Project title:	Managing ornamental plants sustainably (MOPS)
Project number:	CP 124
Work package title:	Assessment of the efficacy of several conventional fungicides and biofungicides against powdery mildew in Aster
Work package leader:	Dr G M McPherson MBPR (Hort)
Report:	Final report, December 2016
Previous report:	None
Key staff:	Adam Ormerod – Trials Manager
Location of work:	Stockbridge Technology Centre
Date work commenced:	6th July 2016
Date work completed (or expected completion date):	18th December 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.

[Name] Adam Ormerod
[Position] Project Leader
[Organisation] STCRF

Signature ..... Date .....

Report authorised by:

[Name] Dr Martin McPherson MBPR (Hort.)
[Position] Science Director
[Organisation] STCRF

Signature ..... Date .....

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Growers Summary

Headline

- In 2016, several products, including conventional fungicides and biopesticides provided effective suppression and/or control of powdery mildew in Aster and a similar level of control could be expected in other ornamental crops, though crop safety would need to be checked assuming the product was authorized for use.
- Some of the integrated programmes devised provided effective disease control but only where the sprays were applied in advance of any visible mildew symptoms.
- A parallel study in 2016 using Ampelomyces quisqualis (in the product AQ10) to explore the possible adaptation of the mycoparasite on particular host crops for maximum efficacy proved inconclusive.

Background and expected deliverables

The HortLINK SCEPTRE programme was very successful in identifying and evaluating novel conventional chemical fungicides and biopesticide products for pest, disease and weed control in edible crops and has proved very valuable in terms of filling gaps in the crop protection armoury as older active substances and products are withdrawn. Whilst this is of some relevance through extrapolation to non-edible crops, including ornamentals, no work was conducted specifically on ornamentals as part of the SCEPTRE programme. The AHDB funded MOPS programme was therefore established in 2014 in response to growers concerns about potential losses of products in the ornamentals sector. Like SCEPTRE it potentially provides a valuable route for the comparative evaluation of important chemical & biologically active substances/products which can then be pursed for registration either by the manufacturers themselves or via AHDB through the active minor uses (EAMU) programme.

In the first year of the project (2014) STC evaluated a range of novel conventional and biological products for the control of rust in both Bellis and Antirrhinum and against powdery mildew in both Aster and Pansy. In the second year (2015) the trials focused on rust in Bellis and powdery mildew in Aster. This year (2016) the focus was on powdery mildew, largely due to the fact that insufficient data was gathered in the 2015 trial.

Such 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 impacting on product quality. 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.

Powdery mildew diseases are usually managed by regular treatment with fungicides. Cultural practices including environmental management, provide partial control, but fungicides are almost invariably necessary for the production of high-quality, saleable plants, especially on particularly susceptible species or cultivars. Some fungicides are more effective as protectants while others have curative/eradicant activity. Resistance can develop when the same fungicide or products from the same fungicide group are used repeatedly on the same crop. Availability of biofungicides on ornamentals could help to reduce development of resistance to conventional fungicides. Some of the existing fungicide mode of action groups are not necessarily safe to use on all ornamental crops and the potential risk of crop damage (phytotoxicity) needs to be evaluated with any new active ingredients as part of the MOPS project.

The replicated trials conducted in year one (2014) delivered very useful information on the efficacy and crop safety of a broad range of novel crop protection products. Further studies in year two (2015) allowed the comparison of additional novel products and also included evaluation of a range of 'prescriptive' and 'managed' disease control programmes incorporating both conventional fungicides and biological products. Whilst very effective control of rust was achieved with some of the straight products and programmes further data on powdery mildew was not obtained due to the poor development of powdery mildew in the designated trial plots. However, this proved interesting nonetheless as the mildew 'infector plants' became heavily colonized by the mycoparasite *Ampelomyces quisqualis* (in AQ10) presumably following use of this product in the 2014 trials . Whilst the product was largely ineffective in controlling or suppressing powdery mildew in aster or pansy in 2014 it appeared to effectively prevent mildew establishment in the 2015 trial. We raised the interesting hypothesis that perhaps the mycoparasite (raised commercially on a totally different host & mildew species) requires an adaptation or acclimatization period on the specific host & mildew species in question for optimum colonization and pathogen suppression. As such, relatively small-scale studies were carried out in 2016 to attempt to determine whether there is a requirement for an 'adaption period' in specific ornamental crops to ensure robust establishment and mildew control by this biopesticide product.

It is important to recognize that whilst the studies conducted help identify potential novel products for use in this sector, their actual approval remains the responsibility of the manufacturers/ marketing agents (on-label approvals) and the AHDB team (minor use or EAMU applications) and the pesticide regulators (CRD) who ultimately authorize products for use in the UK. Even though very promising products have been identified in the work reported it remains very difficult to predict what active substances and products will be supported in the horticultural sector going forward. Whilst every effort is made by AHDB and others to encourage regulatory approval there is no guarantee that specific effective products will be made available for use on either outdoor or protected ornamentals.

Withdrawal from the EU regulatory system through Brexit may have some impact in the longer-term though, at this stage, it is very difficult to predict the outcome of any negotiations and it is probably best to assume that UK pesticide regulations will continue to be guided by EU rules for some time.

Summary of the work and main conclusions

In the Autumn of 2016 replicated glasshouse trials were carried out at Stockbridge Technology Centre to assess the effectiveness of a range of experimental biological and conventional fungicides against Aster powdery mildew. In addition to a comparison of individual novel treatments with single products a number of prescriptive and managed programmes were included using a selection of the products found to be most effective in earlier studies.

Powdery Mildew – Aster 'Cassandra' was selected as a known disease susceptible cultivar for use following discussion with Lyndon Mason, Cut Flower Centre. The Aster crop was infected at the beginning of the trial following the introduction of infector plants. This allowed the disease to spread evenly throughout the trial yielding promising results similar to those from year 1 for conventional and biological products alike. Several prescriptive and managed programmes were evaluated some of which proved to be very successful.

Ten individual fungicides and biofungicides were evaluated alone together (including the standard Signum) with 4 managed and prescriptive programmes together with an untreated control for comparison. Of the individual fungicide product 77 (SDHI+QoI, FRAC codes 7 & 11) was as effective, if not slightly more so, than the standard product Signum (SDHI+QoI, FRAC codes 7 & 11). Takumi (phenyl-acetamide, FRAC code U6), product 10 (SDHI, FRAC code 7) and Product 211 (SDHI, FRAC code 7) provided moderate-good suppression of the disease. Product 156 (SBI: Class III, FRAC code 17) was largely ineffective against powdery mildew in this study.

The two prescriptive programmes consisted of regular or pre-scheduled bi-monthly applications of products, irrespective of visible disease symptoms. Programme 1 used biological products at application timings A1 and A5 and conventional products at A3 and A7. Programme 3 used conventional products at all application timings (see Table 3 for more detail on the actual application timings described here). The two managed programmes consisted of an initial preventative treatment; the crop then monitored and further applications only applied when visible signs of disease appeared. Programme 2 consisted of applications of a biological product (AQ10) at application timings A1 and A2 only, unless the disease continued to develop. In this case, a further treatment was applied at application timing A5 using a different biopesticide (105). Programme 4 commenced with a single application of a conventional product at A1 with a further application using a different mode of action conventional product (156) at A3 as there was some evidence of disease development at this point. Both prescriptive programmes (one with a mixture of biological and conventional products, and one with solely conventional products) had broadly similar (moderate) disease control efficacy at the conclusion of the trial. The managed programme using conventional products only

proved the most successful with exceptionally low disease levels present in the test plots at the conclusion of the trial with only 2 treatment applications being made throughout the trial duration. The managed programme consisting of biological products only proved to be significantly less effective and had moderate- high disease levels at the conclusion of the trial.

It is clear from this study that effective control of powdery mildew can be achieved where early protective treatment applications are made with products with strong efficacy, prior to appearance of visible symptoms in the crop. Whilst the biopesticides trialled were, in general, less effective those that provided moderate suppression of the disease could be very useful in an integrated disease management programme to extend the interval between conventional spray applications. They have the added benefit that they have a completely different mode of action so should go some way to minimizing any risk of resistance developing in the pathogen population from repeated frequent use of the same mode of action fungicides.

Action Points

- Several novel mode of action fungicides were effective and AHDB should pursue one or more of these products for minor use approval
- One biological product (105 : plant extract) provided a good suppression of powdery mildew and AHDB should work with the manufacturer to seek approval for use on ornamental crops to help with disease control, aid pesticide minimisation and to counter resistance development in the pathogen population
- The study provided evidence to show that spray programmes integrating both conventional products with biopesticides can retain effective control of powdery mildew and growers should be encouraged to adopt such strategies rather than relying on conventional products, assuming regulatory authorisation is forthcoming to allow this approach to be adopted.
- The study clearly demonstrated that early, pre-symptomatic, treatment provided the most effective control of powdery mildew and growers are encouraged to consider this when devising their spray programmes.
- As there is a moderate to high risk of resistance development through repeated use of the same mode of action fungicides, growers need to make themselves familiar with FRAC codes and ‘ring the changes’ to avoid repeated use of the same mode of action products.
- No phytotoxicity was observed in this trial, it is advisable for growers to test-treat a few plants of specific species & cultivars when using novel Approved products for the first time.
- Further work is required with microbial biopesticides to ensure compatibility with novel fungicides and to further refine the optimum conditions for their application & efficacy in a range of ornamental crops.

The additional study designed to explore the hypothesis on acclimatised strain *Ampelomyces quisqualis*, was inconclusive and this was considered, in part at least, to be due to the late onset of the pathogen in the trial crop which can't immediately be explained. Work in this area is difficult though due to the need to retain isolates of powdery mildew free from *Ampelomyces* colonization and if further work is proposed it would be necessary to put in place improved facilities to secure, manage and maintain discrete cultures of the obligate pathogen +/- isolates of *A. quisqualis* that have been acclimatised/adapted on the specific host over a minimum 12 month period.

SCIENCE SECTION

Introduction

A replicated efficacy trial was conducted in Autumn 2016 to evaluate the performance of 4 biological products[1] (biofungicides) and 5 conventional pesticides (fungicides) for the control of Aster powdery mildew (*Golovinomyces asterum var. asterum syn. Erisyphe chicoracearum)*. The results obtained were compared with an untreated control and a standard approved treatment (Signum) applied at recommended rates.

Seven applications of the biopesticides and four applications of the conventional fungicides were made in total. The biopesticides were applied at 7 day intervals whereas the conventional products were applied at 14 day intervals. The straight treatments evaluated are listed in Table 2a. The integrated prescriptive and managed spray programmes are listed in Table 2b. Details of the timings and rates of application and climate data are included in Tables 3 and 4. Data was inputted into ARM 9 (Agricultural Research Manager) software and data tables and statistical analysis (ANOVA) generated accordingly.

Materials and methods

Aster 'Cassandra' were sourced as plug plants from the Cut Flower Centre and transplanted into ten cm pots and grown-on. They were 'stopped' twice prior to the start of the trial to encourage shoot development and leafy growth.

Infector plants for the Aster powdery mildew were generated from inoculum present on untreated plants overwintered from the 2015 trial. They were directly inoculated with infected leaf material with heavy sporulation and maintained in a climate conducive to disease progression (dry leaf surfaces and high humidity) for 3 weeks prior to the commencement of the trial. Infector plants were checked regularly to monitor for the presence of *Ampelomyces* prior to their introduction to the trial area to minimize the risk of accidental introduction of the mycoparasite. All plants showed visible powdery mildew symptoms and absence of *A. quisqualis* colonization prior to their introduction.

The trial was commenced at the beginning of September to target autumn weather when optimum conditions for pathogen development (high humidity, moderate temperature) were more likely to occur. The first treatments for powdery mildew control were applied on 08/09/16. Infector plants with powdery mildew were subsequently introduced to the Aster plots on 09/09/16 at one pot/plot to provide a uniform spread of inoculum throughout the trial. The glasshouse floor was subsequently

[1] Note: The term 'biological products' or biopesticides in this report refers to microbial products but also includes SAR inducers and plant extracts

wetted thoroughly in the late afternoon on the following two consecutive days to raise night-time humidity and provide an environment conducive to spore germination and leaf infection. On the 22nd September low levels of *Ampelomyces* were identified on several infector plants and all infector plants were subsequently removed.

During the trial disease severity assessments were carried out on seven separate occasions on the Aster crop (with one assessment prior to introduction of the infector plants to check for any natural colonization by powdery mildew). The details of the timings of these assessments are presented in Table 6.

Site and crop details

Table 1. Test site and plot design information

Test location:	Stockbridge Technology Centre
County	North Yorkshire
Postcode	YO8 3TZ
Soil type/growing medium	Levington M2
Nutrition	Universol Blue (18-11-18 +2.5 MgO + TE)
Crops & Cultivars	Aster ‘ Cassandra’
Glasshouse* or Field	Glasshouse
Date of planting/potting	Aster plugs potted on 7/8/15
Pot size	10cm
Number of plants per plot	12
Trial design (layout in Appendix C)	Randomised block
Number of replicates	6
Plot size w (m), l (m), total area (m²)	0.36m
Method of statistical analysis	ANOVA

*Temperature and relative humidity settings are given in Appendix B

Table 2a. Details of products tested (for Powdery Mildew control)

Treatment	Product	MOPS code number	Active ingredient(s)	Manufacturer	Batch number	% a.i	Formulation type
1	Untreated	-	-	-	-	-	-
2	AQ10	11	*Ampelomyces quisqualis*	Belchim		58% w/w	WG
3	N/D	47	N/D	N/D		50% w/w	WG
4	Serenade (QST713)	178	Bacillus subtilis	Bayer CP		1.34 % w/w	SC
5	N/D	105	N/D	N/D		N.A*	N.A*
6	N/D	77	N/D	N/D		N.A*	N.A*
7	Reflect	10	isopyrazam	Syngenta CP		N.A*	N.A*
8	N/D	211	N/D	N/D		N.A*	N.A*
9	N/D	156	N/D	N/D		N.A*	WG
10	N/D	89	N/D	N/D		50g/l	EW
11	Signum (Standard)	-	Boscalid + Pyraclostrobin	BASF		26.7:6.7% w/w	WG

* - Not Available (Experimental samples – No % a.i information available)

Table 2b. Detail of spray programmes tested (for Powdery mildew control)

Programme No	**A1** **08/09**	**A2** **15/09**	**22/9**	**A3** **29/9**	**A4** **6/10**	**A5** **13/10**	**A6** **20/10**	**A7** **27/10**
Prescriptive Programme 1	AQ10	-	No sprays	77	-	105	_	10
Managed Programme 2	AQ10	AQ10	No sprays	-	-	105 (due to high levels of pm despite mycoparasitism)	-	-
Notes: Managed programme. No more sprays unless mildew appears then consider re-application of AQ10. Microscopy to check for successful mycoparasitism. If not then switch to 77or possibly 105 dependent on severity								
Prescriptive Programme 3	156	-	No sprays	77	-	10	-	89
Managed Programme 4	77	-	No sprays	156	-	No application (still v low levels of pm)	-	-
Notes: Managed programme. No more sprays unless mildew developing. Extend spray interval and use 156, 211 and 89 in sequence if required								

Table 3. Application details for Powdery Mildew treatments

Product name or MOPS code number	Application timing	Dosage rate (product/ha)	Spray volume (L/ha)
Untreated	A1, A2, A3, A4, A5, A6, A7	-	500
11	A1, A2, A3, A4, A5, A6, A7	0.07kg/ha	500
47	A1, A2, A3, A4, A5, A6, A7	0.025kg/ha† (1st 2 sprays) 0.05kg/ha* subsequently	500
178	A1, A3, A5, A7	5-10l/ha	500
105	A1, A3, A5, A7	2.5l/ha	500
77	A1, A3, A5, A7	0.8 l/ha	500
10	A1, A3, A5, A7	1.0 l/ha	500
211	A1, A3, A5, A7	1.0l/ha	500
156	A1, A3, A5, A7	1.2kg/ha	500
89	A1, A3, A5, A7	0.5l/ha	500
Signum (Standard)	A1, A3, A5, A7	1.35kg/ha	500
Programme 1	A1, A3, A5, A7	various	500
Programme 2	A1, A2, A5	various	500
Programme 3	A1, A3, A5, A7	various	500
Programme 4	A1, A3	various	500

Application dates	
A1	08/09/2016 (64 days post-transplant)
A2	15/09/2016
A3	29/09/2016
A4	06/10/2016
A5	13/10/2016
A6	20/10/2016
A7	27/10/2016

Table 4. Application details

Application No.	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**
Application date	8/9/16	15/09/16	29/09/16	06/10/16	13/10/16	20/10/16	27/10/16
Time of day [1]	PM	PM	PM	PM	PM	PM	PM
Application method	Foliar spray	Foliar spray	Foliar spray	Foliar spray	Foliar spray	Foliar spray	Foliar spray
Temperature of air – max/min (°C) [2]	26.4/16.8	30.3/16.3	22.5/14.3	20.6/12.7	16.7/13.2	18.2/12.7	16.6/14.1
Air temperature at application [3]	25.5	28.2	22.5	19.1	16.1	16.5	16.0
Relative humidity (%) [4]	100	53.5	43.6	48.3	77	65	71
Crop growth stage – days post-transplant	64	71	85	92	99	106	113

[1] Applications were conducted between approximately 2pm and 4pm on the dates stated

[2] Air temperatures stated are derived from Priva Integro climate control data

[3] Air temperatures stated are the mean readings between 2pm and 4pm on the days of application derived from Priva Integro climate control data

[4] Relative humidities stated are the mean readings between 2pm and 4pm on the days of application derived from Priva Integro climate control data

Table 5. Target pathogens

Common name	Scientific Name	Infection level pre-application
Aster Powdery Mildew	*Golovinomyces asterum var. asterum (syn. Erisyphe chicoracearum)*	Nil

Infector plants were introduced to the Aster crop on 09/09/16

Table 6. Assessments

Aster Assessment No.	Date	Growth stage (days post-transplant)[2]	Timing of assessment relative to last application	Assessment types
1	05/09/2016	61	3 days Pre A1	Disease severity
2	28/09/2016	84	6 days post A2	Disease severity
3	05/10/2016	91	6 days post A3	Disease severity
4	12/10/2016	98	6 days post A4	Disease severity
5	19/10/2016	105	6 days post A5	Disease severity
6	26/10/2016	112	6 days post A6	Disease severity
7	08/11/2016	125	11 days post A7	Disease severity

[2] Growth stages measured in days post-transplant due to difficulty accurately determining BBCH growth stage due to plants having been 'stopped' twice to encourage leafy growth

Table 7. Assessment scoring criteria

Aster disease severity score	% leaf area infected
0	0
1	1-10%
2	11-25%
3	26-50%
4	51-75%
5	>75%

Results

Table 8 - Effect of treatments on Aster Powdery Mildew

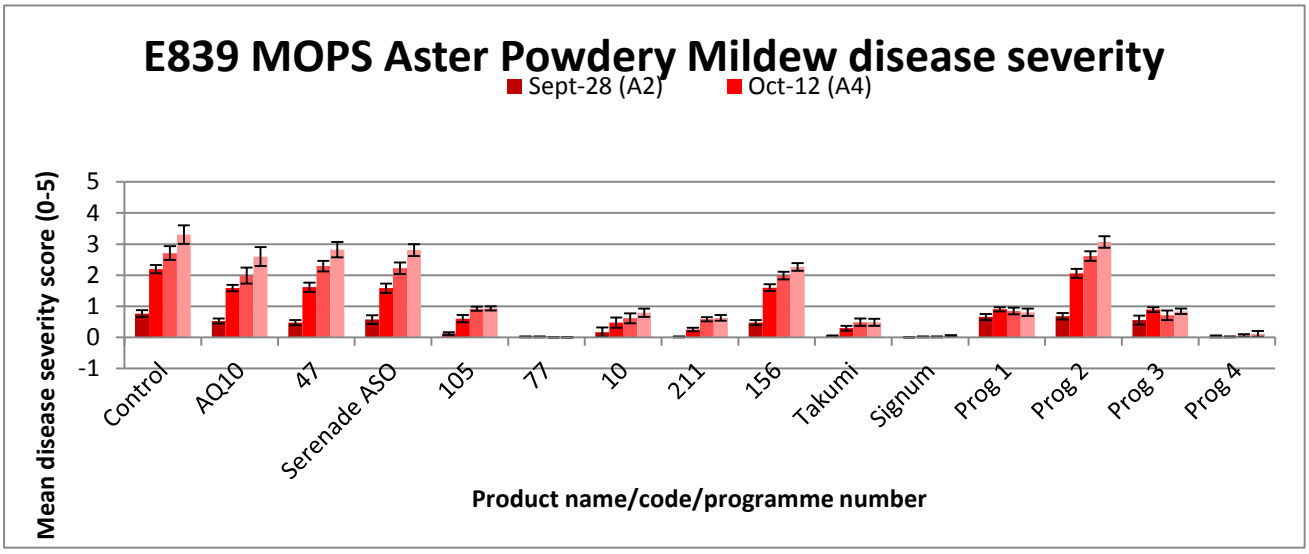
Crop Name		New York aster		New York aster		New York aster		New York aster		New York aster		New York aster	
Part Assessed		LEAF		LEAF		LEAF		LEAF		LEAF		LEAF	
Assessment Date		28/09/2016		05/10/2016		12/10/2016		19/10/2016		26/10/2016		08/11/2016	
Assessment Type		PESSEV		PESSEV		PESSEV		PESSEV		PESSEV		PESSEV	
Assessment Unit		0-5		0-5		0-5		0-5		0-5		0-5	
Collection Basis, Unit		1 PUSTUL		1 PUSTUL		1 PUSTUL		1 PUSTUL		1 PUSTUL		1 PUSTUL	
No of Subsamples		12		12		12		12		12		12	
Trt	Treatment												
No.	Name	2		3		4		5		6		7	
1	Control	0.76	a	1.49	a	2.19	a	2.44	a	2.71	a	3.23	a
2	AQ10	0.53	b	1.1	b	1.58	b	1.88	b	1.99	c	2.49	bc
3	47	0.47	b	1.15	b	1.61	b	2.03	b	2.29	bc	2.74	abc
4	Serenade	0.57	ab	1.14	b	1.58	b	1.9	b	2.22	c	2.74	abc
5	105	0.13	c	0.31	d	0.6	d	0.75	c	0.92	d	0.84	d
6	77	0.01	c	0.01	e	0.01	f	0	e	0	f	0	g
7	10	0.17	c	0.28	d	0.47	de	0.65	cd	0.61	de	0.56	de
8	211	0.01	c	0.06	e	0.25	ef	0.39	d	0.58	de	0.39	ef
9	156	0.47	b	1.11	b	1.6	b	1.82	b	1.99	c	2.18	c
10	89	0.04	c	0.19	de	0.29	e	0.4	d	0.49	e	0.24	f
11	Signum	0	c	0	e	0.01	f	0.01	e	0.01	f	0	g
12	Prog 1	0.65	ab	0.79	c	0.9	c	0.79	c	0.85	de	0.62	de
13	Prog 2	0.68	ab	1.36	a	2.06	a	2.36	a	2.61	ab	2.98	ab
14	Prog 3	0.56	ab	0.79	c	0.89	c	0.88	c	0.71	de	0.68	de
15	Prog 4	0.03	c	0.01	e	0.01	f	0.03	e	0.06	f	0.01	g
LSD P=.05		0.227		0.205		0.273		0.28		0.375		0.064 - 0.716	
S.D.		0.197		0.178		0.237		0.243		0.326		1.070t	
CV		58.08		27.23		25.3		22.34		27.1		19.34t	
Replicate F		4.45		2.108		3.826		2.228		3.176		2.732	
Replicate Prob(F)		0.0014		0.0745		0.004		0.0609		0.0122		0.0259	
Treatment F		12.764		56.949		63.503		79.814		54.854		72.268	
Treatment Prob(F)		0.0001		0.0001		0.0001		0.0001		0.0001		0.0001	

Means followed by same letter or symbol do not significantly differ (P=.05, LSD)

t=Mean descriptions are reported in transformed data units, and are not de-transformed.

Mean comparisons performed only when AOV Treatment P(F) is significant at mean comparison OSL.

Figure 1. Aster Powdery Mildew disease severity



Error bars denote Standard Error

Crop inoculation

In the Aster crop 'infector' plants were introduced into the trial with 1 infector plant showing visible lesions placed in the centre of each plot. With this pathogen the inoculum was spread by water splash from overhead irrigation and by air movement within the glasshouse.

Crop damage

No crop damage e.g. scorch, leaf distortion or stunting was observed during the trial.

Formulations

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

Effect on non-target

No effects were observed on non-target organisms as a result of any treatment applied during the trial.

Discussion

In this efficacy trial one of the main challenges was to secure successful establishment of the relevant pathogen in the crop. This is made more challenging by the fact that the pathogen of interest is obligate meaning it cannot be cultured on artificial media in the laboratory. Infection has to occur either via air-borne spores circulating in the wider environment, inoculation with a spore suspension or via the use of 'infector' plants introduced into the trial area. In each case infection is further encouraged by maintaining an environment conducive to spore development, release, germination and infection. In these trials where natural infection was unlikely (due to the lack of commercial infected crops in the vicinity) pathogen introduction to the crop was achieved with the use of 'infector' plants which were inoculated and propagated in a spatially separate location to the test area prior to the start of the trial. The infector plants were monitored closely, including by microscopy, for visible signs of *Ampelomyces* (small black perithecia within the powdery mildew mycelium) as previous experience had shown how readily this ubiquitous mycoparasite was able to colonise experimental cultures of powdery mildew on host plants. The infector plants were found to be visibly free of the mycoparasite at the point that they were introduced to the trial. To optimize the likelihood of pathogen establishment and trial success the study was conducted during the autumn when environmental conditions were most conducive to mildew infection and spread. Powdery mildew did establish successfully in the Aster trial crop though the appearance of *Ampelomyces quisqualis* on the infector plants approximately 2 weeks after their introduction to the trial (22/9/16) was of some concern. As such, the infector plants were immediately removed from the trial and product applications halted for 1 week to monitor the development of the powdery mildew. Powdery Mildew lesions were noted in the control plots on 28/09/16 and product applications were resumed on 29/09/16. The origin of the *Ampelomyces* on the 'infector' plants is unknown although it may have been present in latent form in the original inoculum only forming visible diagnostic perithecia when climatic conditions were at their optimum.

Infection of the Aster crop progressed steadily in untreated plots following the removal of the 'infector' plants from the trial area. Conventional product 77 had excellent efficacy against Aster powdery mildew when applied on a 14 day spray regime providing complete control of the pathogen through to the end of the trial. Conventional products 211 and 89 provided moderate control but were less effective and failed to provide an equivalent level of disease control. Conventional product 156 was largely ineffective against powdery mildew and only provided a low level of disease suppression at best with a mean disease score at the end of the trial more than double the best performing biological product. Of the biopesticides, product 105 provided the most effective disease suppression and, subject to regulatory approval, potentially making it a valuable addition to an integrated spray programme. If approved it would allow a significant reduction in the frequency of applications of conventional fungicides.

The prescriptive and managed spray programmes yielded interesting results. The two prescriptive programmes provided moderate disease control and one managed programme provided excellent mildew control with a significant reduction in spray applications. The data from this year's trial certainly highlighted the importance of early application of effective products (at the beginning of the infection process) for effective and robust control. This is particularly well illustrated by the exceptional disease control resulting from managed programme 4 where the application of product 77 (the best performing test product) at A1 and 156 at A3 alone resulted in strong disease suppression up until the conclusion of the trial (even though application of product 156 alone was poor). By comparison prescriptive programme 3, which reversed the order of these product applications, gave very poor disease control during the trial period. Even with a further 2 applications of alternating conventional products from different FRAC groups the mean disease levels for programme 3 were significantly much higher by the end of the trial than those for programme 4.

Conclusions

The efficacy trial proved to be highly successful in terms of reinforcing efficacy data generated in 2014 on novel products with good activity against rust in ornamentals and in developing integrated programmes consisting of biologicals and conventionals from different FRAC groups to fulfil requirements of the sustainable use directive and FRAC guidelines for resistance management. In addition it identified product 77 as having a long lasting effect potentially greatly reducing the number of applications required over the course of a growing season. The conventional products provided varying degrees of disease control whereas in general the biological products were less effective even when they were applied as protective applications weekly. Product 105 was perhaps the exception, against Aster powdery mildew at least, as this provided a greater degree of control of the disease than one of the conventional fungicides (156) and the other biopesticides.

In previous years it was concluded that the inoculation technique employed to introduce pathogens into the trial had a significant effect on product performance in the case of the biological products. It was understood that the high disease pressure resulting from direct inoculation with a spore suspension may have overwhelmed some of the biological products which rely on different modes of action to the conventional products. As a result 'infector' plants were used to naturally establish infection and were removed once the disease was visibly present in the crop providing a more realistic simulation for the evaluation of biological products. This year's results for the biological products were broadly comparable with those from the 2014 trial with Serenade ASO showing slightly lower levels of disease control than observed previously.

In terms of the conventional fungicides, several products trialled in 2014 were not included due to registration support issues though 2 new products were included. Of these, product 211 showed a moderate-good level of disease control whereas product 156 proved to have relatively little activity against powdery mildew in Aster. The results for product 10 did not necessarily reflect the exceptional

level of disease control noted in the 2014 trial, though product 77 achieved high levels of control both in 2014 and 2016. The results from the prescriptive and managed programmes appear to show that there is considerable scope to integrate conventional fungicides with biopesticides to maintain effective control whilst also reducing reliance on chemical inputs; thus reducing the risk of resistance development in pathogen populations. The prescriptive programmes which consist of planned product applications at defined points in the growing season (and in advance of visible disease symptoms in the crop) gave consistent control of powdery mildew though were not considered exceptional. By comparison the managed programmes gave more variable results but clearly showed that if designed effectively can improve the overall level of disease control whilst also reducing the overall number of sprays applied. This has implications with respect to both input costs and resistance development; both of which could be very important financially.

AQ10 Adapted strain trial

Introduction

Based on observations in the 2015 efficacy trial a hypothesis was raised that perhaps the mycoparasite raised commercially on a different host crop (and hence a different mildew pathogen[3]) may require a period of acclimatisation or adaptation on the particular host crop and mildew target. An observational (non-replicated) trial was designed and conducted in Autumn 2016 to evaluate the comparative efficacy of 2 different strains of *A. quisqualis* (as present in the plant protection product AQ10) for the control of Aster powdery mildew (*Golovinomyces asterum var. asterum syn. Erisyphe chicoracearum)*. One strain (non-adapted) was from the commercially available product AQ10 from Belchim Crop Protection, the other was a 'local strain' pre-acclimatised on Aster powdery mildew and hence potentially adapted to rapidly colonise any mildew infection in the Aster crop. The results obtained were compared against an *A. quisqualis*-free control treatment for comparison. Details of climate data are included in Appendix G.

Materials and methods

Aster 'Cassandra' were sourced as plug plants from the Cut Flower Centre and transplanted into ten cm pots and grown-on. They were 'stopped' twice prior to the start of the trial to encourage shoot development and leafy growth. The treatments were laid out in blocks spatially separated to avoid cross contamination between plots by water splash. Two applications of *A. quisqualis* were made using the two strains in separate blocks of crop plants. One application was made prior to inoculation with powdery mildew and a further application was made 24hours after the powdery mildew inoculum was introduced. The commercial or 'non-adapted' strain of AQ10 was prepared at the recommended label concentration and a measurement made of the number of CFU's per litre using a haemocytometer. A spore suspension of the 'adapted' or 'acclimatised' strain *A. quisqualis* strain was then prepared from powdery mildew infected and mycoparasitised Aster leaf material agitated in aqueous suspension and then filtered to remove leaf material and the larger spores of powdery mildew. The *A. quisqualis* spore concentration was then determined using a haemocytometer and adjusted to an equivalent concentration to the 'non-adapted' or AQ10 strain. Both spore suspensions were applied to the respective crops at the recommended label rate for the AQ10 product. The crops were inoculated with powdery mildew using a spore suspension on two occasions (31st August and 3rd October) and subsequently monitored for the development of powdery mildew lesions. The floor of the glasshouse was wetted in the afternoon for 2 days after the inoculations to provide optimum conditions conducive to pathogen development. No powdery mildew infection developed following

[3] Species of powdery mildew are host-specific obligate pathogens whereas *Ampelomyces quisqualis* is a mycoparasite that is claimed to colonise most, if not all, mildew species irrespective of the host crop.

the two inoculations with spore suspensions. Therefore, on 17th October a block of 90 powdery mildew infected plants was introduced to the glasshouse (but kept remote from the trial plants to avoid any splash) to provide an airborne source of powdery mildew inoculum. During the trial period the crop was regularly monitored for the appearance of powdery mildew lesions on the leaves in each plot. Disease severity assessments were carried out on two separate occasions (30th November and 12th December) on each Aster crop to measure the number of lesions present on each of 6 plants at 5 sampling locations within each crop. An early assessment was also conducted prior to inoculation to check for any natural colonization by powdery mildew in the trial areas. The details of the test site and plot design are presented in Table 8 below.

Site and crop details

Table 9. Test site and plot design information

Test location:	Stockbridge Technology Centre
County	North Yorkshire
Postcode	YO8 3TZ
Soil type/growing medium	Levington M2
Nutrition	Universol Blue (18-11-18 +2.5 MgO + TE)
Crops & Cultivars	Aster ‘ Cassandra’
Glasshouse* or Field	Glasshouse
Date of planting/potting	Aster plugs potted on 7/8/15
Pot size	10cm
Number of plants per plot	405
Trial design	Non- replicated block
Number of replicates	1 (5 sub samples)
Plot size w (m), l (m), total area (m²)	1.65 x 2.7 (4.455)

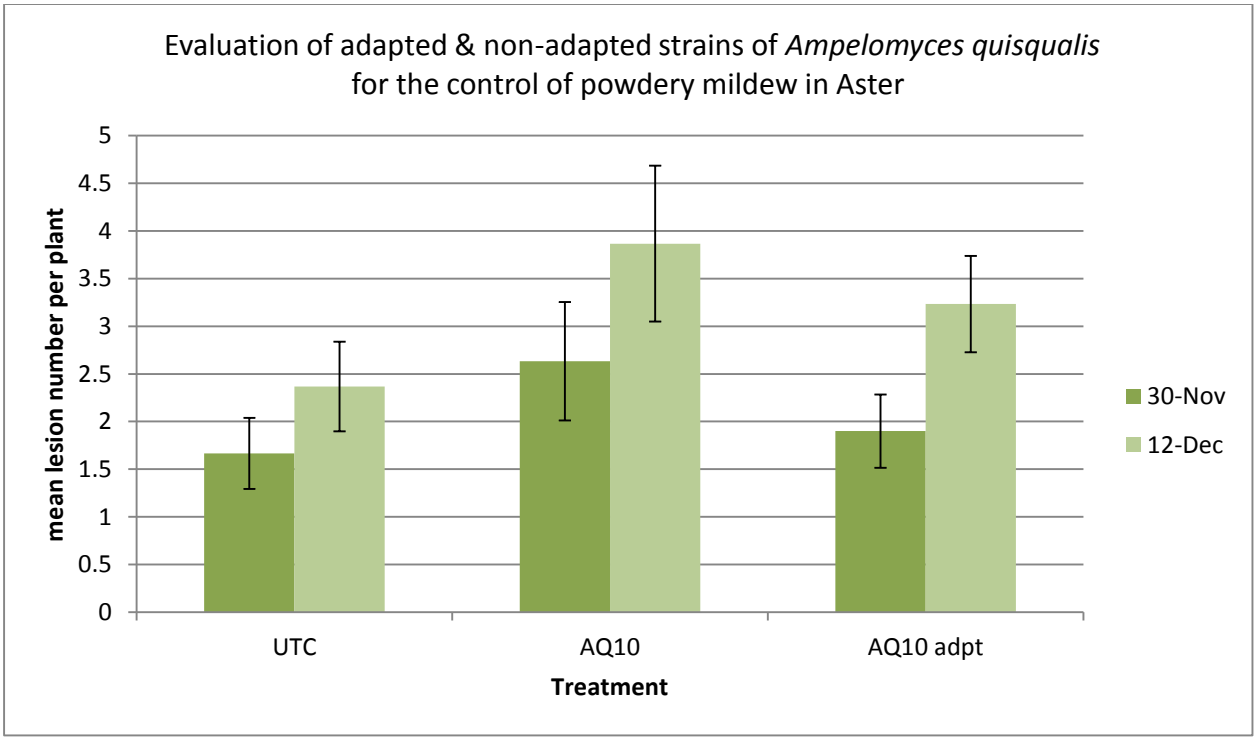
*Temperature and relative humidity settings are presented in Appendix G

Results

Following inoculation by the powdery mildew pathogen disease expression proved to be very slow (even though powdery mildew levels in an adjacent glasshouse for the efficacy evaluation progressed successfully). No satisfactory explanation for this slow development of powdery mildew in this trial was found but it does highlight the difficulties associated with such trials work where there isn't a full understanding or control of pathogen biology, disease epidemiology and environmental conditions.

The pathogen did finally develop in the trial crop areas and detailed infection assessments were conducted on 30th November and 12th December but infection levels remained low (Figure 2). Microscopic examination of infected leaves in each treatment found sporadic colonisation by *A. quisqualis* and the results from this work therefore proved inconclusive. We were therefore not able to confirm or refute the hypothesis that 'adapted' or 'acclimatised' strains of A. quisqualis may be more effective in controlling host-specific strains of powdery mildew in ornamental (and other) crop hosts. Further work is required in this regard.

Figure 2. Evaluation of adapted & non-adapted strains of *Ampelomyces quisqualis*



Error bars denote Standard Error

Discussion

The product AQ10 is interesting and potentially very useful as an alternative, non-chemical, approach for the control of powdery mildew in ornamental (and other) crops. It is based on the activity of the microscopic fungus *Ampelomyces quisqualis* which is a mycoparasite of powdery mildew species. For commercial production purposes it is raised on a non-ornamental host crop and hence a different powdery mildew species to that targeted here.

Observations in a 2015 glasshouse trial at STC where powdery mildew failed to establish successfully was thought to be associated with the successful colonization of the crop by *A. quisqualis*; even though in 2014 trials application of the commercial product AQ10 had been largely ineffective.

This event led us to question whether the strain of *A. quisqualis* originally introduced into the Aster crop in 2014 (via AQ10 application) had become better adapted to colonise Asters and the specific species of powdery mildew on the crop; thus providing highly effective control in 2015. A trial was therefore devised to try to answer this hypothesis during 2016 as this could have potential significance for growers in the longer-term.

Unfortunately, the slow establishment of powdery mildew in the crop areas prevented a robust evaluation of the hypothesis. We still cannot eliminate the possibility of *A. quisqualis* involvement in the lack of disease development as it is possible it may have a fundamental impact on the infection process even in situations where we can't visibly (by eye or microscopy) see any mycoparasite activity. Further work is evidently required in this area but until we have better (quantifiable) serological and/or molecular methods for early detection of *A. quisqualis* in powdery mildew colonies it is difficult to interpret data and results effectively.

Conclusions

Further work is required to better understand and monitor the infection process by *Ampelomyces quisqualis* so that we can track the colonization process in advance of visible symptoms of both the pathogen and the mycoparasite itself.

Appendix A – Study conduct

Stockbridge Technology Centre is Officially Recognised by United Kingdom Chemical Regulations Directorate as competent to carry out efficacy testing in the categories of agriculture, horticulture, stored crops, biologicals & semiochemicals. National regulatory guidelines were followed for the study.

Relevant EPPO/CEB guideline(s)	
PP 1/152(4)	Design and analysis of efficacy evaluation trials
PP 1/135(4)	Phytotoxicity assessment
PP 1/181(4)	Conduct and reporting of efficacy evaluation trials including GEP

GLP compliance will not be claimed in respect of this study.

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

Appendix B – Meteorological data (Efficacy Trial)

Location of the weather station	Cawood. G.R. SE 56158 37171
Distance to the trial site	425m
Origin of the weather data	Met Office Weather station nº 4086
Glasshouse temperature and humidity data derived from Priva Intrgro climate control system.	

Date	mean day temp (^{0}C)	mean day rh (%)	mean night temp(^{0}C)	mean night rh (%)	max temp (^{0}C)	Min Temp (^{0}C)	Sunshine hrs
02/08/2016	20.28	76.24	18.95	83.83	22.9	16.7	0.0
03/08/2016	23.58	55.21	17.71	75.01	27.0	17.2	6.3
04/08/2016	22.48	60.98	18.05	74.18	26.6	16.4	7.0
05/08/2016	24.17	50.80	17.64	71.88	28.7	16.2	8.2
06/08/2016	26.23	51.30	21.62	75.41	30.7	15.0	10.8
07/08/2016	25.43	87.19	17.96	100.00	29.7	18.0	9.7
08/08/2016	22.13	99.95	15.90	100.00	26.5	15.8	9.7
09/08/2016	20.68	99.98	16.59	100.00	24.2	14.2	5.1
10/08/2016	21.33	100.00	17.57	100.00	26.8	15.4	8.9
11/08/2016	20.33	100.00	18.47	100.00	25.4	16.2	0.9
12/08/2016	24.69	99.98	18.16	100.00	29.5	17.3	10.3
13/08/2016	23.32	99.88	17.90	100.00	27.4	16.8	11.1
14/08/2016	22.86	99.92	17.12	100.00	29.7	16.8	4.0
15/08/2016	24.45	99.88	16.27	100.00	30.6	15.1	8.7
16/08/2016	24.94	100.00	16.87	100.00	30.4	14.2	12.8
17/08/2016	24.22	99.02	18.36	100.00	32.1	15.0	6.7
18/08/2016	23.38	93.33	18.14	96.79	28.4	17.2	5.3
19/08/2016	20.48	95.43	17.12	97.92	24.5	16.5	0.9
20/08/2016	20.51	92.25	17.44	96.57	23.3	15.5	2.8
21/08/2016	22.99	96.14	18.87	100.00	27.7	16.6	7.0
22/08/2016	23.74	99.93	19.67	100.00	28.1	17.3	5.0
23/08/2016	27.22	95.88	N/A	N/A	34.5	18.6	9.8
24/08/2016	25.97	99.97	19.52	100.00	30.0	18.9	8.1
25/08/2016	20.08	100.00	19.31	100.00	23.7	17.4	0.0
26/08/2016	23.52	100.00	16.95	100.00	27.7	16.0	11.9
27/08/2016	21.00	100.00	17.58	100.00	26.2	14.8	4.0
28/08/2016	19.63	100.00	16.20	100.00	23.2	16.0	1.4
29/08/2016	23.12	100.00	16.57	100.00	27.4	14.7	11.9
30/08/2016	24.59	100.00	17.86	100.00	28.9	15.1	11.8
Date	mean day	mean day rh (%)	mean night temp(^{0}C)	mean night rh (%)	max temp (^{0}C)	Min Temp (^{0}C)	Sunshine hrs

	temp (^{0}C)						
31/08/2016	22.34	99.93	16.75	100.00	27.8	15.7	6.6
01/09/2016	21.71	100.00	17.65	100.00	26.3	15.1	4.7
02/09/2016	20.43	100.00	16.19	100.00	22.8	15.9	0.9
03/09/2016	19.12	100.00	17.05	100.00	20.9	14.9	1.2
04/09/2016	19.76	100.00	16.75	100.00	24.0	15.4	5.3
05/09/2016	20.79	100.00	19.33	100.00	23.6	16.2	1.2
06/09/2016	25.67	100.00	21.71	100.00	30.8	18.1	5.2
07/09/2016	25.17	100.00	20.06	100.00	29.0	19.9	6.0
08/09/2016	22.33	100.00	16.86	100.00	26.4	16.8	8.8
09/09/2016	21.32	100.00	19.14	100.00	23.5	16.0	2.5
10/09/2016	19.00	100.00	15.00	100.00	22.3	15.0	0.5
11/09/2016	20.10	100.00	15.72	100.00	24.0	14.1	8.5
12/09/2016	22.01	71.29	19.39	81.15	27.3	14.4	5.1
13/09/2016	27.61	59.42	19.45	78.04	34.3	16.8	8.2
14/09/2016	21.53	70.90	16.82	86.41	25.5	16.2	8.4
15/09/2016	23.29	68.76	19.26	80.77	30.3	16.3	6.0
16/09/2016	17.99	73.71	15.96	73.63	19.6	16.0	0.0
17/09/2016	18.55	62.16	14.85	76.83	22.2	14.7	3.6
18/09/2016	22.04	56.54	17.13	78.05	26.4	14.2	10.5
19/09/2016	17.89	75.00	16.29	79.98	19.3	15.9	0.0
20/09/2016	17.39	75.90	15.85	82.59	18.9	15.6	0.4
21/09/2016	19.11	72.55	17.46	82.72	23.3	14.9	3.0
22/09/2016	19.64	57.75	14.51	76.01	22.5	14.3	7.7
23/09/2016	19.19	58.51	15.12	74.03	23.5	13.5	7.5
24/09/2016	19.55	63.47	18.05	70.55	22.0	14.2	1.4
25/09/2016	N/A	N/A	N/A	N/A	17.9	16.9	5.5
26/09/2016	17.46	78.43	15.80	83.16	20.6	13.4	0.0
27/09/2016	18.19	76.25	15.86	74.64	21.3	14.5	0.4
28/09/2016	20.54	70.11	18.96	75.85	24.2	14.9	1.4
29/09/2016	18.96	53.74	14.40	74.16	22.5	14.3	8.8
30/09/2016	17.84	59.47	14.08	78.36	22.2	13.9	8.1
01/10/2016	16.69	73.36	13.84	80.77	20.5	13.1	3.1
02/10/2016	17.15	61.49	12.12	78.53	20.3	12.4	9.2
03/10/2016	17.87	62.47	13.98	81.59	22.4	10.2	9.5
04/10/2016	18.91	66.71	15.54	76.11	22.8	13.1	9.2
05/10/2016	17.15	60.28	13.57	81.13	19.7	13.1	6.8
06/10/2016	16.79	62.45	14.62	83.49	20.6	12.7	8.0
07/10/2016	17.13	77.79	14.64	82.71	20.0	14.3	0.1
08/10/2016	16.29	71.60	14.03	79.83	19.0	13.7	0.9
Date	mean day temp (^{0}C)	mean day rh (%)	mean night temp(^{0}C)	mean night rh (%)	max temp (^{0}C)	Min Temp (^{0}C)	Sunshine hrs

09/10/2016	16.12	67.30	12.76	79.12	19.4	12.2	4.9
10/10/2016	15.85	72.30	12.68	81.35	19.4	10.9	5.2
11/10/2016	16.03	80.12	14.33	82.40	18.9	11.7	1.0
12/10/2016	16.32	73.46	14.14	80.63	18.3	13.9	1.8
13/10/2016	15.00	81.99	14.20	83.29	16.7	13.2	0.2
14/10/2016	15.88	78.96	14.45	81.87	18.0	13.9	2.0
15/10/2016	16.42	73.90	14.00	82.11	18.2	13.8	3.5
16/10/2016	15.99	77.87	14.09	81.56	18.7	12.9	4.5
17/10/2016	16.78	66.68	14.01	80.95	18.6	13.5	7.2
18/10/2016	15.08	72.06	13.71	82.38	17.8	12.6	2.6
19/10/2016	15.47	69.50	14.12	79.83	17.9	13.7	1.2
20/10/2016	15.88	70.83	13.04	79.26	18.2	12.7	4.7
21/10/2016	15.20	75.72	12.80	79.97	17.2	11.8	1.2
22/10/2016	15.18	70.08	13.09	79.96	17.8	12.1	4.6
23/10/2016	14.94	70.85	12.09	79.39	16.6	12.1	4.8
24/10/2016	14.72	70.68	13.08	79.01	17.9	10.0	0.9
25/10/2016	15.17	70.46	14.50	77.63	18.4	10.9	2.5
26/10/2016	16.54	69.11	14.77	79.05	19.2	13.9	2.6
27/10/2016	15.51	75.30	15.10	79.54	16.6	14.1	0.0
28/10/2016	16.16	76.09	15.16	81.97	17.2	14.3	0.0
29/10/2016	17.04	79.24	15.79	81.07	19.2	14.9	0.7
30/10/2016	16.08	76.19	14.82	83.45	17.3	14.8	0.0
31/10/2016	16.78	76.76	13.81	82.45	19.5	13.5	2.5
01/11/2016	14.63	73.83	9.43	78.99	16.4	9.3	5.0
02/11/2016	13.68	68.15	9.92	79.60	16.3	8.5	4.9
03/11/2016	13.84	75.26	12.81	81.20	16.0	9.3	0.0
04/11/2016	14.15	67.20	11.41	78.37	16.9	11.2	4.2
05/11/2016	13.48	65.99	9.19	75.58	15.8	9.2	6.7
06/11/2016	12.48	74.07	9.77	76.90	14.9	8.6	0.5
07/11/2016	13.05	68.77	9.80	76.01	16.5	8.6	4.0
08/11/2016	12.97	79.40	9.89	80.88	15.4	9.0	0.4
09/11/2016	10.61	78.36	7.89	78.21	13.5	7.0	0.1
10/11/2016	13.29	72.84	11.57	79.82	15.3	7.1	2.7
11/11/2016	13.12	73.58	11.18	83.27	16.2	9.1	5.2
12/11/2016	13.84	82.01	10.58	80.27	15.6	10.9	0.4
13/11/2016	14.00	69.40	13.72	82.59	16.4	8.9	4.1
14/11/2016	15.61	78.75	15.68	82.74	16.8	13.6	0.2
15/11/2016	15.27	74.08	11.59	77.20	16.7	11.1	0.7

Appendix C – Agronomic details

Other pesticides - active ingredients / fertiliser applied to the trial area

Date	Product	Rate	Unit
20/9/16 18/10/16	Universol Blue (18-11-18 +2.5 MgO + TE)	1	g/L

Type of irrigation system employed
Hand watering

Appendix D – Trial layout

MOPS Aster Powdery Mildew

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

Stockbridge Technology Centre

complies with the minimum standards laid down in Commission Directive 93/71/EEC 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
Biologicals and Semiochemicals
Stored Crops

Date of issue: **20 May 2011**
Effective date: **1 April 2011**
Expiry date: **31 March 2016**

Certification Number
ORETO 291

Signature _____
Authorised signatory

HSE
Chemicals Regulation Directorate

Department of Agriculture and Rural Development

Appendix F – Photographs

Figure 1. Trial overview at assessment timing A4 (12/10/16)

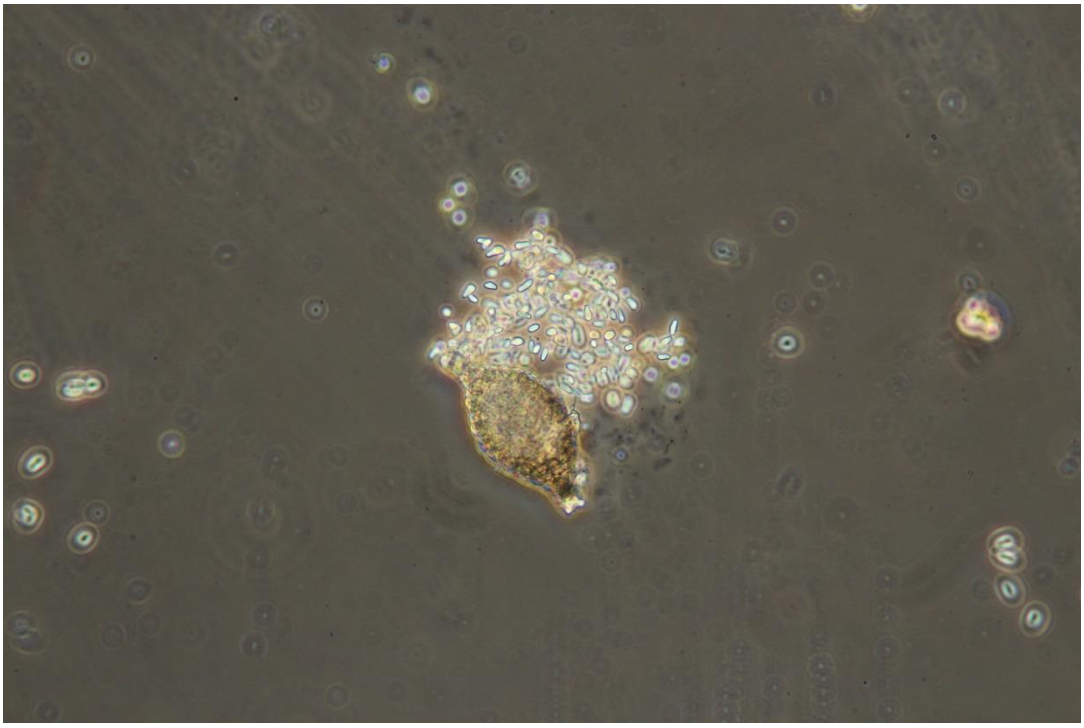


Figure 2. Pycnidium of *Ampelomyces* from an infector plant liberating spores (x 200) 23/09/2016

Figure 3. Untreated control plot showing high levels of powdery mildew infection at assessment timing A4 (12/10/16)

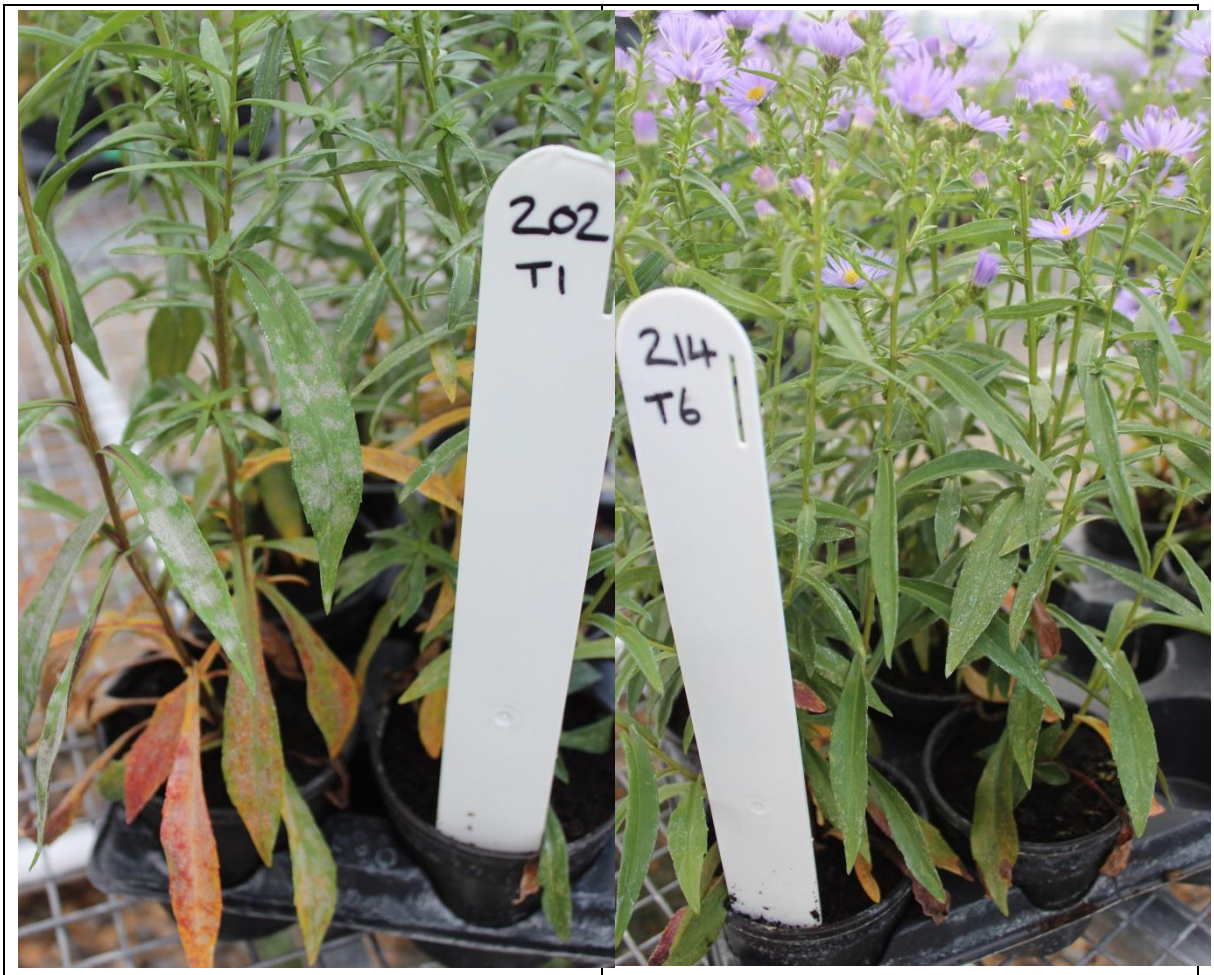


Figure 6. Untreated control vs product 77 treated plot at assessment timing A5 (19/10/16)

Figure 6. product 156 (conventional fungicide) treated plot and product 105 (biopesticide) treated plot at assessment timing A5 (19/10/16)

Appendix G – Meteorological data (AQ10 Trial)

Location of the weather station	Cawood. G.R. SE 56158 37171
Distance to the trial site	425m
Origin of the weather data	Met Office Weather station nº 4086
Glasshouse temperature and humidity data derived from Priva Intrgro climate control system.	

Date	mean daytime temperature (^{0}C)	mean day r/h (%)	mean night temperature (^{0}C)	mean night r/h (%)	Sunshine hours
30/08/2016	27.0	60.2	20.1	78.4	11.8
31/08/2016	24.6	63.9	19.3	78.0	6.6
01/09/2016	23.9	61.1	19.7	74.8	4.7
02/09/2016	22.3	68.3	18.8	79.1	0.9
03/09/2016	20.9	79.8	19.2	84.9	1.2
04/09/2016	22.2	71.3	19.2	82.9	5.3
05/09/2016	22.1	75.2	20.6	87.4	1.2
06/09/2016	26.9	71.9	22.6	81.7	5.2
07/09/2016	25.5	71.0	21.0	83.0	6.0
08/09/2016	23.7	69.5	18.8	80.1	8.8
09/09/2016	22.3	73.6	20.3	81.8	2.5
10/09/2016	20.9	74.3	17.4	84.4	0.5
11/09/2016	21.6	68.9	18.0	82.3	8.5
12/09/2016	23.2	70.1	20.4	81.4	5.1
13/09/2016	28.3	62.8	21.0	78.9	8.2
14/09/2016	23.7	71.3	19.3	83.6	8.4
15/09/2016	25.1	71.5	20.7	81.1	6.0
16/09/2016	20.0	79.4	18.3	82.9	0.0
17/09/2016	21.0	71.5	17.4	82.9	3.6
18/09/2016	24.1	66.8	19.5	82.7	10.5
19/09/2016	20.4	78.5	18.5	85.4	0.0
20/09/2016	19.9	82.5	18.3	87.1	0.4
21/09/2016	20.5	79.6	19.0	87.8	3.0
22/09/2016	21.1	73.5	14.1	82.9	7.7
Date	mean daytime temperature (^{0}C)	mean day r/h (%)	mean night temperature (^{0}C)	mean night r/h (%)	Sunshine hours
23/09/2016	19.1	73.5	14.7	82.6	7.5

24/09/2016	19.2	76.2	18.0	80.7	1.4
25/09/2016	N/A	N/A	N/A	N/A	5.5
26/09/2016	16.7	85.6	15.3	88.5	0.0
27/09/2016	17.8	84.9	15.8	82.8	0.4
28/09/2016	20.4	81.8	19.1	83.8	1.4
29/09/2016	19.2	72.5	14.2	83.1	8.8
30/09/2016	17.8	75.7	13.7	85.1	8.1
01/10/2016	16.8	81.2	13.2	86.7	3.1
02/10/2016	17.2	75.1	12.8	85.4	9.2
03/10/2016	17.6	76.0	13.7	87.9	9.5
04/10/2016	18.6	79.1	14.8	85.3	9.2
05/10/2016	16.5	75.9	13.1	86.3	6.8
06/10/2016	16.2	76.4	14.3	86.9	8.0
07/10/2016	16.2	86.7	14.0	89.2	0.1
08/10/2016	15.5	82.8	13.6	87.2	0.9
09/10/2016	15.7	80.3	12.9	86.4	4.9
10/10/2016	15.5	83.6	12.7	88.0	5.2
11/10/2016	15.1	87.0	13.6	88.2	1.0
12/10/2016	15.4	84.3	13.1	88.5	1.8
13/10/2016	14.1	89.3	13.0	91.0	0.2
14/10/2016	14.6	87.9	13.2	90.0	2.0
15/10/2016	15.2	86.6	13.1	90.7	3.5
16/10/2016	15.0	87.6	13.0	89.4	4.5
17/10/2016	16.0	83.6	13.0	89.5	7.2
18/10/2016	14.0	86.6	12.5	89.8	2.6
19/10/2016	14.4	84.6	12.8	89.5	1.2
20/10/2016	15.0	85.7	12.0	90.5	4.7
21/10/2016	14.1	88.0	11.9	90.5	1.2
22/10/2016	14.1	85.3	12.1	90.5	4.6
23/10/2016	13.8	85.9	11.3	90.6	4.8
24/10/2016	13.5	86.6	12.0	90.0	0.9
25/10/2016	14.0	86.8	13.2	89.5	2.5
26/10/2016	15.7	86.0	14.2	88.9	2.6
Date	mean daytime temperature (^{0}C)	mean day r/h (%)	mean night temperature (^{0}C)	mean night r/h (%)	Sunshine hours
27/10/2016	14.6	88.3	14.6	88.9	0.0
28/10/2016	15.3	88.8	14.3	90.7	0.0

29/10/2016	16.2	89.9	14.9	90.4	0.7
30/10/2016	15.0	88.9	13.8	91.8	0.0
31/10/2016	15.7	89.1	12.5	91.1	2.5
01/11/2016	13.4	87.1	8.7	90.5	5.0
02/11/2016	12.9	85.1	9.2	90.4	4.9
03/11/2016	12.5	90.6	12.1	91.2	0.0
04/11/2016	13.4	86.7	11.3	90.4	4.2
05/11/2016	13.0	84.7	9.3	88.7	6.7
06/11/2016	11.8	90.7	10.0	90.4	0.5
07/11/2016	12.6	86.1	10.1	89.9	4.0
08/11/2016	12.5	86.4	9.8	89.1	0.4
09/11/2016	10.7	91.3	8.1	90.9	0.1
10/11/2016	12.6	86.4	11.2	90.2	2.7
11/11/2016	12.8	85.6	10.8	91.0	5.2
12/11/2016	13.0	90.3	10.4	90.0	0.4
13/11/2016	13.8	83.7	12.8	90.4	4.1
14/11/2016	14.9	88.9	15.2	90.2	0.2
15/11/2016	14.6	86.7	11.8	90.0	0.7
16/11/2016	13.6	86.8	10.7	91.3	2.7
17/11/2016	11.9	88.1	9.2	89.9	2.7
18/11/2016	10.5	89.5	8.6	90.1	1.3
19/11/2016	11.5	87.2	8.8	89.2	2.5
20/11/2016	11.7	88.9	8.7	89.3	0.3
21/11/2016	10.8	92.1	11.7	92.0	0.0
22/11/2016	12.6	89.7	11.5	91.0	1.0
23/11/2016	12.4	89.3	10.2	90.8	1.6
24/11/2016	12.5	88.1	12.0	90.7	0.1
25/11/2016	12.6	88.5	8.6	90.5	2.8
26/11/2016	11.4	90.0	11.8	91.4	0.4
27/11/2016	12.8	88.4	11.8	90.4	1.7
28/11/2016	12.3	87.5	8.5	90.4	4.3
29/11/2016	11.0	85.7	7.9	90.0	4.7
Date	mean daytime temperature (^{0}C)	mean day r/h (%)	mean night temperature (^{0}C)	mean night r/h (%)	Sunshine hours
30/11/2016	11.5	87.5	9.7	90.0	2.8
01/12/2016	12.2	91.1	10.5	92.0	1.5
02/12/2016	12.5	91.6	10.9	92.2	0.0
03/12/2016	12.1	90.8	11.1	91.8	0.0

04/12/2016	12.0	87.8	7.4	89.4	5.2
05/12/2016	9.7	90.8	8.3	91.5	0.0
06/12/2016	10.7	91.0	11.7	92.2	0.0
07/12/2016	13.8	89.7	14.1	90.5	2.4
08/12/2016	14.4	91.0	12.2	91.0	0.7
09/12/2016	14.1	91.6	13.1	92.1	0.0
10/12/2016	13.6	90.5	11.5	91.1	0.0
11/12/2016	12.7	89.0	11.5	91.1	0.2
12/12/2016	11.6	92.1	12.2	92.8	0.0
13/12/2016	12.9	91.5	12.6	92.2	0.0
14/12/2016	13.1	89.9	10.5	90.6	1.6
15/12/2016	12.4	90.4	12.3	91.1	0.0
16/12/2016	12.6	91.4	10.9	91.9	2.8
17/12/2016	11.6	87.9	10.0	90.7	3.3
18/12/2016	12.4	89.3	9.9	90.2	0.3
19/12/2016	11.7	89.9	11.3	91.0	0.0
20/12/2016	11.3	88.3	9.7	90.1	2.2
21/12/2016	11.7	91.3	8.7	91.0	0.8
22/12/2016	11.5	87.2	10.1	90.9	5.4
23/12/2016	11.6	92.3	10.1	92.0	0.0
24/12/2016	11.8	89.7	12.7	89.8	0.0
25/12/2016	14.2	87.5	11.6	89.5	0.7
26/12/2016	11.7	85.4	9.4	90.0	5.5
27/12/2016	11.3	89.3	7.3	90.0	3.1
28/12/2016	10.2	87.2	8.0	90.0	4.0
29/12/2016	10.4	88.2	8.0	90.2	2.1
30/12/2016	11.6	89.7	10.3	91.5	5.0
31/12/2016	12.9	89.0	11.9	90.3	1.6