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The results and conclusions in this report are based on a series of experiments conducted over a one-year period. The conditions under which the experiments were carried out, and the results, have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

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AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

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GROWER SUMMARY

1. Headline

Fungicide programmes, at reduced risk of failure from selection of resistant strains, were devised that gave very good control of powdery mildew on oak and significant control of powdery mildew on hawthorn and did not cause crop damage.

2. Background and expected deliverables

Powdery mildew diseases commonly affect both woody and herbaceous perennial ornamentals causing yellow, crinkled and distorted leaves, premature senescence and reduced vigour. Young, soft shoots are particularly affected. Even with slight infections, the white fungal growth on leaves, stems and flowers, and associated leaf yellowing and distortion, make plants unsightly and unsaleable. Some crop species are affected virtually every year (e.g. hawthorn, oak, honeysuckle, rose), while a wide range of other species are affected less often.

Powdery mildew diseases are usually managed by regular treatment with fungicides and weekly sprays may be necessary to prevent infection. Cultural practices provide partial control, but fungicides are almost invariably necessary for the production of high-quality, saleable plants.

Numerous fungicides have label recommendations for control of powdery mildew diseases and several new ones have recently become available. Often these are first registered for use on cereals but gain wider crop application with time. Until recently any product approved on any outdoor crop could be used on any outdoor ornamental crop, and any product approved on a protected crop could be used on any protected ornamental crop, at growers' own risk, under the Long Term Arrangements for Extension of Use. These arrangements were withdrawn during 2008 and are being replaced with Specific Off-Label Approvals (SOLAs) for individual products. Some products can still be used under LTAEU pending consideration by CRD. Products covered by SOLAs are publicised by the HDC. Robust information is required on the relative efficacy and crop safety of new fungicides for control of powdery mildew diseases on Hardy Nursery Stock (HNS) subjects.

Resistance can develop when the same fungicide or products from the same fungicide group are used repeatedly. There is a relatively high risk of fungicide resistance developing in powdery mildew fungi because of their short life cycles and abundant spore production. The occurrence of fungicide resistant strains in a population of powdery mildew is likely to result in reduced disease control, or complete loss of control, if the predominant fungicide group used to control the disease is that to which some strains are resistant.

The expected deliverables from this project are:

- A summary of knowledge on the activity and attributes of fungicides used for control of powdery mildew disease;
- Information on the relative efficacy of selected novel fungicides and industry standards in controlling powdery mildew on *Acer, Crataegus* and *Lonicera;*
- Information on the crop safety of selected fungicides to *Acer, Crataegus* and *Lonicera;*
- A sustainable fungicide programme for control of powdery mildew diseases on one or more hardy nursery stock species;
- A Factsheet on control of powdery mildew diseases on hardy nursery stock.

3. Summary of the project and main conclusions

Review of fungicides for powdery mildew control

Information on the attributes of fungicides with activity against powdery mildew diseases is summarised in a series of tables in the Year 1 report. This includes information on fungicide group (for resistance management), reported chemical and physical modes of action, efficacy of individual products against powdery mildew diseases as determined in UK and overseas trials (1999-2005), and the risk of fungi developing resistance to fungicides in different chemical mode of action groups. Some of this information is presented in Tables 1 and 2 below for powdery mildew fungicides currently (January 2010) available for use on ornamental crops.

Table 1: Some fungicides and other products permitted for use on ornamental crops (January 2010) with reported activity against powdery mildew diseases

Product	Active ingredient(s)	Crop group on which approved	Situation		SOLA/ Label
			Outdoor	Protected	
Amistar	Azoxystrobin	Ornamentals	✓	✓	0443/09
		Forest nursery	✓	✓	0443/09
Cyflamid	Cyflufenamid	Forest nursery	✓	-	2915/08
		Ornamentals	✓	-	0512/07
Fandango	fluoxastrobin + prothioconazole	Forest nursery	✓	-	0226/09
Flexity	Metrafenone	Ornamental plant production	✓	-	2850/08
Fortress	Quinoxyfen	Ornamental plant production	✓	✓	2852/08
Frupica SC	Mepanipyrim	Forest nursery	✓	✓	2853/08
Juliet	Chlorothalonil	Ornamentals	✓	✓	Label
Nativo 75WG	tebuconazole + trifloxystrobin	Ornamentals	✓	-	LTAEU*
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	Ornamentals	✓	✓	1842/09
Stroby WG	kresoxim-methyl	Rose	✓	✓	Label
Swift SC	Trifloxystrobin	Outdoor ornamental	✓	-	2882/08
Switch	fludioxonil + cyprodinil	Forestry	✓	✓	Label
		Ornamentals	✓	✓	Label
Systhane 20EW	Myclobutanil	Ornamentals	✓	✓	Label
Talius	Proquinazid	Forest nursery	✓	-	0420/09
Thiovit Jet	Sulphur	Ornamentals	✓	✓	LTAEU*

For the most up-to-date information on products available for use on ornamental crops, consult the LIAISON or CRD pesticide database or your crop consultant.

*While SOLA applications are being considered.

Table 2: Reported chemical and physical attributes and resistance risk of some fungicides and other products with reported activity against powdery mildew diseases

Product	Fungicide group and code(s)	FRAC	Chemical attributes	Physical attributes	Resistance risk
Amistar	Strobilurin	11	S+T	P+C+E	High
Bravo 500	Chloronitrile	M5	NS	P	Low
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
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	P+C	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; NS = not systemic; T – translaminar; V – vapour activity

Physical attributes: P – protectant; C – curative; E – eradicant

Efficacy of fungicide products – 2007

Eleven fungicides were evaluated for control of powdery mildew on container-grown *Acer*, *Crataegus* and *Lonicera* in a polythene tunnel. Fungicides were applied every 2-3 weeks from 15 June to 27 September 2007. A low level of powdery mildew on *Crataegus* (7% leaf area affected) was significantly reduced by Flexity (metrafenone), Nativo 75WG (tebuconazole + trifloxystrobin), Stroby WG (kresoxim-methyl), Systhane 20EW (myclobutanil), Thiovit Jet (sulphur) + wetter and Torch Extra (spiroxamine). No powdery mildew developed on the *Acer* or *Lonicera*. Torch Extra caused a leaf scorch on *Crataegus* and *Lonicera*; Thiovit Jet + wetter left an obvious spray deposit on all three crops.

Evaluation of fungicide products - 2008

Eleven fungicide products comprising Bravo 500 (chlorothalonil), Cyflamid (cyflufenamid), Flexity, Fortress (quinoxyfen), Nativo 75WG, potassium bicarbonate + wetter, Stroby WG, Switch (fludioxonil + cyprodinil), Systhane 20EW, and two experimental products (UK384b and UK386a) were evaluated for control of powdery mildew on container-grown *Acer, Crataegus* and *Lonicera* in a polythene tunnel and in a glasshouse between April and September 2008. No powdery mildew occurred naturally on any of the three species in either the tunnel or the glasshouse. Infector plants of *Crataegus* and *Lonicera* bearing spores of powdery mildew placed in the crop and direct inoculation of leaves by dry and wet spore inoculation using affected leaves of *Acer, Crataegus* and *Lonicera* failed to cause powdery mildew. No conclusions can therefore be drawn on the efficacy of these fungicides against powdery mildew. None of the products caused leaf scorch, stunted growth or otherwise visibly affected crop growth.

Evaluation of simple fungicide programmes - 2008

Eight simple programmes consisting of alternating sprays of a fungicide with Bravo 500 were compared for control of powdery mildew on field-grown *Crataegus* seedlings. A total of eight sprays were applied at 14-day intervals from 20 May (2-4 true leaf stage) to 29 August (seedlings around 35-40 cm height). Sprays were applied at 1,000 L/ha. Powdery mildew was first observed on 19 June, on untreated plants only, and six weeks later affected over 90% leaf area of these plants. After five sprays, all programmes except Systhane 20EW alternating with Bravo 500 had significantly reduced the disease compared with the untreated control at this time. Alternating programmes of Signum (2%), Nativo 75WG (2%), Talius (10%), Switch (12%), Frupica SC (17%) or Stroby WG (17% leaf area affected), with Bravo 500 were more effective than alternating programmes of Systhane 20EW (85%), Systhane 20EW + potassium bicarbonate (50%) or Fortress (45%) alternating with Bravo 500 (Figure 1). Efficacy of Systhane 20EW (0.3 ml/L) was improved by addition of potassium bicarbonate (20 g/L).

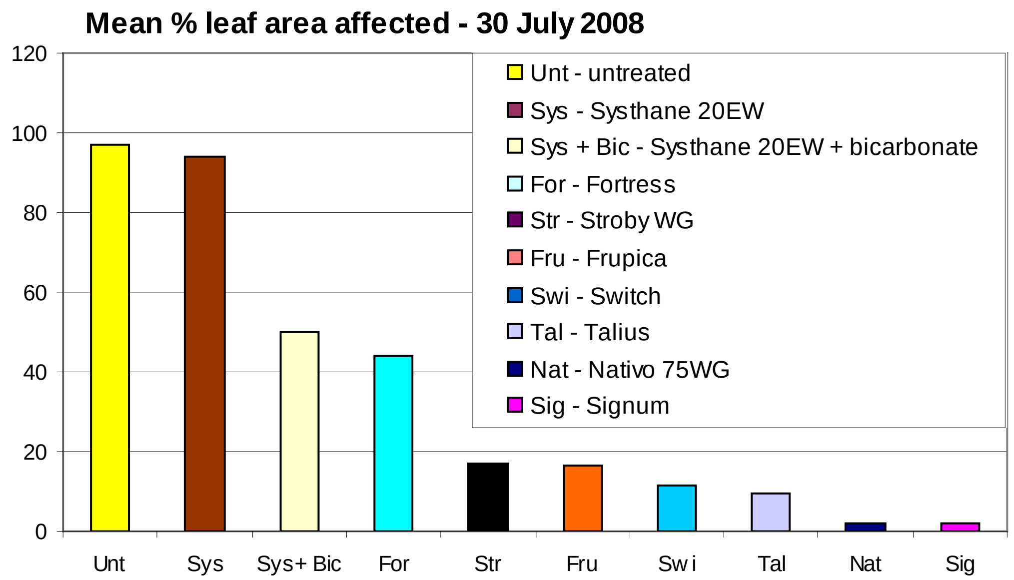

Figure. 1: Effect of fungicide programmes on field-grown *Crataegus* – 2008. Nativo 75WG resulted in stunted crop growth. All fungicides were applied in alternation with Bravo 500 at 14 day intervals.

At the final assessment on 5 September all programmes had over 50% leaf area affected by powdery mildew except for Signum alternating with Bravo 500 (24%), Nativo 75WG alternating with Bravo 500 (42%) and Switch alternating with Bravo 500 (49%).

In September, mean height of plants treated with Nativo 75WG alternating with Bravo 500 (26 cm) was significantly lower than that of untreated plants (38 cm). Stunted growth was evident just two weeks after the first spray of Nativo 75WG had been applied. Previous work has shown that tebuconazole, a component of Nativo 75WG, can have a growth regulatory effect of plants. None of the other treatments reduced plant growth. Treatment with Switch alternating with Bravo 500 resulted in the greatest plant height (44 cm), significantly greater than that of untreated plants.

The relatively poor control achieved with Systhane 20EW was unexpected. This product gave excellent control of *Crataegus* powdery mildew when used every 2 weeks at the same rate at another site in 2007, although the disease pressure was much less. Possibly a greater degree of control would have been achieved in 2008 if used at a higher rate or if sprays of this product had been applied every 14 days rather than every 28.

The addition of potassium bicarbonate to Systhane 20EW resulted in a significant increase in treatment efficacy. The potassium bicarbonate probably eradicated any powdery mildew present at the time of the spray application, resulting in more prolonged control from the protectant and curative activity of Systhane 20EW.

Evaluation of fungicide programmes - 2009

Nine fungicide programmes were evaluated for control of powdery mildew on field-grown *Cratageus* and *Quercus* seedlings. The programmes comprised alternating sprays of two or four fungicides and were designed to reduce the risk of selecting resistant strains of powdery mildew. Sprays were applied at 14 day intervals from 23 May to 27 August 2009. A wetter was used with Thiovit Jet and potassium bicarbonate; Systhane 20EW was applied in mixture with potassium bicarbonate. Sprays were applied at 250 L/ha

On *Crataegus*, powdery mildew was first observed on 4 June and four weeks later affected 75% leaf area on untreated plants. All programmes significantly reduced the disease, though none gave effective season-long control. The most effective programmes after three sprays, which had less than 15% leaf area affected, were:

- Talius, Signum, Cyflamid;
- Thiovit Jet, Systhane 20EW, Thiovit Jet
- Thiovit Jet, Signum, Thiovit Jet

Thiovit Jet applied in alternation with Signum appeared to provide better mildew control than Bravo 500 applied alternately with Signum. At the end of the experiment, two weeks after the final spray, the most effective programme (potassium bicarbonate, Talius, Signum, Cyflamid, Flexity, Talius, Signum) had reduced disease severity from 90% to 49% leaf area affected and increased the proportion of stems more than 40 cm in height from 18 to 45%. None of the programmes caused crop damage.

The greater level of powdery mildew control achieved on *Crataegus* in 2008 than in 2009 was likely due in part to the greater spray volume used (1,000 L/ha compared with 250 L/ha); possibly also the season was less favourable to powdery mildew in 2008 than in the dry summer of 2009. A shorter spray interval (7-10 days) is likely needed to achieve more effective control, especially at the lower spray volume, in a season when disease pressure is high.

On *Quercus*, powdery mildew was first observed on 1 July and increased steadily to affect 11% leaf area of untreated plants by 27 July. At 2 weeks after the final spray, all of the fungicide programmes had significantly reduced the disease from 85% leaf area affected to <9%. The most effective treatment was Thiovit Jet alternating with Signum (0.4% leaf area affected).

Six of the programmes used on *Quercus* were identical to ones used on *Cratageus*; all of them gave much better control on *Quercus* than *Crataegus*. This may have been due to a greater susceptibility of *Quercus* powdery mildew (*Erysiphe alphitoides*) than *Crataegus* powdery mildew (*Podosphaera clandestine*) to the fungicides used, the later appearance of mildew on *Quercus* (which meant 3 protective sprays had been applied compared with 1 on the *Crataegus*), or other factors. None of the programmes caused crop damage. The results of programmes tested on *Crataegus* and *Quercus* in 2009 are summarised in Table 3.

Evaluation of persistence of control from a single spray – 2009

Eight fungicides and a biofungicide (Serenade ASO) were compared for persistence of control following a single spray applied to *Crataegus* seedlings with obvious powdery mildew (25% leaf area affected). Signum and Thiovit Jet + wetter were the two best treatments at three weeks after spray application. Flexity, Systhane 20EW plus bicarbonate and Talius also gave significant control at this time. Cyflamid gave some control for two weeks but not three. Although Bravo 500 and Serenade ASO gave no control in this experiment; they may have preventative activity that would not be shown in this experiment design.

Table 3: Effect of various fungicide programmes on powdery mildew of *Cratageus* and *Quercus* – 11 September 2009

Programme brief name[a]	Spray number (every 14 days)[b]								% leaf area affected[c]	
	1	2	3	4	5	6	7	8	*Crataegus*	*Quercus*
1. Untreated	-	-	-	-	-	-	-	-	90	85
2. Systhane 20EW (Sys)	Thi	Sys	Thi	Sys	Thi	Sys	Thi	Sys	75	4
3. Cyflamid (Cyf)	Thi	Cyf	Thi	Cyf	Thi	Cyf	Thi	Cyf	81	5
4. Fandango (Fan)	Thi	Fan	Thi	Fan	Thi	Fan	Thi	Fan	-	1
5. Flexity (Flx)	Thi	Flx	Thi	Flx	Thi	Flx	Thi	Flx	71	-
6. Signum (Sig)	Thi	Sig	Thi	Sig	Thi	Sig	Thi	Sig	56	<1
7. Swift SC (Swf)	Thi	Swf	Thi	Swf	Thi	Swf	Thi	Swf	-	1
8. Bravo 500/Signum	Bra	Sig	Bra	Sig	Bra	Sig	Bra	Sig	71	-
9. Outdoor crops	Thi	Sig	Thi	Tal	Swi	Sig	Swi	Tal	59	-
10. Outdoor crops	Thi	Sig	Thi	Nat	Swi	Sig	Swi	Nat	-	2
11. Protected crops	Thi	Sig	Thi	Sys	Swi	Sig	Swi	Sys	68	3
12. High disease pressure	Tal	Sig	Cyf	Flx	Tal	Sig	Cyf	Flx	63	3
13. Response to symptoms	-	KHC	Tal	Sig	Cyf	Flx	Tal	Sig	49	-
14. Response to symptoms	-	-	-	KHC	Tal	Sig	Cyf	Flx	-	9

[a] T2-T8 comprised alternation of two fungicides to allow product comparison. In commercial crops, do not use more than two sprays of Cyflamid, Fandango, Flexity, Signum or Swift (see Table 1.1 in Science Section).

T9-T14 comprised alternation of four products and were designed for use on outdoor crops, protected crops, high disease pressure, and a response to first symptoms of mildew, as indicated. These programmes comply with the maximum permitted spray number.

[b] Bra – Bravo 500; Tal – Talius; Nat – Nativo 75WG; Swi – Switch; KHC – potassium bicarbonate.

Silwett-L77 was used as a wetter with Thiovit Jet; Activator 90 was used as a wetter with potassium bicarbonate.; Systhane 20EW was used in mixture with potassium bicarbonate.

[c] Assessed two weeks after the final spray.

Example programmes with reduced resistance risk

A fungicide programme for sustainable control of powdery mildew should:

- provide effective disease control under moderate to severe disease pressure;
- have reduced risk of selecting resistant strains of powdery mildew;
- not use fungicides unnecessarily;
- not exceed maximum permitted spray number on a crop;
- be a relatively simple programme that does not require a grower to use a large number of different fungicides;
- not cause crop damage;
- not leave an obvious spray deposit when the crop is due to be marketed;
- where specified, be appropriate for use on protected crops.

Based on the results obtained in this project and on previous work, three example eight-spray programmes that currently comply with the above requirements are shown below. It is suggested that spray interval is 14 days initially, reducing to 7 days as soon as mildew occurs.

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

*consider adding potassium bicarbonate

In a commercial situation, a grower devising a spray programme will also need to consider other factors including: 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.

4. Financial benefits

Powdery mildew diseases affect many woody and herbaceous perennials, causing unsightly and poor growth which results in downgrading or rejection of plants. Routine fungicide treatment of susceptible species is therefore necessary for the production of high-quality saleable plants. The potential financial benefit to the industry from improved control of powdery mildew diseases through identification of the most effective and sustainable fungicide treatments is significant. A field-crop of a susceptible species, such as *Crataegus* grown from seed, may require treatment every 10-14 days throughout the growing season. Although the cost of fungicides for a programme involving different products may be several thousand pounds, it is likely to represent 1% or less of the of the crop value at the end of the season.

5. Action points for growers

<u>Fungicides active against powdery mildew</u>

1. For outdoor crops of *Crataegus,* use two or more of the following products within a powdery mildew spray programme to ensure a range of active ingredients are used: Cyflamid, Flexity, Frupica SC, Signum, Stroby WG, Systhane 20EW + potassium bicarbonate, Switch or Talius.
2. For outdoor crops of *Quercus,* use two or more of the following products within a powdery mildew spray programme to ensure a range of active ingredients are used: Cyflamid, Fandango, Flexity, Signum, Switch, Swift, Systhane 20EW + potassium bicarbonate or Talius.
3. Potassium bicarbonate (20 g/L) added to Systhane 20EW (0.3 mL/L) can improve control of powdery mildew on *Crataegus* seedlings.
4. On *Crataegus* seedlings with established powdery mildew, it is likely that a single spray of Flexity, Signum, Systhane 20EW + potassium bicarbonate, Talius or Thiovit Jet + Silwett-L77 will give more persistent control than a single spray of Cyflamid or Switch. Bravo 500 and Serenade ASO are unlikely to give any control when mildew is well established.

<u>Avoiding fungicide resistance</u>

5. Use products that contain active ingredients from different fungicide groups to alternate with each other (see Table 2) or with a multi-site inhibitor fungicide such as Thiovit Jet or Bravo 500, in order to reduce resistance risk and preserve fungicide efficacy. Thiovit Jet + Silwett-L77 appeared to give better control than Bravo 500 when used in alternating programmes with Signum.

6. Fandango, Nativo 75WG and Signum each contain two active ingredients from different fungicide groups, both active against powdery mildew. These products are less at risk of selecting resistant strains of powdery mildew than products containing a single site-specific fungicide.

Crop damage

7. Some products with good activity against powdery mildew may cause crop damage. Nativo 75WG (tebuconazole + trifloxystrobin) stunted growth of field-grown *Crataegus* seedlings; Torch Extra (spiroxamine) caused scorch on *Acer* and *Lonicera.* Nativo 75WG did not cause stunting of *Quercus* seedlings when two sprays were applied near the end of a season
8. Thiovit Jet leaves an obvious spray deposit and other fungicides should be considered for treatment close to the point of marketing where appearance is important. This fungicide can also be harmful to some insects used for biological pest control.
9. If you have not used a fungicide on a crop previously, always treat a small area first to check for crop safety.

Spray interval

10. Application of fungicides at 14 day intervals and at 250 L/ha may be insufficient to provide good season-long control on a highly susceptible species such as *Crataegus*. Use a shorter spray interval in this situation; consider using a greater water volume.

Fungicide programmes

11. See the Grower Section for some example fungicide programmes for use in different situations.

SCIENCE SECTION

Introduction

A wide range of fungicides are reported to have activity against powdery mildew diseases. Halstead & Scrace (2000) listed 14 active ingredients for control of powdery mildew on outdoor ornamentals and noted that few of them had label recommendations for use on hardy nursery stock (HNS). The European Plant Protection Organisation (EPPO) guidelines of Good Plant Protection Practice for apple and pear lists 16 main fungicide active ingredients for control of powdery mildew (*Podosphaera leucotricha*) (Anon, 1991). These reports illustrate the wide range of fungicides available for use against powdery mildews. Several new active ingredients and products containing mixtures of active ingredients, effective against powdery mildew diseases, have become available since 2000 and warrant testing on HNS species.

Recent work on control of powdery mildew diseases on outdoor and protected cut flowers demonstrated good activity using Systhane 20EW (myclobutanil), Stroby WG (kresoxim-methyl), Frupica (mepanipyrim) and Thiovit Jet (sulphur) + Agral (O'Neill, 2003). Eight other fungicides tested were either less effective or not suitable for use on cut flowers.

Following recent work evaluating fungicides for crop-safety and control of foliar diseases of rose (Ann *et al.,* 2003), 18 products that provide some control of rose powdery mildew were listed. On rhododendron, three fungicides, Epic (epoxiconazole), Tern (fenpropidin) and Topas (penconazole), were reported to give substantial control of rhododendron powdery mildew (*Erysiphe* sp.) (Kenyon & Dixon, 1995).

The overall aim of this project is to devise crop-safe and effective fungicide programmes that provide sustainable control of powdery mildew on three commonly affected hardy nursery stock species.

In Year 1 we:

1. Reviewed and summarised knowledge on the activity and attributes of fungicides used for control of powdery mildew diseases;
2. Determined the effectiveness of selected novel fungicides, compared with two industry standards, in controlling powdery mildew on *Crataegus*;
3. Determined the crop-safety of selected novel fungicides to *Acer campestre, Crataegus* and *Lonicera.*

In Year 2 we:

1. Further tested selected novel fungicides for control of powdery mildew and crop-safety on container-grown *Acer, Crataegus* and *Lonicera;*
2. Devised and tested some simple (two product) fungicide programmes for control of powdery mildew on field-grown *Crataegus* seedlings;
3. Determined the crop-safety of these programmes to *Crataegus* seedlings.

Specific objective in Year 3 are:

1. Devise and test the effectiveness of fungicides programmes for season-long control of powdery mildew on two crop species;
2. Determine the effect of these programmes on crop growth and marketability;
3. Examine the persistence of control of powdery mildew from a single spray.

1. Efficacy of fungicide programmes

Introduction

Many powdery mildew fungicides are of a type known as single-site inhibitors. There is a moderate or high risk, depending on the specific fungicide, that repeated intensive use of a single-site inhibitor fungicide will result in the selection of powdery mildew strains resistant to it. Multi-site inhibitor fungicides are much less at risk of selecting resistant strains. It is generally recommended to alternate application of fungicides containing active ingredients in different fungicide groups to reduce the risk of resistance development. The objective of this experiment was to devise and test some fungicide programmes that are both effective and have reduced risk of resistance development. These comprised simple programmes involving alternation of a single-site inhibitor with a common multi-site inhibitor (to allow product comparison); programmes using products approved for use on outdoor crops and protected crops; a programme for use at high disease pressure; and a programme initiated in response to first symptoms. Programmes were tested on *Crataegus* powdery mildew (*Podosphaera clandestina;* anamorph: *Oidium cydoniae*) and *Quercus* powdery mildew (*Erysiphe alphitoides*; anamorph *Oidium quercinum*) (Braun, 1995; Takamasu *et al*., 2007). Further information on occurrence of powdery mildew species affecting *Crataegus* and *Quercus* is given in Appendix 1.

Materials and methods

<u>Crop and site details</u>

Two experiments were done on a farm in Warwickshire, one on *Crataegus* seedlings and one on *Quercus* seedlings. Seed of *C. monogyna* (British provenance 405) was sown on 2 April 2009 and *Quercus robur* (British provenance 201) on 20 March 2009 in 5-row beds at 25 cm spacing. Seedlings were irrigated by overhead irrigators as required. Crop diaries are given in Appendix 2.

<u>Treatments</u>

Details of the fungicides used in programmes are shown in Table 1.1. Treatments were applied under an Administrative Experimental Approval where there was no label or SOLA for the chosen use. Nine fungicide programmes were devised and tested on each species (Tables 1.2 and 1.3). Thiovit Jet (sulphur) was used in most treatments. The products selected for evaluation were ones that gave good control in previous experiments in this project, or are reported to have given good control of powdery mildew elsewhere. They were also chosen to represent a range of different fungicide groups.

Fungicides were applied at 14-day intervals from May (two true-leaf stage) to September, starting with the single-site inhibitor. Sprays were applied at 250 L/ha using a knapsack sprayer at 2 bar pressure with an 02 F110 nozzle.

Experimental design and statistical analysis

The experiments were of a randomised block design with four replicates. Plots were 4 m long x 1.25 m (1 bed) wide. The central 2 m length of each plot was used for assessments. Results were examined by analysis of variance; least significant differences (Lsd) at p=0.05 were calculated.

Assessments

Plants were examined for powdery mildew every 2 weeks to determine first occurrence. At two weeks after the fourth and eighth sprays, the percentage leaf area affected by powdery mildew was estimated on 10 adjacent plants in a central row of each plot or by estimating the area affected at three points in a plot and taking the mean. At the final assessment, plant height was recorded on 10 adjacent plants in each plot (5 in *Quercus*).

Table 1.1: Details of fungicides and adjuvants used on *Crataegus* and *Quercus* – 2009

Product	Active Ingredient(s)	Rate Used	Approval	Situation[a]	Max no. sprays permitted[b]
Activator 90	Non-ionic wetting agent	1.25 ml/L	-	-	NS
Bravo 500	Chlorothalonil	2.2 L/ha	Label	O, P	NS
Cyflamid	Cyflufenamid	0.5 L/ha	0512/07	O	2
			2915/08	O	2
Fandango	fluoxastrobin + prothioconazole	1.25 L/ha	0226/09	O	2
Flexity	Metrafenone	0.5 L/ha	2850/08	O	2
Nativo 75WG	tebuconazole + trifloxystrobin	0.4 kg/ha	LTAEU		2
Potassium bicarbonate	Potassium bicarbonate	20 g/L	Commodity substance	O, P	NS
Signum*	boscalid + pyraclostrobin	1.5 kg/ha	1842/09	O, P	2
Silwett L-77	silicon based wetter	0.5 ml/L	-	-	NS
Swift SC	Trifloxystrobin	0.5 L/ha	2882/08	O	2
Switch	cyprodinil +	1 kg/ha	Label	O	3
	fludioxonil	0.8 kg/ha	Label	P	3
Systhane 20EW	Myclobutanil	1.2 ml/L	Label	O, P	NS
Talius	Proquinazid	0.25 L/ha	2883/08	O	2
Thiovit Jet[c]	Sulphur	10 kg/ha	LTAEU	O	NS
		2 kg/ha		P	NS

*The new approval for Signum (1842/09) allows use at a maximum rate of 1.35 kg/ha.

[a]O - Outdoor; P – Protected

[b]NS – Not stated

[c]Thiovit Jet was used in mixture with Silwett-L77; potassium bicarbonate was used in mixture with Activator 90 for treatment 10.

Table 1.2: Detail of fungicide programmes used on *Crataegus* – 2009

Brief title	Programme
1. Control	Untreated
2. Standard	Thiovit Jet/Systhane 20EW + potassium bicarbonate
3. New product	Thiovit Jet/Cyflamid
4. New product	Thiovit Jet/Flexity
5. Comparison of	Thiovit Jet/Signum
6. Bravo & Thiovit Jet	Bravo 500/Signum
7. Outdoor crop programme	Thiovit Jet/Signum/Thiovit Jet/Talius/Switch/Signum/Switch/Talius
8. Protected crop programme	Thiovit Jet/Signum/Thiovit Jet/Systhane + bicarbonate/Switch/Signum/Switch/Systhane + bicarbonate
9. High disease pressure programme	Talius/Signum/Cyflamid/Flexity/Talius/Signum/Cyflamid/Flexity
10. Response to symptoms programme	Potassium bicarbonate at first symptoms, then programme 9.

Note that for Switch and Thiovit Jet, the rates used in Treatment 8 were lower than where they were used elsewhere, in order to comply with the maximum permitted rate for use on a protected crop (see Table 1.1).

Table 1.3: Details of fungicide programmes on *Quercus* – 2009

Brief title	Programme
1. Control	Untreated
2. Standard	Thiovit Jet/Systhane 20EW + potassium bicarbonate
3. New product	Thiovit Jet/Cyflamid
4. New product	Thiovit Jet/Fandango
5. New product	Thiovit Jet/Signum
6. New product	Thiovit Jet + Swift
7. Outdoor crop programme	Thiovit Jet/Signum/Thiovit Jet/Nativo 75WG/Switch/Signum/Switch/Nativo 75WG
8. Protected crop programme	Thiovit Jet/Signum/Thiovit Jet/Systhane + bicarbonate Switch/Signum/Switch/Systhane + bicarbonate
9. High disease pressure programme	Talius/Signum/Cyflamid/Flexity/Talius/Signum/Cyflamid/Flexity
10. First symptoms programme	Potassium bicarbonate at first symptoms then programme 9.

Note that for Switch and Thiovit Jet, the rates used in Treatment 8 were lower than where they were used elsewhere, in order to comply with the maximum permitted rate for use on a protected crop (see Table 1.1).

Results and discussion

<u>Crataegus</u>

Disease control

Powdery mildew was first observed on 4 June when it affected untreated plants only, at trace levels. The disease increased rapidly and by 1 July (2 weeks after the third spray) affected 75% leaf area. Disease levels at this time were reduced by all treatments, the most effective being the 'high disease pressure' programme, where sprays of Talius, Signum and Cyflamid had kept it to 9% leaf area affected (Table 1.4). The 'outdoor programme' of Thiovit Jet/Signum/Thiovit Jet (14% leaf area affected) and the 'standard programme' of Thiovit Jet/Systhane + bicarbonate/Thiovit Jet (13%) were almost as good.

By 11 September (2 weeks after final spray), there were high levels of powdery mildew (≥49% leaf area affected) in all spray treatments and 90% in the untreated control (Table 1.4). The disease was significantly reduced by Thiovit Jet/Flexity (71% leaf area affected), Thiovit Jet/Signum (56%), Bravo 500/Signum (71%), and by all of the four product alternating programmes (49%-68%). Disease was not reduced significantly by Thiovit Jet/Systhane 20EW + bicarbonate (75%) and Thiovit Jet/Cyflamid (81%) at this time.

The use of Thiovit Jet rather than Bravo 500 as a multisite inhibitor fungicide to alternate with Signum resulted in a consistently lower level of disease, although the difference was not statistically significant at any of the assessments.

None of the fungicide programmes, not even the one designed for high disease pressure, gave good, season-long control of powdery mildew. This indicates that in commercial situations, when using a spray volume of 250 L/ha, a 14-day spray interval is too long to maintain control on a very susceptible species such as *Crataegus* seedlings. Similar results were noted in 2008 using simple two spray programmes with a 14 day spray interval, although the best treatment in 2008 (Signum/Bravo 500; 24% leaf area affected at the final assessment) was better than the best treatment in 2009 (response to symptoms programme; 49% leaf area affected at final assessment). A higher spray volume (1,000L/ha) was used in 2008 compared with 2009 (250 L/ha). The reduced control achieved in 2009 was likely due in part to the lower spray volume. A shorter spray interval and/or a higher spray volume need to be considered to achieve more effective control on *Crataegus.*

Crop growth and phytoxicity

None of the fungicide programmes resulted in leaf scorch, obviously stunted growth or other visible crop damage. At the end of the experiment, the mean height of seedlings ranged from 29 cm (untreated) to 43 cm (Bravo/Signum and 'high disease pressure' programme (Table 1.5). The proportion of stems more than 40 cm in height at the end of the experiment was significantly increased (P = 0.039) by all treatments except for Bravo/Signum (Table 1.5). The greatest proportion above 40 cm in height was recorded in the 'high disease pressure' programme (52%) and the least in untreated (18%). The increases in seedling height over untreated appeared to be associated with the level of mildew control.

<u>Quercus</u>

Disease control

Powdery mildew was first observed on *Quercus* seedlings on 1 July. Severity of the disease was less than that on *Crataegus* for much of the year, although it affected 85% leaf area on untreated plants by the end of the experiment (11 September) (Table 1.6).

At two weeks, after the third spray, disease levels ranged from 0.5 to 1.3% leaf area affected and there were no significant differences between treatments. On 27 July, two weeks after the fifth spray, powdery mildew affected 11.3% leaf area on untreated plants and was significantly reduced (P <0.001) by all treatments. Not surprisingly, the response to symptoms programme, where the disease was allowed to reach 1% leaf area affected before the first spray application (1 July), was less effective than the preventative programmes at this stage.

At the final assessment, two weeks after the final spray, levels of powdery mildew following fungicide treatment range from 0.4 to 8.8% leaf area affected, compared with 85% in the untreated (Table 1.6). All treatments significantly (P <0.001) reduced powdery mildew. The three most effective programmes were Thiovit Jet/Signum (0.4%), Thiovit Jet/Fandango (0.9%), and Thiovit Jet/Swift (0.9%). The level of mildew on the response to symptoms programme (8.8%) had increased little over that recorded 6 weeks earlier (6.0%).

Six of the programmes used on *Quercus* were identical to ones used on *Cratageus*; all of them gave much better control of *Quercus* than *Crataegus*. This may have been due to a greater susceptibility of *Erysiphe alphitoides* (on oak) than *Podosphaera clandestina* (on hawthorn) to the fungicides used, the later appearance of mildew on *Quercus* (which meant 3 protective sprays had been applied compared with 1 on the *Crataegus*), or other factors.

Crop growth and phytotoxicity

None of the fungicide programmes resulted in crop damage. At the end of the experiment, there was no significant difference between treatments in either seedling height (range: 24-31 cm) or the proportion above 40 cm height (Table 1.7). Growth on all *Quercus* was reported to be poor in 2009, which would reduce the difference between treatments. The greatest height (33 cm) was recorded for seedlings which had the least powdery mildew (Thiovit Jet/Signum programme), suggesting that control of powdery mildew improved crop growth. Nativo 75WG, which has previously been shown to severely stunt growth of *Crataegus* seedlings after a single early season spray (see Year 2 report), had no adverse effect on height of *Quercus* seedlings when used twice in a programme towards the end of a season (Treatment 7).

Table 1.4: Effect of some fungicide programmes on powdery mildew on field-grown *Crataegus* seedlings - 2009

	Brief title	Spray programme	Mean % leaf area affected		
			1 July (after 3 sprays)	27 July (after 5 sprays)	11 Sept (after 8 sprays)
1.	Control	Untreated	75	90	90
2.	Standard	Thiovit Jet / Systhane 20 EW + potassium bicarbonate	13	55	75
3.	New product	Thiovit Jet / Cyflamid	26	65	81
4.	New product	Thiovit Jet / Flexity	45	58	71
5.	Comparison of Bravo 500 and Thiovit Jet	Thiovit Jet / Signum	20	35	56
6.		Bravo 500 / Signum	36	44	71
7.	Outdoor crops programme	Thiovit Jet/ Signum / Thiovit Jet / Talius / Switch / Signum / Switch / Talius	14	22	59
8.	Protected crops programme	Thiovit Jet/ Signum / Thiovit Jet / Systhane + bicarb / Switch / Signum / Switch / Systhane + bicarb	45	54	68
9.	High Disease Pressure programme	Talius / Signum / Cyflamid / Flexity /Talius / Signum / Cyflamid/Flexity	9	33	63
10.	Response to symptoms programme	Potassium bicarbonate followed by the above programme from first symptoms	23	37	49
Significance (27df)			<0.001	<0.001	0.002
LSD			24.7	23.7	17.27

Eight sprays applied at 14 day intervals from 23 May, <u>except</u> for T10 when the first spray was applied at 1–5% leaf area affected by powdery mildew (4 June).

Table 1.5: Fungicide programmes for powdery mildew - effect on height of *Crataegus* - 2009

	Brief title	Spray programme	Height (cm)	% more than 40 cm
1.	Control	Untreated	29	18 (5.4)
2.	Standard	Thiovit Jet / Systhane 20 EW + potassium bicarbonate	40	45 (6.9)
3.	New product	Thiovit Jet / Cyflamid	39	38 (6.8)
4.	New product	Thiovit Jet / Flexity	38	43 (6.9)
5.	Comparison	Thiovit Jet / Signum	43	48 (7.0)
6.	of Bravo 500 and Thiovit Jet	Bravo 500 / Signum	35	28 (6.3)
7.	Outdoor crops programme	Thiovit Jet/ Signum / Thiovit Jet / Talius / Switch / Signum / Switch / Talius	40	43 (6.9)
8.	Protected crops prov	Thiovit Jet/ Signum / Thiovit Jet / Systhane + bicarb / Switch / Signum / Switch / Systhane + bicarb	40	35 (6.7)
9.	High Disease Pressure programme	Talius / Signum / Cyflamid / Flexity /Talius / Signum / Cyflamid/Flexity	43	52 (7.0)
10.	Response to symptoms programme	Potassium bicarbonate followed by the above programme from first symptoms	42	45 (6.9)
Significance (27df)			0.118	0.039
LSD			8.609	-

( ) – standard error

Table 1.6: Effect of some fungicide programmes on powdery mildew on field-grown *Quercus* - 2009

	Brief title	Spray programme	Mean % leaf area affected		
			1 July (after 3 sprays)	27 July (after 5 sprays)	11 Sept (after 8 sprays)
1.	Control	Untreated	1.3	11.3	85.0
2.	Standard	Thiovit Jet / Systhane 20 EW + potassium bicarbonate	0.5	1.0	4.0
3.	New product	Thiovit Jet / Cyflamid	0.5	1.3	4.5
4.	New product	Thiovit Jet / Fandango	0.8	1.4	0.9
5.	New product	Thiovit Jet / Signum	1.0	0.6	0.4
6.	New product	Thiovit Jet / Swift SC	0.5	0.5	0.9
7.	Outdoor crops programme	Thiovit Jet/ Signum / Thiovit Jet / Nativo 75WG / Switch / Signum / Switch / Nativo 75WG	0.5	1.0	2.0
8.	Protected crops programme	Thiovit Jet/ Signum / Thiovit Jet / Systhane+ bicarbonate / Switch / Signum / Switch / Systhane+ bicarbonate	1.0	1.8	2.5
9.	High Disease Pressure programme	Talius / Signum / Cyflamid / Flexity / Talius/ Signum / Cyflamid / Flexity	0.5	1.5	2.5
10.	Response to symptoms programme	Potassium bicarbonate followed by the above programme from first symptoms.	1.0	6.0	8.8
Significance (27df)			NS	<0.001	<0.001
LSD			-	2.73	3.46

Eight sprays applied at 14 day intervals from 23 May, <u>except</u> for T10 when the first spray is applied at 1–5% leaf area affected by powdery mildew (1 July).

Table 1.7: Fungicide programmes for powdery mildew - effect on height of *Quercus* - 2009

	Brief title	Spray programme	Mean height (cm)	% greater than 40 cm
1.	Control	Untreated	27	5
2.	Standard	Thiovit Jet / Systhane 20 EW + potassium bicarbonate	28	15
3.	New product	Thiovit Jet / Cyflamid	28	10
4.	New product	Thiovit Jet / Fandango	29	10
5.	New product	Thiovit Jet / Signum	33	25
6.	New product	Thiovit Jet / Swift SC	29	15
7.	Outdoor crops programme	Thiovit Jet/ Signum / Thiovit Jet / Nativo 75WG / Switch / Signum / Switch / Nativo 75WG	28	10
8.	Protected crops programme	Thiovit Jet/ Signum / Thiovit Jet / Systhane+ bicarbonate / Switch / Signum / Switch / Systhane+ bicarbonate	31	5
9.	High Disease Pressure programme	Talius / Signum / Cyflamid / Flexity / Talius/ Signum / Cyflamid / Flexity	24	0
10.	Response to symptoms programme	Potassium bicarbonate followed by the above programme from first symptoms	30	5
Significance(27df)			0.268	0.409
LSD			5.9	-

2. Persistence of control from a single spray

Introduction

In order to help determine appropriate spray intervals for different fungicides, an experiment was designed to determine the persistence of powdery mildew control from a single spray.

Materials and methods

Crop and site details

The experiment was done in a commercial area of *Crataegus* seedlings in the same field as the fungicide programmes experiment. No fungicides were applied to the bed in the two weeks preceding the experiment. The level of powdery mildew at the start of the experiment was quite severe at around 25% leaf area affected.

Treatments

1. Untreated
2. Thiovit Jet (10 kg/ha) + Silwett-L77 (0.5 ml/L)
3. Systhane 20EW (1.2 ml/L) + potassium bicarbonate (20 g/L)
4. Cyflamid (0.5 L/ha)
5. Flexity (0.5 L//ha)
6. Signum (1.5 kg/ha)
7. Bravo 500 (2.2 L/ha)
8. Talius (0.25 L/ha)
9. Switch (1 kg/ha)
10. Serenade ASO (10 L/ha)

Sprays were applied once at 250 L/ha on 13 August 2009. Products were used at the same rate as in the fungicide programmes experiment (see Section 1). One additional product, Serenade ASO (*Bacillus subtilis* strain QST713) was included. This biopesticide is reported to have activity against both powdery mildew and fire blight (*Erwinia amylovora*); the latter is an occasional but potentially devastating bacterial disease on *Crataegus*.

Experiment design and statistical analysis

The experiment was a randomised block design with three replicates. Plots were a 2 m length of bed, 1.25 m wide. The central 1 m length was assessed for disease. The three blocks were arranged along one bed.

Assessment

Powdery mildew was assessed at weekly intervals from 13 August 2009 to 3 September 2009 by estimating the percentage leaf area affected in each plot at three positions and taking the mean.

Results and discussion

There were no significant differences between treatments at 1 week after spray application. By 2 weeks after fungicide treatment, the level of powdery mildew on untreated seedlings had increased from 25% to 35% leaf area affected (Table 2.1). At this time, all treatments except for Bravo 500 and Serenade ASO had less mildew than the untreated. At three weeks after treatment, the level of mildew on untreated seedlings had increased to 45% leaf area affected. Five of the nine treatments were giving a significant reduction in powdery mildew at this time. These were Thiovit Jet + Silwett-L77 (23%), Signum (25%), Flexity (28%), Talius (30%) and Systhane 20EW + biocarbonate (31%).

This experiment demonstrates that the protectant fungicide Bravo 500, and the biopesticide Serenade ASO give no control of powdery mildew on *Crataegus* when sprays are applied at a relatively high disease level (25% leaf area affected). Cyflamid and Switch gave control that persisted for 2 weeks but not 3 weeks. Thiovit Jet + Silwett-L77, Systhane 20EW + biocarbonate, Flexity, Signum and Talius gave control for 3 weeks. Only Signum and Thiovit Jet + Silwett-L77 resulted in no increase in disease severity from the baseline level at the start of the experiment.

It would be useful to compare the persistence of control of different fungicides in a situation where fungicides are applied at a lower disease severity (e.g. 1-5% leaf area affected).

Table 2.1: Persistence of powdery mildew control on *Crategus* from a single spray when disease is well established - 2009

	Spray programme	Mean % leaf area affected			
		13 Aug (Baseline)	20 Aug (1 week)	27 Aug (2 weeks)	3 Sept (3 weeks)
1.	Untreated	25	21	35	45
2.	Thiovit Jet + Silwett L-77	26	18	21	**23**
3.	Systhane 20EW + potassium bicarbonate	25	23	28	**31**
4.	Cyflamid	27	20	27	40
5.	Flexity	23	20	23	**28**
6.	Signum	27	22	22	**25**
7.	Bravo 500	26	23	29	39
8.	Talius	22	17	22	**30**
9.	Switch	23	18	24	33
10.	Serenade ASO	27	23	30	39
Significance (9 df)		0.837	0.434	0.009	0.022
LSD		9.389	5.945	6.796	12.10

CONCLUSIONS

Year 1

1. The incidence of *Crataegus* plants affected by powdery mildew was significantly reduced by Cyflamid, Flexity, Nativo 75WG, Systhane 20EW, Stroby WG, Thiovit Jet + Activator 90 and an experimental fungicide.

2. Torch Extra (spiroxamine) at 0.9 ml/L caused leaf scorch on *Crataegus* and *Lonicera* and is not suitable for use on these crops at this rate.

3. Thiovit Jet + Activator 90 left an obvious spray deposit on plants.

Year 2

1. The severity of powdery mildew on field-grown *Crataegus* was significantly reduced by programmes consisting of a single-site inhibitor fungicide (Fortress, Frupica SC, Nativo 75WG, Signum, Stroby WG, Switch, Systhane 20EW, Talius) applied alternatively with a multi-site inhibitor fungicide (Bravo 500) every 14 days from May to September.

2. Control of powdery mildew using Systhane 20EW applied at 0.3 mL/L every 28 days (in alternation with Bravo 500) was significantly improved by addition of potassium bicarbonate (20 g/L).

3. Application of various fungicides active against powdery mildew at 14 day intervals and at 1,000 L/ha was insufficient to provide good, season-long control on a susceptible species such as *Crataegus*. The most effective programmes using this spray interval and volume reduced disease severity by around 75%.

4. Nativo 75WG applied four times at 0.4 g/L to *Crataegus* seedlings significantly reduced seedling growth (by 11.4 cm). Stunted growth was visible after just one spray.

5. Switch applied in alternation with Bravo 500 gave good control of powdery mildew on *Crataegus* and significantly increased growth (by 6.7 cm) compared with untreated plants. Other fungicide programmes that gave good control of powdery mildew appeared to increase growth.

6. No visible crop damage was caused by three high volume sprays of Bravo 500 (2.2 mL/L), Cyflamid (0.5 mL/L), Flexity (1.0 mL/L), Fortress (0.25 mL/L), potassium bicarbonate (20 g/L), Stroby WG (0.3 g/L), Switch (0.8 g/L) or Systhane 20EW (0.3 mL/L) to established container-grown plants of *Acer*, *Crataegus* and *Lonicera*.

Year 3

1. The severity of powdery mildew on *Crataegus* was significantly reduced by nine different fungicide programmes designed to be at low risk of selecting resistant strains of mildew. These comprised alternation of two or four products from different fungicide groups. Some of the programmes are suitable for use on protected ornamentals.

2. The most effective programmes on *Crataegus* after three sprays were Talius/Signum/Cyflamid, Thiovit Jet/Systhane 20EW + bicarbonate/Thiovit Jet and Thiovit Jet/Signum/Thiovit Jet, where leaf area affected was <15%, compared with 75% on untreated plants.

3. Thiovit Jet appeared to provide better control of powdery mildew than Bravo 500 when used in alternation with Signum. Both Thiovit Jet and Bravo 500 are multisite fungicide inhibitors and use of such products in a fungicide programme reduces the risk of selecting resistant strains of mildew.

4. Application of various fungicides active against powdery mildew at 14 day intervals and at 250 L/ha was insufficient to provide good, season-long control on a susceptible species such as *Crataegus*. The most effective programmes using this spray interval and volume reduced disease severity by around 50%.

5. Control of powdery mildew on *Crataegus* was associated with an increase in the proportion of stems more than 40 cm in height at the end of the season.

6. The severity of powdery mildew on *Quercus* was significantly reduced by nine different fungicide programmes designed to be at low risk of selecting resistant strain of powdery mildew.

7. Using these programmes, fungicide treatment at 14 day intervals and at 250 L/ha provided good, season-long control of powdery mildew on *Quercus*.

Disease severity at the end of the experiment was reduced from 85% (untreated) to <9% leaf area affected. The most effective programme was Thiovit Jet/Signum (0.4% leaf area affected).

8. Six of the fungicide programmes tested on *Crataegus* and *Quercus* were identical. All of them gave much better control on *Quercus* than *Crataegus*. Possibly this may be due to a greater susceptibility of *Erysiphe alphitoides* (on *Quercus*) than *Podosphaera clandestine* (on *Crataegus*) to the fungicides, to a lesser or greater extent.

9. None of the fungicide programmes tested on *Crataegus* or *Quercus* in 2009 caused crop damage.

10. Single sprays of Flexity, Signum, Systhane 20EW + potassium bicarbonate, Talius and Thiovit Jet + Silwett-L77 applied to *Crataegus* with obvious powdery mildew (25% leaf area affected) gave control that persisted for 3 weeks.

11. Cyflamid and Switch applied as single sprays to *Crataegus* with obvious powdery mildew gave a reduction in disease that persisted for 2 weeks but not 3 weeks.

12. A single spray of Bravo 500 or Serenade ASO applied to *Crataegus* with obvious powdery mildew (25% leaf area affected) gave no control of the disease.

TECHNOLOGY TRANSFER

Articles

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One jump ahead of mildew. *HDC News* **151**, 24-25

Latest on mildew control. *HDC News* (in press)

Presentation

Fungicide treatments for sustainable control of powdery mildew. HTA Rose Group Technical Seminar, NIAB, Cambridge. 4 December 2008.

Control of powdery mildew diseases on ornamentals. Herbaceous Perennials Technical Discussion Group, SCI, London. 12 January 2010.

Factsheet

Control of powdery mildews on hardy nursery stock (in preparation).

Project meetings

- Meetings with Project Coordinator (Mr J Dewhurst) at J & A Growers on 6 May 2008 and 27 July 2009.
- Meeting with Project Coordinator (Mr J Adlam) at ADAS Boxworth on 6 February 2009.

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APPENDIX 1: Powdery mildew species affecting Crataegus and Quercus

Table 1: Names of some powdery mildew species affecting *Crataegus* and *Quercus*

Species name		Previous name(s)
Sexual stage	Asexual stage	
Crataegus		
Podosphaera clandestina	*Oidium cydoniae*	*Erysiphe oxyacanthe* *Podosphaera oxyacanthe*
Phyllactina mali		*Erysiphe mali*
Quercus		
Erysiphe alphitoides	*Oidium alphitoides*	*Microsphaera alphitoides*
Erysiphe hypophylla	*Oidium* sp.	*Microsphaera hypophylla*
*Erysiphe quercicola**	*Oidium anacardii*	*O. citri*
*Erysiphe hypogena**	*Oidium* sp.	-
*Erysiphe epigena**	*Oidium* sp.	-
Phyllactina roboris	-	*Erysiphe roboris*
Phyllactina guttata	*Ovulariopsis moricola*	Many (e.g. *Erysiphe alni)*
Uncinula pyrenaica	-	-

* Not reported in Europe

Table 2: Host range of some powdery mildew species on *Crataegus* and *Quercus*

Species	Reported hosts	Comments
P. clandestina	Numerous host genera of *Rosaceae* (*Crataegus, Cydonia, Prunus, Spiraea)*	var. *aucupariae* infects *Sorbus*
Ph. Mali	*Crataegus, Malus, Cydonia*	
E. alphitoides	Wide range of oak species including *Q. robur, Q. dentata, Q. crispula, Q. petraea, Q. serrata* Also: *Aesculus hippocastanum, Paeonia lutea*	Common in Europe (including UK). On upper leaf surface; green leaves usually not discoloured brown
E. hypophylla	Various oak species	Rare in Europe. On lower leaf surface
P. roboris	*Castanaea, Quercus*	Not listed as occurring in UK
P. guttata	*Castanaea, Fagus, Quercus*	Listed on *Fagus sylvatica* in UK
U. pyrenaica	-	Recorded once only, in France

APPENDIX 2: Trial diary – Crataegus and Quercus programmes - 2009

6 May 2009	Trials marked out.
23 May 2009	First fungicide sprays to both species.
4 June 2009	Second fungicide application.
	Hallmark applied to *Crataegus* for pest control (SOLA 1642/2008).
	First symptoms of mildew on *Crataegus*, T10 started.
	Error on *Crataegus* plot 22 (T3) – potassium bicarbonate + Silwett-L77 applied as well as Cyflamid.
16 June 2009	Third fungicide application.
	Hallmark applied to both species.
1 July 2009	First disease assessment.
	Fourth fungicide application.
	First symptoms on *Quercus*, T10 started.
16 July 2009	Fifth fungicide application.
27 July 2009	Second disease assessment.
31 July 2009	Sixth fungicide application.
	Hallmark applied to both species.
13 August 2009	Seventh fungicide application.
	Hallmark applied to both species.
13 August 2009	Seventh fungicide application.
27 August 2009	Eighth fungicide application.
11 September 2009	Final disease assessment.

Trial diary – Persistence of control from a single spray

13 August 2009	Baseline disease assessment.
	Fungicides applied.
20 August 2009	7 day assessment.
27 August 2009	14 day assessment.
3 September 2009	21 day assessment.