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Project number:	CP 124
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Work package leader:	Dr Erika Wedgwood
Report:	Annual report, December 2014
Previous report:	None
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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.

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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.

Erika Wedgwood
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Signature Date 12 December 2014

Report authorised by:

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Signature Date 16 December, 2014

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Growers Summary

Headline

- Three novel fungicides and four biofungicide/alternative products showed efficacy against powdery mildew on hawthorn seedlings.
- The fungicide 77 gave better control and fungicides 10 and 39 showed equivalent control of powdery mildew to the standard treatment Signum up to three weeks after the final application.
- Biofungicide/alternative treatments 47, 105, 11 and Serenade ASO (*Bacillus subtilis* strain QST 713) + Silwet L-77 gave suppression of powdery mildew at low disease pressure.

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. 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 such as hawthorn are affected virtually every year 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 to 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.

A range of fungicides have label recommendations for control of powdery mildew in ornamental crops. Some being more effective as protectants while others have curative (usually for a few days only) or eradicant activity. However resistance development is a concern when the same fungicide or products from the same fungicide group are used repeatedly. 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.

Several biofungicides have been shown to have activity against powdery mildew species and some warrant 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 mode of action groups, whilst known to have good activity against

powdery mildew, have not been tested on ornamental crops and this needs to be evaluated as part of the project. The specific objectives therefore are:

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.

Summary of the work and main conclusions

The trial was carried out on field-grown rows of first-year hawthorn seedlings at a nursery (J & A Growers Ltd) that became naturally infected with powdery mildew. 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.

Four conventional chemical fungicides (three novel 77, 10 and 39 and a grower standard Signum (boscalid and pyraclostrobin) and four biological/alternative products (47, 105, 11 and Serenade ASO + Silwet L-77) were applied over a period of eight weeks to a randomised block design with six fold replication (Table 1). The conventional chemical pesticides were sprayed four times at fortnightly intervals and the biological/alternative products were applied eight times at one week intervals, all at 400 L water/ha. Each plot consisted of a sprayed 5-row x 4 m bed length of seedlings, with the central 2 m of row lengths assessed. Untreated plots were sprayed with water at the same water volume (400 L/ha).

Table 1. Treatment list

MOPS code number	Active ingredient(s)	Use/Action
1. Untreated	Tap water	-
2. Signum	boscalid + pyraclostrobin 26.7:6.7 w/w	Preventative and systemic. Powdery mildew on protected and outdoor ornamentals (EAMU 2141 of 2012)
3. 77	Not disclosed	Preventative, systemic, and Curative
4. 10	Not disclosed	Preventative
5. 39	Not disclosed	Preventative and Systemic
6. 47	Not disclosed	Stimulates plant defence mechanisms
7. 105	Not disclosed	Stimulates plant defence mechanisms
8. 11	Not disclosed	Preventative
9. Serenade ASO + Silwet L-77	*Bacillus subtilis* strain QST 713+ 80% w/w trisiloxane	Preventative

	organosilicone copolymers	

Applications started on 30th May 2014 at the two true leaf stage prior to visible infection being observed. Assessments of % powdery mildew severity and phytotoxicity were made weekly, and continued one, two, three and four weeks after the final spray to determine contact and persistence attributes and any effects on plant vigour.

Powdery mildew was first observed in the crop on 26th June 2014, and levels of infection increased rapidly in July, peaking on 8 August at 82% cover in the untreated control (28 days after the final application day in treated plots) (Figure 1). At the assessments carried out prior to the completion of treatment applications (17th July), and in the week after completion, all treatments showed significantly lower powdery mildew severity than the untreated control, with treatment 77 showing better control than Signum and the other two novel fungicides (10 and 39) showing comparable levels of powdery mildew control to Signum. The four biological/alternative products showed good efficacy at low disease levels. Treatments 47 and Serenade ASO + Silwet L-77 still had significantly less powdery mildew than the untreated by the 8 August (21 days after their final application) and overall performed better than 105 and 11 (Figure 1). One week after the final biological/alternative treatment application (three weeks after final conventional chemical fungicide treatment), two novel fungicides showed equivalent control, and treatment 77 showed significantly better control than the standard Signum indicating lasting preventative action (Figure 2). By mid-August the whole-plot assessment showed all treatments had similar levels of powdery mildew severity compared with the untreated control. However an assessment carried out on new growth on the 22nd August demonstrated that the four fungicide treatments (in particular 77 and 39) appeared to show systemic preventative and or curative activity that had significantly reduced levels of powdery mildew on new growth.

No phytotoxicity was observed with any of the treatments. Crop vigour was suppressed by the level of powdery mildew, therefore plots treated with the most effective fungicides showed greatest vigour (Figure 3).

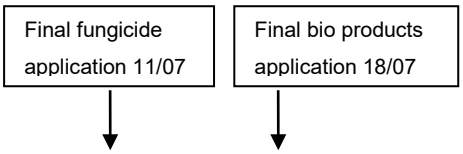

Figure 1. Powdery mildew progression (% cover) during July and August 2014. Serenade + = Serenade ASO + Silwett wetter

Figure 2. % Powdery mildew cover at 01.08.14 assessment two weeks after final treatment application. Letters show significant difference at the 95% confidence level. Serenade + = Serenade ASO + Silwett wetter.

Figure 3. Vigour scores taken on 15.8.14 four weeks after final treatment applications. 1 – 10 scale: 1 = very poor vigour, 10 = excellent vigour. Letters show significant difference at the 95% confidence level. Serenade + = Serenade ASO + Silwett wetter

Novel fungicides 10, 39 and particularly 77 have shown good efficacy during and up to three weeks after treatment, reducing levels of mildew infection by over 50% compared with no treatment. All four biological/alternative products showed suppression of low level mildew infection demonstrating their potential place in programs, and in helping to avoid the development of resistance. Of these treatments 47 (a plant defence mechanism stimulant) and Serenade ASO + Silwet L-77 appeared slightly more effective than 11 and 105.

Action Point

- The most successful of the treatments identified within this project will be taken forward and combined into treatment programs to be tested on hawthorn in 2015

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.

Numerous conventional fungicides have label recommendations for control of powdery mildew in ornamental crops. Often products are first registered for use on cereals but gain wider crop authorisations over time. Some fungicides are more effective as protectants while others 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).

Robust information is required on the relative efficacy and crop safety of new fungicides and biofungicides for control of powdery mildew pathogens on ornamentals. 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. A few biofungicides have been shown to have activity against powdery mildew species and some warrant 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, are not necessarily safe to use on all ornamental crops and this needs to be evaluated as part of the project.

Efficacy of fungicides against powdery mildew species was reviewed in 2010 in AHDB Horticulture project HNS 156. This summarised worldwide knowledge on the activity and attributes of fungicides used for control of powdery mildew diseases on ornamentals including: physical mode of action (protectant, curative, and eradicant), chemical mode of action (fungicide group), systemic activity, efficacy (mean results of 38 experiments between 1998 and 2005). This review along with results from more recent research on powdery mildew control using novel and conventional fungicides in edible crops under the SCEPTRE project (CP 77) was used as a basis to inform decisions on fungicide testing in this project, with the specific objectives being:

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

Materials and methods

The trial site was located in a commercial hawthorn crop using a standard commercial stock which is susceptible to powdery mildew. Plot size was 4 m long with 5 rows (1.5 m wide bed). The outer metre of each plot formed a discard. There were five rows 25 cm apart and nine beds all flanked by a bed either side with sprinkler heads on uprights at 18 m spacing with heads diagonally opposite across the beds. Irrigation was provided to the crop five times during the season (14 mm each time).

The experiments compared conventional chemical fungicides (and products with fungicide-like activity) and biofungicide (microbial or chemical) products within a fully randomised block design with six fold replication. The results were examined as a fully randomised design to allow comparison between conventional and biological treatments. A commercial industry standard fungicide (Signum, containing boscalid and pyraclostrobin) and a water control were included in the set of programmes for comparison. Analysis was carried out by analysis of variance (ANOVA).

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)
Glasshouse* or Field	Field
Date of planting/potting	17 April 2014 seed sown
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 1.5 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

Biological products were applied every 7 days and conventional products every 14 days. For the purposes of this project treatment 6 (a plant defence stimulant) is included as a biological product, together with 105, 11 and Serenade ASO + Silwet L-77. Normal rate of Serenade ASO without wetter would be a little higher than actually used because a wetter was requested to be included by the manufacturer and with this a lower rate was agreed. Rates of all treatments were agreed with the agrochemical company representatives.

Table 2. Detail of products tested

MOPS code number	Active ingredient(s)	Manufacturer	Batch number	% a.i	Formulation type
1. Untreated	tap water	n.a.	n.a.	n.a.	n.a.
2. Signum	boscalid + pyraclostrobin	BASF	12000154 12000154	26.7 % + 6.7%	WG
3. 77	fluopyram +	Bayer Crop	Not Known EV57001784	21.4% +	S

MOPS code number	Active ingredient(s)	Manufacturer	Batch number	% a.i	Formulation type
	trifloxystrobin	Science		21.4%	
4. 10	isopyrazam (IZM)	Syngenta	PE2453/SMO1G002 PE2453/SMO2G009	L	
5. 39	fluxapyroxad	BASF plc	not known 202105	6%	EC
6. 47	acibenzolar-S-methyl	Syngenta	PE2195/SMO2E092		WG
7. 105	*Reynoutria sachalinensis* extract	Syngenta	PE3161/POR2L21202 PE3161/POR2L21202	5%	SC
8. 11	*Ampelomyces quisqualis*, strain M-10	CBC Europe/Belchim (sold by Fargro)	15518		WG
9. Serenade ASO	*Bacillus subtilis* QST713 + *wetter*	Bayer CropScience	EZU1315602 97901 + not known	13.96 g/L	SC

***** ADAS Rosemaund pesticide store database batch identification number. Where two numbers are given this was because a second delivery of chemicals was received to use for the extension of the spray programme after the first four weeks.

Table 3. Treatments

Product name or MOPS code number	Application timing	Dosage rate of named products	Spray volume (L/ha)
1. Untreated	A1,A2,A3,A4,A5,A6,A7,A8	n.a.	400 L/ha
2. Signum	A1,A3,A5,A7	1.35 L/ha	400 L/ha
3. 77	A1,A3,A5,A7	0.8 L/ha	400 L/ha
4. 10	A1,A3,A5,A7	1.0 L/ha	400 L/ha
5. 39	A1,A3,A5,A7	0.3 L/ha	400 L/ha

6. 47	A1,A2,A3,A4,A5,A6,A7,A8	0.025 kg/ha for A1 & A2 then 0.05 kg/ha	400 L/ha
7. 105	A1,A2,A3,A4,A5,A6,A7,A8	2.5 L/ha	400 L/ha
8. 11	A1,A2,A3,A4,A5,A6,A7,A8	0.07 kg/ha	400 L/ha
9. Serenade ASO + Silwet L-77	A1,A2,A3,A4,A5,A6,A7,A8	8 L/ha + 0.2 L/ha	400 L/ha

Application timing	
A1	30.05.14 - 2nd leaf
A2	06.06.14
A3	13.06.14
A4	20.06.14
A5	26.06.14
A6	04.07.14
A7	11.07.14
A8	18.07.14

Application dates refer to the biological products applied weekly, chemical products applied fortnightly

Table 4. Application details

Application No.	**A1**	**A2**	**A3**	**A4**
Application date	30.05.2014	06.06.2014	13.06.2014	20.06.2014
Time of day (24 h)	8.15 – 11.15	8.50 – 9.30	10.30 -12.00	15.45 – 16.45
Application method	Air-assisted back-pack sprayer	Air-assisted back-pack sprayer	Air-assisted back-pack sprayer	Air-assisted back-pack sprayer
Temperature of air during application period (°C)	14.8 – 17.1	15.9 – 16.1	19.1 - 20.7	21.6 – 22.1
Relative humidity during application period (%)	80.1 – 80.2	45.1 - 46.0	45.6 – 45.8	37.1 – 37.2
Cloud cover (%)	cloudy	50%	20%	50%

Crop growth stage	2 leaf 50 – 100 mm tall	4 – 6 leaf 50 – 150 mm tall	8 leaf 120 – 150 mm tall	6 – 8 leaf 200 mm tall
Crop comments	Dry leaves	Dry leaves	Dry leaves	Dry leaves

Application No.	**A5**	**A6**	**A7**	**A8**
Application date	26.06.2014	04.07.2014	11.07.2014	18.07.2014
Time of day (24 h)	14.05 – 15.20	10.30 -11.00	9.30 - 10.45	16.00 -16.50
Application method	Air-assisted back-pack sprayer	Air-assisted back-pack sprayer	Air-assisted back-pack sprayer	Air-assisted back-pack sprayer
Temperature of air during application period (°C)	20.6 – 20.8	21.1 – 22.2	22.1 – 22.3	26.0 – 26.0
Relative humidity during application period (%)	46.9 – 47.1	59.1 - 61.2	48.2 – 49.1	53.0 – 53.0
Cloud cover (%)	75	50	50 - 80	30
Crop growth stage	8 leaf 150 mm tall	8 – 9 leaf 150 mm tall	10- 12 leaf 200 mm tall	12 – 16 leaf
Crop comments	Dry leaves	Dry leaves	Dry leaves	Dry leaves
Other*:				

*Includes soil temperature and moisture details where relevant.

Air-assisted backpack RM11/207 operating at 2 bar with 1 m spray boom width for A1, but thereafter 1.5 m (nozzles 0.5 m spacing). Nozzle 03-F110, except at A8 over dense crop 04 F110.

Target pest(s)

Table 5. Target pest

Common name	Scientific Name	Infection level pre-application
Powdery mildew	*Podosphaera clandestina*	Zero (present in some plots

		after A4)

Natural infection, no inoculation given.

Assessments

Assessments were carried out on the central 2m length of each plot comprising approximately 100 closely spaced hawthorn seedlings. The proportion of the total leaf area with powdery mildew cover across these plants was assessed until mid-August. At the final assessment the % of leaf area covered by powdery mildew along the plot was recorded separately on the older, lower, layer of leaves and on the younger, higher, leaves as differences had become apparent.

Table 6. Assessments

Assess-ment Number	Date	Growth stage	Assessment timing relative to last application	Assessment type(s)
Plots were monitored weekly for disease and phytotoxicity prior to each subsequent treatment application from 30/05/14, no phytotoxicity was observed and disease did not develop till 26/06/14 after 4 applications, assessments commenced at this time.				
1	26/06/14	6-8 Leaves	7 days after A4	% disease cover (severity) per plot
2	04/07/14	6-10 leaves	7 days after A5	% disease cover (severity) per plot
3	11/07/14	8-12 leaves	7 days after A6	% disease cover (severity) per plot
4	01/08/14	12-30 leaves	14 days after A8	% disease cover (severity) per plot
5	08/08/14	15-40 leaves	21 days after A8	% disease cover (severity) per plot
6	15/08/14	15-50 leaves	28 days after A8	% disease cover (severity) per plot
7	22/08/14	15-50 leaves	35 days after A8	% disease cover (severity) per plot and crop vigour (1-10 scale)

Results

Control of powdery mildew

No powdery mildew was observed prior to 26 June 2014. It was then seen at very low levels in four plots; 30 and 51 (both untreated), plot 22 (treatment 8) and plot 45 (treatment 6) on this date.

Infection increased over the next two weeks to nearly 10 % powdery mildew cover in the untreated control (Table 7.1). All treatments significantly reduced levels of powdery mildew compared with the untreated control at this stage. The final biological/alternative treatment application was made on 18 July, 7 days after the levels of powdery mildew had increased to 10.5 % in the untreated control. By the assessment 14 days later on 1 August the powdery mildew severity had increased greatly in the untreated plots to a mean 74.2 % of the total leaf area. At this time all but treatment 105 continued to show significant efficacy, and treatment 77, with 9.2 % powdery mildew, showed better efficacy than Signum, with 23.3 %. Plots of the other two novel conventional chemical fungicides (10 and 39) also had less than a quarter of total leaf area covered by powdery mildew.

Differences were less obvious 21 days after the final applications, with all treatments showing on average at least 50 % powdery mildew cover. Despite this high level of infection, all treatments with the exception of 105 and 11 continued to achieve equivalent control compared with the industry standard Signum. By four weeks after the final application none of the treatments showed a reduction in powdery mildew compared with the untreated control. At the final assessment, rather than assess whole plants, the data collection was split between lower and upper tissues. With the assessment of lower tissues (i.e. those which would have received the treatment applications) levels of mildew were variable but no real trends could be identified. With the upper tissues / new growth, treatments 77, 10 and 39 showed less than 45 % cover compared with 73 % in the untreated control. This was equivalent to the industry standard Signum, suggesting some potential systemic protection from these treatments (Table 7.2).

Table 7.1 Effect of treatments on mean % powdery mildew cover on whole plants assessed on the dates shown just before each fungicide application (A5 to A8)

Product name or MOPS code	**26.06.2014**	**04.07.2014**	**11.07.2014**	**15.07.2014 (2 days pre-A8)**
1. Untreated	1.00	6.33	10.50	Not recorded as mildew had not progressed beyond that recorded on 11.07.2014
2. Signum	0.00	0.33	0.50	
3. 77	0.00	0.00	0.00	
4. 10	0.00	0.00	0.00	
5. 39	0.00	0.00	0.00	
6. 47	0.17	1.33	3.67	

7. 105	0.00	1.33	4.50	
8. 11	0.33	1.17	4.50	
9. Serenade ASO + Silwet L-77	0.00	1.17	2.83	
F value (40df)	**NS**	**<0.001**	**<0.001**	n.a.
LSD	**0.717**	**1.970**	**3.255**	n.a.

Table 7.2 Effect of treatments on mean % powdery mildew cover assessed on the dates shown up until five weeks after final fungicide application (A8) on 17th July. The final assessment separated new (top third of plant) and older lower down hawthorn growth.

Product name or MOPS code	**01.08.14**	**08.08.14**	**15.08.14**	**22.08.14 lower**	**22.08.14 upper**
1. Untreated	74.17	81.67	74.17	70.00	73.33
2. Signum	23.33	52.50	63.33	73.33	45.00
3. 77	9.17	51.67	69.17	76.67	36.67
4. 10	22.50	60.00	69.17	78.33	43.33
5. 39	16.67	55.00	71.67	86.67	33.33
6. 47	45.83	60.83	60.83	73.33	61.67
7. 105	64.17	70.83	65.00	61.67	61.67
8. 11	60.83	70.83	66.67	66.67	68.33
9. Serenade ASO +Silwet L-77	49.17	64.17	65.00	75.00	66.67
F value (40 df)	**<0.001**	**<0.001**	**NS**	**0.001**	**<0.001**
LSD	**11.650**	**13.770**	**10.990**	**10.02**	**11.51**

Crop vigour

The crop was quite variable between beds. Crop vigour was moderate in general, suppressed due to the effects of powdery mildew infection. Treatment 10 and Signum showed significantly better vigour compared with the untreated with plants in these treatments being taller and showing more new growth (Table 8).

Table 8. Effect of treatments on crop vigour four weeks after final application, scored on a one to nine scale where one is very poor vigour and nine is excellent vigour.

Product name or MOPS code	Crop vigour 15.08.14
1. Untreated	5.08
2. Signum	7.17
3. 77	6.33
4. 10	6.50
5. 39	6.25
6. 47	6.08
7. 105	6.00
8. 11	5.50
9. Serenade ASO + Silwet L-77	5.83
F value (40 df)	**0.044**
LSD	**1.138**

Crop damage

No phytotoxicity was observed at any assessment

Formulations

Problems associated with nozzle blockages or uneven spray pattern during mixing and application were not encountered for any of the products under test.

Effect on non-target

No effects on non-target organisms were observed.

Discussion

Powdery mildew was first observed in the crop on 26th June 2014, and levels of infection increased rapidly in July, peaking in early August at 82 % cover in the untreated control. At the assessments carried out prior to the completion of treatment applications (15th July) all treatments showed significantly less powdery mildew % cover than the untreated control, with treatments 77, 10 and 39 showing equivalent levels of mildew to Signum the fungicide standard. The four biological/alternative products showed good efficacy at low disease levels but were unable to maintain control when applications ceased. Treatment 47 and Serenade ASO + Silwet L-77 performed slightly better than 105 and 11. Two weeks after the final biological/alternative treatment application (three weeks after final fungicide treatment) novel fungicides 10 and 39 showed equivalent control and treatment 77 showed significantly better efficacy than the standard treatment Signum, showing lasting preventative action. By mid-August (five weeks after final application) all plots showed similar levels of % powdery mildew cover compared with the untreated control. However an assessment carried out on new growth on the 22nd August appeared to demonstrate that the four conventional chemical fungicide treatments (in particular 77 and 39) had systemic activity, as less of the area of unsprayed new leaf growth had powdery mildew compared with that in the biopesticide plots.

Commercially the aim would be to achieve plants with no powdery mildew, but 5 - 10 % would be considered acceptable. Whilst treatments were being applied (and at lower disease pressure up till 17th July) this was achieved by all treatments and up to three weeks after by treatment 77. Treatment applications in this trial ceased in mid-July, six to seven weeks earlier than perhaps would be done commercially and by mid-August commercially acceptable levels of powdery mildew control had not been maintained in any treatment. Once chemical treatments stopped working there was a big increase in powdery mildew across all plots; this can be a feature of small plot work as inoculum spreads from the untreated and lower efficacy treatment plots. The 81% severity in the untreated in early August would be a strong challenge for all products. It should be noted that interpretation of the later observations is needed if seeking to extrapolate to the situation in a commercial crop.

No phytotoxicity was observed with any of the treatments. Crop vigour was suppressed by the level of powdery mildew, therefore plots treated with the most effective fungicides showed greatest vigour.

Conclusions

Novel fungicides 10, 39 and particularly 77 have shown good efficacy during an 8 week treatment program and up to three weeks after completion of this program, reducing levels of mildew infection by over 50% compared with no treatment. Infection pressure was high in the period after spray applications ceased. All four biological/alternative products showed suppression of mildew infection at low levels of disease when applied weekly demonstrating their potential for use in crop protection programs, and in helping with the avoidance of resistance development. Of these treatments 47 (a plant defence mechanism stimulant) and Serenade ASO + Silwet L-77 appeared slightly more effective than 11 and 105. Combinations of the most promising of these products will be tested in combined resistance management programs together with approved products in 2015.

References

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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 be claimed in respect of this study.

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)	Efficacy evaluation of plant protection products – Phytotoxicity assessment, will be used to guide experimental methods.	PP 1/135(3)
PP 1/181(3)	Conduct and reporting of efficacy evaluation trials including GEP	PP 1/181(3)
PP1/196 (2)	Efficacy evaluation of fungicides – Fungi on woody ornamentals	PP1/196 (2)

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

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 website

Long-term averages from Birmingham airport 25 miles away			
Month/period	**Min temp (ºC)**	**Max temp (ºC)**	**Rainfall (days experiencing >1mm)**
May	6.0	15.3	11
June	9.2	18.8	9
July	11.1	20.6	8
August	10.8	20.1	10

Source: http://www.wellesbourneairfield.com/daily.htm and http://www.yr.no/place/United_Kingdom/England/Birmingham_Airport/statistics.html

Average conditions during the trial:

Month/period	**Av temp (ºC)**	**Min temp (ºC)**	**Max temp (ºC)**	**Av RH (%)**	**Rainfall (mm)**
May	12.7	0.3	24.7	81	68
June	15.8	5.7	24.6	79	68
July	18.7	8.8	28.6	75	39
August	15.5	5.6	24.3	78	63

Weather at treatment application and charts of in-field data logger recording of temperature and relative humidity shown as daily means:

Month/period	**Temp at application (ºC)**	**RH %**	**Rainfall (mm)**
30.05.2014	14.8	80.1	0
06.06.2014	15.9	45.1	0
13.06.2014	19.1	45.6	0
20.06.2014	21.6	37.2	0
26.06.2014	20.6	46.9	0

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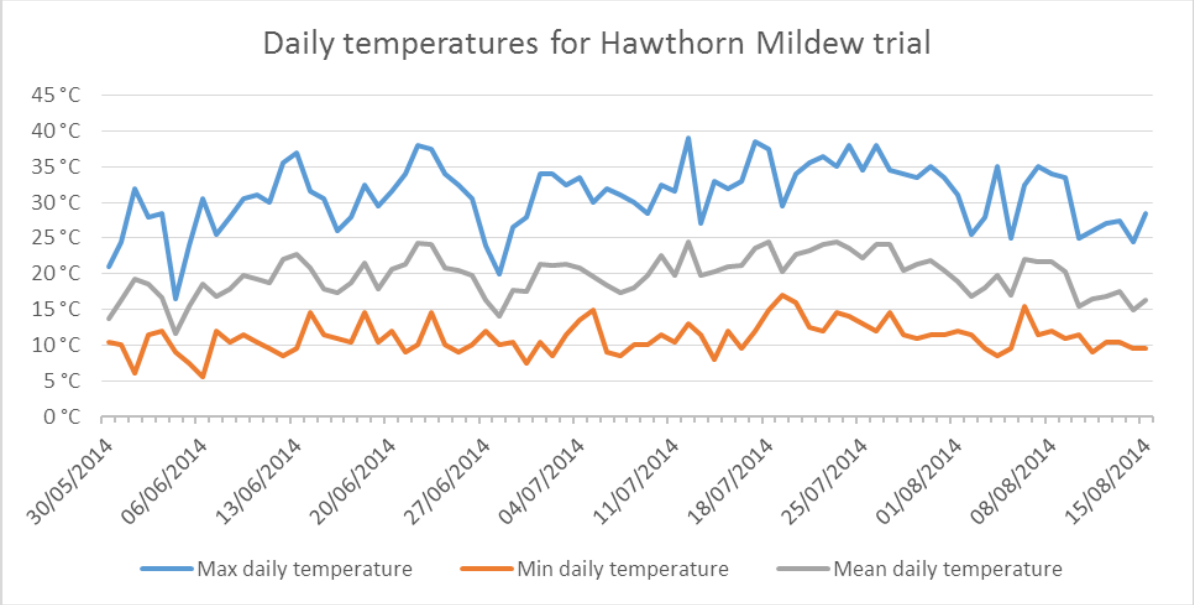
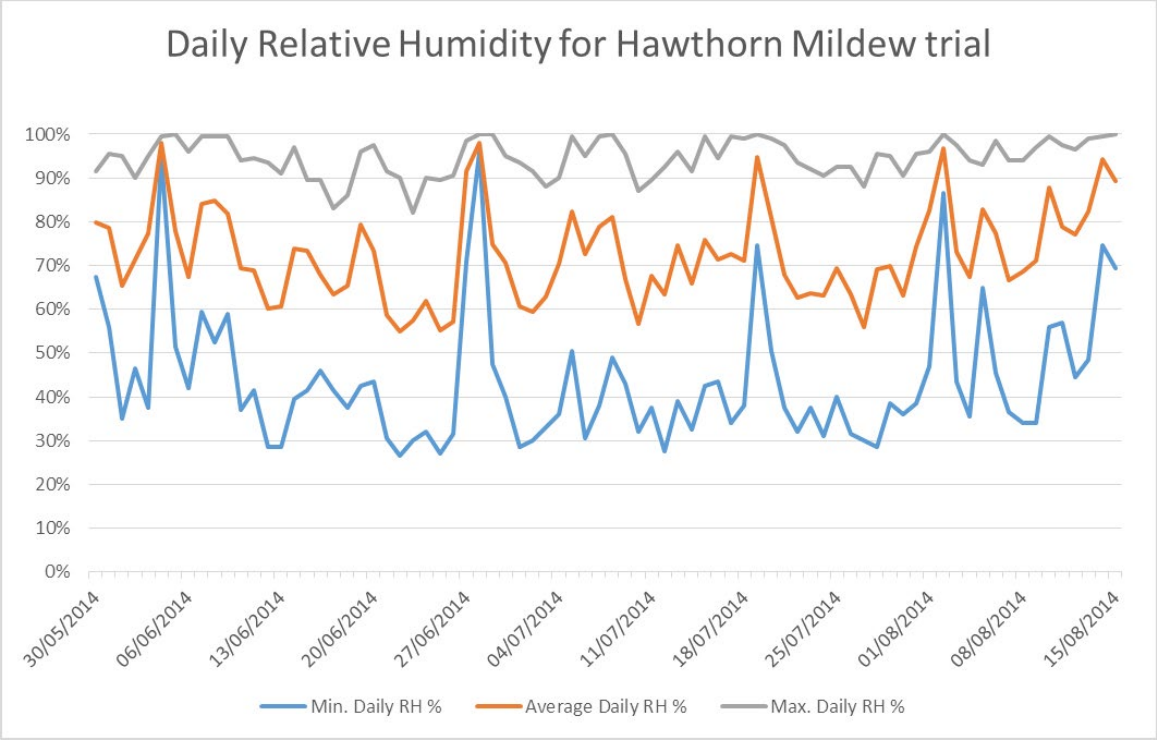
Month/period	Temp at application (°C)	RH %	Rainfall (mm)
04.07.2014	21.1	59.1	0
11.07.2014	22.1	48.2	0
18.07.2014	26.0	53.0	0





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Appendix C – Agronomic details

Growing system

Crop	Cultivar	Planting/sowing date	Row width (m) or pot spacing
Hawthorn	*Crataegus monogyna* – Italian Provenance	17/04/2014	250 mm, 271 viable seed per metre

Previous cropping (field crops only)

Year	Crop
2013	*Quercus robur*
2012	Fallow
2011	*Prunus spinosa*
2010	*Fraxinus excelsior*
2009	*Salix capraea*

Cultivations (field crops only)

Date	Description	Depth
Pre drilling	Sub soil Plough Flat lift bed formed	355 mm (14 inches)

Other pesticides - active ingredient(s) / fertiliser(s) applied to the trial area

Date	Product	Rate	Unit
Basal dressing – pre drilling	Hydro Complex partner (Yara)	500	Kg/ha
May, June & July – Top dressing	Calcium Nitrate (Yara)	150	Kg/ha
29/04/2014	Pre emergence herbicide Centium Stomp Aqua	150 2.9	ml/ha L/ha
28/05/2014	Glyphosate inter row spray	2.5	L/ha
27/06/2014	Glyphosate inter row spray	2.5	L/ha

Details of irrigation regime (field crops)

Crop irrigated 5 times during the season, receiving 14mm each time – 2 hours at 7mm per hour.

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Appendix D – Trial layout

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

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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

Certification Number
ORETO 339

Signature

Authorised signatory

HSE
Chemicals Regulation Directorate

Department of Agriculture and Rural Development

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Appendix F – Photographs

Powdery mildew on hawthorn at J&A Growers 21 days after the last biopesticide application on 18.07.14. Last conventional chemical applications on 11.07.14. Mean of six replicates 82 % leaf area with powdery mildew in the untreated and 53 % in the standard, Signum.

Figure 1. Untreated control - 08.08.14

Figure 2. Untreated control - 08.08.14

Figure 3. Signum – 08.08.14

Figure 4. Signum – 08.08.14

Figure 5. Treatment 77 – 08.08.14

Figure 6. Treatment 77 – 08.08.14

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Figure 7. Treatment 10 – 08.08.14	Figure 8. Treatment 10 – 08.08.14
	
Figure 9. Treatment 39 – 08.08.14	Figure 10. Treatment 39 – 08.08.14
	
Figure 11. Treatment 47 - 08.08.14	Figure 12. Treatment 47 - 08.08.14

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Figure 13. Treatment 105 - 08.08.14	Figure 14. Treatment 105 - 08.08.14
	
Figure 15. Treatment 11 - 08.08.14	Figure 16. Treatment 11 - 08.08.14
	
Figure 17. Serenade ASO + Silwet L-77 - 08.08.14	Figure 16. Serenade ASO + Silwet L-77 - 08.08.14

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