Project title:	Managing ornamental plants sustainably (MOPS)
Project number:	CP 124
Work package title:	Powdery mildew (*Podosphaera clandestina*) on hawthorn (*Crataegus monogyna)*
Work package leader:	Dr Erika Wedgwood
Report:	Final report, December 2015
Previous report:	Annual report, December 2014
Key staff:	Erika Wedgwood Dennis Churchill Chris Dyer Matthew Hamilton
Location of work:	J & A Growers Ltd Bradshaw Farm Wasperton Warwick CV35 8BF
Date work commenced:	01 April 2014
Date work completed (or expected completion date):	31 March 2016

The results and conclusions in this report are based on an investigation 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.]

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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Signature .... Date 12 December 2015.

Report authorised by:

John Atwood
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Signature . Date 26 January 2016

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GROWERS SUMMARY

Headlines

- Fungicides (77, 10 and 39) controlled powdery mildew similar to standard Signum (boscalid + pyraclostrobin).
- Biofungicide products (47, 105, 11 and Serenade ASO (*Bacillus subtilis* strain QST 713 + Silwet L-77)) showed suppression at low disease levels; 105 and Serenade ASO allowed reduced use of conventional fungicides in a programme.

Background and expected deliverables

Powdery mildew diseases commonly affect a wide range of woody and herbaceous perennial ornamentals, pot and bedding plants and cut flower species, causing yellow, crinkled and distorted leaves, premature senescence and reduced vigour. Powdery mildew diseases are usually managed by regular treatment with fungicides with sprays at 7 to 14 day intervals often necessary to prevent economic crop damage. Cultural practices provide partial control, but fungicides are almost invariably necessary for the production of high-quality, saleable plants.

A range of conventional fungicides have label recommendations for control of powdery mildew in ornamental crops, often under Extensions of Authorisation for Minor Use (EAMUs). However resistance development is a concern when the same fungicide or products from the same fungicide group are used repeatedly and growers aim to select products with different FRAC (Fungicide Resistance Action Committee) mode of action Groups. Alternative modes of action to conventional products are possible with biofungicides, each often having various modes of pathogen control.

Work with edible crops within the SCEPTRE project, CP 77, (which finished in 2015) identified a number of novel conventional and alternative plant protection products with efficacy against powdery mildews and so those with the potential to secure an EAMU were brought forward for testing on ornamentals in the current project.

Several biofungicides shown to have activity against powdery mildew species, in particular in work within project CP 77 warranted testing against powdery mildew pathogens on protected and outdoor ornamentals in CP 124.

Therefore, although some plant protection products are known to have activity against powdery mildew in other crops, they have not been tested on ornamental crops and this was evaluated as part of the current project. The specific objectives therefore were:

1. To identify novel biological and conventional products with activity against powdery mildew of hawthorn and define their performance in relation to current standard treatments.
2. To assess whether products cause any phytotoxicity on hawthorn.

Within Objective 1, work in 2014 aimed to examine the relative efficacies of products, and work in 2015 then aimed to examine the integration of the products into programmes.

Summary of the work and main conclusions

The experiments in 2014 and 2015 were carried out in different fields of first-year hawthorn *Crataegus monogyna* seedlings at a tree nursery (J & A Growers Ltd) that became naturally infected with powdery mildew (*Podosphaera clandestina*). Each plot consisted of a sprayed 5-row x 4 m bed length of seedlings, with the central 2 m assessed. Protectant fungicide applications commenced at two-leaf stage, as routine for this crop. Untreated plots were sprayed with water at 400 L/ha. The plots were overhead irrigated in order to provide sufficient moisture for growth.

In 2014, when the same products were re-applied to each plot commencing on 30 May, conventional fungicides were sprayed at 400 L/ha four times at fortnightly intervals (finishing on 11 July) and the biological/alternative products were applied eight times at weekly intervals, (finishing on 18 July). Four conventional chemical fungicides, three novel products (77, 10 and 39) and Signum (boscalid and pyraclostrobin) as a grower standard, and four biological/alternative products (47, 105, 11 and Serenade ASO *Bacillus subtilis* + Silwet L-77) were applied.

In 2014, powdery mildew increased rapidly in July, following first observation on 26 June, peaking on 8 August at 82% cover in the untreated control (Figure 1). All treatments had significantly less powdery mildew than the untreated during the application period (Figure 2). Product 77 showed better control than Signum up to three weeks after application, and the other two novel conventional fungicides (10 and 39) showed comparable levels to Signum up to a week after their final application. The four biological/alternative products showed good efficacy at low disease levels. Overall, product 47 and Serenade ASO performed better than products 105 and 11 and plots treated with Product 47 and Serenade ASO still had significantly less powdery mildew than the untreated 21 days after their final application (Figure 1). No phytotoxicity was observed with any of the treatments.

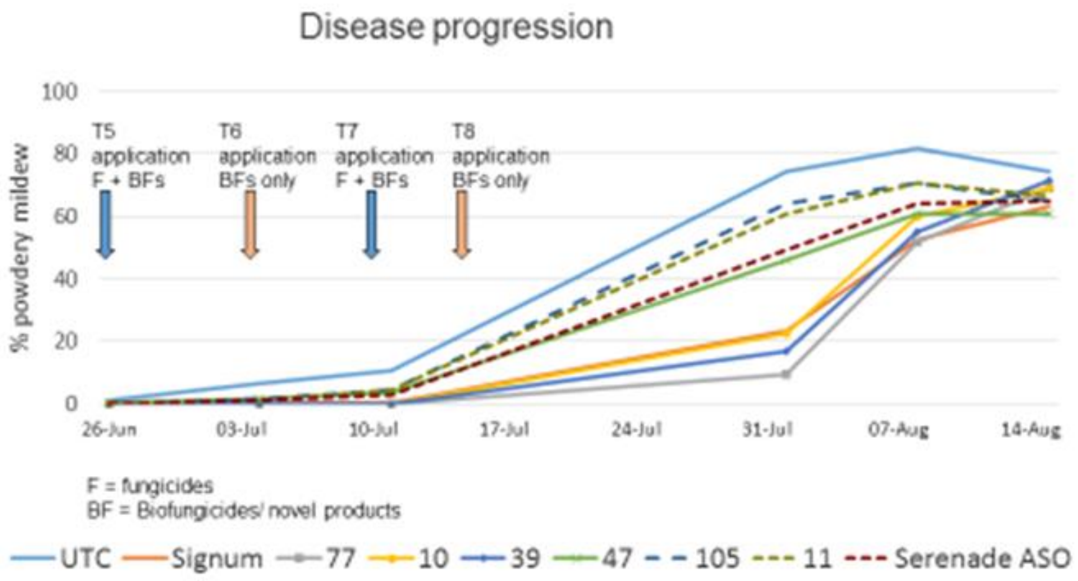
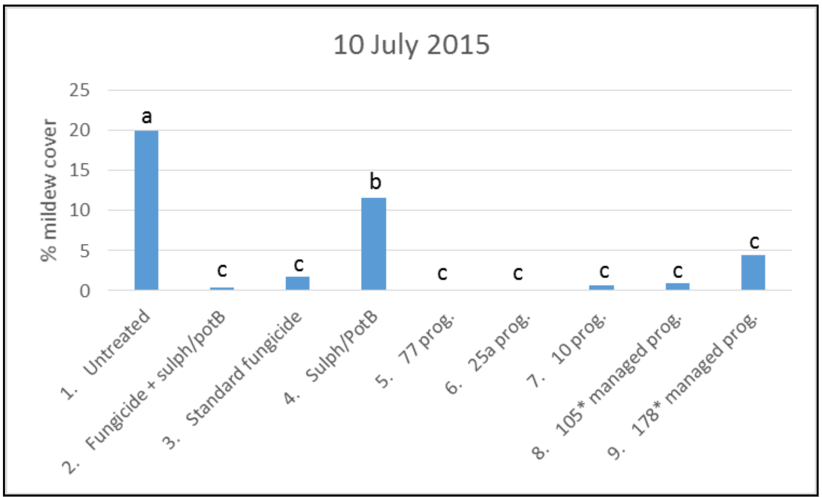


Figure 1. Powdery mildew progression in 2014 at the time of the last four applications of biofungicides and last two conventional product timings and for a month after Timing 8.



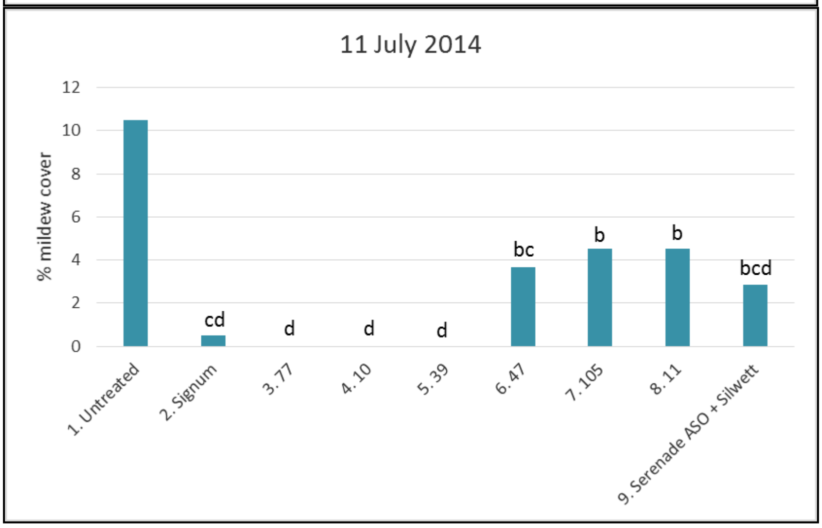


Figure 2. In 2014, just before Timing 7: equivalent powdery mildew control by novel conventional treatments to Signum and lower efficacy from the biofungicides was shown. In 2015, just before Timing 5: equivalent powdery mildew control by novel conventional treatments and the managed programmes to the grower tank-mix was shown

In 2015, products found effective in 2014 were tested within 13-application programmes at the ten day intervals usually used by the host grower. Experimental products were integrated into programmes with standard products with authorisation for use on outdoor hawthorn, aiming to alternate products with different FRAC codes (Table 1). Three programmes (5, 6 and 7) included a novel conventional product 77, 25a or 10 at Timings 3, 7 and 11 (Table 2). Two managed programmes (8 and 9) included the biofungicide products 105 and Serenade ASO, commencing use at Timings 1 and 2. There were options for biofungicide use at six other timings provided there was no new mildew visible and this resulted in one further biofungicides application at Timing 5. The experimental programmes were compared with a programme (2) based on that used by the grower which included tank-mixing with sulphur or potassium bicarbonate. Programmes 3 and 4 separated out the tank-mix components, for comparison with the experimental programmes.

Table 1. Products, active ingredients and rates used in the 2015 programmes for powdery mildew control in hawthorn. Information on coded products is not able to be disclosed

MOPS code	**Product**	**Active ingredients**	**FRAC code**	**Dose rate at 400 L of water/ha**
Standard	Signum	boscalid + pyraclostrobin	7+11	1.35 kg/ha
Standard	Vivid	pyraclostrobin	11	1.0 L/ha
Standard	Talius	proquinazid	13	0.25 L/ha
Standard	Flexity	metrafenone	U8	0.5 l/ha
Standard	Cyflamid	cyflufenamid	U6	0.5 L/ha
Standard	Systhane 20EW	myclobutanil	3	0.12 L/ha (30 ml/100L)
Standard	Nimrod	bupirimate	8	1.52 L/ha (380 ml/100L)
Standard	Kumulus	sulphur	M2	2.5 L/ha
Standard	Karma	potassium bicarbonate	-	10 kg/ha
10	conventional	single active	known	Not disclosed
25a	conventional	mixture	known	Not disclosed
77	conventional	mixture	known	Not disclosed
105	biological	various	known	Not disclosed
178	Serenade ASO* + Silwet L77	*Bacillus subtilis* + 80% w/w trisiloxane	44	8 L/ha + 0.05% wetter (50ml/100L water)

Table 2. 2015: Eight fungicide programmes for 13 timings against powdery mildew on hawthorn. *= After Timing 2 biofungicides 105 or 178 were applied at pre-determined timings instead of conventional products only when their plots in Programme 8 and 9 had no new mildew visible.

No	Timing 1 Day 0	Timing 2 Day 10	Timing 3 Day 20	Timing 4 Day 30	Timing 5 Day 40	Timing 6 Day 50	Timing 7 Day 60
	4 June	15 June	25 June	3 July	10 July	20 July	31 July
1	Untreated (water)	Untreated (water)	Untreated (water)	Untreated (water)	Untreated (water)	Untreated (water)	Untreated (water)
2	Systhane +sulphur	Flexity +sulphur	Signum +sulphur	Nimrod +sulphur	Talius +sulphur	Systhane +sulphur	Signum +sulphur
3	Systhane	Flexity	Signum	Nimrod	Talius	Systhane	Signum
4	Sulphur	Sulphur	Sulphur	Sulphur	Sulphur	Sulphur	Sulphur
5	Systhane	Flexity	77	Nimrod	Talius	Systhane	77
6	Systhane	Flexity	25a	Nimrod	Talius	Systhane	25a
7	Systhane	Flexity	10	Nimrod	Talius	Systhane	10
8	105	105	77 Not 105*	Nimrod	105* Not Talius	Systhane Not 105*	77
9	178	178	77 Not 178*	Nimrod	178* Not Talius	Systhane Not 178*	77

Table 2 contd. Programmes used on hawthorn against powdery mildew in 2015

No.	Timing 8 Day 70	Timing 9 Day 80	Timing 10 Day 90	Timing 11 Day 100	Timing 12 Day 110	Timing 13 Day 120
	9 August	18 August	27 August	4 September	11 September	19 September
1	Untreated (water)	Untreated (water)	Untreated (water)	Untreated (water)	Untreated (water)	Untreated (water)
2	Cyflamid +sulphur	Talius +pot.bi	Flexity +pot.bi	Vivid +pot.bi	Cyflamid +pot.bi	Systhane +pot.bi
3	Cyflamid	Talius	Flexity	Vivid	Cyflamid	Systhane
4	Sulphur	Pot.bi	Pot.bi	Pot.bi	Pot.bi	Pot.bi
5	Cyflamid	Talius	Flexity	77	Cyflamid	Systhane
6	Cyflamid	Talius	Flexity	25a	Cyflamid	Systhane
7	Cyflamid	Talius	Flexity	10	Cyflamid	Systhane
8	Cyflamid	Talius Not 105*	Flexity Not 105*	77	Cyflamid	Systhane Not 105*
9	Cyflamid	Talius Not 178*	Flexity Not 178*	77	Cyflamid	Systhane Not 178*

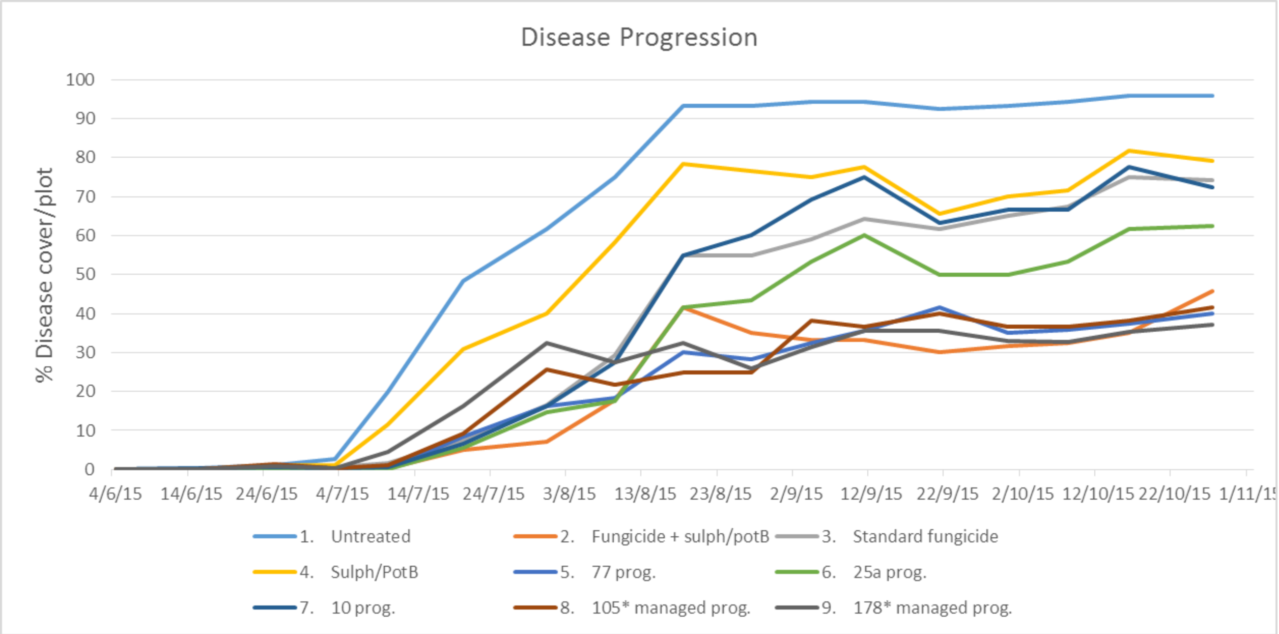


Figure 3. Powdery mildew progression in 2015, with fungicide applications at the same 13 10-day interval timings for Programmes 2 to 9 between 4 June and 19 September

Programmes commenced on the 4 June 2015 (after a cold period delayed crop growth) and were completed on the 19 September (Table 2). There was only a small amount of mildew visible for the first month of monitoring, but there was a rapid increase, much faster than in 2014, from mid-July (Figure 2) so that by 18 August the untreated plants had 93 % mildew cover (Figure 3). Infection also rose rapidly in treated plots at this time to between 30 % and 78 % mildew cover, before almost levelling out at the same time as in the untreated to give a minimum of 35 % cover in treated plots by 16 October.

In 2015, all the novel conventional and alternative products tested were effective against hawthorn powdery mildew and had no phytotoxic effects. Three of the experimental programmes (5, 8 and 9) performed as well as the grower's standard programme (2) which had otherwise similar alternating products but tank-mixed with either sulphur or potassium bicarbonate. These programmes had used novel conventional product 77 at four timings instead or either Signum or Vivid. Novel conventional product 10 and, to a lesser extent product 25a, gave poorer control in their programmes (6 and 7) than product 77 (5), but nevertheless gave at least equivalent control to the grower's programme minus the addition of either sulphur or potassium bicarbonate (3). Sulphur followed by potassium bicarbonate half way through the programme (4) was shown to have some efficacy compared with the untreated (1). When the biological products 105 and Serenade ASO were used in programmes (8 and 9) when visible pathogen spread was at a low level, either naturally or following treatment, they were both equally able to fully substitute for the protection that would otherwise have been given by conventional products.

Action Points

- Protectant fungicide programmes alternating conventional products with different modes of action tank-mixed initially with sulphur and then potassium bicarbonate can be used to achieve the best powdery mildew control on hawthorn
- Serenade ASO (and in future other biofungicides such as product 105 gaining EAMUs) can replace conventional products before mildew becomes established in the crop
- Serenade ASO and other biofungicides are best applied in an integrated programme with conventional products as their efficacy is not as great as conventional products
- Managed programmes should be developed using crop monitoring prior to each spray timing so that if no new mildew is visible then the protection offered by a biofungicide should be adequate rather than using a conventional product that would be of greater benefit retained for use in a more challenging situation
- Check for future EAMUs for novel conventional and biological products identified in this research and look at their modes of action to determine their best positions in spray programmes.

SCIENCE SECTION

Introduction

Powdery mildew diseases commonly affect a wide range of woody and herbaceous perennial ornamentals, pot and bedding plants and cut flower species, 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 often unsaleable. Some crop species/cultivars are affected virtually every year (e.g. aster, hawthorn, monarda, rose, phlox, pansy, and verbena), while a wide range of other species are affected sporadically depending on climatic and other variables.

Powdery mildew diseases are usually managed by regular treatment with fungicides and sprays at 7-14 day intervals may be necessary to prevent economic crop damage. Cultural practices provide partial control, but fungicides are almost invariably necessary for the production of high-quality, saleable plants.

Several conventional fungicides have label recommendations for control of powdery mildew in ornamental crops, mostly as protectants although some have curative (usually for a few days only) or eradicant activity. Resistance can develop when the same fungicide or products from the same fungicide group are used repeatedly on the same crop. With powdery mildew fungi there is a relatively high risk of fungicide resistance developing because of their short life-cycles and abundant spore production. There are reports of powdery mildews on a range of crops (e.g. apple, cucumber, wheat) developing resistance to various groups of fungicides (e.g. strobilurins, triazoles).

Effective conventional fungicides from at least two and preferably more mode-of-action groups are needed in order to be able to devise anti-resistance programmes and maintain effective disease control. The ability of growers to cover the period of protection required across the months when powdery mildew infection is likely to cause damage is limited by the label restrictions (in place for resistance management) on the number of applications for some products to two a year or per crop e.g. Signum (boscalid + pyraclostrobin) under EAMU 2141/2012 for ornamentals, Talius (proquinazid) under EAMU 2850/2008 for forest nursery crops and Cyflamid (cyflufenamid) under EAMU 0512/2007 for outdoor ornamentals. Secondly, for ornamentals there is only one FRAC code 7 active (boscalid). Thirdly, the trend for products being registered in the UK to be mixtures of actives from different FRAC groups (in place for resistance management) further affects growers' programmes as two modes of action are “used up” in one application and growers need to seek products from a third FRAC group for the next application. The fourth issue for growers is the threat from the EU endocrine disruptor review in which a number of important triazole fungicides (e.g. myclobutanil) are under threat of withdrawal of authorisation for use.

Effective conventional fungicides from at least two and preferably more mode-of-action groups are needed in order to be able to devise anti-resistance programmes and maintain effective disease control. Alternative modes of action to conventional products are possible with biofungicides. These products often each have multiple modes of action such as plant stimulation of defence responses (the main action of plant extracts and other biologically active chemicals), hyper-parasitism (by fungi), enzymatic action (particularly by bacteria) as well as competing with the pathogen for space and resources (all beneficial microbes).

A few novel biofungicides were shown to have activity against powdery mildew species on edible crops in SCEPTRE CP 77 (e.g. products 11, 47, 105 and Serenade ASO *Bacillus subtilis* strain QST713 tested under code 178) and warranted testing against powdery mildew pathogens on ornamentals. Availability of biofungicides effective against powdery mildews on ornamentals could help to reduce development of resistance to conventional fungicides. Some of the existing mode of action groups, whilst known to have good activity against powdery mildew, required phytotoxicity assessment on ornamental crops.

In 2014, novel products were screened for efficacy against hawthorn powdery mildew (*Podosphaera clandestina*). Hawthorn mildew was chosen as the target pathogen as this species has a wider host range (across the Rosaceae) than many other powdery mildew species. Conventional products 10, 39 and in particular 77 gave very effective control, and non-conventional products 11, 47, 105 and Serenade ASO gave less protection.

Within CP124, work was also carried out in 2014 under protection on powdery mildews of aster *Golovinomyces asterum* var. *asterum* (syn. *Erisyphe chicoracearum*) and pansy (*Podosphaera violae*). Conventional products 77 and 25a were the best performing on aster, although products 10, 28 and 89 were also effective. Biopesticide products AQ 10 (*Ampelomyces quisqualis*, strain M-10) 11, 47, Serenade ASO and in particular product 105 reduced mildew, but much less than the conventional products.

In 2015, aster and hawthorn were again used as host species and experimental programmes devised and tested incorporating a selection of the novel products used in 2014. The coded products provided potential further options for alternations of mode of action and were used to help to stretch the programme over the 13 applications required from early June to late September. Managed programmes were included where biofungicides were swapped for conventional products at pre-determined timings if disease levels were escalating.

In 2015, conventional product 39 used on hawthorn in 2014 was replaced by a co-formulation product 25a, as it was more likely to be marketed soon. Non-conventional products 47 and 11 used in 2014 were also excluded from testing on hawthorn as it became apparent that they were unlikely to become available for use on outdoor ornamentals in the near future. The grower's standard programme in 2015 was an alternation of tank-mixes which utilised results on efficacy from project HNS 156.

Materials and methods

Site and crop details

Table 1. Test site and plot design information

Test location:	
County	Warwickshire
Postcode	CV35 8BF
Soil type/growing medium	Sandy loam
Nutrition	Base dressing 500 kg/ha, then calcium nitrate at 2 leaf
Crop	Hawthorn
Cultivar	*Crataegus monogyna* – Italian Provenance (untreated)
Location*	Field
Date of sowing	16 April 2015
Pot size	Not applicable
Number of plants per plot	Approx. 30 / metre row (5 rows / plot) 271 seeds sown per m^2
Trial design (layout in Appendix C)	Randomised block
Number of replicates	Six
Plot size w (m), l (m), total area (m^2)	4 m x 1.25 m, including 1 m not scored at either end
Method of statistical analysis	Analysis of variance

*Temperature and relative humidity settings are given in Appendix B

Treatment details

Table 2. Detail of products tested in 2015

MOPS code number	Active ingredient(s)	Manufacturer	Store number	Concentration of active/s	Formulation type
1. Untreated	Tap water	n.a	n.a	n.a	n.a
2. Signum	boscalid + pyraclostrobin	Bayer Crop Science	RM 220415 AG	26.7 % + 6.7%	WG
3. Vivid	pyraclostrobin	BASF	RM220415-BE + RM030615-A	23.8%	EC
4. Talius	proquinazid	DuPont	RM110515 C	20%	EC
5. Flexity	metrafenone	BASF	Rrm220415-AI	25.2%	SC
6. Cyflamid	cyflufenamid	Certis	RM280515-B	5.3%	Emulsion in water
7. Systhane 20EW	myclobutanil	Dow	RM110515 D	20%	Oil in water
8. Nimrod	bupirimate	Adama	RM 050515 B	27.2%	EC
9. Kumulus	sulphur	BASF	RM050515 C	80%	WG
10. Karma	potassium bicarbonate	Certis	RM050515-A	85%	SP
11. 10	N/D	N/D	N/D	N/D	N/D
12. 25a	N/D	N/D	N/D	N/D	N/D
13. 77	N/D	N/D	N/D	N/D	N/D
14. 105	N/D	N/D	N/D	N/D	N/D
15. 178 + Silwett L77	+ wetter	N/D	N/D	N/D	N/D

Table 3. 2015: Eight fungicide programmes for 13 timings against powdery mildew on hawthorn. *= After Timing 2 biofungicides 105 or 178 were applied at pre-determined timings instead of conventional products only when their plots in Programme 8 and 9 had no new mildew visible.

No	Timing 1 Day 0	Timing 2 Day 10	Timing 3 Day 20	Timing 4 Day 30	Timing 5 Day 40	Timing 6 Day 50	Timing 7 Day 60
	4 June	15 June	25 June	3 July	10 July	20 July	31 July
1	Untreated (water)	Untreated (water)	Untreated (water)	Untreated (water)	Untreated (water)	Untreated (water)	Untreated (water)
2	Systhane +sulphur	Flexity +sulphur	Signum +sulphur	Nimrod +sulphur	Talius +sulphur	Systhane +sulphur	Signum +sulphur
3	Systhane	Flexity	Signum	Nimrod	Talius	Systhane	Signum
4	Sulphur	Sulphur	Sulphur	Sulphur	Sulphur	Sulphur	Sulphur
5	Systhane	Flexity	77	Nimrod	Talius	Systhane	77
6	Systhane	Flexity	25a	Nimrod	Talius	Systhane	25a
7	Systhane	Flexity	10	Nimrod	Talius	Systhane	10
8	105	105	77 Not 105*	Nimrod	105* Not Talius	Systhane Not 105*	77
9	178	178	77 Not 178*	Nimrod	178* Not Talius	Systhane Not 178*	77

Table 3 contd. Programmes used on hawthorn against powdery mildew in 2015

No.	Timing 8 Day 70	Timing 9 Day 80	Timing 10 Day 90	Timing 11 Day 100	Timing 12 Day 110	Timing 13 Day 120
	9 August	18 August	27 August	4 September	11 September	19 September
1	Untreated (water)	Untreated (water)	Untreated (water)	Untreated (water)	Untreated (water)	Untreated (water)
2	Cyflamid +sulphur	Talius +pot.bi	Flexity +pot.bi	Vivid +pot.bi	Cyflamid +pot.bi	Systhane +pot.bi
3	Cyflamid	Talius	Flexity	Vivid	Cyflamid	Systhane
4	Sulphur	Pot.bi	Pot.bi	Pot.bi	Pot.bi	Pot.bi
5	Cyflamid	Talius	Flexity	77	Cyflamid	Systhane
6	Cyflamid	Talius	Flexity	25a	Cyflamid	Systhane
7	Cyflamid	Talius	Flexity	10	Cyflamid	Systhane
8	Cyflamid	Talius Not 105*	Flexity Not 105*	77	Cyflamid	Systhane Not 105*
9	Cyflamid	Talius Not 178*	Flexity Not 178*	77	Cyflamid	Systhane Not 178*

Table 4. The number of application timings per product across the experiment in 2015, with dose rates and water volume.

Product name or MOPS code number	Application timing	Dosage rate (product/ha)	Spray volume (L/ha)
1. Untreated (water)	A1,A2,A3,A4,A5,A6,A7, A8,A9,A10,A11,A12,A13	n/a	400 L
2. Signum	A3,A7	1.35 kg/ha	400 L
3. Vivid	A11	1.0 L/ha	400 L
4. Talius	A5,A9	0.25 L/ha	400 L
5. Flexity	A2,A10	0.5 L/ha	400 L
6. Cyflamid	A8,A12	0.5 L/ha	400L
7. Systhane 20EW	A1,A6,A13	0.12 L/ha (30 ml/100L)	400 L
8. Nimrod	A4	1.52 L/ha (380 ml/100L)	400 L
9. Kumulus	A1,A2,A3,A4,A5,A6,A7,A8	2.5 L/ha	400 L
10. Karma	A9,A10,A11,A12,A13	10 kg/ha	400 L
11. Product 10	A3,A7,A11	1.0 L/ha	400 L
12. Product 25a	A3,A7,A11	1.0 L/ha	400 L
13. Product 77	A3,A7,A11	0.8 L/ha	400 L
14. Product 105	A1,A2,A5 (option at A3,A6,A10,A13 not taken)	2.5 L/ha	400 L
15. Product 178	A1,A2,A5 (option at A3,A6,A10,A13 not taken)	8 L/ha	400 L
15. Silwet L-77 (with 178)	A1,A2,A5	0.2 L/ha	400 L

Table 4 Continued. The number of application timings per product across the experiment in 2015, with dose rates and water volume.

Application timing	
A1	04/06/15 – 4th leaf
A2	11DAA1
A3	10DAA2
A4	8DAA3
A5	7DAA4
A6	10DAA5
A7	11DAA6
A8	9DAA7
A9	9DAA8
A10	9DAA9
A11	7DAA10
A12	7DAA11
A13	10DAA12

Programme 1 used water on untreated plots as the control untreated to be able to record any effect on the mildew of wetting the leaves.

Programme 2 was based around seven conventional fungicides with a range of modes of action and having authorisation for use on the crop and each was tank mixed with sulphur initially then as disease pressure built up this was replaced by potassium bicarbonate half way through the programme. This was a slight adaptation of that used by J. & A. Growers.

The experimental Programmes 5 to 9 with novel products did not tank mix (to aid result interpretation) and so as a direct comparison Programme 3 was the grower's standard programme minus the sulphur or potassium bicarbonate. Programme 4 tested the sulphur / potassium bicarbonate programme to see what activity they might be adding to the Programme 2 tank-mixes.

Programmes 5, 6 and 7 used products 77, 25a and 10, respectively at three timing slots in the programme, replacing either the Signum or Vivid used in standard Programmes 2 and 3.

In the managed programmes, 8 and 9, the biofungicide products 105 and Serenade ASO (product 178) were fixed to be applied at Timings 1 and 2, but at Timings 3, 5, 6, 9, 10 and 13 if there was new mildew development there was an option to instead use the same conventional product as in the experimental Programme 5. This resulted in only one optional selection at Timing 5 which meant that from Timing 6 the Programmes 5, 8 and 9 became identical in the products applied.

All fungicide applications were carried out following assessment of the plots within the central 2 m for any phytotoxicity from earlier sprays and the % cover of powdery mildew. All treatments were applied to the full 4m length of each plot, under good spraying conditions, using an Oxford precision sprayer with a 1.5 m boom and 03F110 nozzles, as for 2014. Details of the applications are given in Table 4 and disease assessments are shown in Table 6.

The grower uses a routine insecticide programme against midge (the pest destroys the hawthorn growing points) tank-mixed with the fungicides against powdery mildew. Calypso (thiacloprid) was selected to be the product with the least possibility of causing problems as a tank-mix with the novel products in the experiment plots. It was applied to all plots (Programmes 1 to 9) as a programmed spray at Timing 6 with Systhane, at Timing 8 with Cyflamid, at Timing 10 with Flexity and Timing 13 with Systhane.

Table 5. Application details for the 13 spray Timings (A1-A13) between June and September 2015.

Application No.	A1	A2	A3	A4	A5
Application date	04/06/15	15/06/15	25/06/15	03/07/15	10/07/15
Time of day	10.00 am - 11.30am	09.30 am - 11.30 am	09.30 am - 11.45 am	09.00 am - 12.20 pm	10.50 am - 12.45 pm
Application method	Oxford precision sprayer	Oxford precision sprayer	Oxford precision sprayer	Oxford precision sprayer	Oxford precision sprayer
Temperature of air – max/min (°C)	19.1 - 20.1	16.5 - 22.5	21.9 - 22.1	21.6 - 22.5	21.6 - 23.5
Relative humidity (%)	42.1 - 42.3	52.5 - 68.5	74.1 - 75.2	54.6 - 55.2	42.1 - 43.0
Cloud cover (%)	30	0	20	20	30
Crop growth stage	4 leaf <10cm high	6 leaf <15cm high	8 leaf <15cm high	14 leaf <15cm high	20 leaf <40cm high
Crop comments	Dry leaves	Dry leaves First signs of mildew	Dry leaves Mildew 1%	Dry leaves Some mildew seen	Dry leaves Mildew seen
Other*:	Surface soil dry; subsoil moist	Surface soil dry; subsoil moist	Surface soil dry; subsoil moist	Surface soil dry; subsoil moist	Surface soil damp; subsoil damp

Table 5 Continued. Application details for the 13 spray Timings (A1-A13) between June and September 2015.

Application No.	A6	A7	A8	A9	A10
Application date	20/07/15	31/07/15	09/08/15	18/08/15	27/08/15
Time of day	1.00 pm – 2.00 pm	9.30 am - 12.10 pm	8.40 am - 10.40 am	9.30 am - 11.10 am	8.30 am - 10.20 am
Application method	Oxford precision sprayer	Oxford precision sprayer	Oxford precision sprayer	Oxford precision sprayer	Oxford precision sprayer
Temperature of air – max/min (°C)	22.1 - 22.3	20.6 - 21.4	19.1 - 19.5	18.2 - 18.9	18.1 - 19.6
Relative humidity (%)	77 - 78	55.6 - 56	67.2 - 68.1	61.2 - 63.1	76.4 - 79.9
Cloud cover (%)	100	0	0	70	80
Crop growth stage	22 leaf <50 cm high	30 leaf <50 cm high	30 leaf <50 cm high	40 leaf <60 cm high	45 leaf <60 cm high
Crop comments	Dry leaves, mildew seen	Dry leaves, some mildew seen	Dry leaves, mildew seen	Dry leaves, mildew seen across plots	Dry leaves, mildew seen
Other*:	Surface soil dry; subsoil damp	Surface soil dry; subsoil damp	Surface soil damp; subsoil damp	Surface soil dry; subsoil damp	Surface soil damp; subsoil damp

Table 5 Continued. Application details for the 13 spray Timings (A1-A13) between June and September 2015.

Application No.	A11	A12	A13
Application date	04/09/15	11/09/15	21/09/15
Time of day	9.30 am - 11.10 am	8.45 am - 11.30 am	8.50 am - 12.10 am
Application method	Oxford precision sprayer	Oxford precision sprayer	Oxford precision sprayer
Temperature of air – max/min (°C)	18.2 - 18.7	17.6 - 18.9	16.9 - 18.1
Relative humidity (%)	71.2 - 69.3	55.6 - 56.1	68.1 - 72.1
Cloud cover (%)	40	70	60
Crop growth stage	48 leaf <60 cm high	55 leaf <70 cm high	55 leaf <70 cm
Crop comments	Widespread mildew	Mildew seen on leaves	Mildew seen
Other*:	Surface soil damp; subsoil damp	Surface soil dry; subsoil damp	Surface soil damp; subsoil damp

*Includes soil temperature and moisture details where relevant

Target pest

Table 6. Target pest

Common name	Scientific Name	Infection level pre-first application
Powdery mildew	*Podosphaera clandestina*	0%. Natural infection.

Assessments

Table 7. Assessments and growth stage of hawthorn at each treatment timing and to 36 days after final fungicide applications.

Assessment No.	Date	Growth stage	Timing of assessment relative to last application	Assessment type
1	04/06/15	4 leaves	Pre-treatment	% disease cover (severity) per plot
2	15/06/15	6 leaves	11DAA1	% disease cover (severity) per plot
3	25/06/15	8 leaves	10DAA2	% disease cover (severity) per plot
4	03/07/15	14 leaves	8DAA3	% disease cover (severity) per plot
5	10/07/15	20 leaves	7DAA4	% disease cover (severity) per plot
6	20/07/15	22 leaves	10DAA5	% disease cover (severity) per plot
7	31/07/15	30 leaves	11DAA6	% disease cover (severity) per plot
8	09/08/15	30 leaves	9DAA7	% disease cover (severity) per plot
9	18/08/15	40 leaves	9DAA8	% disease cover (severity) per plot
10	27/08/15	45 leaves	9DAA9	% disease cover (severity) per plot
11	04/09/15	50 leaves	7DAA10	% disease cover (severity) per plot
12	11/09/15	55 leaves	7DAA11	% disease cover (severity) per plot
13	21/09/15	55 leaves	10DAA12	% disease cover (severity) per plot
14	30/09/15	55 leaves	9DAA13	% disease cover (severity) per plot
15	08/10/15	60 leaves	17DAA13	% disease cover (severity) per plot
16	16/10/15	60 leaves	25DAA13	% disease cover (severity) per plot
17	27/10/15	62 leaves	36DAA13	% disease cover (severity) per plot

DAA – Days after application

Results

Control of powdery mildew

Mildew levels are shown below in Table 8 and graphical representations are given in Figure 1. There were highly significant differences between the programmes starting on 3 July and continuing to the final observations on the 27 October 2015. The grower standard tank-mix (Programme 2), which included the Signum and Vivid substituted by novel fungicides in the experimental Programmes 5, 6 and 7, performed very well. The addition of sulphur followed by substitution with potassium bicarbonate in this standard was shown to give better control than the same conventional products alone at each application (Programme 3). The sulphur and potassium bicarbonate programme (Programme 4) gave a low level of control, but still significantly better than the untreated.

The three novel conventional products 77, 25a and 10 (used in Programmes 5, 6 and 7, respectively) were each first applied at Timing 3 on 25 June when there was little mildew in plots of all programmes. The next application was at Timing 7 on 31 July after all had received the same alternation of authorized products which had resulted in a mean 16% mildew. After this, plots with products 10 and 25a started to show more mildew so that by 18 August the plots in Programme 5 treated with 77 had 30% mildew, significantly less mildew (P>0.001) than with 25a, and these had significantly less mildew than the 55% in product 10 plots (which was the same as for the standard minus sulphur). All three products were re-applied on the 4 September, but at the next assessment levels in 25a and 10 had continued to rise while levels in product 77 were held. The holding of levels below 36% on 11 September in Programme 5 was also seen in Programmes 8 and 9 where three early applications were of biofungicides, continuing to match to performance of the grower standard tank-mix without requiring the activity boost given by the addition of sulphur/potassium bicarbonate.

For Programmes 8 and 9, the planned use of biofungicides 105 and 178 (Serenade ASO) started when no plots had any mildew, and only a trace was reported in two programmes at the second application. The option of a third consecutive application was not taken on 25 June as new mildew was seen on the biofungicide plots. However, following application of product 77 and then Nimrod the decision was taken (with the support of the grower) to take the option to use the biofungicides on 10 July rather than a conventional product. At the next assessment on 20 July there was no significant difference between the biofungicide treated plots and most of those having used Talius instead (although Programme 6 was significantly better than Programme 9 with Serenade ASO).

Table 8. Percentage cover of powdery mildew on hawthorn at 10 day intervals on each of 13 days just before fungicide application

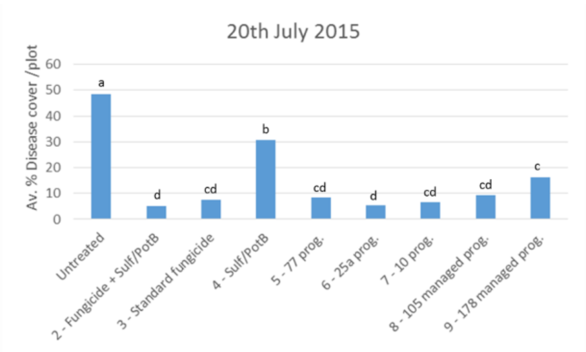
Programme number and type of programme or MOPS product code under study	04/06/15	15/06/15	25/06/15	03/07/15
1. Untreated	0	0.33	1.00	2.67
2. Fungicide + sulphur / PotB.	0	0.00	0.50	0.33
3. Standard fungicide	0	0.00	0.83	0.58
4. Sulphur / PotB.	0	0.00	1.00	1.08
5. 77 prog.	0	0.00	0.83	0.33
6. 25a prog.	0	0.00	0.42	0.25
7. 10 prog.	0	0.33	0.58	0.42
8. 105* managed prog.	0	0.00	1.25	0.33
9. 178* managed prog.	0	0.00	0.92	0.33
F value (df)	N/A	0.026 (40df)	0.350 (40df)	<0.001 (40df)
LSD	N/A	0.266	0.716	0.945

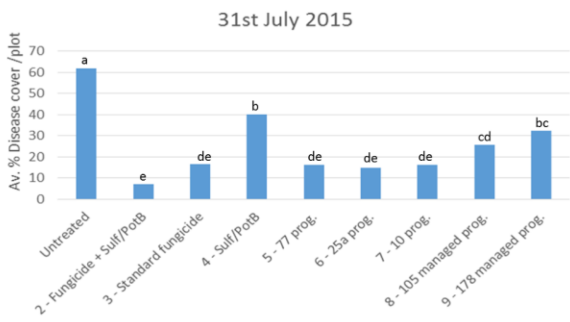
Programme number, and type of programme or MOPS product code under study	10/07/15	20/07/15	31/07/15	09/08/15
1. Untreated	20.00	48.3	61.7	75.0
2. Fungicide + sulphur / PotB.	0.42	5.0	7.0	17.8
3. Standard fungicide	1.75	7.5	16.5	29.2
4. Sulphur / PotB.	11.67	30.8	40.0	58.3
5. 77 prog.	0.08	8.3	16.2	18.3
6. 25a prog.	0.17	5.5	14.8	17.5
7. 10 prog.	0.67	6.7	16.2	27.5
8. 105* managed prog.	1.0	9.3	25.7	21.7
9. 178* managed prog.	4.5	16.2	32.5	27.5
F value (df)	<0.001 (40)	<0.001 (40)	<0.001 (40)	<0.001 (40)
LSD	4.741	10.16	14.12	12.16

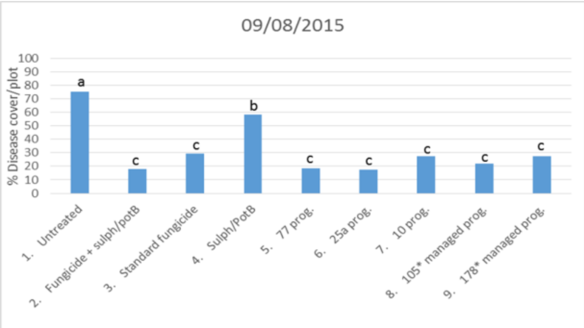
Programme number, and type of programme or MOPS product code under study	18/08/15	27/08/15	04/09/15	11/09/15
1. Untreated	93.3	93.3	94.2	94.2
2. Fungicide + sulphur / PotB.	41.7	35.0	33.3	33.3
3. Standard fungicide	55.0	55.0	59.2	64.2
4. Sulphur / PotB.	78.3	76.7	75.0	77.5
5. 77 prog.	30.0	28.3	32.5	35.5
6. 25a prog.	41.7	43.3	53.3	60.0
7. 10 prog.	55.0	60.0	69.2	75.0
8. 105* managed prog.	25.0	25.0	38.3	36.7
9. 178* managed prog.	32.4	26.0	31.5	35.6
F value (df)	<0.001 (39)	<0.001 (39)	<0.001 (39)	<0.001 (39)
LSD	11.21	12.78	10.79	9.79

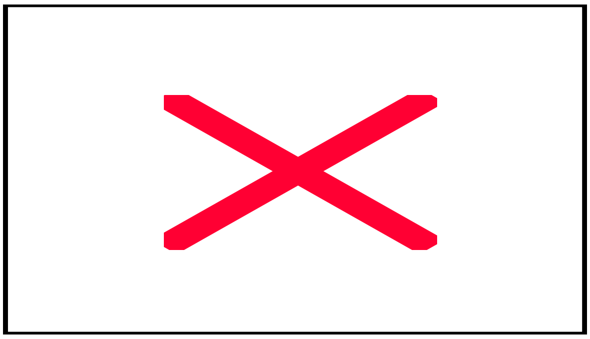
Programme number, and type of programme or MOPS product code under study	21/09/15	30/09/15	08/10/15	16/10/15
1. Untreated	92.5	93.3	94.2	96.0
2. Fungicide + sulphur / PotB.	30.0	31.7	32.5	35.0
3. Standard fungicide	61.7	65.0	67.5	75.0
4. Sulphur / PotB.	65.5	70.0	71.7	81.7
5. 77 prog.	41.7	35.0	35.8	37.5
6. 25a prog.	50.0	50.0	53.3	61.7
7. 10 prog.	63.3	66.7	66.7	77.5
8. 105* managed prog.	40.0	36.7	36.7	38.3
9. 178* managed prog.	35.6	32.9	32.7	35.2
F value (df)	<0.001 (39)	<0.001 (39)	<0.001 (39)	<0.001 (39)
LSD	11.17	10.10	10.00	10.37

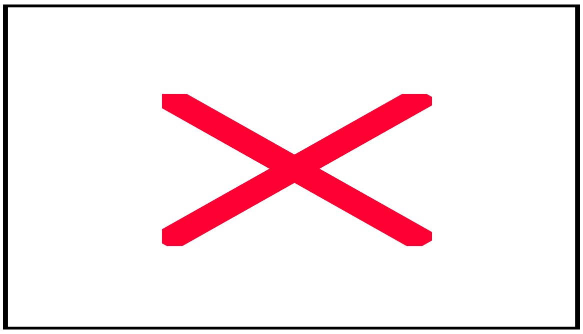
Programme number, and type of programme or MOPS product code under study	27/10/15
1. Untreated	96.0
2. Fungicide + sulphur / PotB.	45.8
3. Standard fungicide	74.2
4. Sulph/PotB	79.2
5. 77 prog.	40.0
6. 25a prog.	62.5
7. 10 prog.	72.5
8. 105* managed prog.	41.7
9. 178* managed prog.	37.2
F value (df)	<0.001 (39)
LSD	12.14

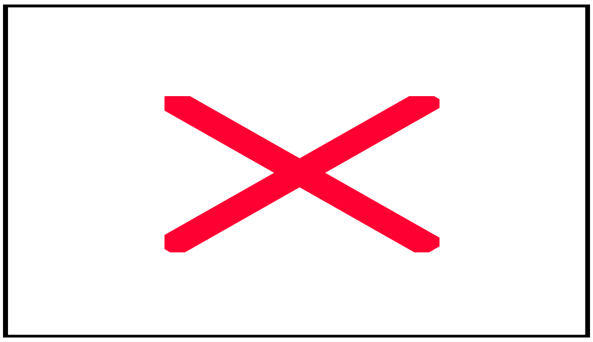

20th July 2015
Av. % Disease cover /plot
0
10
20
30
40
50
60
a
d
cd
b
cd
d
cd
cd
c
Untreated
2 - Fungicide + Sulf/PotB
3 - Standard fungicide
4 - Sulf/PotB
5 - 77 prog.
6 - 25a prog.
7 - 10 prog.
8 - 105 managed prog.
9 - 178 managed prog.

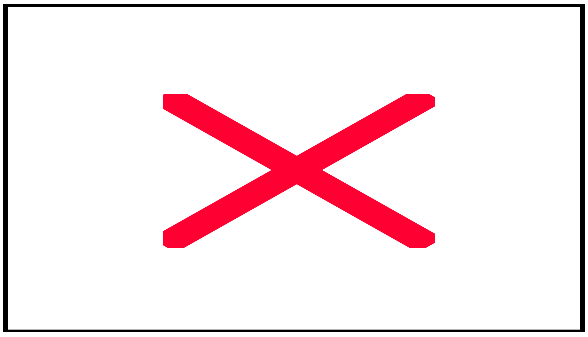

31st July 2015
Av. % Disease cover /plot
0
10
20
30
40
50
60
70
a
e
de
b
de
de
de
cd
bc
Untreated
2 - Fungicide + Sulf/PotB
3 - Standard fungicide
4 - Sulf/PotB
5 - 77 prog.
6 - 25a prog.
7 - 10 prog.
8 - 105 managed prog.
9 - 178 managed prog.

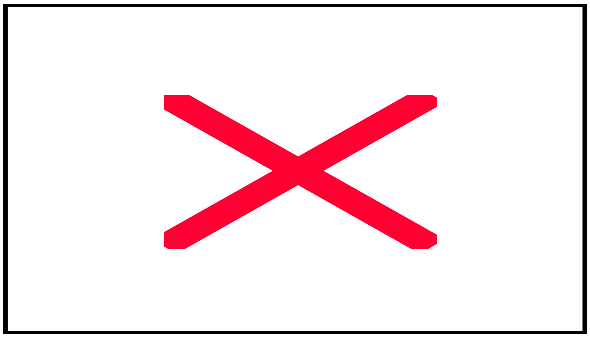

09/08/2015
% Disease cover/plot
0
10
20
30
40
50
60
70
80
90
100
a
c
c
b
c
c
c
c
c
1. Untreated
2. Fungicide + sulph/potB
3. Standard fungicide
4. Sulph/PotB
5. 77 prog.
6. 25a prog.
7. 10 prog.
8. 105* managed prog.
9. 178* managed prog.











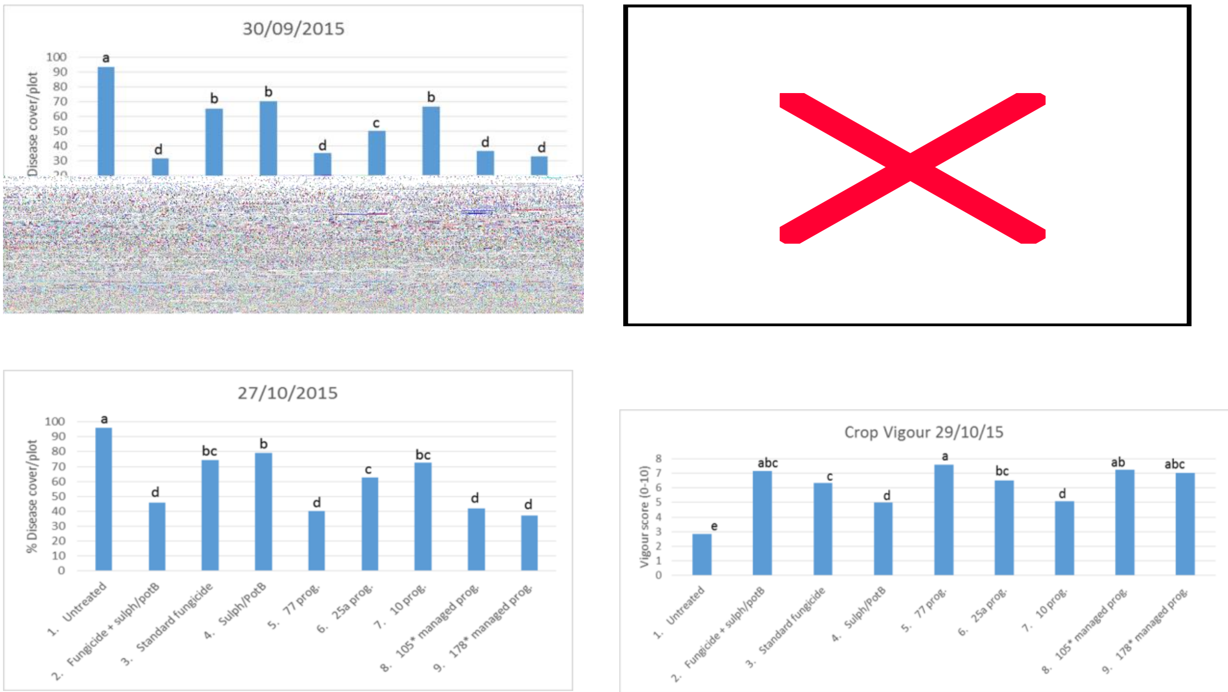


Figure 1. Charts for each assessment in 2015 once the untreated was over 2% showing mean mildew levels recorded at 10 day intervals just before each fungicide timing and three times after the final applications on 27 September. Where the letters on the % disease cover bars differ then the programmes had significantly ($P<0.001$) different levels of control. At the final assessment vigour is shown to have reduced with increasing mildew.

Crop vigour

By mid-June 2015 it was noted that the plant growth had been slowed by;

- Cold nights, warm days
- Cold Northerly drying winds
- Herbicide effects which in good conditions the plants grow quickly through

After this time conditions improved and vigour was directly related to the severity of mildew cover (Table 9 and Figure 1). Mildew cover causes a reduction in leaf size and distortion leading to a reduction in photosynthetic ability and thus reduction in plant height (Table 9). The programmes with the tank-mix components separately in Programmes 3 and 4, and Programme 7 with product 10 had plants with significantly less vigour and height, with the untreated plants being significantly less vigorous and shorter then these. Photographs of the plots are shown in Appendix F.

Table 9. Effect of treatments on crop vigour at the last assessment on 29 October 2015

Programme number and type of programme or MOPS product code under study	Vigour Index 1= poor, 10 = very good
1. Untreated	2.83
2. Fungicide + sulphur / pot. bicarb. prog	7.17
3. Standard fungicide prog.	6.33
4. Sulphur or potassium bicarbonate.	5.00
5. 77 prog.	7.58
6. 25a prog.	6.50
7. 10 prog.	5.08
8. 105* managed prog.	7.25
9. 178* managed prog.	7.02
F value (df)	<0.001 (39)
LSD	0.879

Crop height

Table 10. Effect of treatments on crop height at the last assessment on 29 October 2015

Programme number and type of programme or MOPS product code under study	Plant height in cm
1. Untreated	37.37
2. Fungicide + sulphur / pot. bicarb prog.	64.55
3. Standard fungicide prog.	59.22
4. Sulphur or potassium bicarbonate.	51.92
5. 77 prog.	67.57
6. 25a prog.	60.45
7. 10 prog.	53.57
8. 105* managed prog.	66.08
9. 178* managed prog.	63.89
F value (df)	<0.001 (39)
LSD	7.135

Crop Damage

No phytotoxicity was seen at any stage, including no adverse effect from the use of Calypso in all programmes as a tank-mix at four of the treatment timings.

Formulations

Observations were made of ease of mixing of the formulations and for any conspicuous problems associated with nozzle blockages or uneven spray pattern during mixing and application.

No problems were encountered during mixing or application of any of the product formulations under test.

Effect on non-targets

No adverse effects or otherwise were noted on non-target pests. Calypso was applied against midges on the 20 July, 9 August, 27 August and 21 September. No diseases other than powdery mildew were present.

Discussion

By 25 June 2015 some plots of the managed Programmes 8 and 9 had mildew so the there was a switch for biologicals to conventionals for Timing 3, with odd plants in a few plots affected throughout all treatments. The grower considered that such early infection was because the site had had the worst spring growth that he had experienced, with cold nights and low soil temperatures into early June. The plants had thus been under stress, which could have aided powdery mildew infection.

In a managed programme there might need to be assessment of the prevailing weather conditions and crop growth as well as disease levels so that if it is cold and plants are under stress then conventionals should be used and biologicals used when active plant growth occurs. Conventional products could then be selected if infection was seen. Although in 2015 the biofungicides were unable to be used for as long as they might in a less cold May/June, they were able to replace the conventional products at three timings and thus in a commercial situation could aid the “stretching” of spray programmes to cover the “at risk” period where this would otherwise be difficult because of restrictions on repeat use of certain conventional products imposed by resistance management.

Further investigations are needed to determine if any benefits could be gained from the use of sulphur / potassium bicarbonate as tank-mixes with the novel products or whether this might adversely affect the products or cause phytotoxicity to the plants. Tank-mixing ability with insecticides (such as those regularly used by growers to control midge) and any effects on efficacy or crop safety also need to be evaluated.

Conclusions

- Novel conventional products 10, 25a and 77 and biofungicides 105 and Serenade ASO used in programmes were effective at reducing powdery mildew on hawthorn seedlings
- Programmes which included product 77 had the greatest efficacy, matching that of the grower standard programme tank-mix with sulphur / potassium bicarbonate
- Biofungicides were able to replace conventional products at positions within alternating programmes before the prevalence of environmental conditions for rapid disease spread
- There was no phytotoxicity to hawthorn from any of the products tested

References

CP 77 SCEPTRE (HortLINK 2010-2014). Sustainable Crop & Environmental Protection–Targeted Research for Edibles [http://www.hdc.org.uk/sceptre]

Ann, D., O'Neill, T. and Atwood, J. (2004). Control of the main foliar diseases of container-grown roses. Horticultural Development Council Factsheet 12/04 Rose foliar diseases. Project No. HNS 106 & 106a.

O'Neill, T. (2010). Development of fungicide treatments for sustainable control of powdery mildew. Horticultural Development Company Final Report Project HNS 156.

Appendix A – Study conduct

ADAS UK Ltd. are officially recognised by United Kingdom Chemical Regulations Directorate as competent to carry out efficacy testing in the categories of agriculture and horticulture. National regulatory guidelines were followed for the study.

GLP compliance will not be claimed in respect of this study, it was however carried out to ORETO standards and ADAS internal quality management procedures.

Relevant EPPO/CEB guideline(s)		**Variation from EPPO**
PP 1/152(3)	Design and analysis of efficacy evaluation trials	PP 1/152(3)
PP 1/135(3)	Phytotoxicity assessment.	PP 1/135(3)
PP 1/181(3)	Conduct and reporting of efficacy evaluation trials including GEP	PP 1/181(3)
PP 1/196	Efficacy evaluation of fungicides – Fungi on woody ornamentals	PP 1/196 (2)

There were no significant deviations from the EPPO and national guidelines.

After treatment on the 9 August plot 19 was omitted from analysis (to leave 5 replicates) as the distribution of mildew in the plot suggested a spray miss.

Appendix B – Meteorological data

Location of the weather station	Wellesbourne airfield
Distance to the trial site	1.9 miles
Origin of the weather data	Wellesbourne airfield data

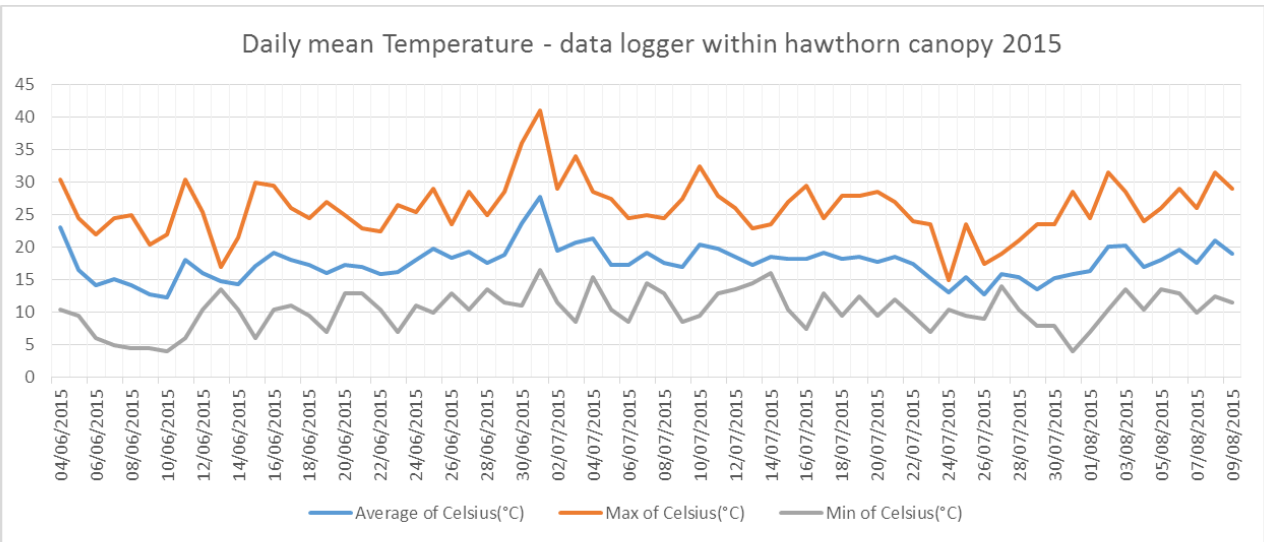
Long-term averages for 2015 from Birmingham airport 25 miles away

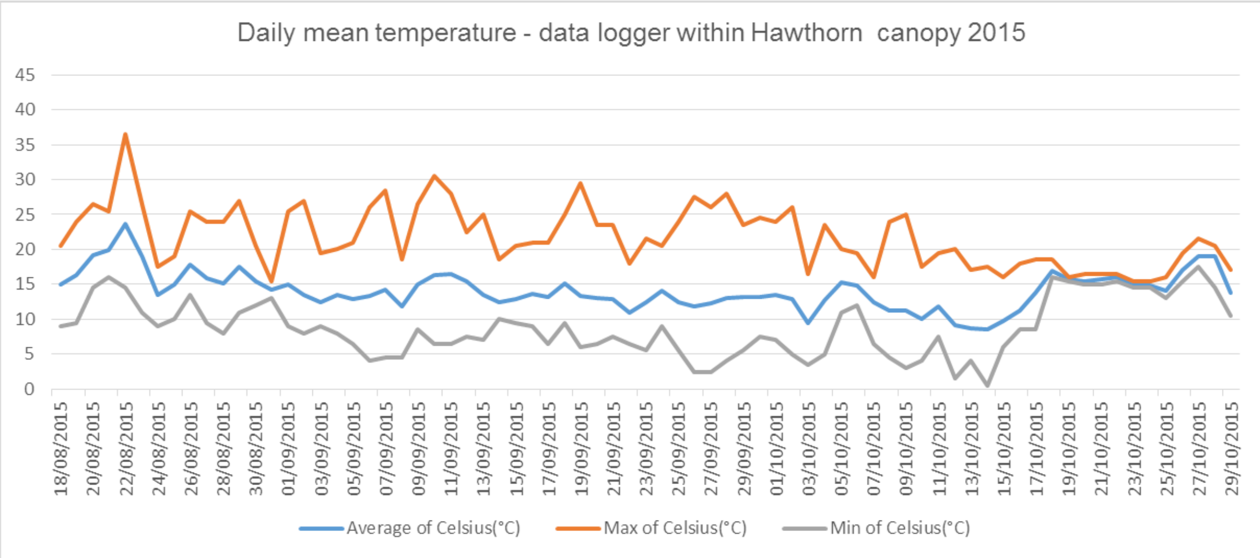
Month/period	Min temp (ºC)	Max temp (ºC)	Rainfall (mm)
June	9.2	18.8	9
July	11.1	20.6	8
August	10.8	20.1	10
September	8.8	17.6	9
October	6.2	13.8	9

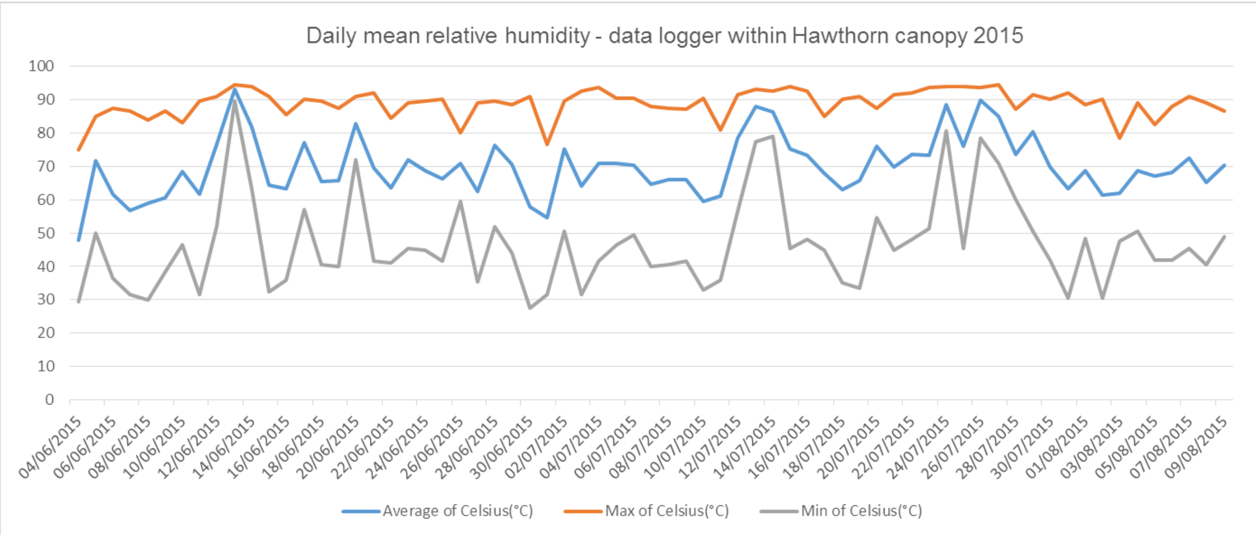
Average conditions in 2015 during the trial:

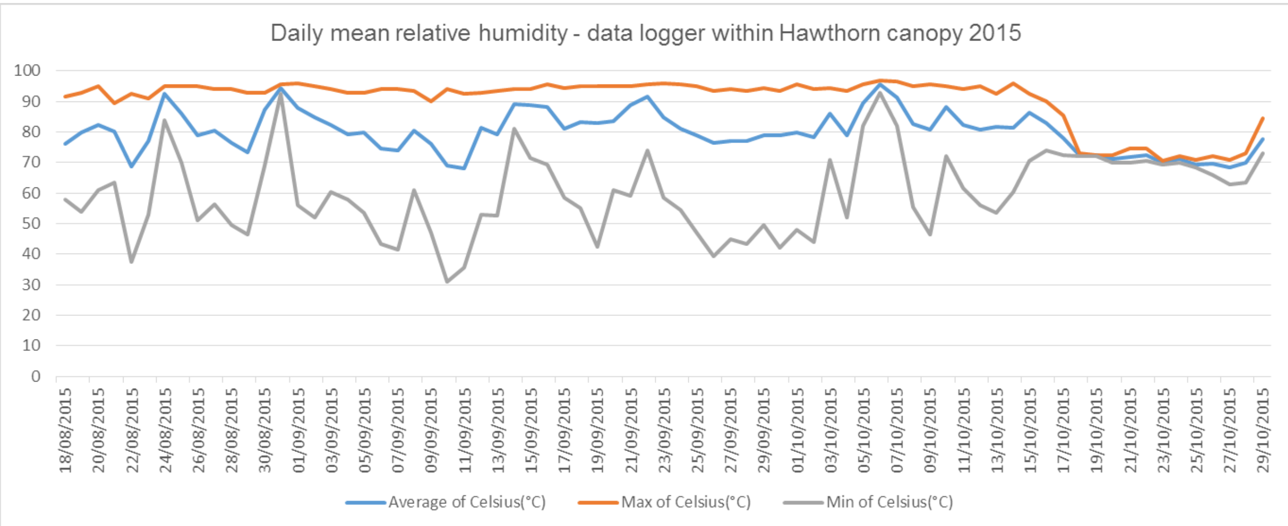
Month/period	Av temp (ºC)	Min temp (ºC)	Max temp (ºC)	Av RH (%)*	Rainfall (mm)
June	15.0	4.0	29.2	74	16
July	16.6	4.7	33.3	75	58
August	16.7	7.8	28.8	77	78
September	12.8	2.8	21.8	82	59
October	11.3	2.4	19.4	88	67

In-crop mean daily temperature and relative humidity between June and October 2015:




Daily mean temperature - data logger within Hawthorn canopy 2015
45
40
35
30
25
20
15
10
5
0
18/08/2015
29/10/2015
Average of Celsius(°C)
Max of Celsius(°C)
Min of Celsius(°C)


Daily mean relative humidity - data logger within Hawthorn canopy 2015
100
90
80
70
60
50
40
30
20
10
0
04/06/2015
09/08/2015
Average of Celsius(°C)
Max of Celsius(°C)
Min of Celsius(°C)


Daily mean relative humidity - data logger within Hawthorn canopy 2015
100
90
80
70
60
50
40
30
20
10
0
18/08/2015
29/10/2015
Average of Celsius(°C)
Max of Celsius(°C)
Min of Celsius(°C)

Appendix C – Agronomic details

Growing system in 2015

Crop	Cultivar	Sowing date	Row width (m) or pot spacing
Hawthorn *Crataegus monogyna*	Italian Provenance	15/04/2015	0.25m, 271 viable seed per metre

Previous cropping

Year	Crop
2014	Grass ley
2013	Grass ley
2012	Spring barley

Cultivations in 2015

Description of equipment used
Plough
Flatlift
Bed former

Other pesticides - active ingredient(s) / fertiliser(s) applied in 2015

Date	Product	Rate
06/04/2015	Hydro complex partner	500kg/ha
22/06/2015	Calcium Nitrate	250kg/ha
20/07/2015 Timing 6	Tank mixed with treatments in Programmes 1 to 9 Calypso (thiacloprid) against midge	0.24 L/ha
21/07/2015	Calcium Nitrate	250kg/ha
09/08/2015 Timing 8	Tank mixed with treatments in Programmes 1 to 9 Calypso (thiacloprid) against midge	0.24 L/ha
27/08/2015 Timing 10	Tank mixed with treatments in Programmes 1 to 9 Calypso (thiacloprid) against midge	0.24 L/ha
21/09/2015 Timing 13	Tank mixed with treatments in Programmes 1 to 9 Calypso (thiacloprid) against midge	0.24 L/ha

Details of irrigation regime in 2015

Date	**Type**	**Amount applied (mm)**
20/04	Water	10
28/05	Water	10
05/06	Water	10
10/06	Water	10
29/06	Water	10
09/07	Water	10
22/07	Water	10
07/08	Water	10
13/08	Water	10
29/09	Water	10

Type of irrigation system employed
Overhead static sprinkler heads at 18m intervals down beds either side of the trial area

Appendix D – Trial layout (Treatments in each programme shown below)

8	6	2	7	5	1	9	3	4	DISCARD
6	6	6	6	6	6	6	6	6	
46	**47**	**48**	**49**	**50**	**51**	**52**	**53**	**54**	
1	7	6	2	3	4	5	9	8	DISCARD
5	5	5	5	5	5	5	5	5	
37	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	
2	6	1	4	8	5	7	9	3	DISCARD
4	4	4	4	4	4	4	4	4	
28	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	
9	1	8	6	7	4	5	2	3	DISCARD
3	3	3	3	3	3	3	3	3	
19	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	
7	8	2	3	1	9	6	4	5	DISCARD
2	2	2	2	2	2	2	2	2	
10	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	
3	9	6	5	7	2	4	1	8	DISCARD
1	1	1	1	1	1	1	1	1	
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	

Treatment number

Replicate number

Plot number

CP 124 (MOPS) Hawthorn powdery mildew experimental treatment programmes 2015 compared with grower's standard T2

No.	Timing 1	Timing 2	Timing 3	Timing 4	Timing 5	Timing 6	Timing 7	Timing 8	Timing 9	Timing 10	Timing 11	Timing 12	Timing 13
	4 June	15 June	25 June	3 July	10 July	20 July	31 July	9 Aug	18 Aug	27 Aug	4 Sept	11 Sept	19 Sept
1	UT (water)	UT (water)	UT (water)	UT (water)	UT (water)	UT (water)	UT (water)	UT (water)	UT (water)	UT (water)	UT (water)	UT (water)	UT (water)
2	Systhane +sulphur	Flexity + sulphur	Signum +sulphur	Nimrod +sulphur	Talius +sulphur	Systhane +sulphur	Signum +sulphur	Cyflamid +sulphur	Talius +pot.bi	Flexity +pot.bi	Vivid +pot.bi	Cyflamid +pot.bi	Systhane +pot.bi
3	Systhane	Flexity	Signum	Nimrod	Talius	Systhane	Signum	Cyflamid	Talius	Flexity	Vivid	Cyflamid	Systhane
4	sulphur	sulphur	sulphur	sulphur	sulphur	sulphur	sulphur	sulphur	pot.bi	pot.bi	pot.bi	pot.bi	pot.bi
5	Systhane	Flexity	77	Nimrod	Talius	Systhane	77	Cyflamid	Talius	Flexity	77	Cyflamid	Systhane
6	Systhane	Flexity	25a	Nimrod	Talius	Systhane	25a	Cyflamid	Talius	Flexity	25a	Cyflamid	Systhane
7	Systhane	Flexity	10	Nimrod	Talius	Systhane	10	Cyflamid	Talius	Flexity	10	Cyflamid	Systhane
8	105*	105*	77 Not 105*	Nimrod	105* Not Talius	Systhane Not 105*	77	Cyflamid	Talius Not 105*	Flexity Not 105*	77	Cyflamid	Systhane Not 105*
9	178*	178*	77 Not 178*	Nimrod	178* Not Talius	Systhane Not 178*	77	Cyflamid	Talius Not 178*	Flexity Not 178*	77	Cyflamid	Systhane Not 178*

Managed programmes in Treatments 8 & 9: Biofungicides* could have been selected on the spray days at timings 3, 5, 6, 9, 10 and 13 if there was no new mildew in those plots, otherwise a conventional product would have been the option selected.

Appendix E – Copy of the Certificate of Official Recognition of Efficacy Testing Facility or Organisation

Certificate of

Official Recognition of Efficacy Testing Facilities or Organisations in the United Kingdom

This certifies that

ADAS UK Limited

complies with the minimum standards laid down in Regulation (EC) 1107/2009 for efficacy testing.

The above Facility/Organisation has been officially recognised as being competent to carry out efficacy trials/tests in the United Kingdom in the following categories:

Agriculture/Horticulture
Stored Crops
Biologicals and Semiochemicals

Date of issue:	10 May 2013
Effective date:	18 March 2013
Expiry date:	17 March 2018

Signature ______ Authorised signatory

Certification Number
ORETO 339

HSE Chemicals Regulation Directorate

Department of Agriculture and Rural Development

Appendix F – Photographs

Example plots each treatment in Replicate 1 on 2 September 2015 (before Timing 12)

Figure 1. Untreated control

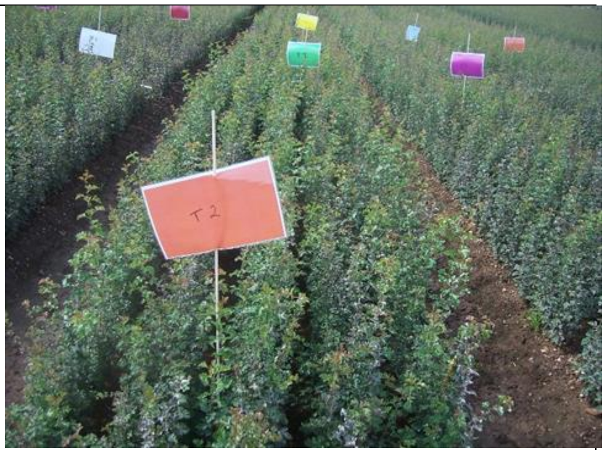


Figure 2. fungicide + sulph/PotB

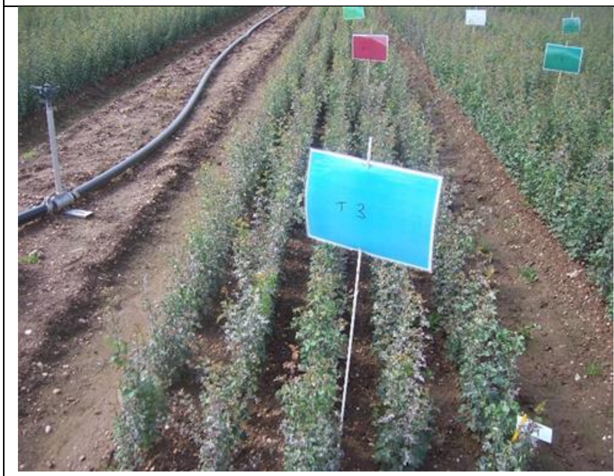


Figure 3. standard fungicide

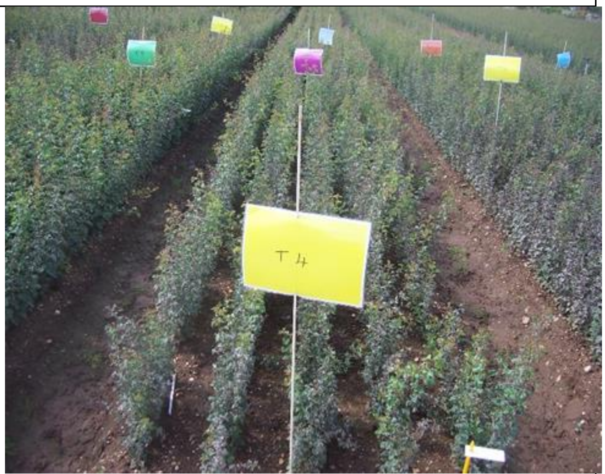


Figure 4. Suph/PotB

Figure 5. 77 programme

Figure 6. 25a programme

Figure 7. 10 programme

Figure 8. 105* managed programme

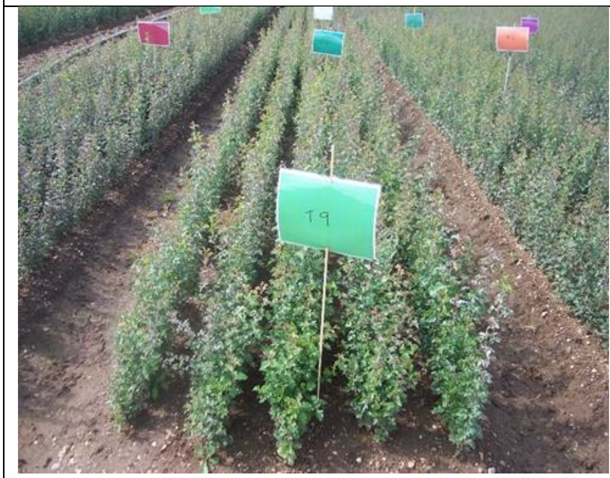


Figure 9. 178* managed programme