unsaleable or of reduced quality. Severe damage can cause leaf and shoot death. Although numerous fungicides are available for powdery mildew control, weekly applications may be needed to maintain adequate control.

2 *Crataegus* powdery mildew causing powdery white marks and leaf discolouration

Biology of powdery mildews

Susceptible crops

As a group, the various powdery mildew fungi attack a wide range of hardy nursery stock and herbaceous perennials (Table 1). Some of the main nursery stock species affected include: *Acer, Clematis, Corylus, Crataegus, Euonymus, Hydrangea, Malus, Quercus, Rhododendron, Ribes* and *Rosa*. Major herbaceous crops affected include: *Aquilegia, Aster, Delphinium, Euphorbia, Geranium and Phlox*. Most species of the pathogens affect only a few crops. For example, there is no risk of powdery mildew from *Rosa* affecting *Quercus*, or vice-versa. However, if conditions are favourable for development of powdery mildew in one crop they may be equally favourable to disease development on another crop, so different powdery mildews may appear on different crop species at a similar time. Some hosts can be affected by two or more different species of powdery mildew (for example *Neoerysiphe galeopsidis* and *Erysiphe elevata* on *Catalpa*), which may differ in the symptoms they produce and other features. Powdery mildews are relatively common on both field-grown and protected crops, affecting plants grown in both soil and in containers.

Causal fungi

The taxonomy of powdery mildew fungi was recently extensively revised based on DNA sequence data. As a consequence, the names of some common powdery mildew fungi have changed. Powdery mildew fungi are now grouped into five tribes. These are shown in Table 2 together with some representative powdery mildew genera and species affecting hardy nursery stock or herbaceous species.

Table 1: Some hardy nursery stock and herbaceous perennials affected by powdery mildew in the UK

Hardy nursery stock	Herbaceous perennials
Acer (maple, sycamore)	*Acanthus*
Amelanchier (serviceberry)	*Anemone*
Catalpa (Indian bean tree)	*Aquilegia* (columbine)
Clematis	*Artemesia*
Cornus (dogwood)	*Aster* (Michaelmas daisy)
Cotinus (smoke tree)	*Centaurea* (cornflower)
Crataegus (hawthorn)	*Coreopsis*
Eucalyptus (gum tree)	*Delphinium*
Euonymus (spindle)	*Dendranthema* (chrysanthemum)
Fagus (beech)	*Dianthus* (carnation, pinks)
Forsythia	*Euphorbia*
Hebe (veronica)	*Geranium* (crane's-bill)
Hydrangea	*Limonium* (sea lavender)
Laurus (sweet bay)	*Penstemon*
Lonicera (honeysuckle)	*Phlox*
Mahonia	*Polemonium* (Jacob's ladder)
Malus (crab apple)	*Pulmonaria* (lungwort)
Photinia	*Salvia* (sage)
Potentilla	*Scabiosa* (scabious)
Prunus (cherry laurel)	*Solidago* (golden rod)
Quercus (oak)	*Stachys*
Rhododendron (and azalea)	*Verbascum* (mullein)
Ribes (flowering currant)	*Verbena*
Rosa (rose)	*Viola*
Spiraea	

Table 2: The five tribes of powdery mildew fungi (Erysiphales) and some representative genera and species

Tribes	Genera	Example species and host
Phyllactineae	*Phyllactinia*	*P. guttata* on beech
Erysiphe	*Erysiphe* section *Microsphaera*	*E. alphitoides* on oak
	Erysiphe section *Uncinula*	*U. necator* on grapevine
Blumeriae	*Blumeria*	*B. graminis* on grasses
Golvinomycetaceae	*Golvinomyces*	*G. cichoracearum* on *Aster*
	Neoerysiphe	*N. galeopsidis on Catalpa*
Cystotheceae	*Podosphaera* section *Podosphaera*	*P. pannosa* on rose
	Podosphaera section *Sphaerotheca*	*P. fusca* on *Phlox*
	Sawadaea	*S. bicornis* on *Acer*

Symptoms

Unlike most fungal pathogens, powdery mildews tend to grow superficially on plant surfaces. They are visible as white or off-white fungal growth usually on the upper surface of leaves, though sometimes the lower leaf surface is also affected. They are most common on young growth and can also affect stems, buds and flowers. Infected plants may show yellow, crinkled and twisted leaves, aborted flowers and fruit and premature senescence. Infection slows growth and causes a delay in reaching the desired marketing height or stem diameter. Severe damage can cause leaf and shoot death. As affected leaves yellow and deteriorate, small green islands of apparently healthy tissue are left; these mark the fungal infection points and are the last areas to die.

The first sign of powdery mildew infection is white strands on the surface of the host which, over time, become powdery in appearance as they develop dispersal spores. The fungus may develop as distinct colonies or spots (for example on *Phlox*), usually with a ragged edge, or as a general white growth over the leaf surface (for example on *Geranium*). As colonies stop producing spores they become thicker and feltier (for example on rose) and the centres may turn brown. In late summer or autumn, tiny black specks (spore cases) may develop in the colonies. In some hosts (for example *Prunus, Rhododendron* and *Rosa*), leaf tissue in the area under the mildew colonies turns red.

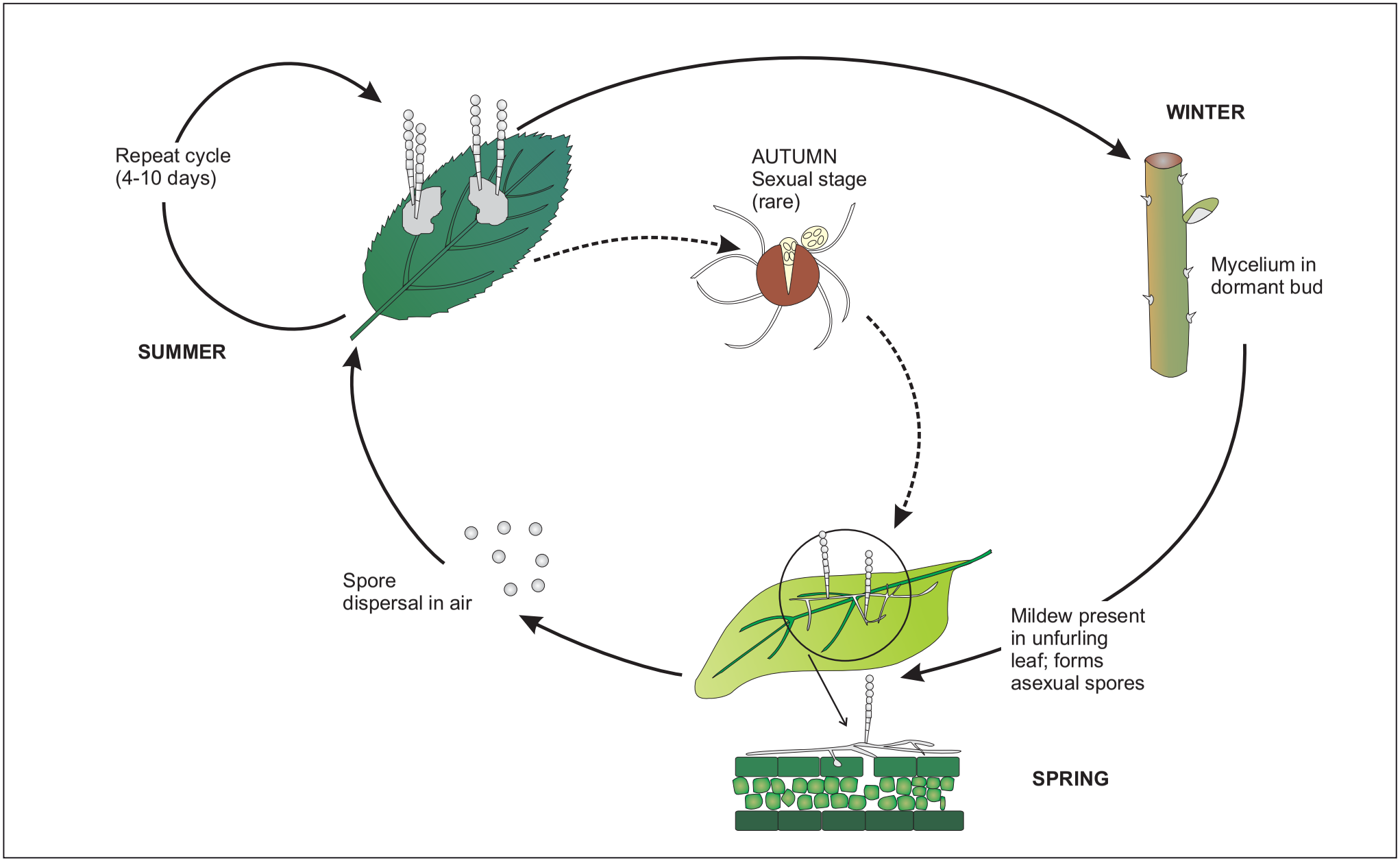
On some deciduous species, where the fungus overwinters as hyphae on woody stems or in buds (for example *Malus* and *Quercus*), apparently healthy new shoots can be suddenly and completely covered by mildew in the spring from these so-called 'primary infections'.

Disease sources and spread

The life cycles of these diseases are not fully understood. Rose powdery mildew caused by the fungus *P. pannosa* is the most studied and is summarised here (Diagram 1).

Air-borne dispersal spores are the most important means of spread. These spores are relatively short-lived, although survival for up to 3 months has been described at 0-3ºC.

Diagram 1 Life-cycle of rose powdery mildew



Spores can also be spread on the hands and clothing of staff, and possibly by some insects. Under humid conditions, the spores germinate quickly (2-6 hours) and infect leaves or other plant parts, growing both over the surface and within epidermal cells, where they extract nutrients. Rose leaves are most susceptible in the 3 days following unfurling.

Under optimum conditions the disease cycle is completed in 3-7 days and fresh dispersal spores are produced. The spores are produced successively and remain attached to each other in chains, giving colonies their characteristic powdery appearance. Individual spores or clumps of spores are broken off by air currents and carried to new infection sites. Several cycles of infection and spore production are required for an epidemic to develop.

The rose powdery mildew fungus survives between seasons as dormant infections, sometimes visible on stems and thorns. It has also been found on rudimentary leaves of buds and on inner bud scales. Dormant infections become active and start producing spores as temperatures rise in the spring. The spores are dispersed in the wind and initiate infections on the new season's growth. In glasshouse crops, fungal growth may slowly progress throughout the winter and infection cycles continue, albeit at a much slower pace.

Conditions favouring disease development

Generally, powdery mildew infection is favoured by high humidity but not free water, followed by a drier period for subsequent development. Warm dry days followed by cool humid nights, as often found in early summer are ideal. A weather-forecasting model that identifies periods when environmental conditions favour rose powdery mildew is in development (HDC funded project HNS 165).

Various studies on powdery mildews have shown a dependence on temperature and humidity. Optimal conditions for spore germination are temperatures around 22ºC and a relative humidity near 100%. Germination at lower humidities down to 50% is possible, but much less common. In marked contrast to downy mildews, the development of powdery mildews is adversely affected by the presence of films of water on the leaf surface; water

3 *Delphinium* powdery mildew affecting the stem

4 Rose powdery mildew can severely disfigure flower buds

5 Rose powdery mildew can severely disfigure flowers

6 *Phlox* powdery mildew usually shows as distinct white spots

droplets reduce the number of spores which grow to a sporulating colony.

Once a spore has infected a leaf, subsequent development is favoured by drier conditions. This partly explains why the disease is usually more troublesome when the weather is warm and settled, with the high humidity requirement for spore germination being satisfied during cool, damp nights.

Control strategy

Successful control of powdery mildew diseases needs an integrated strategy involving a combination of varietal selection, good cultural management and selective fungicide use. For crops that are field-grown and then potted, observations in roses indicate a clear link between severe disease in the field and poor establishment after potting, often referred to as spring die-back. Maintaining good control of powdery mildew, and other foliar diseases, for as long as possible before lifting, will help to maintain plant vigour and reduce establishment failure during containerisation.

Varietal resistance

Much of the information about varietal resistance is anecdotal and, in some crop species, is complicated by the existence of different races of the fungi. The geographic distribution of different races and their impact on varietal resistance is not well understood. It is possible that a variety highly resistance in one locality could prove susceptible in another. Claims made about the specific resistance of different varieties therefore need treating with some caution.

Healthy mother stock

Careful selection of mother stock from which cuttings are taken or where roots are divided is important. Plants should be carefully examined to ensure freedom from visible powdery mildew. Circumstantial evidence suggests that in some species, powdery mildew may occur as a latent infection in visibly healthy cuttings. A programme of preventative fungicide sprays will minimise the risk of powdery mildew on stock plants.

Crop management

Minimising the occurrence of very high humidity around plants will have a significant effect in helping to prevent powdery mildew. The following measures will help to achieve this:

- Undertake overhead watering early in the day or at other times when plant surfaces are more likely to dry quickly.
- Encourage good air circulation around plants by spacing them as generously as the economics of production will permit.
- Where production is under protection, ensure adequate ventilation including, if necessary, the use of fans. (Although increased air movement will disseminate spores, there is likely to be an overall benefit in disease control if the air circulation is good enough to keep humid air from accumulating around plant surfaces).
- For the more mildew susceptible species and varieties, avoid heavily-shaded sites.
- Ensure plants do not suffer drought or root damage, as this is believed to make them more susceptible to powdery mildew.

7 Production of spores in chains results in colonies developing a powdery appearance

8 Rose powdery mildew can overwinter as white fungal growth, especially around the thorns

Nursery hygiene

Pruning infected shoots or cutting back herbaceous plants at the end of the season and destroying infected plant material will help prevent overwintering of powdery mildews. Raking and destroying fallen leaves from around plants may also inhibit overwintering.

Where practical, and especially for high value glasshouse crops, wash hands and use a coverall after having worked in crops of the same or a related species affected by powdery mildew.

Fungicides and fungicide programmes

Foliar sprays of fungicides remain the cornerstone of powdery mildew control for most growers. A wide range of fungicides is available (Table 3). Note however that some products are now permitted only on forest nurseries. Information on various attributes of some commonly used fungicides is listed in Table 4.

There are many programmes that could be devised based on these products. Example programmes that are likely to provide good control based on how individual products performed in recent trials, are suggested (Table 5). Initiating fungicide sprays at the first sign of disease is possible only if crops are actively checked for the advent of powdery mildew.

For effective control it is important that:

- Programmes commence before or immediately after the disease is present.
- Products from at least two different 'fungicide groups' (see Table 4) are used, where both products are active against powdery mildew.
- Products from different fungicide groups are used alternately, or in mixtures (where allowed).
- The spray interval is reduced (for example from 14 days to 7 days or less) when conditions favour powdery mildew.
- Spray application achieves good coverage of leaves throughout the crop canopy (for example

9 Clean production beds will minimise the spread of a range of diseases including powdery mildew

adjust nozzle type, arrangement, spray pressure and water volume, as necessary).

- Fungicides are used in combination with other control strategies where available.
- Newly unfurled leaves and rapid extension growth are protected as these are the most susceptible to infection; rapid production of new shoots necessitates repeated application.

When devising a powdery mildew spray programme, other factors to consider include: any other diseases to which the crop is susceptible and that require fungicide treatment, previous experience with product efficacy and crop safety on the species to be treated; timing of the first spray in relation to crop growth stage or first appearance of powdery mildew and the effect of weather and other factors on spray interval.

Crop safety

Many of the fungicides listed in Table 3 with potential for control of powdery mildew do not have specific label recommendations for use on individual nursery stock or perennial herbaceous species. Use under a Specific Off-Label Approval (SOLA) is at growers' own risk. Before use, a copy of the SOLA notice of approval must be obtained and any conditions complied with. It is strongly recommended that, when used for the first time on a new crop or variety, a fungicide is first tested on a small number of plants to ensure there is no phytotoxicity risk. Grower experience suggests spray damage is most likely to occur:

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

Some fungicides recently used in experimental work on the control of powdery mildews that have caused crop damage include:

- Nativo 75WG (tebuconazole + pyraclostrobin) – caused stunted growth of field-grown *Crataegus* seedlings and slightly reduced stem length of container-grown *Phlox* plants. No adverse effect was observed when applied to *Quercus* seedlings in late summer or to container grown woody *Crataegus*.
- Torch Extra (spiroxamine) – caused leaf scorch on *Crataegus* and honeysuckle, but did not damage *Acer*.
- Sulphur sprays – observations from elsewhere suggest they may cause leaf yellowing and reddening on some crops. Sulphur sprays did not cause damage to *Crataegus* or *Quercus* seedlings or container-grown *Aquilegia* or *Phlox* plants, although they did leave an obvious pale brown spray deposit.

Fungicide resistance

The development of fungicide resistance is a real risk in powdery mildew species, especially when fungicides are used intensively. Fungicide resistance has resulted in loss of control or reduced control in related powdery mildew fungi affecting wheat and barley (*Blumeria graminis*) and cucumber (*Podosphaera*

macularis), for example. The DMI (for example Systhane 20EW) and QoI (for example Amistar) groups appear to be most at 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 fungicides of the same fungicide or fungicide group are used in sequence, then a completely different fungicide group is used.
- For QoI fungicides, no more than 50% of the total sprays of this type of fungicide are used per crop.
- Broad mode-of-action fungicides with powdery mildew activity (for example Thiovit Jet) are incorporated into the programme; and that single mode-of-action fungicides are not solely relied on.
- Label recommendations are followed carefully and the manufacturer's recommended dose rate is used.
- Fungicides alone are not relied on for disease control and the cultural control measures detailed in this factsheet are also followed.

For further advice on strategies to minimise the risk of selecting resistant strains, see the FRAG-UK Technical leaflet: Fungicide Resistance, which can be downloaded from: www.pesticides.gov.uk.

Further information

Reports on HDC funded projects on the control of powdery mildew on cut flowers (BOF 44), hardy nursery stock (HNS 156) and rose (HNS 165) are available from the HDC by either phoning 0247 669 2051 or visiting www.hdc.ahdb.org.uk.

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Additional information

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Specific fungicide information for powdery mildew control

Table 3: Some fungicides and biofungicides permitted for use on ornamental crops (January 2011) with reported activity against powdery mildew diseases

Product	Active ingredient(s) and fungicide group	Crop group on which approved	Situation		SOLA/Label
			Outdoor	Protected	
Amistar	Azoxystrobin	Forest nursery Ornamentals	✓ ✓	✓ ✓	0443/09 0443/09
Bumper	Propiconazole	Ornamentals	✓	✓	0707/09
Cyflamid	Cyflufenamid	Forest nursery Ornamentals	✓ ✓	- -	2915/08 0512/07
Fandango	Fluoxastrobin + prothioconazole	Forest nursery	✓	-	0226/09
Flexity	Metrafenone	Ornamental plant production	✓	-	2850/08
Fortress	Quinoxyfen	Ornamental plant production Forest nursery	✓ ✓	✓ ✓	2852/08 2852/08
Frupica SC	Mepanipyrim	Forest nursery	✓	✓	2853/08
Juliet	Chlorothalonil	Ornamentals	✓	✓	Label[a]
Nativo 75WG	Tebuconazole + trifloxystrobin	Ornamentals	✓	-	LTAEU[b]
Nimrod	Bupirimate	Rose	✓	✓	Label
Potassium bicarbonate	Potassium bicarbonate	Non-edible crops	✓	✓	Commodity substance
Scotts Octave	Prochloraz Mn	Ornamentals	✓	✓	Label
Serenade ASO	*Bacillus subtilis*	Ornamental plant production	✓	✓	0246/09
Signum	Boscalid + pyraclostrobin	Ornamental plant production	✓	✓	1842/09
Stroby WG	Kresoxim-methyl	Rose	✓	✓	Label
Swift SC	Trifloxystrobin	Ornamental plant production	✓	-	2882/08
Switch	Fludioxonil + cyprodinil	Forest nursery Ornamentals	✓ ✓	✓ ✓	Label Label
Systhane 20EW	Myclobutanil	Ornamentals	✓	✓	Label
Talius	Proquinazid	Forest nursery	✓	-	0420/09
Thiovit Jet	Sulphur	Ornamentals	✓	✓	LTAEU[b]

a Not permitted after 31 August 2011. b Long-Term Arrangements of Extension of Use. Use of a product under a SOLA or the LTAEU is at growers` own risk.

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Table 4: Reported chemical and physical attributes and resistance risk of some fungicides and biofungicides with reported activity against powdery mildew diseases

Product	Fungicide group	FRAC code	Chemical attributes	Physical attributes	Resistance risk
Amistar	Strobilurin	11	S+T	P+C+E	High
Bumper	DMI	3	S	P+C	Medium
Cyflamid	Phenyl acetamide	U6	S(poor) T+V	P+C	Medium
Fandango	Strobilurin + DMI	11+3	S/S	P+C/P+C+E	High/Medium
Flexity	Benzophenone	U8	S	P+C	Resistance not known
Fortress	Quinoline	13	S+V	P	Medium
Frupica SC	Anilinopyrimidine	9	NS	P	Medium
Juliet	Chloronitrile	M5	NS	P	Low
Nativo 75WG	DMI + strobilurin	3+11	S/T+V	P+C+E/P+C	Medium/High
Nimrod	Hydroxypyrimidine	8	S+T+V	P+C	Medium
Potassium bicarbonate	Not classified	NC	NS	E	Low
Scotts Octave	DMI	3	S	P+E	High
Serenade ASO	Not classified	NC	-	P	Low
Signum	Carboxamide + strobilurin	7+11	S+T/T	P+C/P+C	Medium/High
Stroby WG	Strobilurin	11	S+V	P+C+E	High
Swift SC	Strobilurin	11	T+V	P+C	High
Switch	Phenylpyrrole + anilinopyrimidine	12+9	NS/NS	P/P	Low to medium/ Medium
Systhane 20EW	DMI	3	S	P+C	High
Talius	Quinazolinone	U7	S+T+V	P+C	Medium
Thiovit Jet	Sulphur	M2	NS	P	Low

Information from The Pesticide Manual (Tomlin, 2006), manufacturer's literature and the Fungicide Resistance Action Committee (FRAC) (www.frac/info). FRAC codes are used to distinguish between fungicide groups with different modes of action. For products containing two active ingredients, the reported activity and resistance risk of each active ingredient is given. The overall resistance risk of the products above containing two active ingredients is likely to be lower than that of the individual active ingredients.

Chemical attributes:	S	Systemic (moves within the plant)
	NS	Not systemic
	T	Translaminar (moves through the leaf from one surface to the other)
	V	Vapour activity (fungicide has effect on tissue separate from that to which it is applied, for example from one plant to a close neighbour)
Physical attributes:	P	Protectant (stops spore germination and/or infection)
	C	Curative (stops symptom development following infection before typical symptoms develop)
	E	Eradicant (dries up fungal growth)

Table 5: Some example spray programmes for powdery mildew

Spray number	Programme 1: Field crop of forest nursery	Programme 2: Protected crop of ornamentals	Programme 3: Field crop of ornamentals
1.	Thiovit Jet+wetter	Thiovit Jet+wetter	Systhane 20EW*
2.	Cyflamid	Signum	Signum
3.	Thiovit Jet+wetter	Thiovit Jet+wetter	Cyflamid
4.	Talius	Systhane 20EW	Flexity
5.	Switch	Switch	Systhane 20EW*
6.	Cyflamid	Signum	Signum
7.	Switch	Switch	Cyflamid
8.	Talius	Systhane 20EW	Flexity

*In recent trials (HNS 156), efficacy against powdery mildew on *Crataegus* was improved by addition of potassium bicarbonate.