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 Antirrhinum and Powdery mildew in Aster and Pansy
Work package leader:	Dr G M McPherson MBPR (Hort)
Report:	Annual report, December 2014
Previous report:	None
Key staff:	Adam Ormerod – Trials Manager Amanda Hewick – Technical support Gavin Milson – Technical support
Location of work:	Stockbridge Technology Centre
Date work commenced:	19th May 2014
Date work completed (or expected completion date):	December 2014

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]	Plant Pathology Project Leader
[Organisation]	STCRF

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

Report authorised by:

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

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

CONTENTS

Growers Summary

Headline

- Several novel conventional fungicides have been identified with excellent activity against both powdery mildew and rust in a range of ornamental crops.
- Biopesticide products were generally less effective, though one product provided excellent control of rust in Bellis and another provided moderate suppression of powdery mildew in Aster. The trials have provided potentially important new information in terms of how future biopesticide trials should be conducted.

Background and expected deliverables

The SCEPTRE programme has been very successful in identifying and evaluating novel conventional chemical fungicides and biopesticide products for pest disease and weed control in edible crops and offers considerable scope to fill gaps in the crop protection armoury as active substances and products are withdrawn.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 response to growers concerns about potential losses of products in the ornamentals sector and in this regard is extremely important to the industry and sits alongside the minor use programme to ensure effective crop protection products remain available in the future.

The replicated trials outlined below expect to deliver useful information on the efficacy and crop safety of a range of novel crop protection products (conventional chemical and biopesticide products) for the control of both powdery mildew and rust pathogens in ornamentals. Whilst the initial studies conducted in year 1 of the project have been a success in this regard, the actual approval of specific products remains the responsibility of the manufacturers and/or marketing agents (on-label approvals), the HDC team (extrapolated approvals for minor use or EAMU) and the pesticide regulators (CRD) who ultimately authorize products for use in the UK.

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 specific cultivar selections or through the use of fungicide sprays, often indirectly as a result of powdery mildew control. 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 and rust diseases are usually managed by regular treatment with fungicides. 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 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 mode of action groups are not necessarily safe to use on all ornamental crops and the potential risk of phytotoxicity needs to be evaluated as part of the project.

Summary of the work and main conclusions

In the Summer/Autumn of 2014 a series of replicated glasshouse trials were carried out at Stockbridge Technology Centre to assess the effectiveness of a range of experimental biopesticides and conventional fungicides against powdery mildew and rust affecting commonly grown ornamental plants. Two host crops were grown for each target pathogen to maximise the chance of successfully establishing infection by these obligate pathogens,

Powdery Mildew – Aster ‘Cassandra’ and Pansy ‘Early Flowering Mix’ were selected as likely disease susceptible cultivars for use. Disease progression in the Aster crop was consistent and yielded good results with marked differences between the untreated plots and the experimental products with the conventionals performing better than the biopesticides. The disease progression amongst the pansy crop was far less widespread with low disease pressure making a meaningful comparison of the effectiveness of the experimental products more difficult.

Rust – Bellis ‘Goliath mixed’ and Antirrhinum ‘Magic Carpet Mixed’ were selected as disease susceptible cultivars. 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 for conventional and biopesticide products alike. The Antirrhinum crop was artificially inoculated with a spore suspension of the rust fungus. This resulted in an even infection across the trial area, good disease progression ensued, offering a stern test for the various products under evaluation.

The conventional products overall provided a high degree of disease control whereas in general the biopesticide products were less effective with the exception of one biopesticide which proved highly effective against Bellis rust. Important lessons were also learned about the inoculation technique employed to introduce the pathogens into the trials and the ways that these might be adapted in future studies to achieve a more natural reflection of disease pressure experienced by growers.

Action Points

This years' work has identified several promising new products that warrant further evaluation in the next phase of the MOPS project. Whilst very little phytotoxicity was observed in the host crops tested here their effect on a wider range of crops needs to be explored together with the development of spray programmes combining conventional and biopesticide products. The standard product Signum worked particularly well against both rust and powdery mildew in these trials and, as part of an integrated programme, it ought to help maintain effective disease control and at the same time also mitigate the risk of resistance developing in the pathogen population.

Science Section

Introduction

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, and in hardy nursery stock e.g. rose, hypericum and mahonia. Rust pathogens are hemi-basidiomycete fungi and can be very host-specific e.g. bellis rust (*Puccinia distincta*) will not cross-infect antirrhinum (*Puccinia antirrhini*) and *vice versa* though some are heteroecious and have alternate hosts, including tree species. In general, rust diseases tend to be controlled either by avoiding susceptible species or specific cultivar selections or through the use of fungicide sprays, often indirectly as a result of powdery mildew (an ascomycete fungus) control. Specific rust fungicides are quite limited and rely on the use of azole products primarily. Such products can be damaging (phytotoxic) on some horticultural crops and cultivars and their future availability and use within the EU pesticide review programme is at risk.

Powdery mildew diseases commonly affect a wide range of woody and herbaceous perennial ornamentals, pot and bedding plants and cut flower species, causing yellow, crinkled and distorted leaves, premature senescence and reduced vigour. Young, soft shoots are particularly affected. Even with slight infections, the white fungal growth on leaves, stems and flowers, and associated leaf yellowing and distortion, make plants unsightly and often unsaleable. Some crop species/cultivars are affected virtually every year (e.g. aster, hawthorn, monarda, rose, phlox, pansy, verbena), while a wide range of other species are affected sporadically depending on climatic and other variables.

Powdery mildew and rust diseases are usually managed by regular treatment with fungicides. 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 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 mode of action groups are not necessarily safe to use on all ornamental crops and this needs to be evaluated as part of the project.

Four replicated trials were conducted in summer/autumn 2014 to evaluate the efficacy of 4 biopesticide[1] (biofungicides) and 8 conventional pesticides (fungicides) for the control of Bellis rust (*Puccinia distincta*), Antirrhinum rust (*Puccinia antirrhini*), Pansy powdery mildew (*Podosphaera violae syn. Sphaerotheca macularis*) 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 the manufacturers label rate.

Eight applications of biopesticide products and four applications of conventional products were made during the trial period. The biopesticides were applied weekly whereas the conventional products were applied at two week intervals. Biopesticide and conventional treatments were spatially separated within the glasshouse in order to minimise any potential interactions between the conventional products on biopesticide products and *vice versa*. Treatments applied are listed in Tables 2a and 2b and 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 'biopesticide' products in this report refers to microbial products but also includes SAR inducers and plant extracts

Materials and methods

Aster ‘Cassandra’ was sourced as plug plants from the Cut Flower Centre and transplanted into 11cm pots and grown on. They were ‘stopped’ 3 times prior to the start of the trial to encourage shoot development and leafy growth. Bellis ‘Goliath Mixed’, Antirrhinum ‘Magic Carpet Mixed’ and Pansy ‘Early Flowering Mixed’ were sourced as seed sown in modules at STC and later transplanted into 6 packs for the trial.

The trial was commenced at the end of August 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 27/8/14, 1 day after occasional spots were found in the Aster plots. Infector plants with powdery mildew were subsequently introduced to the Aster plots on 28/8/14 at 1 pot/plot to provide a uniform spread of inoculum throughout the trial. On 28/8/14 the Pansies were inoculated with a spore suspension prepared from mildew infected Viola leaves. Both the Aster and Pansy crop were subsequently misted with water and covered with polythene sheet overnight on the following 2 consecutive days to provide an environment conducive to spore germination and subsequent leaf infection.

The first signs of rust infection were observed in the Bellis crop on 28/8/14 and the treatments were commenced on 29/8/14. Bellis infector plants with active rust infection were placed within the plots on 01/09/14. At the same time a spore suspension of Antirrhinum rust was prepared from infected leaf material, and applied to the Antirrhinum crop. As above, both crops were covered with polythene overnight on 2 consecutive days in order to maintain elevated humidity and provide a climate conducive to spore germination and infection.

During each trial, disease severity assessments were carried out 3 times on each crop and a plant vigour assessment was carried out on the Aster and the Bellis crop at the conclusion of the trial. 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)
Crop & Cultivar	Bellis 'Goliath Mixed' Antirrhinum ' Magic Carpet Mixed' Pansy 'Early Flowering Mixed' Aster ' Cassandra'
Glasshouse* or Field	Glasshouse
Date of planting/potting	Aster plugs potted on 20/06/14 Antirrhinum, Pansy and Bellis sown 03/07/14, potted on to 6 packs 04/08/14
Pot size	11cm (Aster) & Plantpak MC6 6-packs (Bellis, Pansy & Antirrhinum)
Number of plants per plot	12
Trial design (layout in Appendix C)	Randomised block
Number of replicates	4/6 (Conventionals/Biopesticides)
Plot size w (m), l (m), total area (m²)	0.28m
Method of statistical analysis	ANOVA

*Temperature and relative humidity settings are given in Appendix B

Table 2a. Detail of products tested (Rust)

Treatment	Product	MOPS code number	Active ingredient(s)	Manufacturer	Batch number	% a.i	Formulation type
1	Untreated (Inoculated)	-	-	-	-	-	-
2	Untreated (Uninoculated)	-	-	-	-	-	-
3	Signum (Standard)	-	Boscalid + pyraclostrobin	BASF	12-000207	26.7:6.7% w/w	WG
4	Reysa [A18905A]	105	Extract of *Reynoutria sachaliensis*	Syngenta CP	PE3161	N.A*	N.A*
5	Bion	47	Acibenzolar-S-methyl	Syngenta CP	PE2195	50% w/w	WG
6	Serenade ASO		Bacillus subtilis strain QST713	Bayer CP	0097901	1.34 % w/w	SC
7	Amistar Top	177	Azoxystrobin+ difenoconazole	Syngenta CP	PE1794	200:125 g/l	SC
8	Luna Sensation	77	Fluopyram+ trifloxystrobin	Bayer CS	EV57001784	N.A*	N.A*
9	A15149W	10	Isopyrazam	Syngenta CP	PE2453	N.A*	N.A*
10	BAS 71700F	25a	Fluxapyroxad+ difenoconazole	BASF	258048	N.A*	N.A*
11	Cyflamid	89	Cyflufenamid	Certis	40971	50 g/l	EW
12	Switch		Cyprodonil+ fludioxonil	Syngenta CP	?	37.5:25% w/w	WG

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

Table 2b. Detail of products tested (Powdery Mildew)

Treatment	Product	MOPS code number	Active ingredient(s)	Manufacturer	Batch number	% a.i	Formulation type
1	Untreated (Uninoculated)	-	-	-	-	-	-
2	Untreated (Inoculated)	-	-	-	-	-	-
3	Signum (Standard)	-	Boscalid + pyraclostrobin	BASF	12-000207	26.7:6.7% w/w	WG
4	AQ10		*Ampelomyces quisqualis* strain M-10	Fargro	L3213546	58% w/w	WG
5	Bion	47	Acibenzolar-S-methyl	Syngenta CP	PE2195	50% w/w	WG
6	Reysa (A18905A)	105	Extract of *Reynoutria sachaliensis*	Syngenta CP	PE3161	N.A*	N.A*
7	Serenade ASO		*Bacillus subtilis* strain QST713	Bayer CP	0097901	1.34 % w/w	SC
8	Luna Sensation	77	Fluopyram & trifloxystrobin	Bayer CS	EV57001784	N.A*	N.A*
9	A15149W	10	isopyrazam	Syngenta CP	PE2453	N.A*	N.A*
10	BAS 71700F	25a	Fluxapyroxad + difenoconazole	BASF	258048	N.A*	N.A*
11	Tectura	28	Boscalid + metconazole	BASF	007967202	133:60g/l	SC
12	Cyflamid	89	cyflufenamid	Certis	40971	50g/l	EW

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

Table 3a. Application details for rust treatments

Product name or MOPS code number	Application timing	Dosage rate (product/ha)	Spray volume (L/ha)
1. Untreated water control (Inoculated)	A1, A2, A3, A4, A5, A6, A7, A8	-	500
2. Untreated water control (Uninoculated)	A1, A2, A3, A4, A5, A6, A7, A8	-	500
3.Signum (Standard)	A1, A3, A5, A7	1.35kg/ha	500
4. 105	A1, A2, A3, A4, A5, A6, A7, A8	2.5l/ha	500
5. 47	A1, A2, A3, A4, A5, A6, A7, A8	0.025kg/ha† (1st 2 sprays) 0.05kg/ha* subsequently	500
6. Serenade ASO (QST713)	A1, A2, A3, A4, A5, A6, A7, A8	10l/ha	500
7. 177	A1, A3, A5, A7	1.0 l/ha	500
8. 77	A1, A3, A5, A7	0.8 l/ha	500
9. 10	A1, A3, A5, A7	1.0 l/ha	500
10. 25a	A1, A3, A5, A7	1.0l/ha	500
11. 89	A1, A3, A5, A7	0.5l/ha	500
12. Switch	A1, A3, A5, A7	0.8kg/ha	500

Application Dates (rust trials)	
A1	29/8/14† (25 days post transplanting)
A2	5/9/14†
A3	12/9/14*
A4	19/9/14*
A5	25/9/14*
A6	2/10/14†
A7	10/10/14†
A8	17/10/14†

† - 47 applied at 0.025kg/ha rate

* - 47 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)
1. Untreated (Uninoculated)	A1, A2, A3, A4, A5, A6, A7, A8	-	500
2. Untreated (Inoculated)	A1, A2, A3, A4, A5, A6, A7, A8	-	500
3.Signum (Standard)	A1, A3, A5, A7	1.35kg/ha	500
4. AQ10	A1, A2, A3, A4, A5, A6, A7, A8	0.07kg/ha	500
5. 47	A1, A2, A3, A4, A5, A6, A7, A8	0.025kg/ha† (1st 2 sprays) 0.05kg/ha* subsequently	500
6. 105	A1, A2, A3, A4, A5, A6, A7, A8	2.5l/ha	500
7. Serenade ASO (QST713)	A1, A3, A5, A7	10l/ha	500
8. 77	A1, A3, A5, A7	0.8 l/ha	500
9. 10	A1, A3, A5, A7	1.0 l/ha	500
10.25a	A1, A3, A5, A7	1.0l/ha	500
11. 28	A1, A3, A5, A7	1.0l/ha	500
12. Cyflamid	A1, A3, A5, A7	0.5l/ha	500

Application dates (powdery mildew trials)	
A1	27/8/14† (25 days post transplanting Pansy, 70 days post transplanting Asters)
A2	3/9/14†
A3	10/9/14*
A4	19/9/14*
A5	25/9/14*
A6	2/10/14†
A7	10/10/14†
A8	17/10/14†

† - 47 applied at 0.025kg/ha rate

* - 47 applied at 0.05kg/ha rate

Table 4a. Product application details (Rust)

Application No.	A1	A2	A3	A4	A5	A6	A7	A8
Application date	29/8/14	5/9/14	12/9/14	19/9/14	25/9/14	2/10/14	10/10/14	17/10/14
Time of day [1]	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
Temperature of air – max/min (°C) [2]	22.0/12.5	28.6/13.0	23.7/10.0	18.3/15.3	21.1/8.5	20.4/7.9	19.4/8.2	22.3/10.7
Air temperature at application [3]	19.7	27.6	20.4	18.0	19.5	19.6	17.8	18.9
Relative humidity (%) [4]	73	50	67	84	72	57	57	71
Cloud cover (%) [5]	100	100	100	100	100	25	0	12.5
Crop growth stage – days post-transplant (Antirrhinum)	25	31	38	45	51	58	66	73
Crop growth stage – days post-transplant (Bellis)	25	31	38	45	51	58	66	73

[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	A8
Application date	27/8/14	3/9/14	10/9/14	19/9/14	25/9/14	2/10/14	10/10/14	17/10/14
Time of day [1]	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
Temperature of air – max/min (°C) [2]	25.3/11.0	25.0/14.3	27.3/9.8	18.3/15.3	21.1/8.5	20.4/7.9	19.3/8.2	22.2/10.7
Air temperature at application [3]	22.9	22.8	26.0	18.0	19.5	19.6	17.8	18.9
Relative humidity (%) [4]	53	60	52	84	72	57	57	71
Cloud cover (%) [5]	62.5	100	50	100	100	25	0	12.5
Crop growth stage – days post-transplant (Aster)	70	77	84	93	99	106	114	121
Crop growth stage – days post-transplant (Pansy)	25	32	39	48	54	60	68	75

[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*	Trace
Antirrhinum Rust	*Puccinia antirrhini*	Nil
Pansy Powdery Mildew	*Podosphaera violae*	Nil
Aster Powdery Mildew	*Golovinomyces asterum* var. *asterum* (syn. *Erisyphe chicoracearum)*	Trace

Pansy downy mildew and Antirrhinum rust plots were inoculated with spore suspensions prepared from infected leaf material. The plots were inoculated on 28/08/14 and 01/09/14 respectively

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
1	30/09/14	57	5 days post A5	Disease severity
2	16/10/14	73	6 days post A7	Disease severity
3	03/11/14	91	17 days post A8	Disease severity & Plant vigour
Antirrhinum Assessment No.	**Date**	**Growth stage (days post- transplant)**	**Timing of assessment relative to last application**	**Assessment type**
1	30/09/14	57	5 days post A5	Disease severity
2	21/10/14	78	4 days post A8	Disease severity
3	31/10/14	87	14 days post A8	Disease severity
Aster Assessment No.	**Date**	**Growth stage (days post- transplant)**	**Timing of assessment relative to last application**	**Assessment types**
1	18/09/14	90	8 days post A3	Disease severity
2	16/10/14	118	6 days post A7	Disease severity
3	31/10/14	133	14 days post A8	Disease severity & Plant vigour

Pansy Assessment No.	Date	Growth stage (days post- transplant)	Timing of assessment relative to last application	Assessment type
1	30/09/14	57	5 days post A5	Disease severity
2	21/10/14	78	4 days post A8	Disease severity
3	10/11/14	98	24 days post A8	Disease severity

Table 6b. Assessment scoring criteria

Pansy disease severity score	% leaf area infected	Aster disease severity score	% leaf area infected	Bellis disease severity score	% leaf area infected	Antirrhinum disease severity score	% leaf area infected		Plant vigour score	Description (in relation to plant vigour)
0	0	0	0	0	0	0	0		0	Plant dead
1	1-2%	1	1-10%	1	1-2%	1	1-5%		1	Plants very chlorotic, large areas of leaf necrosis, lesions extensive
2	3-5%	2	11-25%	2	3-5%	2	6-10%		2	Plants chlorotic with some leaf necrosis, moderate lesion severity
3	6-10%	3	26-50%	3	6-10%	3	11-25%		3	Plants only slightly chlorotic, no leaf necrosis, low/moderate lesion severity
4	11-25%	4	51-75%	4	11-25%	4	26-50%		4	Very slight chlorosis, no leaf necrosis, very low lesion severity
5	>25%	5	>75%	5	>25%	5	>50%		5	Healthy plant, no chlorosis or leaf necrosis. Trace levels of disease only/no lesions present

Results

Table 7a - Effect of treatments on Antirrhinum rust (Conventional products)

Pest Type				D Disease		D Disease		D Disease	
Pest Code				PUCCAN		PUCCAN		PUCCAN	
Pest Scientific Name				*Puccinia antirrhini*		*Puccinia antirrhini*		*Puccinia antirrhini*	
Pest Name				Rust of snapdragon		Rust of snapdragon		Rust of snapdragon	
Crop Code				ATHMM		ATHMM		ATHMM	
Crop Scientific Name				*Antirrhinum majus*		*Antirrhinum majus*		*Antirrhinum majus*	
Crop Name				Great snapdragon		Great snapdragon		Great snapdragon	
Part Assessed				LEAF -		LEAF -		LEAF -	
Assessment Date				30/09/2014		21/10/2014		31/10/2014	
Assessment Type				DISEASE SEVERITY		DISEASE SEVERITY		DISEASE SEVERITY	
Assessment Unit				0-5		0-5		0-5	
Sample Size, Unit				2 2		2 2		2 2	
Collection Basis, Unit				2 POT		2 POT		2 POT	
Number of Subsamples				2		2		2	
Trt	Treatment								
No.	Name or code	Rate	Unit	1		2		3	
1	Inoculated			1.6	a	2.6	a	3.5	a
2	Uninoculated			0	c	0.6	c	0.7	c
3	Signum	1.35	kg/ha	0	c	0	d	0	d
7	177			0	c	0	d	0	d
8	77			0	c	0	d	0	d
9	10			0	c	0	d	0	d
10	25A			0	c	0	d	0	d
11	89			0.9	b	1.1	b	1.3	b
12	Switch			0.6	b	0.9	bc	1.7	b
LSD (P=.05)				0.41		0.21t		0.23t	
Standard Deviation				0.28		0.15t		0.16t	
CV				81.68		15.09		15.12	
Replicate F				0.547		2.235		1.254	
Replicate Prob(F)				0.6551		0.1101		0.3125	
Treatment F				16.856		25.499		34.621	
Treatment Prob(F)				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.

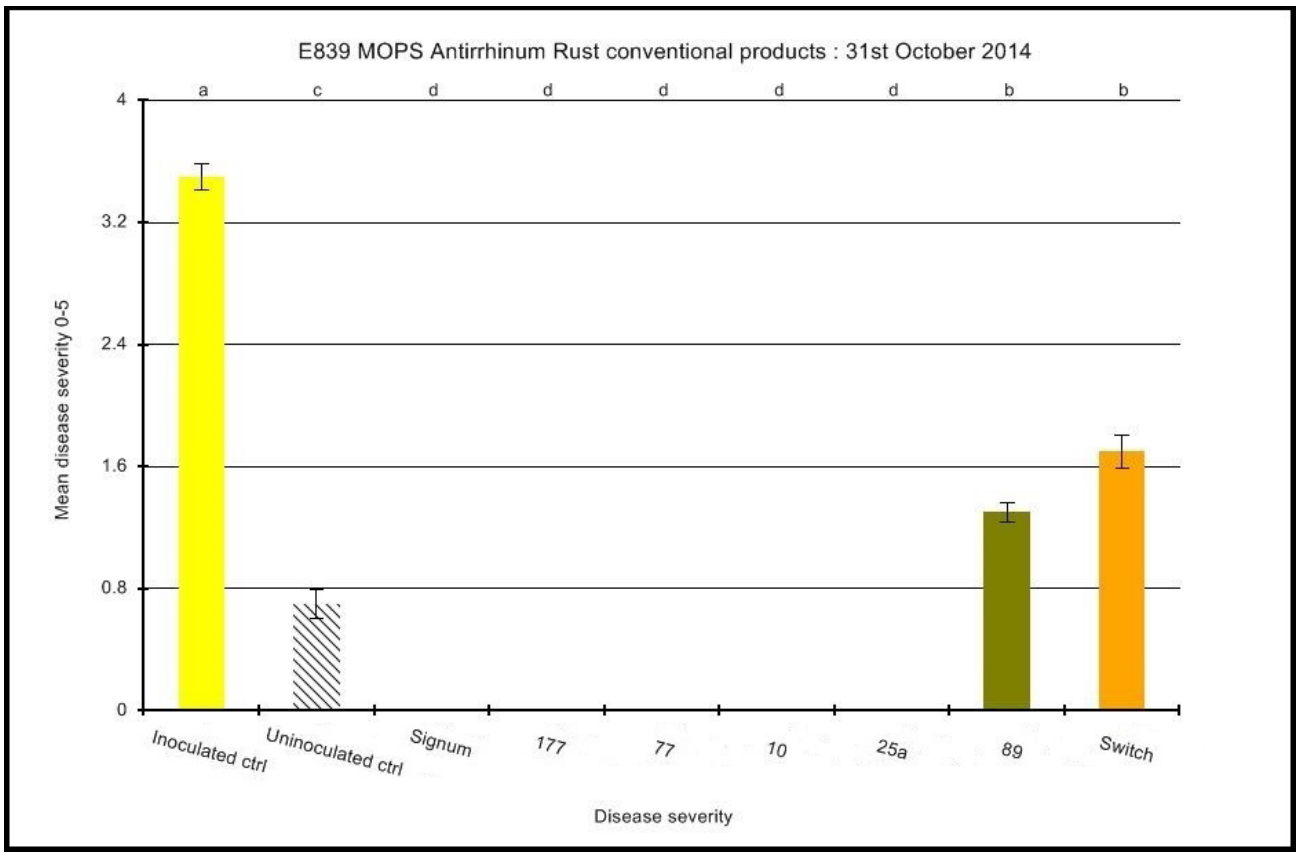
Mean comparisons performed only when AOV Treatment P(F) is significant at mean comparison OSL.

Table 7b - Effect of treatments on Antirrhinum rust (Biopesticide products)

Pest Type			D Disease		D Disease		D Disease	
Pest Code			PUCCAN		PUCCAN		PUCCAN	
Pest Scientific Name			*Puccinia antirrhini*		*Puccinia antirrhini*		*Puccinia antirrhini*	
Pest Name			Rust of snapdragon		Rust of snapdragon		Rust of snapdragon	
Crop Code			ATHMM		ATHMM		ATHMM	
Crop Scientific Name			*Antirrhinum majus*		*Antirrhinum majus*		*Antirrhinum majus*	
Crop Name			Great snapdragon		Great snapdragon		Great snapdragon	
Part Assessed			LEAF -		LEAF -		LEAF -	
Assessment Date			30/09/2014		21/10/2014		31/10/2014	
Assessment Type			DISEASE SEVERITY		DISEASE SEVERITY		DISEASE SEVERITY	
Assessment Unit			0-5		0-5		0-5	
Sample Size, Unit			2 2		2 2		2 2	
Collection Basis, Unit			2 POT		2 POT		2 POT	
Number of Subsamples			2		2		2	
Trt	Treatment							
No.	Name or code		1		2		3	
1	Inoculated		1.7	a	3.2	a	4.4	a
2	Uninoculated		0.2	c	1	c	1.4	c
4	105		1.4	ab	1.9	b	2.9	b
5	47		1	b	1.7	bc	1.9	c
6	Serenade ASO		1.5	ab	2.1	b	2.8	b
LSD (P=.05)			0.55		0.75		0.75	
Standard Deviation			0.45		0.63		0.62	
CV			39.37		31.79		23.08	
Replicate F			1.732		1.416		0.721	
Replicate Prob(F)			0.1734		0.2613		0.6154	
Treatment F			10.61		9.52		20.365	
Treatment Prob(F)			0.0001		0.0002		0.0001	

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

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


E839 MOPS Antirrhinum Rust conventional products : 31st October 2014
a c d d d d d b b
4
3.2
2.4
1.6
0.8
0
Mean disease severity 0-5
Inoculated ctrl
Uninoculated ctrl
Signum
177
77
10
25a
89
Switch
Disease severity

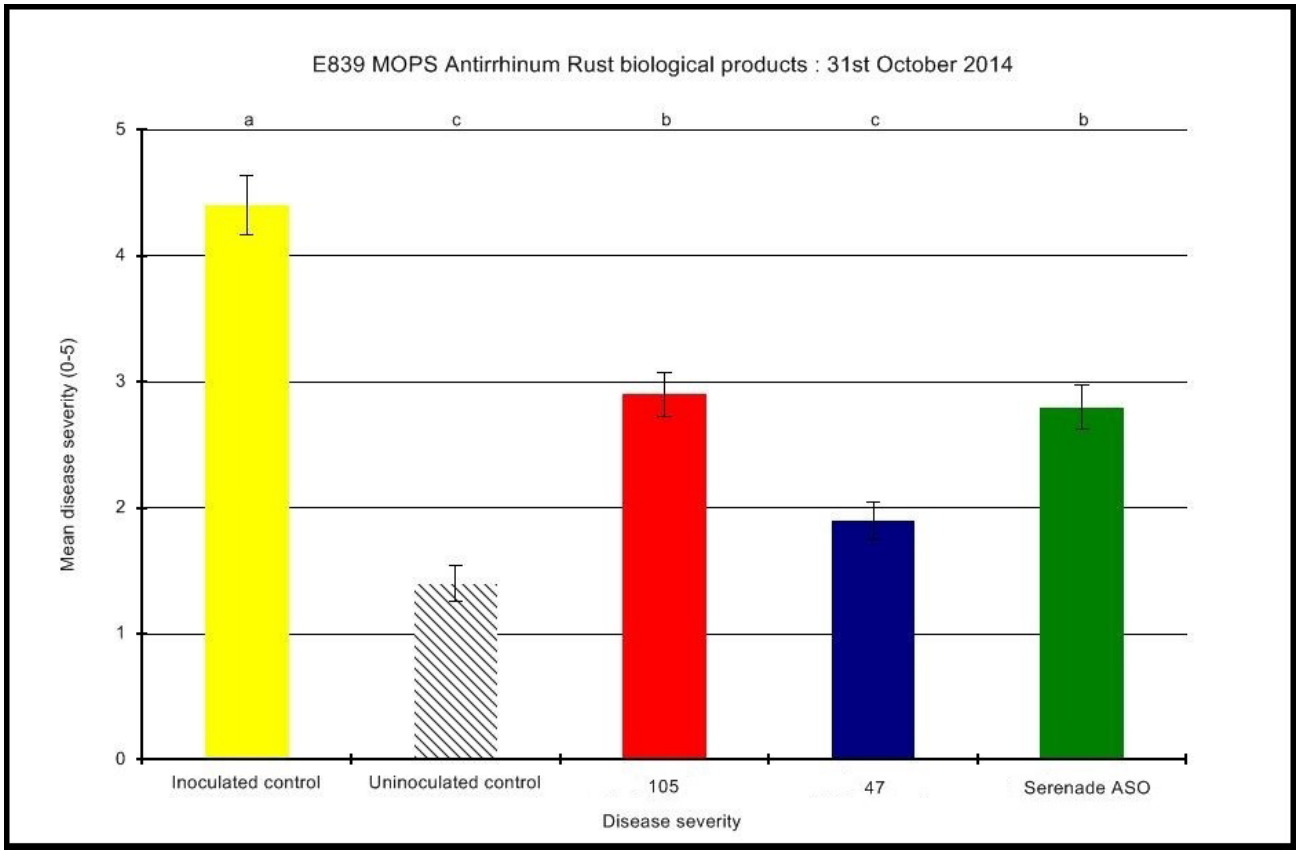

E839 MOPS Antirrhinum Rust biological products : 31st October 2014
a c b c b
5
4
3
2
1
0
Mean disease severity (0-5)
Inoculated control
Uninoculated control
105
47
Serenade ASO
Disease severity

Table 7c - Effect of treatments on Bellis rust (Conventional products)

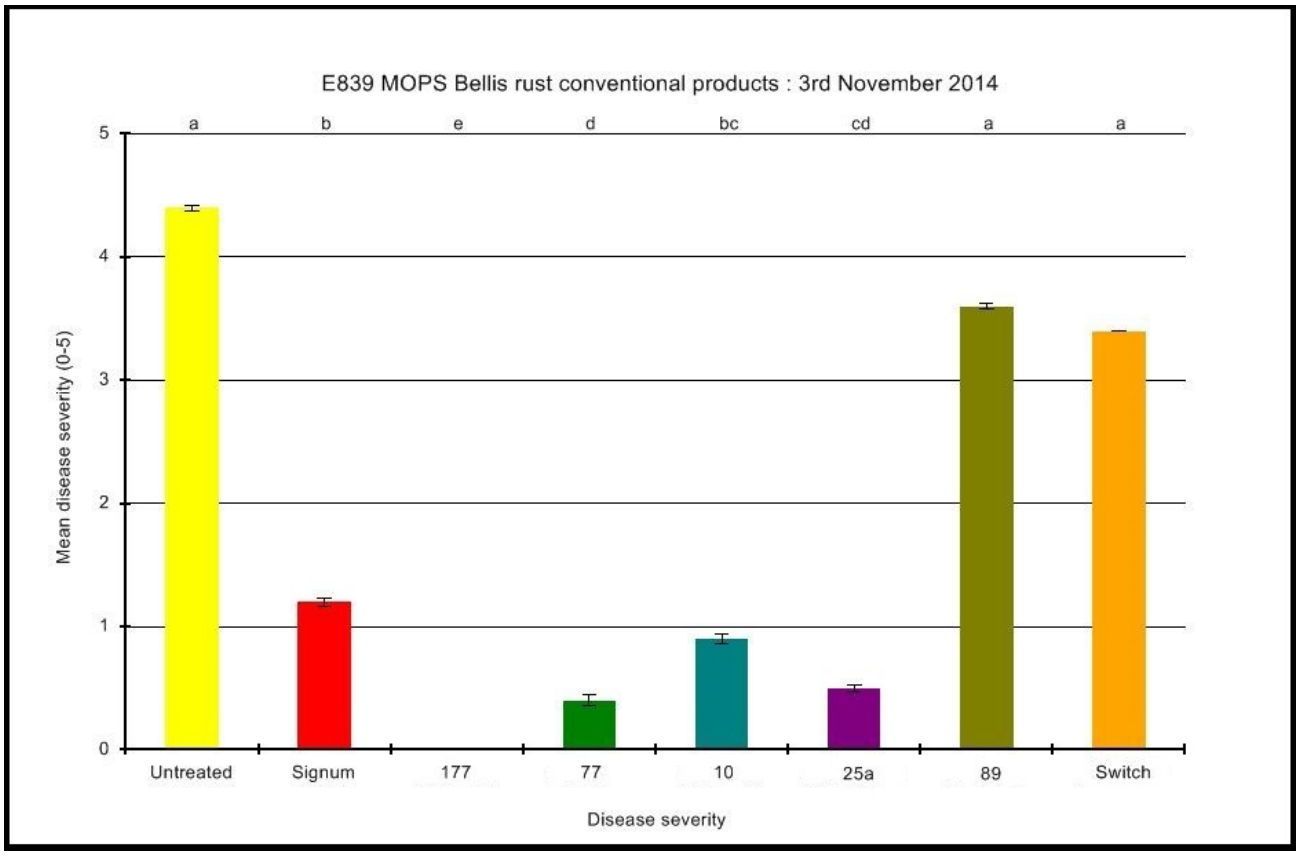
Pest Type				D Disease		D Disease		D Disease		D Disease	
Pest Code				PUCCDI		PUCCDI		PUCCDI		PUCCDI	
Pest Scientific Name				*Puccinia distincta*		*Puccinia distincta*		*Puccinia distincta*		*Puccinia distincta*	
Pest Name				Rust of Daisy		Rust of Daisy		Rust of Daisy		Rust of Daisy	
Crop Code				BELPE		BELPE		BELPE		BELPE	
Crop Scientific Name				*Bellis perennis*		*Bellis perennis*		*Bellis perennis*		*Bellis perennis*	
Crop Name				English daisy		English daisy		English daisy		English daisy	
Crop Variety				Goliath mixed		Goliath mixed		Goliath mixed		Goliath mixed	
Part Assessed				LEAF -		LEAF -		LEAF -		LEAF -	
Assessment Date				30/09/2014		16/10/2014		03/11/2014		03/11/2014	
Assessment Type				DISEASE SEVERITY		DISEASE SEVERITY		DISEASE SEVERITY		VIGOR	
Assessment Unit				0-5		0-5		0-5		0-5	
Sample Size, Unit				2 POT		2 POT		2 POT		1 PLOT	
Collection Basis, Unit				2 POT		2 POT		2 POT		1 PLOT	
Number of Subsamples				2		2		2		1	
ARM Action Codes								AL			
Trt	Treatment										
No.	Name or code	Rate	Unit	1		2		3		4	
1	Untreated			1.6	a	3.8	ab	4.4	ab	1.3	c
3	Signum	1.35	kg/ha	0	c	0.9	d	1.2	c	4.3	a
7	177			0	c	0	e	0	f	4.8	a
8	77			0	c	0	e	0.4	e	4.8	a
9	10			0	c	0.1	e	0.9	cd	4.8	a
10	25A			0	c	0	e	0.5	de	4.8	a
11	89			0.9	b	3.3	b	3.6	b	2.3	b
12	Switch			0.6	b	2	c	3.4	b	2.8	b
LSD (P=.05)				0.41		0.57		0.10t		0.74	
Standard Deviation				0.28		0.39		0.07t		0.51	
CV				81.68		25.08		16.6		14.9	
Replicate F				0.547		1.582		1.283		0.679	
Replicate Prob(F)				0.6551		0.2198		0.3029		0.5737	
Treatment F				16.856		77.624		67.919		36.643	
Treatment Prob(F)				0.0001		0.0001		0.0001		0.0001	

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

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

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

AL = Automatic log transformation of X+1


E839 MOPS Bellis rust conventional products : 3rd November 2014
a b e d bc cd a a
Mean disease severity (0-5)
0 1 2 3 4 5
Untreated Signum 177 77 10 25a 89 Switch
Disease severity

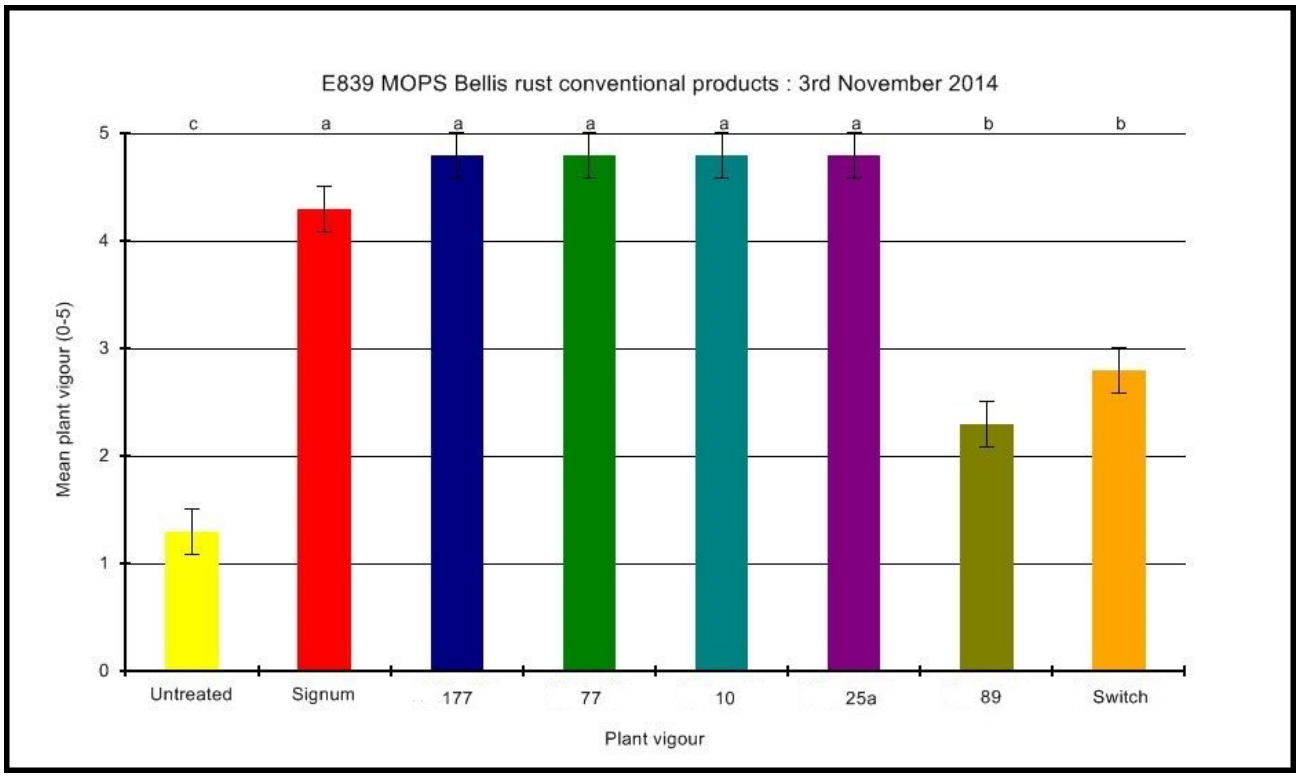
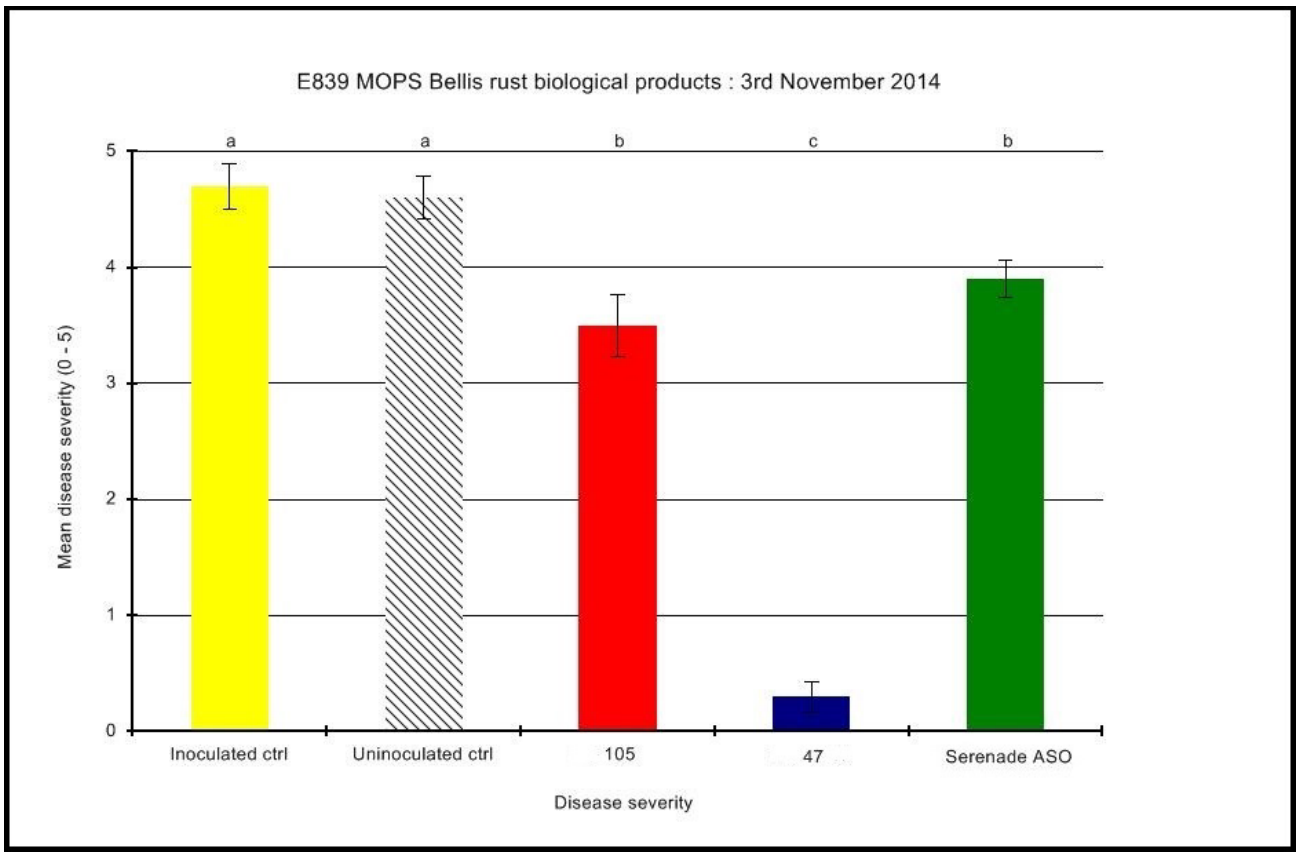

E839 MOPS Bellis rust conventional products : 3rd November 2014
c a a a a a b b
Mean plant vigour (0-5)
0 1 2 3 4 5
Untreated Signum 177 77 10 25a 89 Switch
Plant vigour

Table 7d - Effect of treatments on Bellis rust (Biopesticide products)

Pest Type				D Disease		D Disease		D Disease		D Disease	
Pest Code				PUCCDI		PUCCDI		PUCCDI		PUCCDI	
Pest Scientific Name				*Puccinia distincta*		*Puccinia distincta*		*Puccinia distincta*		*Puccinia distincta*	
Pest Name				Rust of Daisy		Rust of Daisy		Rust of Daisy		Rust of Daisy	
Crop Code				BELPE		BELPE		BELPE		BELPE	
Crop Scientific Name				Bellis perennis		Bellis perennis		Bellis perennis		Bellis perennis	
Crop Name				English daisy		English daisy		English daisy		English daisy	
Crop Variety				goliath mix		goliath mix		goliath mix		goliath mix	
Part Assessed				LEAF -		LEAF -		LEAF -		LEAF -	
Assessment Date				30/09/2014		16/10/2014		03/11/2014		03/11/2014	
Assessment Type				DISEASE SEVERITY		DISEASE SEVERITY		DISEASE SEVERITY		VIGOR	
Assessment Unit				0-5		0-5		0-5		0-5	
Sample Size, Unit				2 POT		2 POT		2 POT		1 PLOT	
Collection Basis, Unit				2 POT		2 POT		2 POT		1 PLOT	
Number of Subsamples				2		2		2		1	
Trt	Treatment										
No.	Name	Rate	Unit	1		2		3		4	
1	Untreated			1.7	a	3.3	a	4.7	a	1.5	c
4	105			1.4	ab	2.5	bc	3.5	b	2.5	b
5	47			1	b	0.3	d	0.3	c	4.2	a
6	Serenade ASO			1.5	ab	2.4	c	3.9	b	2.7	b
LSD (P=.05)				0.55		0.53		0.58		0.8	
Standard Deviation				0.45		0.44		0.48		0.66	
CV				39.37		18.9		14.23		26.89	
Replicate F				1.732		2.652		3.758		1.758	
Replicate Prob(F)				0.1734		0.0537		0.0146		0.1676	
Treatment F				10.61		42.87		81.263		16.364	
Treatment Prob(F)				0.0001		0.0001		0.0001		0.0001	

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

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


E839 MOPS Bellis rust biological products : 3rd November 2014
a
a
b
c
b
5
4
3
2
1
0
Mean disease severity (0 - 5)
Inoculated ctrl
Uninoculated ctrl
105
47
Serenade ASO
Disease severity

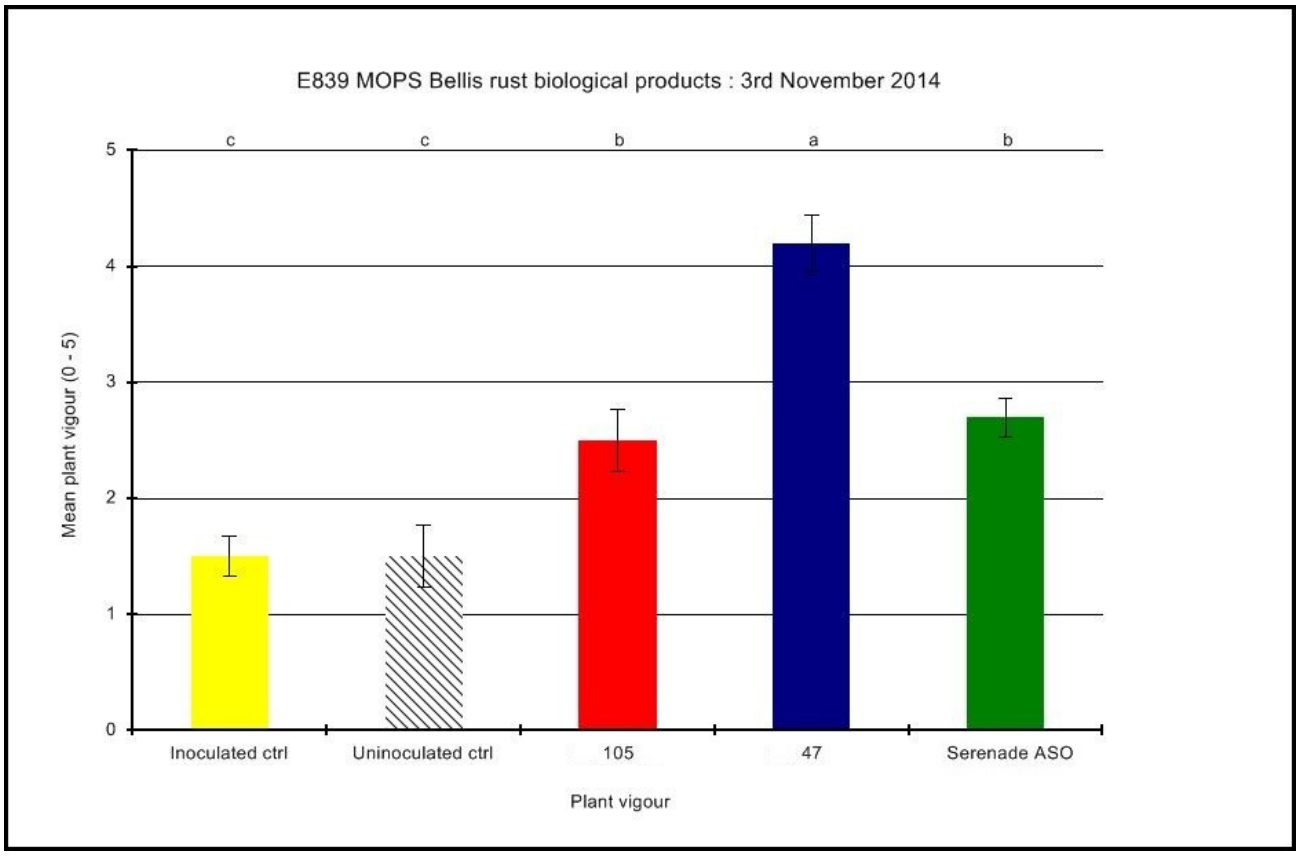

E839 MOPS Bellis rust biological products : 3rd November 2014
c
c
b
a
b
5
4
3
2
1
0
Mean plant vigour (0 - 5)
Inoculated ctrl
Uninoculated ctrl
105
47
Serenade ASO
Plant vigour

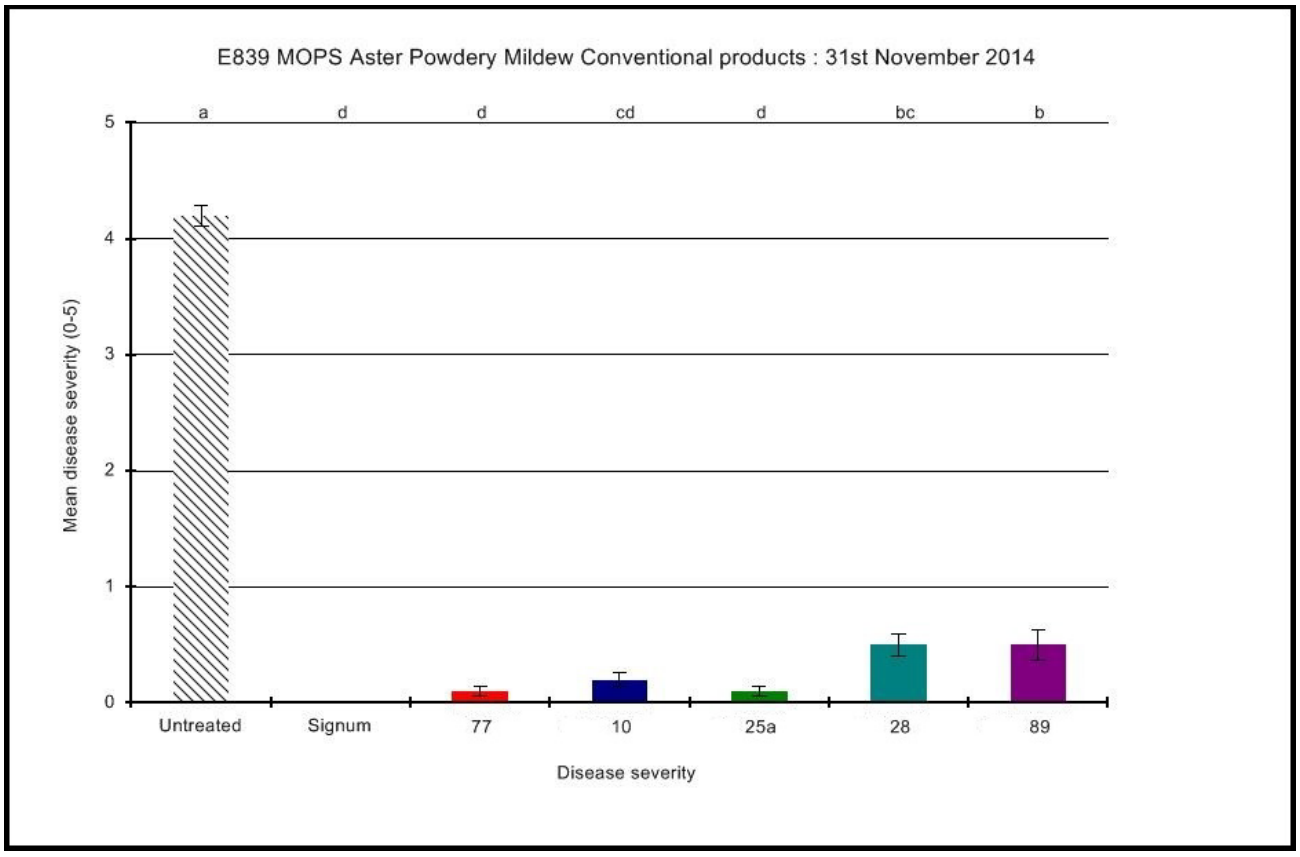
Table 7e - Effect of treatments on Aster mildew (Conventional products)

Pest Type				D Disease		D Disease		D Disease		D Disease	
Pest Code				ERYSCI		ERYSCI		ERYSCI		ERYSCI	
Pest Scientific Name				*Golovinomyces asterum*		*Golovinomyces asterum*		*Golovinomyces asterum*		*Golovinomyces asterum*	
Pest Name				Powdery mildew of aster		Powdery mildew of aster		Powdery mildew of aster		Powdery mildew of aster	
Crop Code				ASTNB		ASTNB		ASTNB		ASTNB	
Crop Scientific Name				*Symphyotrichum novi-belgii*		*Symphyotrichum novi-belgii*		*Symphyotrichum novi-belgii*		*Symphyotrichum novi-belgii*	
Crop Name				New York aster		New York aster		New York aster		New York aster	
Crop Variety				Cassandra		Cassandra		Cassandra		Cassandra	
Part Assessed				LEAF -		LEAF -		LEAF -		LEAF -	
Assessment Date				18/09/2014		16/10/2014		31/10/2014		31/10/2014	
Assessment Type				DISEASE SEVERITY		DISEASE SEVERITY		DISEASE SEVERITY		VIGOR	
Sample Size, Unit				12 12		12 12		12 12		1 PLOT	
Collection Basis, Unit				12 12		12 12		12 12		1 PLOT	
Number of Subsamples				12		12		12		1	
ARM Action Codes						AA					
Trt	Treatment										
No.	Name	Rate	Unit	1		2		3		4	
1	Untreated			1.5	a	3.8	a	4.2	a	2	c
3	Signum	1.35	kg/ha	0	b	0	c	0	d	5	a
8	77			0.1	b	0	c	0.1	d	4.3	b
9	10			0.1	b	0	bc	0.2	cd	4.3	b
10	25A			0	b	0	c	0.1	d	4.5	ab
11	28			0.2	b	0.1	b	0.5	bc	4	b
12	89			0.1	b	0.2	b	0.5	b	4	b
LSD (P=.05)				0.58		1.37t		0.31		0.67	
Standard Deviation				0.39		0.92t		0.21		0.45	
CV				137.42		37.03		26.03		11.25	
Replicate F				0.862		0.317		0.143		1.412	
Replicate Prob(F)				0.4785		0.813		0.933		0.2719	
Treatment F				7.792		72.273		209.345		17.706	
Treatment Prob(F)				0.0003		0.0001		0.0001		0.0001	

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

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

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


E839 MOPS Aster Powdery Mildew Conventional products : 31st November 2014
a
d
d
cd
d
bc
b
5
4
3
2
1
0
Mean disease severity (0-5)
Untreated
Signum
77
10
25a
28
89
Disease severity

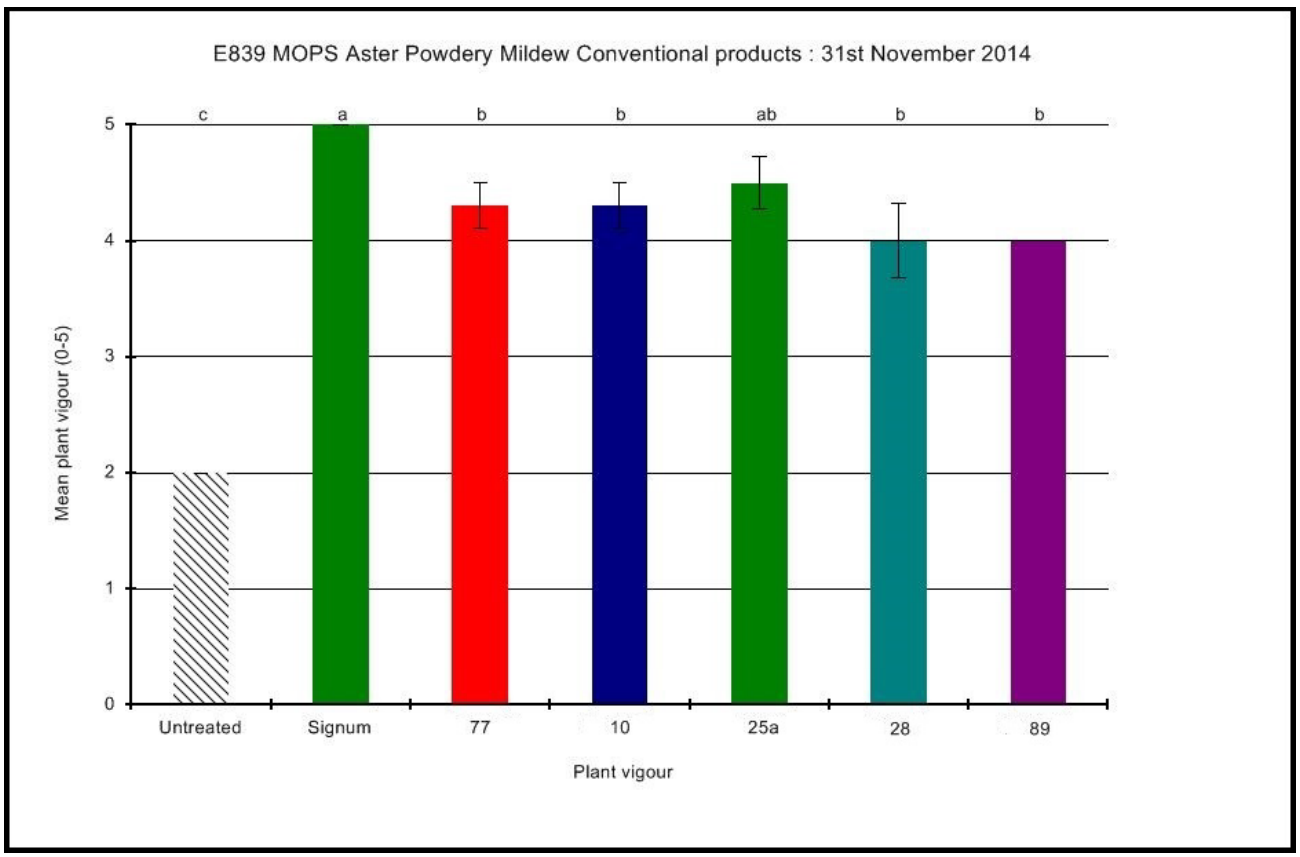

E839 MOPS Aster Powdery Mildew Conventional products : 31st November 2014
c
a
b
b
ab
b
b
5
4
3
2
1
0
Mean plant vigour (0-5)
Untreated
Signum
77
10
25a
28
89
Plant vigour

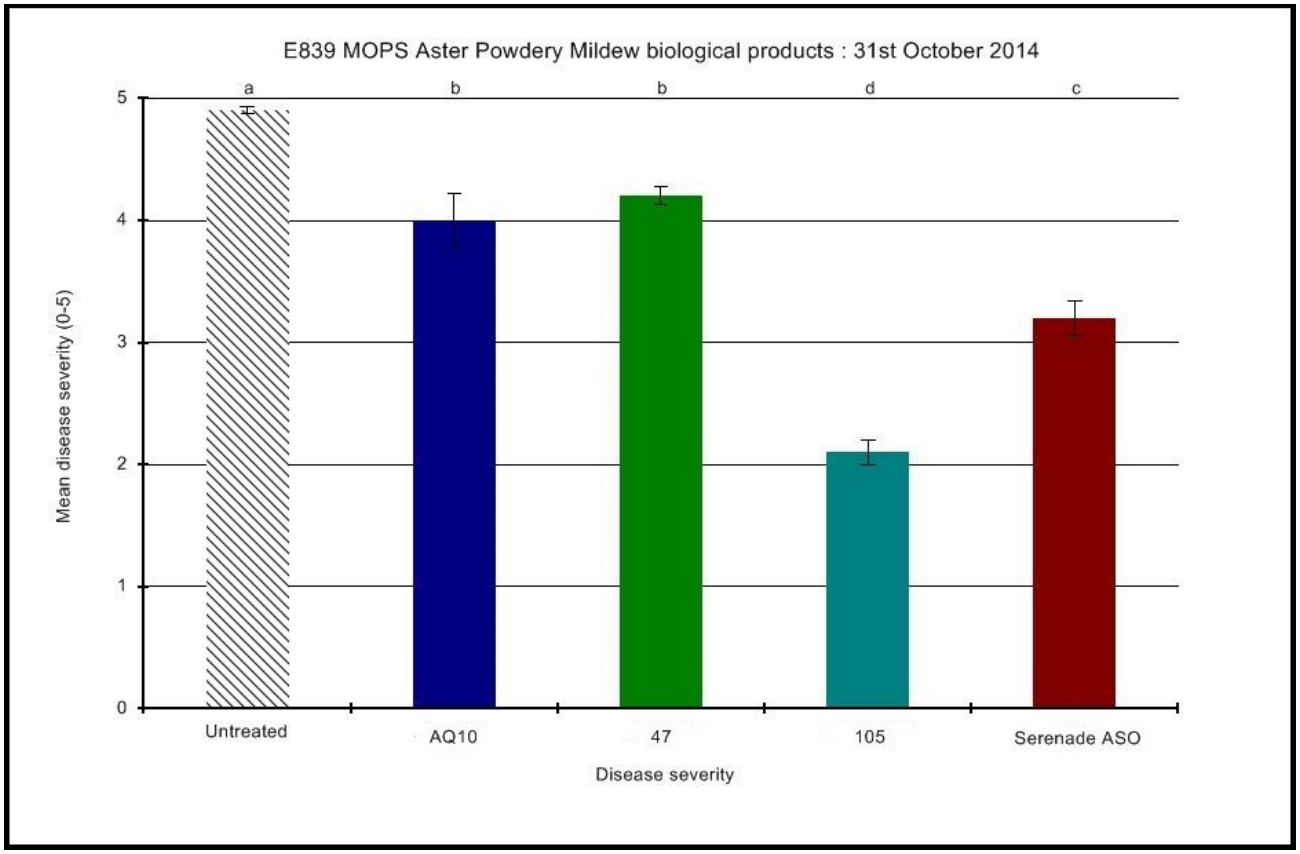
Table 7f - Effect of treatments on Aster mildew (Biopesticide products)

Pest Type				D Disease		D Disease		D Disease		D Disease	
Pest Code				ERYSCI		ERYSCI		ERYSCI		ERYSCI	
Pest Scientific Name				*Golovinomyces asterum*		*Golovinomyces asterum*		*Golovinomyces asterum*		*Golovinomyces asterum*	
Pest Name				Powdery mildew of aster		Powdery mildew of aster		Powdery mildew of aster		Powdery mildew of aster	
Crop Code				ASTNB		ASTNB		ASTNB		ASTNB	
Crop Scientific Name				*Symphyotrichum novi-belgii*		*Symphyotrichum novi-belgii*		*Symphyotrichum novi-belgii*		*Symphyotrichum novi-belgii*	
Crop Name				New York aster		New York aster		New York aster		New York aster	
Crop Variety				Cassandra		Cassandra		Cassandra		Cassandra	
Part Assessed				LEAF -		LEAF -		LEAF -		LEAF -	
Assessment Date				18/09/2014		16/10/2014		31/10/2014		31/10/2014	
Assessment Type				DISEASE SEVERITY		DISEASE SEVERITY		DISEASE SEVERITY		VIGOR	
Sample Size, Unit				12 12		12 12		12 12		1 PLOT	
Collection Basis, Unit				12 12		12 12		12 12		1 PLOT	
Number of Subsamples				12		12		12		1	
Trt	Treatment										
No.	Name	Rate	Unit	1		2		3		4	
1	Untreated			2.9	a	4.8	a	4.9	a	1.5	d
4	AQ10			2.3	ab	4.1	b	4	b	2.3	c
5	47			2.5	ab	4.1	b	4.2	b	2.7	bc
6	105			1.1	c	2	d	2.1	d	3.5	a
7	Serenade ASO			2	b	3	c	3.2	c	3.2	ab
LSD (P=.05)				0.65		0.45		0.52		0.64	
Standard Deviation				0.54		0.37		0.43		0.52	
CV				24.95		10.31		11.59		19.88	
Replicate F				1.778		1.783		1.4		0.778	
Replicate Prob(F)				0.1682		0.1672		0.2712		0.578	
Treatment F				9.461		54.066		36.978		13.196	
Treatment Prob(F)				0.0003		0.0001		0.0001		0.0001	

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

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

Missing data estimates are included in columns:Average=1,2,3,4


E839 MOPS Aster Powdery Mildew biological products : 31st October 2014
a
b
b
d
c
5
4
3
2
1
0
Mean disease severity (0-5)
Untreated
AQ10
47
105
Serenade ASO
Disease severity

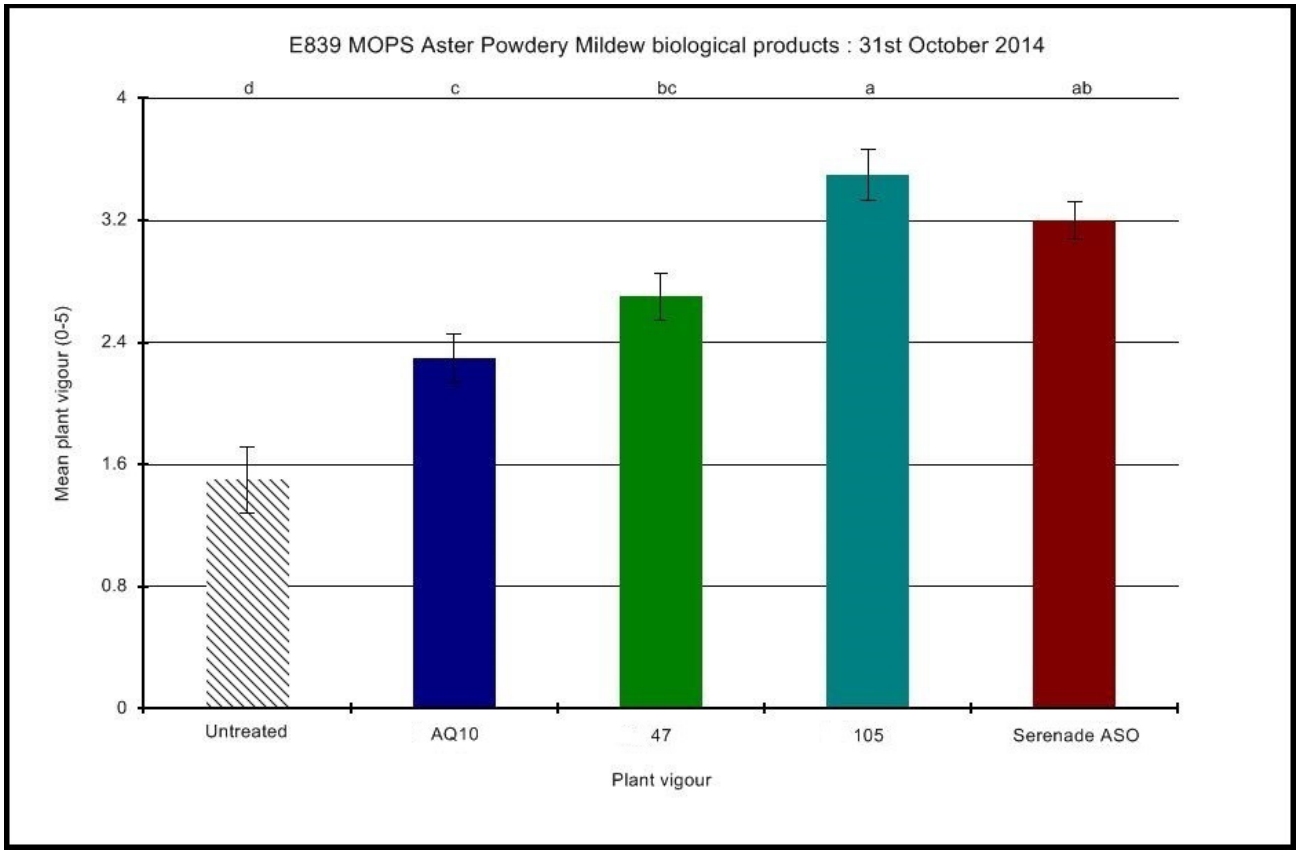

E839 MOPS Aster Powdery Mildew biological products : 31st October 2014
d
c
bc
a
ab
4
3.2
2.4
1.6
0.8
0
Mean plant vigour (0-5)
Untreated
AQ10
47
105
Serenade ASO
Plant vigour

Table 7g - Effect of treatments on Pansy mildew (Biopesticide products)

Pest Type				D Disease		D Disease		D Disease	
Pest Code				PODOSP		PODOSP		PODOSP	
Pest Scientific Name				*Podosphaera violae*		*Podosphaera violae*		*Podosphaera violae*	
Pest Name				Powdery mildew of pansy		Powdery mildew of pansy		Powdery mildew of pansy	
Crop Code				VIOTR		VIOTR		VIOTR	
Crop Scientific Name				*Viola tricolor*		*Viola tricolor*		*Viola tricolor*	
Crop Name				Wild violet		Wild violet		Wild violet	
Crop Variety				early flowering mix		early flowering mix		early flowering mix	
Part Assessed				LEAF -		LEAF -		LEAF -	
Assessment Date				30/09/2014		21/10/2014		10/11/2014	
Assessment Type				DISEASE SEVERITY		DISEASE SEVERITY		DISEASE SEVERITY	
Assessment Unit				0-5		0-5		0-5	
Sample Size, Unit				2 2		2 2		2 2	
Collection Basis, Unit				2 2		2 2		2 2	
Number of Subsamples				2		2		2	
Trt	Treatment								
No.	Name	Rate	Unit	1		2		3	
1	Uninoculated			1.1	a	1.5	a	1.4	a
2	Inoculated			1.3	a	1.4	a	1.2	a
4	AQ10			0.9	ab	1.3	a	1.2	a
5	47			0.7	bc	0.7	b	0.9	ab
6	105			0.4	c	0.5	b	0.5	b
7	Serenade ASO			0.7	bc	0.7	b	0.6	b
LSD (P=.05)				0.36		0.51		0.21t	
Standard Deviation				0.3		0.42		0.18t	
CV				35.92		42.65		14.72	
Replicate F				1.334		1.072		1.147	
Replicate Prob(F)				0.2886		0.4037		0.3671	
Treatment F				6.513		6.188		4.595	
Treatment Prob(F)				0.0008		0.0011		0.0055	

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.

Missing data estimates are included in columns : Average=1,2,3

Table 7h - Effect of treatments on Pansy mildew (Conventional products)

Pest Type				D Disease		D Disease		D Disease	
Pest Code				PODOSP		PODOSP		PODOSP	
Pest Scientific Name				*Podosphaera violae*		*Podosphaera violae*		*Podosphaera violae*	
Pest Name				Powdery mildew of pansy		Powdery mildew of pansy		Powdery mildew of pansy	
Crop Code				VIOTR		VIOTR		VIOTR	
Crop Scientific Name				*Viola tricolor*		*Viola tricolor*		*Viola tricolor*	
Crop Name				Wild violet		Wild violet		Wild violet	
Crop Variety				early flowering mix		early flowering mix		early flowering mix	
Part Assessed				LEAF -		LEAF -		LEAF -	
Assessment Date				30/09/2014		21/10/2014		10/11/2014	
Assessment Type				DISEASE SEVERITY		DISEASE SEVERITY		DISEASE SEVERITY	
Assessment Unit				0-5		0-5		0-5	
Sample Size, Unit				2 2		2 2		2 2	
Collection Basis, Unit				2 2		2 2		2 2	
Number of Subsamples				2		2		2	
Trt	Treatment								
No.	Name	Rate	Unit	1		2		3	
1	Uninoculated			1.1	a	1.4	a	1.4	a
2	Inoculated			1.3	a	1.3	a	1.2	a
3	Signum	1.35	kg/ha	0	b	0	b	0	b
8	77			0	b	0	b	0	b
9	10			0	b	0	b	0	b
10	25A			0	b	0	b	0	b
11	28			0.1	b	0	b	0	b
12	89			0	b	0	b	0	b
LSD (P=.05)				0.24		0.06t		0.07t	
Standard Deviation				0.16		0.04t		0.04t	
CV				52.37		44.51		48.98	
Replicate F				0.778		1.394		0.682	
Replicate Prob(F)				0.5195		0.2724		0.5729	
Treatment F				44		69.274		57.375	
Treatment Prob(F)				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.

Crop inoculation

Inoculation of the trial crops relied either on a natural infection via the placement of 'infector plants' in the crop or through the use of a spore suspension made up from infected leaves gathered from either a wild or garden source. Where spore suspensions were applied the uninoculated control plots were first covered with polythene. Following inoculation, the trial area was covered with polythene sheet overnight to encourage infection with the respective pathogens. One infector plant per plot was introduced to the Aster crop and thirty infector plants were spaced evenly amongst the Bellis crop. For the Aster and Bellis crops, where 'infector' plants were introduced into the trial, treatments 1 and 2 (Uninoculated and inoculated controls) have been amalgamated into an 'untreated' group for the purposes of statistical analysis.

Crop vigour

Crop vigour was scored late in the trial as a method of distinguishing those plots where plants were suffering from leaf necrosis and discolouration due to the effects of the pathogens. Plants were scored on a 0-5 scale where 0 = dead plant and 5 = highest vigour. Plants with a vigour score of 3 or less were considered unmarketable. The results of the vigour assessments are presented in column 4 of Tables 7 a-h.

Crop damage

No crop damage e.g. scorch was observed during the trial though product 28 appeared to have a growth regulatory effect on the Pansy crop only. This resulted in moderate stunting of the plants together with a darker leaf colour than other treatments.

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. All the pathogens of interest in this trials series were 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, via the use of 'infector plants' introduced into the trial area or as a spore suspension prepared from infected leaf material sourced from elsewhere. In all cases, infection is further encouraged by maintaining an environment conducive to spore development, release, germination and infection. In these trials pathogen introduction to the crop was achieved either with previously prepared 'infector plants' or with spore suspensions prepared from externally sourced infected leaf material. As it happens, for the Bellis rust and the Aster mildew the pathogens were found at trace levels in the crop simultaneously with 'infector plant' introduction. Due to the climatic preferences of the pathogens studied the decision was made to delay the start of the trials slightly until the autumn when lower glasshouse temperatures were more easily achieved whilst maintaining high humidity conducive to disease development.

We were successful in establishing infection in all four crops and in the case of the Aster, Bellis and Antirrhinum the pathogens developed to high levels thus providing a stern test for the various products evaluated. For the Pansy trial, infection was much slower to develop and was somewhat variable across the plots. As such, the data from this trial needs to be treated with greater degree of caution due to the variability and lower disease pressure achieved.

Most of the products applied in these trials appeared crop safe though a low level of phytotoxicity was observed in the Pansy crop where stunting and leaf darkening was noted with product 28. This could arguably be perceived as an advantage commercially; negating the need for regular PGR applications.

Antirrhinum

Rust established successfully in the Antirrhinum trial following the application of a spore suspension of the pathogen, due to the absence of naturally occurring infection by late summer. The inoculum was prepared from infected leaves taken from an external garden source. The disease developed quite rapidly and provided a robust test for the products evaluated. The conventional products 177, 77, 10, 25a and the standard Signum all gave complete control of rust over the duration of the trial. 89 and Switch gave some level of disease suppression in comparison to the untreated inoculated control but at a significantly lower level than that of the other conventional products. The biopesticide products, whilst providing a significant reduction in disease severity in comparison to the inoculated control, didn't achieve the same level of rust suppression as the conventional

products. Coded product 47 yielded the best level of control out of the biopesticide products and was significantly better than both HDC-105 and Serenade ASO.

Bellis

Infection of the Bellis occurred naturally simultaneously with the introduction of infector plants into the trial area and it is believed this originated from air-borne spores. The spray programme commenced shortly after the appearance of initial small rust pustules in the crop. A number of conventional products (177, 77, 25a & 10) had excellent efficacy against Bellis rust, with code 177 providing complete control of the rust throughout the duration of the trial. code 89 and Switch were less effective and failed to provide an equivalent level of disease suppression and improved plant vigour. Of the biopesticide products 105 and Serenade ASO did not provide effective protection from the disease and these treatments had a low mean plant vigour score with implications for potential marketability of the plants. In contrast code 47 provided strong control of rust performing comparably with a number of the conventional products in terms of disease control and plant vigour. It provided effective control of rust throughout the trial duration and is certainly worth exploring further. It is slightly surprising that the same level of control achieved in the Bellis trial wasn't replicated in the Antirrhinum trial; it is considered that the different approaches to pathogen inoculation may have influenced this. For future trials of biopesticide products the method of pathogen introduction needs to be explored in more detail.

Aster

Infection of the Asters occurred rapidly following the introduction of infector plants in the trial area as a natural infection occurred simultaneously with their introduction. As such, the spray programme commencing shortly after traces of powdery mildew were observed in the crop. By the final assessment all the conventional products provided broadly comparable disease suppression with codes 77 and 25a performing best in terms of powdery mildew control with product 25a providing a slightly better mean plant vigour score. Overall the biopesticide products were much less effective though of the biopesticides, code 105 provided the best disease suppression and corresponding high plant vigour score, although not at a level comparable with the performance of any of the conventional products. By the end of the trial disease levels were much higher where control had relied on the biopesticides compared with the conventional products. This poorer overall disease control with the biopesticides allowed inoculum levels to increase resulting in a greater overall infection pressure and disease control failure. Once the powdery mildew became established it would have presented the biopesticide treatments a significant challenge in terms of maintaining disease control as they are best used as protectant products and generally have little in the way of eradicant activity.

Pansy

Powdery mildew infection in the Pansy trial was achieved by application of a spore suspension due to the absence of naturally occurring infection by late summer. The inoculum was prepared from infected leaves from an external garden source. Progress of the disease in both the biopesticide and conventional trials, whilst successful was particularly slow and variable. It is unclear whether this was due to the glasshouse climate at the time of inoculation, the virulence of the specific pathogen isolate used or the possible tolerance of the cultivar of pansy used for the trial. By the end of the trial a *Ramularia* sp was noted at low levels in 29 of the 56 plots and *Botrytis* infection affected senescing flower heads leading to secondary infection of leaf and stem tissues was noted. Whilst the disease assessments showed a greater efficacy of the conventionals over the biopesticides, the results should be treated with caution as the variable and low disease pressure and presence of other pathogens prevents meaningful comparisons between treatments from being drawn.

Conclusions

The various trials conducted proved to be highly successful in terms of identifying novel products with good activity against both powdery mildew and rust in ornamentals. The conventional products overall provided a high degree of disease control whereas, in general, the biopesticide products were much less effective even though they were applied weekly as protective applications. Code 47 was perhaps the exception, against Bellis rust at least, as this provided near 100% control of rust. It would appear here that by varying the inoculation technique employed to introduce the pathogens into the trial it may have had a significant effect on product performance in the case of the biopesticide products. The resulting disease pressure following inoculation via a spore suspension, whilst having a negligible effect on the efficacy of the conventional products, may have overwhelmed some of the biopesticide products which rely on different modes of action. Efforts to establish a more natural progressive infection of the crop through the use of ‘infector’ plants may provide a more realistic simulation for the evaluation of biopesticide products thus allowing a more meaningful comparison of conventional and biopesticide products to take place. It is important to note though that whilst this could be a very useful approach and should be encouraged, it can be difficult to apply practically due for the need for a large number of ‘infector’ plants infected with a specific pathogen in advance of the trial commencing. For such obligate pathogens prevailing weather conditions can make this very difficult to achieve in some seasons as sourcing such pathogens can be challenging and to ensure successful establishment of the pathogen once the trial has commenced it is often necessary to resort to inundative approaches using foliar sprays containing specific spore inoculum.

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)		**Variation from EPPO**
PP 1/152(3)	Design and analysis of efficacy evaluation trials	PP 1/152(3)
PP 1/135(3)	Phytotoxicity assessment	PP 1/135(3)
PP 1/181(3)	Conduct and reporting of efficacy evaluation trials including GEP	PP 1/181(3)

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 Intrgro climate control system.	

Date	Mean daily Temp/ ^{0}C	Max daily temp/ ^{0}C	Min daily temp/ ^{0}C	Mean daily RH%	Mean RH% 2pm-4pm	Mean Temp/ ^{0}C 2pm – 4pm	Sunshine hrs
01/07/2014	20.2	33.2	10.1	99.8	100.0	29.5	4.8
02/07/2014	19.7	29.4	11.3	99.9	100.0	26.2	4
03/07/2014	19.9	25.6	17.1	99.9	100.0	23.3	1.3
04/07/2014	20.0	26.6	15.6	99.9	100.0	24.8	1.7
05/07/2014	20.7	27.4	15.2	99.7	100.0	26.4	5.4
06/07/2014	18.0	26.2	11.6	99.9	100.0	24.5	0.7
07/07/2014	18.8	28.4	10.2	99.9	100.0	25.3	5.3
08/07/2014	18.5	28.4	13.5	99.9	100.0	23.9	3.1
09/07/2014	19.4	29.4	11.3	99.9	100.0	27.8	10.4
10/07/2014	18.7	29.1	12.8	100.0	100.0	28.3	5.3
11/07/2014	21.4	33.1	13.6	99.9	100.0	32.0	4.3
12/07/2014	22.8	33.0	13.3	99.8	100.0	31.0	4.3
13/07/2014	21.3	29.2	15.1	99.7	100.0	27.3	1.5
14/07/2014	19.6	27.5	11.4	99.9	100.0	25.0	6.6
15/07/2014	20.2	27.8	14.1	100.0	100.0	25.2	3.6
16/07/2014	20.3	30.6	11.9	99.9	100.0	27.6	3.9
17/07/2014	23.0	36.1	13.3	99.8	100.0	32.9	11.2
18/07/2014	21.0	29.2	14.8	99.8	99.9	25.1	1.2
19/07/2014	19.9	27.8	16.2	99.5	100.0	22.5	0.3
20/07/2014	22.1	30.1	17.0	99.4	99.9	27.4	3.7
21/07/2014	23.6	32.7	16.5	99.8	100.0	31.5	12
22/07/2014	23.0	34.7	14.6	99.7	100.0	31.9	8.4
23/07/2014	23.0	34.5	16.1	99.9	100.0	34.0	10
24/07/2014	24.0	36.1	14.5	99.7	100.0	35.1	12.9
25/07/2014	24.2	36.5	16.1	99.8	100.0	34.4	11

26/07/2014	24.3	36.4	14.6	99.8	100.0	32.7	5.8
27/07/2014	21.1	28.8	14.7	99.9	100.0	26.0	9.3
28/07/2014	20.9	33.6	12.2	99.9	100.0	30.5	7.6
29/07/2014	19.6	29.4	12.6	99.8	100.0	24.8	3.3
30/07/2014	18.1	24.6	12.5	99.9	100.0	20.5	2.4
31/07/2014	19.8	24.9	15.1	84.4	55.9	22.2	0.3
01/08/2014	19.2	25.1	14.3	76.9	66.0	23.2	0.1
02/08/2014	19.6	26.5	15.9	78.6	66.0	23.4	2.2
03/08/2014	19.1	27.5	11.8	60.6	39.0	25.4	11.4
04/08/2014	19.8	28.7	11.8	57.7	31.0	28.0	13
05/08/2014	19.4	29.0	12.0	68.4	41.0	27.1	5.1
06/08/2014	20.7	27.4	16.1	75.5	59.1	26.1	6.3
07/08/2014	19.6	27.7	13.3	60.3	38.1	25.4	4.1
08/08/2014	18.1	28.8	12.6	79.6	77.0	22.7	2.2
09/08/2014	20.1	28.3	14.0	64.8	35.8	27.6	10.1
10/08/2014	16.3	21.1	13.3	84.5	75.3	18.9	0.3
11/08/2014	18.0	26.8	13.3	63.6	40.9	25.1	7.8
12/08/2014	17.1	25.5	12.4	68.0	43.5	23.6	6.7
13/08/2014	18.4	25.9	13.0	69.4	52.1	23.0	7.1
14/08/2014	17.4	27.5	11.6	70.3	45.0	24.6	2.1
15/08/2014	16.8	24.2	12.1	73.9	65.8	21.1	3.5
16/08/2014	15.5	21.0	11.8	71.1	62.2	17.9	0.9
17/08/2014	16.5	22.5	12.5	69.0	51.9	20.8	8.4
18/08/2014	15.9	23.5	12.4	65.8	48.0	20.6	4.4
19/08/2014	15.1	22.1	9.6	66.3	45.8	20.3	7.7
20/08/2014	14.7	23.0	8.7	66.9	47.4	20.6	3.5
21/08/2014	14.6	20.9	10.9	72.9	57.7	17.1	1.6
22/08/2014	15.4	24.1	10.3	69.3	40.6	22.4	6.1
23/08/2014	14.4	24.6	8.0	70.3	43.8	22.3	7.7
24/08/2014	15.3	23.0	7.9	64.5	42.6	21.6	8.4
25/08/2014	14.5	18.3	12.1	84.6	74.0	16.5	0
26/08/2014	16.9	25.5	11.9	72.6	53.4	22.6	8.6
27/08/2014	16.7	25.3	11.0	72.9	52.8	22.9	2.9
28/08/2014	18.7	25.5	14.3	72.7	58.2	23.0	5.6
29/08/2014	16.3	22.0	12.5	80.9	72.8	19.7	0.6

30/08/2014	17.8	25.5	13.3	74.5	51.5	23.4	7
31/08/2014	17.8	28.1	10.6	68.9	41.7	26.8	10.2
01/09/2014	17.6	25.9	13.2	72.2	47.2	24.6	3.4
02/09/2014	17.2	27.7	10.2	75.5	55.6	24.3	6.9
03/09/2014	18.4	25.0	14.3	79.3	60.1	22.8	0.5
04/09/2014	18.1	24.4	13.7	80.5	66.6	22.2	1.2
05/09/2014	18.3	28.6	13.0	78.5	49.9	27.6	4.8
06/09/2014	15.4	18.0	12.2	91.6	88.5	17.3	0
07/09/2014	15.7	24.6	8.9	73.5	44.3	23.2	10.3
08/09/2014	15.5	26.2	8.9	74.6	48.5	23.9	7.2
09/09/2014	16.0	24.3	10.0	76.1	51.6	23.6	5.4
10/09/2014	16.8	27.3	9.8	77.8	51.8	26.0	8.1
11/09/2014	16.6	26.4	9.8	76.6	55.2	24.3	7.7
12/09/2014	15.5	23.7	10.0	81.6	67.1	20.4	0.9
13/09/2014	15.5	20.0	10.7	85.7	73.9	19.2	0
14/09/2014	15.0	19.5	11.2	84.6	70.5	19.0	0
15/09/2014	16.5	21.2	13.7	88.8	80.1	20.2	0.2
16/09/2014	17.9	26.2	14.6	82.2	61.6	24.1	3.9
17/09/2014	16.2	18.8	13.8	85.5	79.8	18.5	0
18/09/2014	18.4	26.6	15.5	84.6	61.2	25.8	1.3
19/09/2014	16.6	18.3	15.3	89.3	84.2	18.0	0
20/09/2014	15.3	17.9	11.4	87.7	86.8	16.5	0
21/09/2014	13.2	21.1	8.7	74.8	53.9	18.0	4.1
22/09/2014	14.2	22.9	7.7	72.3	48.8	21.7	5.2
23/09/2014	14.4	21.5	8.7	79.5	61.5	19.4	2.6
24/09/2014	15.2	22.5	10.2	71.3	44.3	20.2	6
25/09/2014	14.8	21.1	8.5	80.4	71.6	19.5	0.2
26/09/2014	16.9	24.0	10.2	70.0	42.4	23.2	5.6
27/09/2014	13.5	20.3	7.0	78.3	62.0	19.3	3.2
28/09/2014	16.5	26.6	10.5	79.4	47.7	25.7	4.1
29/09/2014	15.7	20.5	10.8	87.2	79.8	19.3	0.9
30/09/2014	17.4	24.4	13.6	80.8	55.8	23.4	4.5
01/10/2014	17.0	24.8	12.7	76.9	65.9	19.6	3.5
02/10/2014	13.7	20.4	7.9	74.4	57.3	19.6	7
03/10/2014	16.3	23.2	11.6	75.8	58.0	21.6	4.1

04/10/2014	13.4	17.2	7.7	77.5	63.6	14.5	1.5
05/10/2014	11.1	18.9	6.2	75.3	49.5	18.2	4.2
06/10/2014	10.6	12.0	8.9	87.7	91.9	11.3	0
07/10/2014	10.4	13.6	7.4	88.1	83.4	12.2	0
08/10/2014	10.2	15.4	6.6	88.2	83.9	13.9	2.7
09/10/2014	12.0	17.5	8.5	81.1	62.6	16.4	3.1
10/10/2014	12.5	19.4	8.2	78.2	56.7	17.8	6.7
11/10/2014	10.9	20.3	6.5	86.1	77.5	15.4	2.4
12/10/2014	9.2	14.6	5.5	88.2	77.1	13.4	0.8
13/10/2014	11.1	14.2	8.5	89.4	87.1	13.5	0
14/10/2014	11.4	12.2	10.9	91.2	92.3	11.7	0
15/10/2014	11.7	14.3	8.3	92.0	84.5	13.5	0
16/10/2014	14.1	20.1	11.7	87.5	73.2	17.4	2.9
17/10/2014	15.2	22.3	10.7	85.1	70.5	18.9	4.3
18/10/2014	17.2	20.6	15.2	83.2	69.4	19.9	0
19/10/2014	16.5	22.3	12.4	74.7	54.0	21.6	5.4
20/10/2014	12.8	16.0	11.6	82.8	69.5	15.5	0.7
21/10/2014	13.2	28.0	8.0	76.2	53.6	19.4	5.3
22/10/2014	12.2	20.3	7.7	87.6	90.0	16.0	2.1
23/10/2014	14.5	19.9	10.0	88.9	77.5	18.4	1.1
24/10/2014	14.3	19.5	9.3	91.3	76.1	18.4	0
25/10/2014	13.1	21.1	7.6	88.4	75.6	18.2	3.9
26/10/2014	14.2	17.5	11.5	94.3	92.1	16.5	0
27/10/2014	15.5	18.4	13.0	94.3	92.2	17.5	0.2
28/10/2014	15.6	22.2	12.3	86.6	71.2	18.9	0.9
29/10/2014	13.1	21.4	6.9	88.2	75.3	17.4	3.6
30/10/2014	15.0	20.8	11.7	93.4	85.4	18.4	1
31/10/2014	16.7	21.4	14.1	90.4	77.5	19.5	1.5
01/11/2014	16.3	21.3	13.9	82.7	64.6	18.4	4.5
02/11/2014	No data	No data	No data	No data	No data	No data	0.9
03/11/2014	11.9	19.6	8.0	85.7	62.9	18.2	8
04/11/2014	10.0	20.6	4.7	88.1	71.7	17.9	4
05/11/2014	10.2	20.3	4.3	84.1	67.3	17.0	6.8
06/11/2014	8.7	14.4	3.4	92.4	93.0	12.2	0.6
07/11/2014	11.7	19.9	8.4	96.1	96.4	13.7	0.6

08/11/2014	9.3	11.1	6.4	96.7	97.0	11.0	0
09/11/2014	10.2	20.5	5.5	90.2	80.1	17.1	3.4
10/11/2014	9.9	20.0	5.9	94.3	88.7	14.2	0.6
11/11/2014	12.3	18.3	10.0	93.1	88.6	14.8	0.1
12/11/2014	12.1	19.6	8.2	93.0	84.1	15.9	1
13/11/2014	11.5	14.4	8.5	95.1	92.1	13.2	0
14/11/2014	11.5	15.7	8.7	95.6	91.0	14.8	0.3
15/11/2014	9.6	12.7	6.9	95.1	93.6	11.8	0
16/11/2014	10.3	14.1	9.0	95.2	91.8	12.6	0

Appendix C – Agronomic details

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

Date	Product	Rate	Unit
26/8/14	Subdue (Metalaxyl- M) – Antirrhinum only (for protection from Pythium root rot)	0.024	ml/L
28/8/14	Chess (Pymetrozine) – Bellis only (for aphid control)	0.5	ml/L
1/8/14* 20/8/14* 10/9/14 26/9/14 13/10/14	Universol Blue (18-11-18 +2.5 MgO + TE) (* Asters only initially)	1	g/L

Type of irrigation system employed
Hand watering

Appendix D – Trial layout

MOPS Powdery Mildew (Aster and Pansy)

Conventionals

Replicate 1			Replicate 2 w. controls				Replicate 3			Replicate 4 w. controls			
Plot 1 Trt 3	Plot 2 Trt 10	Plot 3 Trt 12	Plot 4 Trt 11	Plot 5 Trt 1	Plot 6 Trt 12	Plot 7 Trt 8	Plot 8 Trt 10	Plot 9 Trt 3	Plot 10 Trt 8	**Plot 11** **Trt 2**	Plot 12 Trt 9	Plot 13 Trt 3	Plot 14 Trt 10
Plot 15 Trt 9	Plot 16 Trt 11	Plot 17 Trt 8	Plot 18 Trt 9	Plot 19 Trt 3	**Plot 20** **Trt 2**	Plot 21 Trt 10	Plot 22 Trt 12	Plot 23 Trt 9	Plot 24 Trt 11	Plot 25 Trt 12	Plot 26 Trt 8	Plot 27 Trt 1	Plot 28 Trt 11

Biopesticides

Replicate 1			Replicate 2 w. controls				Replicate 3		Replicate 4		Replicate 5 w. controls			Replicate 6	
Plot 29 Trt 5	Plot 30 Trt 4	Plot 31 Trt 7	Plot 32 Trt 6	**Plot 33** **Trt 2**	Plot 34 Trt 7	Plot 35 Trt 4	Plot 36 Trt 6	Plot 37 Trt 4	Plot 38 Trt 6	Plot 39 Trt 7	Plot 40 Trt 1	Plot 41 Trt 6	Plot 42 Trt 5
Plot 43 Trt 7	Plot 44 Trt 6	Plot 45 Trt 5	Plot 46 Trt 1	Plot 47 Trt 4	Plot 48 Trt 5	Plot 49 Trt 6	Plot 50 Trt 7	Plot 51 Trt 5	**Plot 52** **Trt 2**	Plot 53 Trt 4	Plot 54 Trt 5	Plot 55 Trt 4	Plot 56 Trt 7

MOPS Rust (Antirrhinum and Bellis)

Conventionals

central bench

Replicate 1				Replicate 2					Replicate 3				Replicate 4				
Plot 1 Trt 1	Plot 2 Trt 12	Plot 3 Trt 7	Plot 4 Trt 11	**Plot 5 Trt 2**	Plot 6 Trt 10	Plot 7 Trt 8	Plot 8 Trt 3	Plot 9 Trt 9	**Plot 10 Trt 2**	Plot 11 Trt 12	Plot 12 Trt 1	Plot 13 Trt 9	Plot 14 Trt 10	Plot 15 Trt 11	Plot 16 Trt 7	Plot 17 Trt 1	Plot 18 Trt 8
Plot 19 Trt 10	Plot 20 Trt 8	**Plot 21 Trt 2**	Plot 22 Trt 9	Plot 23 Trt 3	Plot 24 Trt 11	Plot 25 Trt 7	Plot 26 Trt 1	Plot 27 Trt 12	Plot 28 Trt 10	Plot 29 Trt 7	Plot 30 Trt 3	Plot 31 Trt 11	Plot 32 Trt 8	**Plot 33 Trt 2**	Plot 34 Trt 9	Plot 35 Trt 12	Plot 36 Trt 3

Biopesticides

Bench 1

Replicate 1		Replicate 2			Replicate 3		
Plot 37 TRt 4	**Plot 38 Trt 2**	Plot 39 TRt 5	**Plot 40 Trt 2**	Plot 41 Trt 4	Plot 42 TRt 5	Plot 43 Trt 1	Plot 44 Trt 6
Plot 45 Trt 1	Plot 46 Trt 5	Plot 47 Trt 6	Plot 48 Trt 1	Plot 49 Trt 6	**Plot 50 Trt 2**	Plot 51 Trt 4	

Biopesticides

Bench 2

Replicate 4		Replicate 5			Replicate 6		
Plot 52 Trt 2	Plot 53 Trt 4	Plot 54 Trt 6	Plot 55 Trt 5	Plot 56 Trt 1	**Plot 57 Trt 2**	Plot 58 TRt 6	Plot 59 Trt 4
Plot 60 Trt 6	Plot 61 Trt 1	Plot 62 Trt 5	**Plot 63 Trt 2**	Plot 64 Trt 4	Plot 65 Trt 5	Plot 66 Trt 1	

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

Appendix F – Photographs

Figure 1. Scoring matrix for Aster powdery mildew disease severity

Figure 2. Untreated control in Aster powdery mildew trial (28/10/2014)

Figure 3. Signum treated plot in in Aster powdery mildew trial (28/10/2014)

Figure 4. Code 25a treated plot in Aster powdery mildew trial (28/10/2014)

Figure 5. Untreated control vs Code 47 treated plot in Bellis rust trial (17/10/2014)

Figure 6. Untreated control vs Code 177 treated plot in Bellis rust trial (17/10/2014)

Figure 7. Untreated inoculated control plot in the Antirrhinum rust trial (29/10/2014)

Figure 8. Code 10 treated plot in the Antirrhinum rust trial (29/10/2014)

Figure 9. Powdery mildew leaf infection on an untreated plot in the Pansy trial