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 Rust in Bellis and Powdery mildew in Aster
Work package leader:	Dr G M McPherson MBPR (Hort)
Report:	Annual report, December 2015
Previous report:	None
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Location of work:	Stockbridge Technology Centre
Date work commenced:	7th July 2015
Date work completed (or expected completion date):	18th December 2015

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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.

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CONTENTS

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GROWERS SUMMARY

Headline

- Several integrated programmes provided effective disease control but it was found to be important to apply the sprays in advance of any visible symptoms in the crop.
- The 2015 trials have provided important information about possible acclimatization or adaption requirements of the mycoparasite *Ampelomyces quisqualis* for effective disease control.

Background and expected deliverables

The SCEPTRE programme (AHDB Horticulture project CP 077) was very successful in identifying and evaluating novel conventional chemical insecticides, fungicides and biopesticide products for pest, disease and weed control in edible crops and has provided considerable scope to fill gaps in the crop protection armoury as older active substances and products are withdrawn.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 MOPS programme was established in 2014 in response to growers concerns about potential losses of products in the ornamentals sector. In this regard it is extremely important to the industry and sits alongside the minor use programme to ensure effective crop protection products remain available in the future.

In the first year of the project, STC evaluated a range of novel conventional and biological products for the control of rust in bellis and antirrhinum and powdery mildew in aster and pansy. Rust is a sporadic commercial problem on a range of ornamental species including bedding plants e.g. antirrhinum and bellis, cut flowers and bulbs e.g. chrysanthemum and hollyhock, in herbaceous perennials e.g. heuchera and in hardy nursery stock e.g. rose, hypericum and mahonia. In general, rust diseases tend to be controlled either by avoiding susceptible species or cultivars or through the use of fungicide sprays, often indirectly applied to achieve control of powdery mildew. Specific rust fungicides are quite limited and rely on the use of 'azole' products primarily.

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.

Powdery mildew diseases are also usually managed by regular treatment with fungicides. In the case of both diseases cultural practices provide partial control, but fungicides are almost invariably necessary for the production of high-quality, saleable plants. 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 active substance or products from the same fungicide group are used repeatedly on the same crop. The availability of biofungicides for use on ornamentals could help to reduce development of resistance to conventional fungicides. Some of the existing mode of action groups are not necessarily safe to use on all ornamental crops and the potential risk of 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) have 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 biofungicide products.

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 and/or marketing agents (on-label approvals), the AHDB team (extrapolated approvals for minor use or EAMU) 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 outdoor or protected ornamentals.

Summary of the work and main conclusions

In the summer/autumn period of 2015 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 and bellis rust. In addition to treatments with single products a number of prescriptive and managed programmes were trialled using a selection of the trial products.

Powdery mildew – Aster 'Cassy' was selected as a candidate disease susceptible cultivar for use following discussion with Lyndon Mason, Cut Flower Centre. Disease progression in the aster crop proved to be slow and sporadic which was later found to be caused by an extensive colonization of the powdery mildew inoculum with the mycoparasite *Ampelomyces quisqualis* as found in the product AQ10.

Rust – Bellis 'Goliath Mixed' was selected as disease susceptible cultivar following its successful use in year one of the project. The Bellis crop was infected naturally 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 the previous year for conventional and biological products alike. Several prescriptive and managed programmes were evaluated some of which proved to be very successful. It is clear that the most effective control of the disease can be achieved if spray applications are made in advance of visible symptoms in the crop. Late applications made when the disease is first seen proved to be less effective. An integrated programme of conventional fungicides and biocontrol products was very effective suggesting that the frequency of fungicide application can potentially be reduced significantly.

Action points for growers

This years' phase of the MOPS project confirmed the efficacy of several of the products that were identified as promising in year one of the project. Whilst no phytotoxicity was observed in the host crops tested their effect on a wider range of crops needs to be explored further (see separate phytotoxicity report). This years' work identified spray programmes which effectively controlled disease levels in the rust (host) crop, some integrating both biological and conventional products and others a combination of conventional products from a range of FRAC groups.

The work on powdery mildew, whilst disappointing in terms of poor disease establishment, did highlight the potential efficacy of AQ10 (*Ampelomyces quisqualis*) though further work is required to determine if an adaption period is required on a particular host or mildew species to ensure a more robust response following its application to a range of ornamental crops.

SCIENCE SECTION

Introduction

Two replicated trials were conducted in autumn 2015 to evaluate the efficacy of 4 biological products[1] (biofungicides) and 9 conventional pesticides (fungicides) for the control of Bellis rust (*Puccinia distincta*) and Aster powdery mildew (*Golovinomyces asterum var. asterum syn. Erisyphe chicoracearum)*. The results obtained were compared with untreated controls and the trial was validated by inclusion of a standard approved treatment (Signum) applied at recommended rates.

Nine applications of biological products and five applications of conventional products were made in the Bellis trial, and seven applications of biologicals and four applications of conventionals in the Aster trial. The biologicals were applied at one week intervals whereas the conventional products were applied at two week intervals. Biological and Conventional treatments were spatially separated within the glasshouse in order to minimize any potential interactions between the conventional products and biological products. Treatments of single products applied are listed in Tables 2a and 2c. Treatments as part of spray programmes are listed in Tables 2b and 2d. Details of the timings and rates of application and climate data are included in Tables 3a ,3b, 4a and 4b. Data was inputted into ARM 9 (Agricultural Research Manager) software and data tables and statistical analysis (ANOVA) generated accordingly

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

Materials and methods

Aster ‘Cassy’ were sourced as plug plants from the Cut Flower Centre and transplanted into eleven cm pots and grown-on. They were ‘stopped’ twice prior to the start of the trial to encourage shoot development and leafy growth. Bellis ‘Goliath Mixed’ was sourced as seed sown in modules and later transplanted into 6/packs for the trial.

Infector plants for both the Bellis rust and Aster powdery mildew were generated from inoculum present on overwintered plants maintained from the heavily infected untreated control plots from the previous year’s MOPS efficacy trials. Bellis rust spores from these plants were used to sequentially inoculate two further generations of Bellis plants to maintain a thriving population of ‘infector’ plants ensuring an abundance of inoculum was present at the start of the trial. Infected Aster plants from year one control plots were potted on into 10L pots (three plants/pot) in winter 2014/15 and whilst the previous year’s heavily infected foliage died back new growth in the summer of 2015 showed significant recolonization by powdery mildew.

The trials were 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 23/09/15. Infector plants with powdery mildew were subsequently introduced to the Aster plots on 7/10/15 at one pot/plot to provide a uniform spread of inoculum throughout the trial. The Aster crop was subsequently misted with water 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.

The Bellis treatment applications were commenced on 11/9/15. Bellis infector plants with actively sporulating rust pustules were placed within the plots on 21/09/15 and, as above, the crop was subsequently misted with water 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. The first signs of rust infection were observed in the Bellis crop on 25/09/15.

During the trial disease severity assessments were carried out on five separate occasions on the Bellis crop and on three occasions in the Aster crop. 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	Bellis 'Goliath Mixed' Aster ' Cassy'
Glasshouse* or Field	Glasshouse
Date of planting/potting	Aster plugs potted on 7/8/15 Bellis sown 7/7/15, potted on to 6 packs 07/8/15
Pot size	11cm (Aster) & Plantpak MC6 6-packs Bellis
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 (m^2)	0.4m x 0.8m (0.32 m^2)
Method of statistical analysis	ANOVA

*Temperature and relative humidity settings are given in Appendix B

Table 2a. *Details of products tested (for Rust control)*

Treatment	Product	Active ingredient(s)	Manufacturer	Batch number	% a.i	Formulation type
1	Untreated	-	-	-	-	-
2	Signum (Standard)	Boscalid + Pyraclostrobin	BASF	12-000418	26.7:6.7% w/w	WG
3	105	N/D	N/D	N/D	N/D	N/D
4	47	N/D	N/D	N/D	N/D	N/D
5	177	N/D	N/D	N/D	N/D	N/D
6	77	N/D	N/D	N/D	N/D	N/D
7	10	N/D	N/D	N/D	N/D	N/D
8	25a	N/D	N/D	N/D	N/D	N/D
9	89	N/D	N/D	N/D	N/D	N/D
10	173	N/D	N/D	N/D	N/D	N/D

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

Table 2b. *Detail of spray programmes tested (for Rust control)*

Programme No	Wk1 11/09	Wk2 18/09	Wk3 25/09	Wk4 02/10	Wk5 09/10	Wk6 16/10	Wk7 23/10	Wk8 29/10	Wk 9 05/11
1*	47	-	105	-	177	-	25a	-	10
2+	47	47	†	†	†	177	25a	177	10
Managed Programme 2 Notes: Two initial treatments with 47. No more sprays unless rust appears, then treat with 177. Apply 25a if symptoms reappear. † = no visible signs of infection – no products applied									
3*	25a	-	77	-	177	-	173	-	77
4+	25a	†	†	†	†	25a	77	177	173
Managed Programme 4 Notes: One initial treatment with 25a. No more sprays unless rust appears. Sequentially apply products as programme 3 if rust reappears. * Prescriptive programmes + Managed programmes † = no visible signs of infection – no products applied									

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

Treatment	Product	Active ingredient(s)	Manufacturer	Batch number	% a.i	Formulation type
1	Untreated	-	-	-	-	-
2	Signum (Standard)	Boscalid + Pyraclostrobin	BASF	12-000418	26.7:6.7% w/w	WG
3	11	N/D	N/D	N/D	N/D	N/D
4	105	N/D	N/D	N/D	N/D	N/D
5	178	N/D	N/D	N/D	N/D	N/D
6	77	N/D	N/D	N/D	N/D	N/D
7	10	N/D	N/D	N/D	N/D	N/D
8	25a	N/D	N/D	N/D	N/D	N/D
9	28	N/D	N/D	N/D	N/D	N/D
10	89	N/D	N/D	N/D	N/D	N/D
11	156	N/D	N/D	N/D	N/D	N/D

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

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

Programme No	Wk1 23/09	Wk2 02/10	Wk3 09/10	Wk4 16/10	Wk5 23/10	Wk6 29/10	Wk7 05/11
1*	11	_	77	_	105	_	10
2+	11	11	–	–	–	–	–
Notes: Managed programme. No more sprays unless mildew appears then consider re-application of 11. Microscopy to check for successful mycoparasitism. If not then switch to 77 or possibly 105 dependent on severity							
3*	156	_	77	_	25a	_	89
4+	77	–	–	–	–	–	–
Notes: Managed programme. No more sprays unless mildew developing. Extend spray interval and use 25a & 89 in sequence if required * Prescriptive programmes + Managed programmes							

Table 3a. *Application details for Rust 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, A8, A9	-	500
Signum (Standard)	A1, A3, A5, A7, A9	1.35kg/ha	500
105	A1, A2, A3, A4, A5, A6, A7, A8, A9	2.5l/ha	500
47	A1, A2, A3, A4, A5, A6, A7, A8, A9	0.025kg/ha† (1st 2 sprays) 0.05kg/ha* subsequently	500
178	A1, A2, A3, A4, A5, A6, A7, A8, A9	10l/ha	500
177	A1, A3, A5, A7, A9	1.0 l/ha	500
77	A1, A3, A5, A7, A9	0.8 l/ha	500
10	A1, A3, A5, A7, A9	1.0 l/ha	500
25a	A1, A3, A5, A7, A9	1.0l/ha	500
89	A1, A3, A5, A7, A9	0.5l/ha	500
173	A1, A3, A5, A7, A9	0.8kg/ha	500
Programme 1	A1, A3, A5, A7, A9	various	500
Programme 2	A1, A2, A6, A7, A8, A9	various	500
Programme 3	A1, A3, A5, A7, A9	various	500
Programme 4	A1, A6, A7, A8, A9	various	500

Application Dates (rust trials)	
A1	11/09/2015† (21 days post transplanting)
A2	18/09/2015†
A3	25/09/2015*
A4	02/10/2015*
A5	09/10/2015*
A6	16/10/2015*
A7	23/10/2015*
A8	29/10/2015*

† - Bion applied at 0.025kg/ha rate

* - Bion applied at 0.05kg/ha rate

Table 3b. 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
Signum (Standard)	A1, A3, A5, A7	1.35kg/ha	500
11	A1, A2, A3, A4, A5, A6, A7	0.07kg/ha	500
105	A1, A3, A5, A7	2.5l/ha	500
178	A1, A3, A5, A7	5-10l/ha	500
77	A1, A3, A5, A7	0.8 l/ha	500
10	A1, A3, A5, A7	1.0 l/ha	500
25a	A1, A3, A5, A7	1.0l/ha	500
28	A1, A3, A5, A7	1.0l/ha	500
89	A1, A3, A5, A7	0.5l/ha	500
156	A1, A3, A5, A7	1.2kg/ha	500
Programme 1	A1, A3, A5, A7	various	500
Programme 2	A1, A2	various	500
Programme 3	A1, A3, A5, A7	various	500
Programme 4	A1	various	500

Application dates (powdery mildew trials)	
A1	25/09/2015 (35 days post transplanting)
A2	02/10/2015
A3	09/10/2015
A4	16/10/2015
A5	23/10/2015
A6	29/10/2015
A7	05/11/2015

Table 4a. Product application details (Rust)

Application No.	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**
Application date	11/9/15	18/9/15	25/9/15	2/10/15	9/10/15	16/10/15	23/10/15	29/10/15	5/11/15
Time of day [1]	PM	PM	PM	PM	PM	PM	PM	PM	PM
Application method	Foliar spray	Foliar spray	Foliar spray	Foliar spray	Foliar spray	Foliar spray	Foliar spray	Foliar spray	Foliar spray
Temperature of air – max/min (°C) [2]	23.88/10.6	22.36/7.9	20.7/8.9	23.8/6.7	23.16/9.02	12.5/8.7	16.6/5.91	14.18/7.7	18.4/15.3
Air temperature at application [3]	22.4	20.6	19.4	22.7	22.4	12.4	14.2	13.5	17.6
Relative humidity (%) [4]	53.6	55.2	46.6	49.3	60.3	83.2	76.8	93.0	85.8
Cloud cover (%) [5]	37.5	87.5	50	100	100	100	100	100	100
Crop growth stage – days post-transplant	35	41	48	56	61	70	77	84	91

[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

[5] Cloud cover % readings derived from Met Office data from Station no 4086 – Cawood. G.R. SE 56158 37171

Table 4b. Application details (Powdery Mildew)

Application No.	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**
Application date	25/9/15	2/10/15	9/10/15	16/10/15	23/10/15	29/10/15	05/11/15
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]	20.7/8.9	23.8/6.7	23.16/9.02	12.5/8.7	16.6/5.91	14.18/7.7	18.4/15.3
Air temperature at application [3]	19.4	22.7	22.4	12.4	14.2	13.5	17.6
Relative humidity (%) [4]	46.6	49.3	60.3	83.2	76.8	93.0	85.8
Cloud cover (%) [5]	50	100	100	100	100	100	100
Crop growth stage – days post-transplant	48	56	61	70	77	84	91

[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

[5] Cloud cover % readings derived from Met Office data from Station no 4086 – Cawood. G.R. SE 56158 37171

Table 5. Target pathogens

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

Infector plants were introduced to the Aster and Bellis crops on 28/08/14 and 01/09/14 respectively

Table 6a. Assessments

Bellis Assessment No.	Date	Growth stage (days post- transplant)	Timing of assessment relative to last application	Assessment types [2]
1	2/10/15	56	7 days post A3	Nº of infected leaves
2	14/10/15	68	5 days post A5	Nº of infected leaves
3	26/10/15	80	3 days post A7	Nº of infected leaves
4	13/11/15	97	8 days post A9	% LAI
5	24/11/15	108	19 days post A9	% LAI
Aster Assessment No.	**Date**	**Growth stage (days post- transplant)**	**Timing of assessment relative to last application**	**Assessment types**
1	02/10/15	56	9 days post A1	% LAI
2	16/10/15	70	7 days post A3	% LAI
3	6/11/15	90	1 day post A7	% LAI

[2] %LAI = % Leaf Area Infected

Table 6b. Assessment scoring criteria

Aster disease severity score	% leaf area infected	Bellis disease severity score	% leaf area infected	Bellis assessment symptom description
0	0	0	0	No lesions present on leaves
1	1-10%	1	< 1%	All single lesions on infected leaves
2	11-25%	2	1-5 %	Mostly single lesions on infected leaves
3	26-50%	3	5-10%	Mixture of single and multiple lesions on infected leaves
4	51-75%	4	10-25%	Mostly multiple lesions on infected leaves
5	>75%	5	>25%	Multiple lesions on majority of infected leaves

Results

Table 7c. *Effect of treatments on Bellis rust*

Crop Code		BELPE		BELPE		BELPE		BELPE		BELPE	
Crop Scientific Name		*Bellis perennis*		*Bellis perennis*		*Bellis perennis*		*Bellis perennis*		*Bellis perennis*	
Crop Name		English daisy		English daisy		English daisy		English daisy		English daisy	
Crop Variety		Goliath mix		Goliath mix		Goliath mix		Goliath mix		Goliath mix	
Part Rated		LEAF		LEAF		LEAF		LEAF		LEAF	
Rating Date		02/10/2015		14/10/2015		26/10/2015		13/11/2015		24/11/2015	
Rating Type		Disease severity		Disease severity		Disease severity		Disease severity		Disease severity	
Rating Unit		NUMBER		NUMBER		NUMBER		0-5		0-5	
ARM Action Codes						AL		AL		AS	
Trt No	Product code										
		1		2		3		4		5	
1	Control	0.1	a	15.8	a	40.1	a	4.9	a	4.9	a
2	105	0.2	a	2.5	cde	8.5	cd	1.9	c	2.1	c
3	47	0	a	0.4	ef	2.1	e	0.7	e	0.8	e
4	177	0.1	a	0.2	f	0	h	0	g	0	h
5	77	0	a	0.8	def	0.8	f	0.1	fg	0.3	fgh
6	10	0	a	0.3	f	0.6	fg	0.2	fg	0.4	fg
7	25a	0	a	0.1	f	0.1	gh	0.1	fg	0.1	gh
8	89	0	a	6.7	b	15.4	b	2.5	b	2.9	b
9	173	0	a	3.7	c	12.5	bc	1.7	c	2.2	c
10	Signum	0	a	1	def	7.4	d	1.4	cd	1.5	d
11	Prog 1	0.3	a	1.8	c-f	1.7	e	0.3	f	0.1	gh
12	Prog 2	0.3	a	2.7	cd	2.9	e	0.7	e	0.6	ef
13	Prog 3	0	a	0.1	f	0.1	h	0.1	fg	0	h
14	Prog 4	0.2	a	2.6	cde	5.4	d	1	de	0.8	e
LSD P= 0.05		0.24		2.25		0.18t		0.09t		0.19t	
Standard Deviation		0.21		1.95		0.16t		0.07t		0.16t	
CV		267.1		70.79		25.01t		28.37t		13.67t	
Replicate F		2.411		0.383		1.262		0.441		0.469	
Replicate Prob(F)		0.0456		0.859		0.2909		0.8183		0.7983	
Treatment F		1.72		27.76		63.008		60.668		53.355	
Treatment Prob(F)		0.0775		0.0001		0.0001		0.0001		0.0001	

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

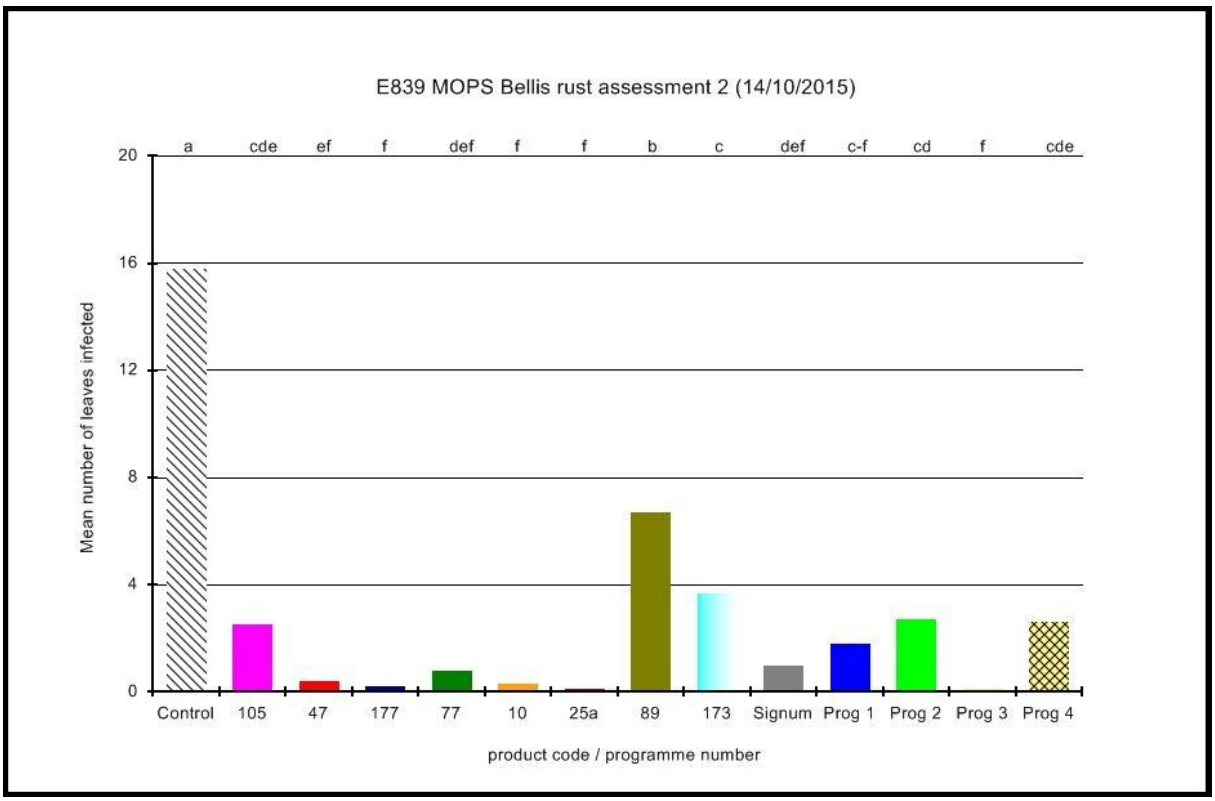
t=Mean descriptions are reported in transformed data units, and are not de-transformed.

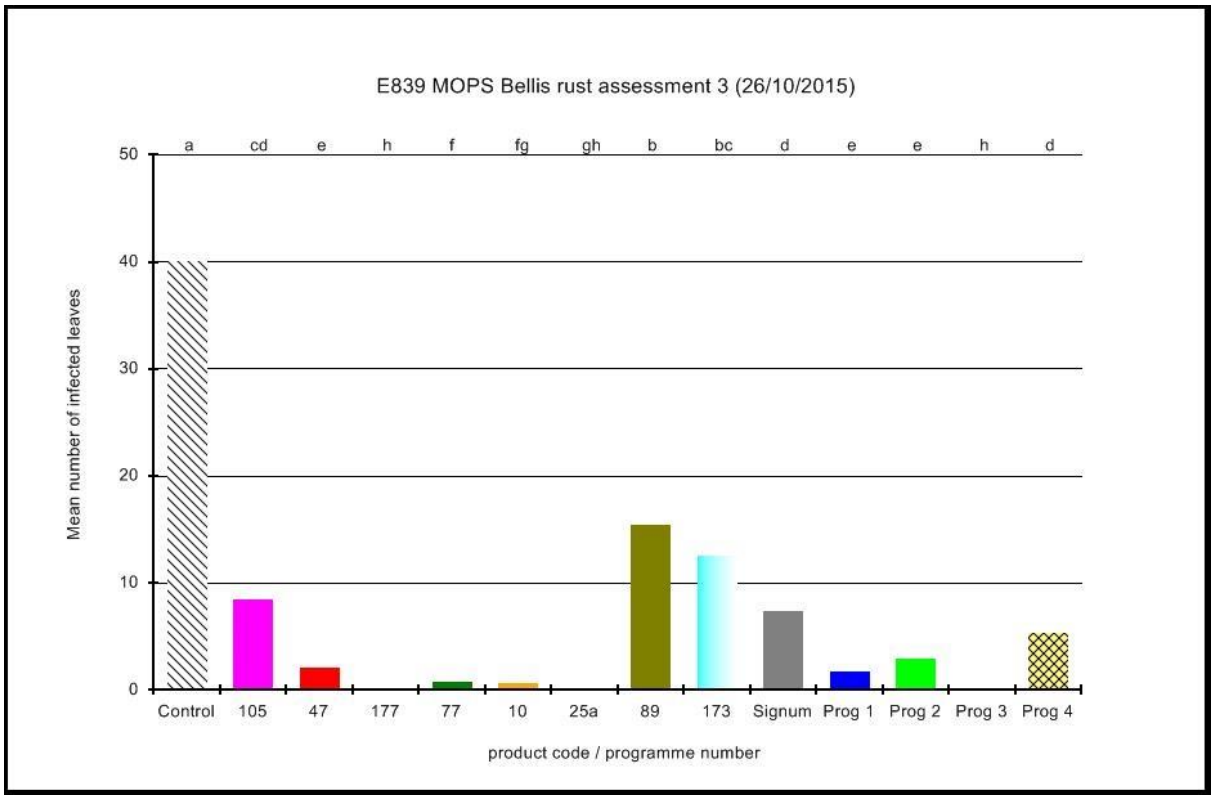
Mean comparisons performed only when AOV Treatment P(F) is significant at mean comparison OSL.

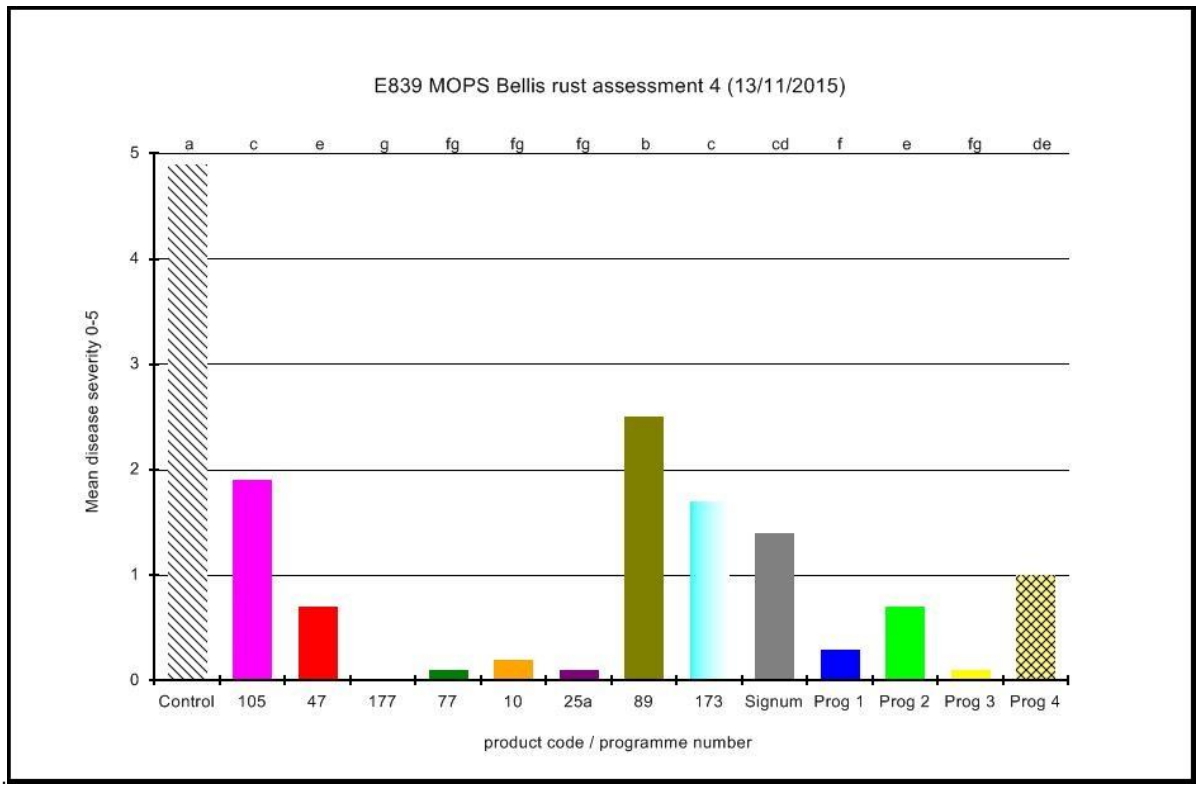
ARM Action Codes

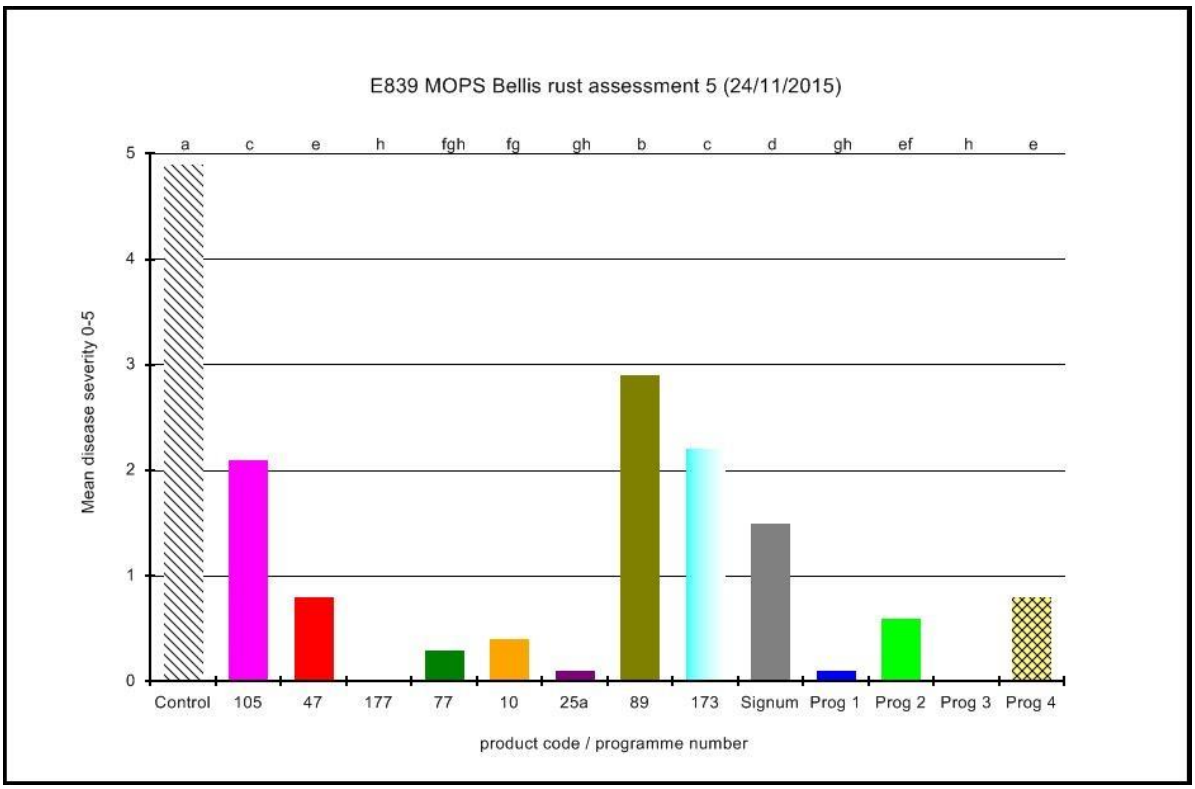
AL = Automatic log transformation of X+1

AS = Automatic square root transformation of X+0.5


E839 MOPS Bellis rust assessment 2 (14/10/2015)
a cde ef f def f f b c def c-f cd f cde
20
16
12
8
4
0
Mean number of leaves infected
Control 105 47 177 77 10 25a 89 173 Signum Prog 1 Prog 2 Prog 3 Prog 4
product code / programme number


E839 MOPS Bellis rust assessment 3 (26/10/2015)
a cd e h f fg gh b bc d e e h d
50
40
30
20
10
0
Mean number of infected leaves
Control 105 47 177 77 10 25a 89 173 Signum Prog 1 Prog 2 Prog 3 Prog 4
product code / programme number


E839 MOPS Bellis rust assessment 4 (13/11/2015)
a c e g fg fg fg b c cd f e fg de
Mean disease severity 0-5
0 1 2 3 4 5
Control 105 47 177 77 10 25a 89 173 Signum Prog 1 Prog 2 Prog 3 Prog 4
product code / programme number


E839 MOPS Bellis rust assessment 5 (24/11/2015)
a c e h fgh fg gh b c d gh ef h e
Mean disease severity 0-5
0 1 2 3 4 5
Control 105 47 177 77 10 25a 89 173 Signum Prog 1 Prog 2 Prog 3 Prog 4
product code / programme number

Crop inoculation

For the Aster and Bellis crops ‘infector’ plants were introduced into the trial. Within the Aster crop 1 infector plant was placed in the centre of each plot. Within the Bellis crop 6/packs of infected Bellis were interspersed throughout the trial area. With both pathogens 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 or leaf distortion 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 series of screening trials one of the main challenges was to secure successful establishment of the relevant pathogens in the respective crops. This is made more challenging by the fact that the pathogens of interest are obligate meaning that they cannot be cultured on artificial media in the laboratory. Infection has to occur naturally either via air-borne spores circulating in the wider environment, or via the use of 'infector' plants introduced into the trial area. In either case infection is further encouraged by maintaining an environment conducive to spore development, release, germination and infection. In these trials where natural infection did not occur 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. Due to the climatic preferences of the pathogens studied the trials were conducted in autumn when optimum glasshouse temperatures were more easily achieved whilst maintaining high humidity conducive to disease development. We were successful in establishing infection in the Bellis crop and the Bellis rust developed to significant levels thus providing a stern test for the various products evaluated. For the Aster trial infection by powdery mildew was much slower and more sporadic in its development in the infector plants due to unexpected mycoparasitism of the test pathogen by *Ampelomyces quisqualis* most likely originally introduced in 2014 during evaluation of the biopesticide product AQ10.There was no disease transfer from the 'infector plants' to the trial crop.

Aster

Generation of infector plants from the inoculum present on the previous year's Aster progressed slowly and sporadically despite the ideal conditions for infection being maintained in the propagation area. Attempts to inoculate were made both by the use of a spore suspension sprayed directly onto the foliage of the plants and the direct application of powdery mildew spores from infected leaf material from a variety of sources. When the infector plants were introduced to the trial area on 7/10/15 around 50% showed early signs of visible powdery mildew infection and it was expected that the pathogen would develop and spread within the untreated plots given ideal climatic conditions. Over subsequent weeks the infection failed to progress significantly and 1 month later on 6/11/15 30% of the infector plants remained disease-free and levels of infection on the infector plants originally showing visible symptoms had advanced only slightly. Samples of powdery mildew were taken from the leaf surfaces of several of the infector plants for microscopic analysis which confirmed mycoparasitism by *Ampelomyces quisqualis* (Figure 2). By the end of the trial period the powdery mildew had failed to spread from the infector plants to any of the trial plots preventing any meaningful comparison of the efficacy of the fungicides to be evaluated in the trial.

Bellis

Infection of the Bellis progressed steadily in the untreated plots following the introduction of infector plants into the trial area. The spray programmes commenced 2 weeks prior to the introduction of infector plants to allow a period of time for products with a protectant/elicitor activity to take effect. A number of conventional products (177, 77, 25a & 10) had excellent efficacy against Bellis rust, with 177 providing complete control of the rust by the end of the trial. As was the case in the 2014 trials 89 and 173 were less effective and failed to provide an equivalent level of disease suppression. Of the biological products 105 did not provide effective protection from the disease and the levels of rust within the plots for this treatment have implications for potential marketability of the plants. In contrast 47 provided strong control of rust performing comparably with a number of the conventionals in terms of disease suppression. It provided relatively effective control of rust throughout the trial duration although not to the same extent as the previous year. The spray programmes yielded good results with prescriptive programmes yielding the best disease control. Programme 3 provided complete control of the rust by the end of the trial and programme 1 control was comparable with product 25a applied as a straight treatment. The managed programmes which relied on strategic application of products when the first signs of rust infection were detected in the trial plots did not result in such effective disease control. This suggests that spore germination and initial leaf infection occur without manifesting any foliar symptoms visible to the naked eye, and that by the time that sporulation is evident on the leaf surfaces the ability of the products to control disease progression is more limited.

Conclusions

The Bellis trial conducted 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. The conventional products overall provided a high degree of disease control whereas in general the biological products were less effective even when they were applied as protective applications weekly. Product 47 was perhaps the exception, against Bellis rust at least as this provided a greater degree of control of rust than that of the industry standard Signum. Last year it was concluded that the inoculation technique employed to introduce the 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 (on Antirrhinum) whilst having a negligible effect on the efficacy of the conventional products may have overwhelmed some of the biological products which rely on different modes of action. As a result this year ‘infector’ plants were used to naturally establish infection providing a more realistic simulation for the evaluation of biological products. In the case of the Bellis rust this year’s results

were broadly comparable with those from last year for the straight products. The results from the prescriptive and managed programmes appear to show that prescriptive programmes that consist of planned product applications at defined points in the growing season (and in advance of visible disease symptoms in the crop) were more effective at controlling disease levels over the duration of the trial than managed programmes that rely on visible appearance of disease in the crop to trigger the application of trial products.

The failure of the Aster powdery mildew to establish and spread in any of the test plots is disappointing as it has prevented us from gathering additional data on individual products and fungicide programmes. However, its successful colonization of the trial area presents some very interesting questions about the effective use of mycoparasites in disease control. As the product was largely ineffective in 2014 and yet highly successful (accidentally) in 2015 it questions whether there needs to be an adaption period to acclimatise the mycoparasite a. on the host crop and b. against the host-specific powdery mildew pathogen. It is recommended that further work should be undertaken to specifically explore this aspect of mycoparasite epidemiology and parasitism in 2016.

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.

GLP compliance will not be claimed in respect of this 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

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

Appendix B – Meteorological data

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 Integro climate control system.	

Date	Mean daytime temp/ ^{0}C	Mean nightime temp/ ^{0}C	Minimum temp/ ^{0}C	Maximum temp/ ^{0}C	Mean daytime RH/%	Mean nightime RH/%	Sunshine hours
01/09/2015	18.5	12.8	11.5	24.2	58.7	90.7	5.3
02/09/2015	17.1	11.9	10.9	20.9	64.0	82.6	1.7
03/09/2015	14.7	11.7	10.2	17.3	64.1	87.1	0.0
04/09/2015	14.8	12.0	10.6	18.0	63.3	77.4	0.3
05/09/2015	15.0	12.1	8.1	18.1	55.2	82.1	3.6
06/09/2015	19.8	8.6	7.1	24.4	51.3	80.7	9.4
07/09/2015	18.3	10.9	8.8	24.2	63.1	85.4	4.1
08/09/2015	14.9	11.4	9.4	18.0	73.5	86.8	0.0
09/09/2015	16.8	12.0	11.1	20.7	68.6	79.5	0.0
10/09/2015	21.3	11.3	9.5	26.5	56.1	92.2	8.6
11/09/2015	19.7	11.8	10.6	23.9	65.4	88.8	6.8
12/09/2015	17.4	13.6	9.8	21.9	76.4	90.8	3.0
13/09/2015	17.5	9.8	8.5	22.0	62.7	87.5	4.1
14/09/2015	14.1	9.8	8.1	17.3	85.1	88.0	0.0
15/09/2015	16.6	12.3	9.8	21.1	74.9	92.8	3.2
16/09/2015	15.8	9.3	7.8	20.8	64.1	88.8	2.8
17/09/2015	16.3	9.9	7.6	22.0	61.7	85.3	4.4
18/09/2015	16.2	10.5	7.9	22.4	72.3	86.6	1.6
19/09/2015	19.7	10.6	8.4	24.4	60.7	89.9	8.1
20/09/2015	16.9	10.8	8.3	20.7	66.5	89.0	3.6
21/09/2015	15.7	13.1	9.9	19.0	82.4	84.3	0.8
22/09/2015	16.5	9.8	8.2	20.3	63.8	90.4	7.2
23/09/2015	16.4	11.7	9.8	19.6	65.4	82.9	3.0
24/09/2015	15.7	12.3	10.5	19.4	64.8	90.7	7.0
25/09/2015	16.9	10.5	8.9	20.7	57.4	84.1	8.8
26/09/2015	15.6	8.6	7.2	23.0	70.0	86.6	2.5
27/09/2015	15.0	10.2	8.3	21.1	75.9	89.8	3.4
Date	**Mean daytime temp/ ^{0}C**	**Mean nightime temp/ ^{0}C**	**Minimum temp/ ^{0}C**	**Maximum temp/ ^{0}C**	**Mean daytime RH/%**	**Mean nightime RH/%**	**Sunshine hours**

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28/09/2015	15.9	9.0	7.8	21.9	76.3	92.6	4.5
29/09/2015	16.7	9.9	8.2	23.7	71.3	93.5	5.3
30/09/2015	18.3	9.5	7.7	23.8	63.6	91.3	8.6
01/10/2015	16.1	9.3	7.9	22.2	75.2	92.0	6.9
02/10/2015	16.7	8.6	6.7	23.8	69.3	92.9	x
03/10/2015	15.6	9.1	7.8	22.8	80.6	92.8	x
04/10/2015	17.4	9.3	8.7	24.5	71.1	92.4	3.2
05/10/2015	15.0	9.2	8.1	17.4	96.0	91.5	0.0
06/10/2015	20.0	15.5	14.0	26.3	81.5	98.2	1.8
07/10/2015	15.4	14.1	10.8	18.9	87.6	96.1	0.0
08/10/2015	16.9	9.5	7.3	24.9	78.9	90.3	5.3
09/10/2015	17.0	9.9	9.0	23.2	79.1	94.1	4.5
10/10/2015	15.9	10.1	8.4	21.2	82.0	94.3	0.3
11/10/2015	17.2	10.5	9.4	24.3	73.1	94.1	5.1
12/10/2015	13.6	8.7	6.5	20.0	80.8	92.2	4.9
13/10/2015	12.2	9.2	7.8	16.0	82.2	93.7	0.4
14/10/2015	13.8	8.5	7.8	18.4	74.0	93.5	4.9
15/10/2015	12.9	9.2	8.5	18.4	86.1	94.0	0.8
16/10/2015	11.4	10.4	8.7	12.5	87.7	92.9	0.0
17/10/2015	13.2	9.3	8.5	16.9	79.0	95.5	1.4
18/10/2015	12.8	10.9	9.8	14.6	88.1	90.9	0.0
19/10/2015	15.7	9.2	7.3	22.8	76.9	95.5	3.5
20/10/2015	14.9	9.7	7.9	20.6	78.7	93.7	3.1
21/10/2015	17.1	10.3	10.2	23.5	81.7	94.9	1.8
22/10/2015	15.1	13.8	8.0	19.5	71.0	85.4	2.8
23/10/2015	12.0	7.4	5.9	16.6	83.3	94.2	0.0
24/10/2015	12.0	10.4	7.3	15.5	87.9	89.1	0.4
25/10/2015	12.9	6.8	5.8	18.2	79.4	95.2	0.0
26/10/2015	13.1	7.9	6.9	18.1	84.4	93.2	3.7
27/10/2015	13.5	11.1	11.2	15.5	92.6	96.6	0.0
28/10/2015	12.6	11.7	7.8	14.7	95.8	97.4	0.0
29/10/2015	12.7	9.0	7.7	14.2	94.0	96.8	0.0
30/10/2015	15.7	10.8	10.0	19.9	92.5	97.3	0.3
31/10/2015	14.4	10.9	10.2	15.9	92.6	84.2	0.2
01/11/2015	14.5	10.5	9.6	17.4	90.4	85.4	0.0
Date	**Mean daytime temp/ ^{0}C**	**Mean nightime temp/ ^{0}C**	**Minimum temp/ ^{0}C**	**Maximum temp/ ^{0}C**	**Mean daytime RH/%**	**Mean nightime RH/%**	**Sunshine hours**
02/11/2015	12.7	11.6	10.5	14.8	96.3	96.8	0.0
03/11/2015	13.2	10.3	9.7	16.4	91.9	97.9	0.0

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04/11/2015	17.3	15.7	15.0	20.0	81.3	85.6	0.0
05/11/2015	17.2	16.1	15.3	18.4	85.0	84.2	0.0
06/11/2015	17.1	17.6	15.5	18.1	86.3	85.1	0.0
07/11/2015	17.1	16.0	14.2	21.5	81.1	84.5	2.2
08/11/2015	15.8	15.8	14.7	16.9	83.7	79.4	0.0
09/11/2015	17.0	15.9	16.0	19.0	77.9	78.7	0.8
10/11/2015	19.1	18.0	17.1	21.1	76.4	80.0	0.4
11/11/2015	17.4	17.9	15.6	19.2	82.2	81.7	0.1
12/11/2015	16.9	15.9	15.2	18.8	77.8	81.8	1.2
13/11/2015	13.6	16.0	11.8	16.8	85.9	80.5	1.8
14/11/2015	13.5	15.5	11.2	16.8	87.5	77.3	0.0
15/11/2015	17.3	16.4	16.2	18.9	83.4	88.2	0.0
16/11/2015	15.0	17.0	13.8	17.9	71.2	82.9	0.0
17/11/2015	15.2	15.7	14.6	16.5	83.5	77.9	0.0
18/11/2015	15.1	15.9	13.8	16.6	80.8	77.4	0.5
19/11/2015	15.1	15.7	12.7	16.6	73.8	76.7	0.1
20/11/2015	14.1	15.6	11.9	16.6	79.5	67.9	1.8
21/11/2015	12.8	14.8	9.3	15.9	66.6	66.5	4.9
22/11/2015	13.5	14.8	10.2	16.4	68.8	62.1	2.2
23/11/2015	13.8	15.2	12.3	16.4	80.7	61.3	0.0
24/11/2015	14.3	15.6	12.0	16.3	75.4	75.6	0.0
25/11/2015	14.6	15.5	11.9	16.5	75.3	66.9	4.0
26/11/2015	15.8	15.3	14.0	18.3	73.7	73.5	0.6
27/11/2015	14.9	16.2	11.1	16.9	79.6	80.9	0.2
28/11/2015	12.9	11.0	10.1	14.2	77.4	77.6	0.0
29/11/2015	13.6	12.4	11.2	15.6	76.1	78.9	0.0
30/11/2015	12.9	11.3	10.4	14.5	77.9	76.0	0.0
01/12/2015	15.3	11.3	10.7	19.9	74.3	76.7	1.5
02/12/2015	14.4	15.7	11.1	17.1	81.5	77.4	0.3
03/12/2015	11.6	10.7	9.7	13.0	95.7	97.5	0.0
04/12/2015	11.9	9.1	7.3	14.1	94.3	94.6	0.8
05/12/2015	13.0	11.8	11.6	14.1	82.9	92.6	0.0
06/12/2015	11.7	13.0	7.6	14.6	89.1	87.0	0.0

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Appendix C – Agronomic details

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

Date	Product	Rate	Unit
13/10/15	Aphox (pirimicarb) (for aphid control)	0.5	g/L
18/9/15 9/10/15 23/10/15	Universol Blue (18-11-18 +2.5 MgO + TE)	1	g/L

Type of irrigation system employed
Hand watering

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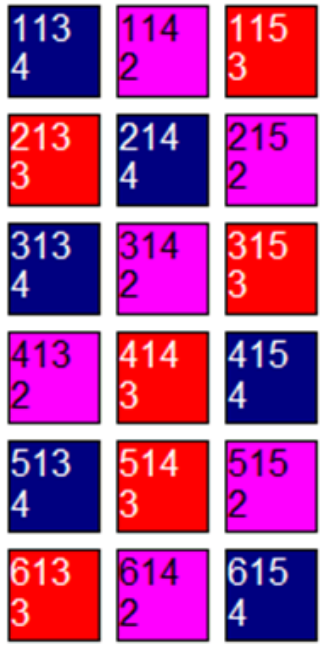
Appendix D – Trial layout

MOPS Aster Powdery Mildew

Conventionals



Biologicals

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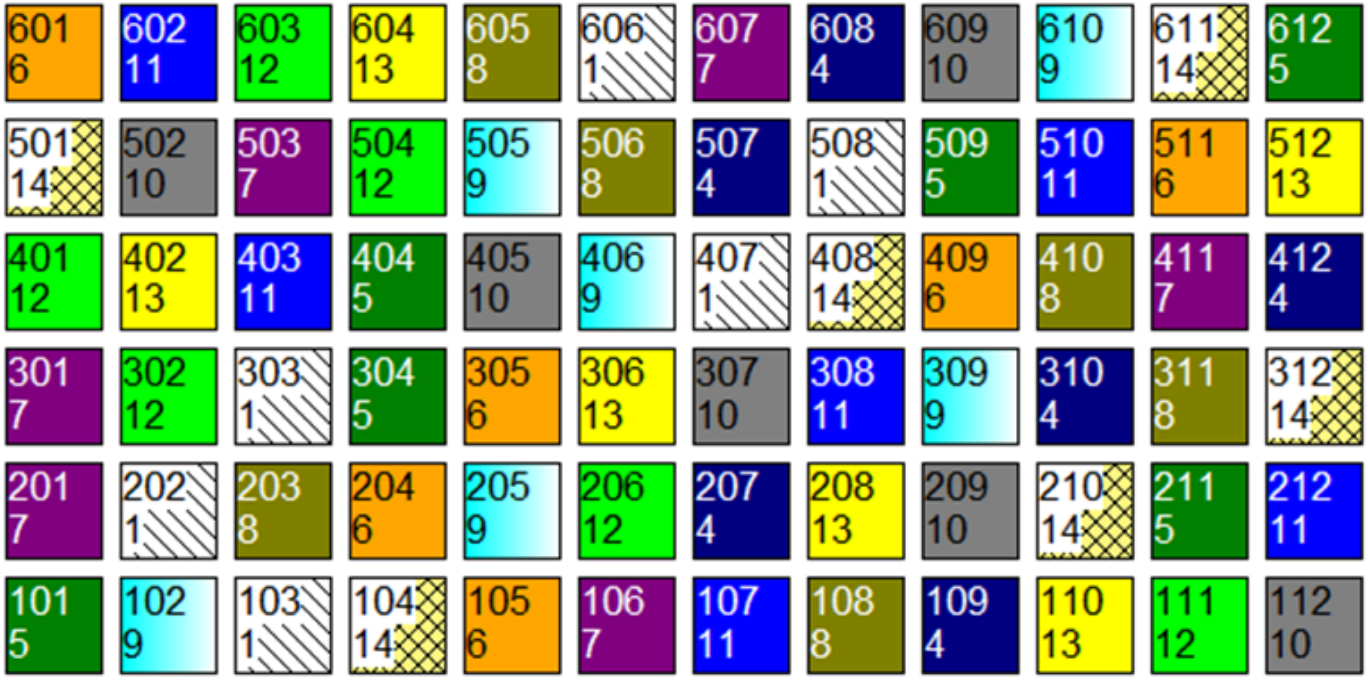
MOPS Bellis Rust



Conventionals

Biologicals

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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

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**

Signature _____
Authorised signatory

Certification Number
ORETO 291

HSE
Chemicals Regulation Directorate

Department of Agriculture and Rural Development

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Appendix F – Photographs

Figure 1. Infector plant with moderate disease level within an uninfected plot

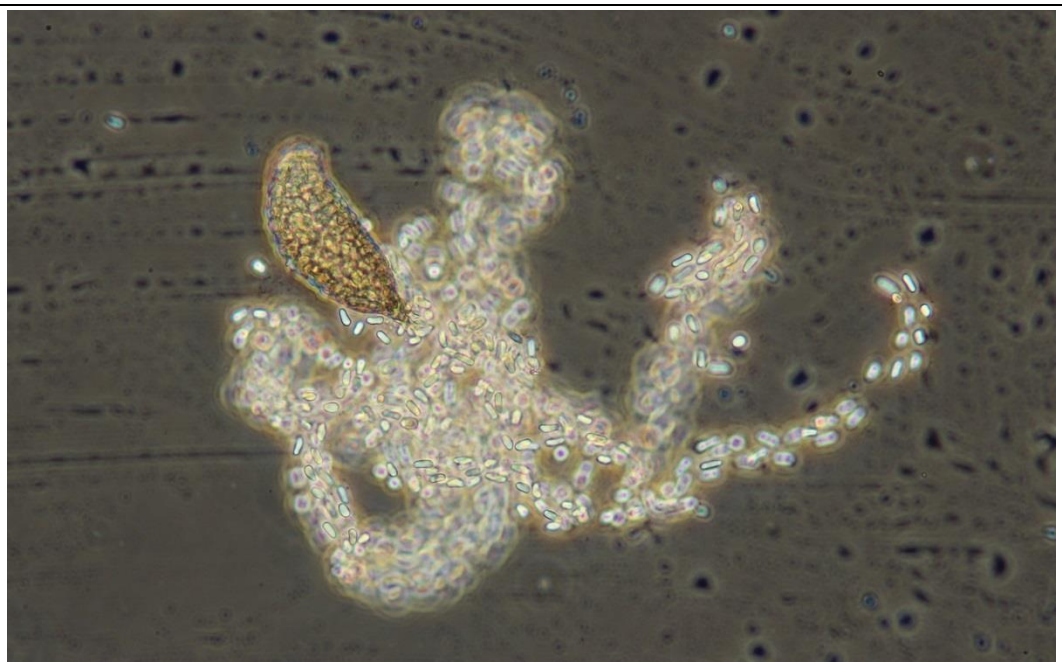

Figure 2. Pycnidium of *Ampelomyces* from an infector plant liberating spores (x 200) 6/11/15

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Figure 3. Overview of efficacy trial at first assessment (2/10/15)

Figure 4. Diseased Bellis infector plant with heavy sporulation (2/10/15)

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Figure 5. Untreated control vs product 47 treated plot in Bellis rust trial (26/11/2015)

Figure 6. Untreated control vs product 177 treated plot in Bellis rust trial (26/11/2015)

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