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Annual report:	Year 3, February 2014
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The results and conclusions in this report are based on investigations 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 results, especially if they are used as the basis for commercial product recommendations.

David Piccaver

David Piccaver, chairman of the Sceptre project from its inception, sadly, died suddenly on 13 December 2013 aged 69 after a short illness. David was a highly effective chairman, much respected by all consortium members. He was a strong advocate for the project's aims, his views were always well considered and he listened to each individual's contribution. As well as that more public 'front,' David also worked tirelessly behind the scenes. He gave his time to meet all the Sceptre research groups, encouraging researchers and identifying where he could help. A key attribute was he was always well prepared. David will be greatly missed and has set the standard for others to follow.

CONTENTS

GROWER SUMMARY

Headline

- Potential new pesticide and biopesticide control treatments identified for key pests, diseases and weeds on field vegetables, soft fruit, protected edibles and top fruit.
- Bandsprayed residual herbicides applied between planting rows, combined with a low dose over the row, improves weed control options in leek and cauliflower.

Background

Numerous widely used conventional chemical pesticides have already or are predicted to become unavailable over the next decade as new European legislation takes effect. Resultant gaps in crop protection threaten severely to reduce the profitability of growing some edible crops – carrots, lettuce and soft fruit for example – and will likely impact on the profitability of many others.

The decline in availability of approved crop protection chemicals is occurring for several reasons:

- failure of active substances to remain Annex I (a positive list of active substances permitted in the EC) following review of substances that had been approved under the Pesticide Registration Directive (91/414/EEC);
- some active substances were not supported by crop protection companies for economic reasons and were withdrawn from the pesticides review;
- implementation of Regulation (EC) (1107/2009) that requires assessment of inherent hazard as well as risk;
- implementation of the Water Framework Directive (WFD), a measure that particularly impacts on herbicides and molluscicides;
- adoption of the Sustainable Use Directive (SUD), which became compulsory on 1 January 2014, whereby crop protection chemicals must be used only to supplement alternative (non-chemical) methods of control.

The effect of these measures on future availability of pesticides, the resultant gaps in crop protection, and the likely impact on profitability of growing major crops has been estimated in studies funded by the HDC and Defra (project IF01100). The outcomes from these reports were used to help identify the highest priority targets for research in the Sceptre project (Appendix 1).

The costs of finding and developing new pesticides are prohibitive for many crops; horticultural crops are 'minor crops' in a global crop protection market. Registration of products is complex and usually expensive and requiring detailed biological and residue studies for each specific crop (in some instances extrapolation from one crop to another similar crop is permitted). Microbial pesticides and botanical pesticides (biopesticides) also face large registration costs.

New technologies and a new approach are needed to develop treatments with plant protection products that support sustainable production of edible crops. Opportunities available include:

- new chemical actives;
- a rapidly increasing number of biopesticides in the registration pipeline;
- better targeted application;
- greater use of non-chemical crop protection methods;
- anti-resistance strategies to prolong the life of actives;
- a coordinated approach so that the majority of products and treatments with potential are evaluated;
- interaction between researchers so that results on one pest are used to inform studies on a similar pest;
- collection of all relevant data so that results can be immediately used to support registration data packages;
- training of the next generation of applied crop protection specialists.

This project aims to identify effective plant protection opportunities with the potential to fill the gaps and to develop integrated pest, disease and weed management programmes compliant with the new Sustainable Use Directive. The most promising conventional pesticides and biopesticides now coming to the market and some new technologies, including non-plant protection product methods of pest control, will be evaluated.

A broad Consortium has been assembled to deliver this work comprising applied crop protection researchers and representatives of growers, agrochemical companies, biological crop protection companies, produce marketing organisations, retailers and the industry levy body; organisations outside the consortium are invited to supply products. The Consortium researchers comprise three teams (pests, diseases and weeds) working across the major organizations currently delivering applied crop protection research.

Summary

In Year 3, 52 conventional plant protection products based on chemical pesticides, 21 based on microorganisms, 7 based on botanical extracts and 3 others were screened against pest, disease and weed problems identified as high priority targets on edible crops. Twenty-nine experiments were completed and a further two are in progress.

An overview of the target pests investigated in 2013, by sector and crop, is given (Table 1). The numbers and types of products tested in each experiment shown (Table 2) and the broad results are listed (Table 3) and then described. Novel products with good potential to fill crop protection gaps have been identified in all crop sectors (Tables 4-6).

Table 1. Overview of crop pest combinations with experiments completed in 2013

Sector and Pest	Crop				
Field vegetables	Brassica	Lettuce	Leek	Onion	Field veg
Downy mildew				✓	
Powdery mildew	✓				
Ring spot	✓				
Rust			✓		
Aphid	✓	✓			
Caterpillar	✓	✓	✓		
Cabbage root fly	✓				
Thrips			✓		
Annual weeds					✓
Soft fruit	Strawberry	Raspberry	Bush/Cane		
Crown rot	✓				
Mucor/Botrytis	✓				
Aphid		✓			
Capsid (Lygus)	✓				
Annual weeds		✓	✓		
Perennial weeds	✓	✓	✓		
Protected edibles	Cucumber	Tomato	Pepper		
Botrytis		✓			
Pythium	✓				
Whitefly		✓			
Red spider		✓			
Aphid			✓		
Top fruit	Apple	Pear			
Powdery mildew	✓				
Botrytis in store		✓			

Table 2. Overview of experiments in 2013 showing numbers and types of products tested individually

Trial	Crop	Target	Novel products tested					
			micro-org	Botanical	Salt/ other	Total bio	Chemical	TOTAL products
1.1	Leek	Rust	2	1	0	3	8	11
1.2	Brassica	Powdery mildew	2	1	0	3	5	8
1.3	Brassica	Ring spot	1	1	0	2	2	4
1.4	Spring onion	Downy mildew	2	0	1	3	7	10
1.5	Leek	Onion thrips	0	2	0	2	3	5
1.6	Lettuce	Aphid	2	2	0	4	3	7
1.6	Lettuce	Caterpillar	3	1	0	4	2	6
1.7	Brassica (sprouts)	CRF, aphids, caterpillar	2	3	2	7	6	13
1.7a	Brassica	CRF (2012)	2	2	0	4	0	4
1.8	Field Vegetables	Annual Weeds	0	0	0	0	3	3
1.9	Cauliflower and leek	Band spraying for weeds	N/A	N/A	N/A	N/A	N/A	N/A
1.10	Cauliflower, leek	Electric weed control	N/A	N/A	N/A	N/A	N/A	N/A
2.1	Raspberry	Cane diseases[b]	-	-	-	-	-	-
2.2	Strawberry	Mucor and Botrytis	0	0	3	3	1	4
2.3	Strawberry	Crown rot	2	0	0	2	3	5
2.4	Strawberry	Capsid (Lygus)	0	0	0	0	2	2
2.5	Raspberry	Aphid	1	2	0	3	1	4
2.6	Blackcurrant	Herbicide crop safety	0	2	0	2	4	6
2.7	Raspberry	Herbicide crop safety	0	2	0	2	1	3
2.8	Soft fruit	Bioherbicides & herbicides for perennial weeds	0	2	0	2	1	3
3.1	Tomato	Botrytis	4	1	0	5	4	9
3.2	Cucumber	Pythium	7	1	1	9	11	20
3.3	Cucumber	Phomopsis[b]	-	-	-	-	-	-
3.4	Tomato	Spider mite and whitefly	2	1	0	3	0	3
3.5	Pepper	Aphid	2	1	0	3	0	3
4.1	Apple	Powdery mildew	2	3	0	5	2	7
4.2	Pear	Botrytis	3	0	0	3	0	3
	Annual unique products for FV[c]		10	5	0	15	25	40
	Annual unique products for PE		8	3	0	11	23	34
	Annual unique products for SF		5	5	2	12	18	30
	Annual unique products for TF		7	2	1	10	8	18
	Annual unique products – herbicides		0	2	0	2	7	9
	Annual unique products – fungicides		15	2	3	20	37	57
	Annual unique products – insecticides		6	3	0	9	8	17
	TOTAL UNIQUE PRODUCTS Y3		**21**	**7**	**3**	**31**	**52**	**83**

[a] Excluding the standard (reference) product and treatments using 2 or more products.

[b] Experiment still in progress.

[c] Annual totals include products used in IPM programmes.

N/A – not applicable.

Table 3. Overview of experiment results on individual products[a] – 2013

Topic	Number treatments demonstrating control*			Pest level on untreated
	Pesticides	Bio-pesticides	Other method	
Field vegetables				
1.1 Leek: Rust	8 (8)	2 (2)	-	Low
1.2 Brassica: Powdery mildew	5 (4)	2 (0)	-	High
1.3 Brassica: Ring spot	2 (2)	1 (0)	-	Low
1.4 Spring onion: Downy mildew	2 (2)	1 (0)	-	Moderate
1.5 Leek: Thrips	3 (1)	2 (0)	-	Moderate
1.5 Leek moth	3 (3)	2 (2)	-	Moderate
1.6 Lettuce: Aphids (3 trials)	3 (3)	4 (0)	-	Low
1.6 Lettuce: Caterpillar	2 (2)	4 (4)		High
1.7 Brassica: CRF	2 (2)	0 (0)	-	High
1.7 Brassica: Aphid	3 (2)	4 (2)	-	Moderate
1.7 Brassica: Caterpillar	3 (2)	4 (3)	-	Moderate
1.7a Brassica: CRF (2012)	NT	4 (1)	-	High
1.8 Vegetables: Annual weeds	3 (NR)	NT	-	High
1.9 Vegetables: Band spraying (4 sites)	NA	NA	✓	High
1.10 Vegetables: Electrical weed control (2 sites)	NA	NA	✓	Moderate
Soft fruit				
2.2 Strawberry: Soft rot	1 (1)	0 (0)	-	Moderate
2.3 Strawberry: Crown rot	-	-	-	Very low
2.4 Strawberry: European tarnished bug	3 (2)	NT	-	High
2.5 Raspberry: Aphid	1 (1)	2 (1)	-	Moderate
2.6 Blackcurrant: Herbicides	-	-	-	NA
2.7 Raspberry: Herbicides	1 (1)	2 (2)	-	Moderate
2.8 Fruit: Perennial weeds	1 (1)	2 (2)	-	High
Protected edibles				
3.1 Tomato: Grey mould	4 (4)	5 (0)	-	Moderate
3.2 Cucumber: Pythium	11 (5)	9 (0)	-	Moderate
3.4 Tomato: Spider mites & whitefly	IPM	IPM	-	Moderate
3.5 Pepper: Aphids	NT	1 (1)	-	Moderate-
Top fruit				
4.1 Apple: Powdery mildew (2 trials)	2 (2)	5 (5)	-	High
4.2 Pear: Botrytis rot in store (2012/13)	NT	1 (0)	-	High

[a] Many experiments also tested treatment programmes using two or more products applied alternately or in mixture; results are presented in the individual experiment reports.

* Compared with untreated; excludes approved reference products. ( ) – number equal to or better than the chemical reference product. NR – no reference product for comparison. NT – none tested. NA – not applicable.

Table 4. Leading novel products (product name or code number in numerical order) identified for control of diseases: 2011-2013

Target	Crop	Year	Exp ref.	Reference product	Leading 3 products					
					Fungicides			Biofungicides		
Field vegetables										
Alternaria	Brassica	2011	1.1	Rudis	Sig	24	28	06	43	47
	Brassica	2012	1.4	Signum	*	*	*	06	40	49
Downy mildew	Brassica	2011	1.2	Folio Gold	24	26	83	47	-	-
	Onion	2013	1.4	Mixtures	20	24	-	-	-	-
Powdery mildew	Brassica	2012	1.1	Rudis	24	28	89	90	11+adj	136
	Brassica	2013	1.2	Rudis	24	28	89	11	90	90+40
Ring spot	Brassica	2012	1.2	Signum	10	24	Nat	38	43	90
	Brassica	2013	1.3	Ami/Rud	10	24	25a	90	-	-
Rust	Leek	2012	1.3	Amistar	10	27	46	*	*	*
	Leek	2013	1.1	Amistar Top	Ami	31	118	Ser	105	-
Soft fruit										
Crown rot	Strawberry	2012	2.3	Paraat	24	-	-	40	Pre	-
Soft rot	Strawberry	2011	2.1	-	Sig	Thi	77	-	-	-
		2012	2.3	Signum	25a	77	-	-	-	-
		2013	2.2	-	37	-	-	-	-	-
Spur blight	Raspberry	2012	2.1	Switch	08	32	77	*	*	*
Protected edibles										
Botrytis	Tomato	2011	3.2	Switch	08	31	77	Pre	09	38
	Tomato	2012	3.2	Signum	08	25a	118	-	-	-
	Tomato	2013	3.1	Rov/Swi/Sig	**31**	**77**	**118**	-	-	-
Powdery mildew	Cucumber	2011	3.1	Systhane	10	77	88	38	80	90
	Cucumber	2012	3.1	Sys/Nim	08	25a	77	90	105	90+03
Pythium	Cucumber	2013	3.2	Previcur Energy	46	139	183	-	-	-
Top fruit										
Botrytis	Pear	2012	4.2	Rovral WG	*	*	*	38	98	99
	Pear	2012	4.2	Rovral WG	*	*	*	38	-	-
Powdery mildew	Apple	2011	4.1	Systhane	47	77	Cos	38	80	90
	Apple	2012	4.1	Systhane	**25a**	**32**	**159**	158	160	162
	Apple	2013	4.1	Systhane	88	118	-	90	105	11+adj

* – no products in this category evaluated. Ami – Amistar; Cos – Cosine; Nat – Nativo 75WG; Nim – Nimrod; Pre – Prestop; Rov – Rovral WG; Ser – Serenade ASO; Sig – Signum, Swi – Switch; Sys – Systhane 20EW; Thi – Thianosan DG; adj – adjuvant.

Please see individual experiment reports, within the annual reports, for full details.

Up to 3 leading products are listed, arranged in numerical order. All products listed resulted in a significant reduction compared with the untreated control and were equal to or better than (numbers in bold) the reference product. Products resulting in severe phytotoxicity have been excluded.

Table 5. Leading novel products (product name or code number in numerical order) identified for control of pests: 2011-2013

Target	Crop	Year	Exp ref.	Reference product	Leading 3 products					
					Insecticides			Bio-insecticides		
Field vegetables										
Aphid	Brassica	2011	1.4	Movento	50	59	60	62	92	-
	Brassica	2013	1.7	Movento	59	60	-	62	130	-
	Carrot	2011	1.8	Biscaya	50	54	75	-	-	-
	Lettuce	2011	1.6	Movento	54	-	-	-	-	-
	Lettuce	2013	1.6	Movento	50	59	60	51	62	-
Caterpillar	Brassica	2013	1.7	Steward	48	143	-	64	Lep	130
	Lettuce	2013	1.6	Tracer	48	50	-	Lep	94	130
Cabbage root fly	Brassica	2011	1.5	Tracer	50	55	-	-	-	-
	Brassica	2012	1.8	Tracer	50	55	-	*	*	*
	Brassica	2013	17a	Tracer	*	*	*	130	-	-
	Brassica	2013	1.7	Tracer	50	55	-	*	*	*
Moth	Leek	2012	1.7	Tracer	50	-	-	62	130	-
	Leek	2013	1.5	Tracer	48	50	142	62	-	-
Thrips	Leek	2011	1.7	Tracer	48	50	54	-	-	-
	Leek	2013	1.5	Tracer	48	50	142	62	130	-
Whitefly	Brassica	2012	1.8	Movento	54	59	60	*	*	*
Soft fruit										
Aphid	Raspberry	2011	2.2	Calypso	70	-	-	62	-	-
	Raspberry	2012	2.4	Calypso	50	54	60	51	62	130
	Raspberry	2013	2.5	Calypso	50	-	-	62	130	-
Lygus	Strawberry	2011	2.3	Calypso	Che	149	54	53	-	-
	Strawberry	2012	2.5	Calypso	60	149	-	*	*	*
	Strawberry	2013	2.4	Chess	**59**	149	-	*	*	*
Protected edibles										
Aphid	Pepper	2013	3.5	Chess	*	*	*	130	-	-
	Tomato	2011	3.3	-	53	86	-	01	52	62
Spider mite	Tomato	2012	3.3	Oberon	131	-	-	01	62	92
	Tomato	2012	3.3	Borneo	131	-	-	62	Nat	92
	Tomato	2013	3.4	Borneo	*	*	*	51	62	130
WFT	Pepper	2012	3.5	Pyrethrum	*	*	*	01	62	Nat
	Pepper	2011	3.5	-	48	50	54	52	81	82
Whitefly	Tomato	2011	3.4	-	54	60	-	52	62	92
	Tomato	2012	3.4	Chess	54	106	-	01	62	130
	Tomato	2013	3.4	Chess	*	*	*	51	-	-

* – no products in this category evaluated. Che – Chess; Lep- Lepinox Plus; Nat – Naturalis-L

See Table 4 footnotes. Please see individual experiment reports, within the annual reports, for full details.

Table 6a. Leading novel herbicide products[a] identified for crop safety– multi field vegetable crop screening, Lincolnshire. Pre = applied pre-emergence of drilled crop or pre-transplanting crop; post = post-emergence of drilled crop or post-transplanting crop; () possibly safe

Crop	2011		2012		2013					
	pre	post	post	post	pre	post	pre	post	pre	post
Drilled										
Broad bean	105			(123)			165		166	
Bulb onion		105	76	(123)	164		165	165	166	166
Carrot	105	105	76		164				166	166
Coriander	105	105	76						166	
Dwarf French bean	105				164		165		166	
Leek		105	76	(123)	164		165	165	166	166
Parsnip	105	105	76						166	166
Pea	105			(123)			165	165	166	
Transplanted										
Cauliflower	105						165	165	166	
Celery	105	105	76						166	166
Courgette	NT	NT	NT	NT			165	165	166	
Lettuce	(105)	(105)		(123)				165	166	

NT courgette not tested in 2011 and 2012.

Mizuna, rocket, swede and baby leaf spinach - no safe solutions.

[a] 105 tested pre-and post-weed emergence in 2011; 123 (at low doses) and 76 tested post-weed-emergence only in 2012; 164, 165 and 166 tested pre-and post-weed emergence in 2013. 165 did not control emerged weeds.

Please see Sceptre Annual Reports for full details.

Table 6b. Leading novel products (product name or code number in numerical order) identified for control of weeds: 2011-2013

Target	Crop/weed	Year	Exp. Ref.	Reference product	Leading 3 products					
					Herbicides			Bioherbicides		
Field vegetables										
Annual weeds	Cauliflower	2012	1.10	Rapsan + Gamit	74	DG	SA	*	*	*
	Cauliflower	2013	1.9	Rapsan + Gamit	A	B	-	*	*	*
	Leek	2013	1.9	Wing P + Defy	C	D	-	*	*	*
	Onion	2012	1.10	Stomp Aqua	WP	DG	-	*	*	*
Fruit										
Annual weeds	Mixture	2012	1.12	Rosate 36	*	*	*	116	-	-
		2013	2.7	Shark	124	-	-	109	116	-
Perennial weeds	Dock	2011	2.4	-	R+S	72	102	-	-	-
	Dock	2012	1.12	Rosate 36	124	-	-	116	-	-
	Dock	2013	2.8	Rosate 36	124	-	-	109	116	-
	Nettle	2011	2.4	-	R+S	72	102	-	-	-
	Nettle	2012	1.12	Rosate 36	124	-	-	-	-	-
	Nettle	2012	2.7	Roundup	72	-	-	*	*	*
	Nettle	2013	2.8	Rosate 36	124	-	-	109	116	-
	Thistle	2011	2.4	-	R+S	72	102	-	-	-
	Thistle	2012	1.12	Rosate 36	124	-	-	116	-	-
	Thistle	2012	2.7	Roundup	72	109	135	*	*	*

* – no products in this category evaluated.

Please see individual reports, within the Annual Sceptre reports, for details.

A – Wing P + Dual Gold + Gamit 36CS + Kerb Flo; B – Rapsan 500 (in row) with Wing P + Dual Gold + Gamit 36CS + Kerb Flo between rows; C – Wing P (in row) with Wing P + Defy between rows; D – Wing P (in row) with Stomp Aqua + Defy between rows.

DG – Dual Gold; SA – Stomp Aqua; WP – Wing P; R+S – Roundup + Shark.

Field vegetables

1.1. Leek: Evaluation of fungicides and biofungicides for control of rust

A trial was conducted outside in summer 2013 to evaluate nine fungicides and three biofungicides for control of rust (*Puccinia allii*) on leek cv. Darwin. An untreated control and a grower standard, Amistar Top (azoxystrobin + difenoconazole) were included. Fungicides were applied twice at 14 day intervals from inoculation and biofungicides five times at 7 day intervals from 1 week pre-inoculation. Although disease severity was low (1% leaf area affected on untreated plants) there were significant differences between treatments. At 6 weeks after inoculation, rust severity was reduced by Amistar, Amistar Top, Signum and six coded fungicides (10, 27, 31, 24, 25a, 118). Amistar Top, 31 and 118 gave >90% control. Serenade ASO and two coded biofungicides (40, 105) gave no reduction at 6 weeks although Serenade ASO and 105 had less disease than the untreated at 8 weeks. No phytotoxic symptoms were observed.

1.2 Brassicas: Evaluation of fungicides and biofungicide programmes for control of powdery mildew

A trial was conducted in an unheated polythene tunnel in summer 2013 to evaluate seven fungicides, three biofungicides and two fungicide/biofungicide programmes for control of powdery mildew (*Erysiphe cruciferarum*) on swede cv. Emily. Rudis (prothioconazole) and Nativo 75WG (tebuconazole + trifloxystrobin) were included as grower standards. Fungicides were applied twice at a 14 day interval from inoculation, and biofungicides and the fungicide/biofungicide programmes at 7 day intervals. At 6 weeks after inoculation disease severity on untreated plants was high (73% leaf area affected). All treatments reduced powdery mildew with Rudis, two coded fungicides (24, 28) and one five spray programme (90 applied 3x followed by Rudis twice), reducing it by >90%. The three biofungicide treatments (90, 90+40 and 11) each reduced mildew by around 25%. The biofungicide 90 applied four times, followed by Rudis, was much more effective than Rudis at inoculation followed by biofungicide 90 applied three times. Moderate phytotoxicity was observed with the biofungicide 11, which was used as recommended with a wetter; and slight phytotoxicity with biofungicide 90.

1.3 Brassicas: Evaluation of funigicide and biofungicide programmes for control of ring spot and other foliar diseases

A field trial was conducted in Lincolnshire in autumn 2013 to evaluate three fungicide products (Rudis, and coded products 24 and 25a), four fungicide programmes (Amistar/Rudis/Amistar; Signum/Rudis/Signum; Nativo 75WG/Rudis/Nativo 75WG; 10/Amistar Top/10), two biofungicides (Serenade ASO and coded product 90) and one programme of mixtures of a biofungicide (105) with Amistar and Rudis, for control of ring spot (*Mycosphaerella brassicicola*) and other leaf spots on cabbage cv. Caraflex. Brassica leaf debris affected by ring spot was laid between plots to provide natural infection. Fungicide treatments consisted of three sprays at 14 day intervals and biofungicides of six sprays at 7 day intervals. Widespread ring spot occurred in late November and affected 3% leaf area and 1% area of heads. The disease was reduced by all treatments except Serenade ASO. Several treatments were still providing good control over 1 month after the final spray. Low levels of downy mildew (*Hyaloperonospora parasitica*), dark leaf spot (*Alternaria* spp.), white blister (*Albugo candida*), black rot (*Xanthomonas campestris* pv. *campestris*) and light leaf spot (*Pyrenopeziza brassicae*) occurred naturally. The most effective treatment for ring spot was biofungicide 105 admixed with Amistar alternating with 105 admixed with Rudis in a 3-spray programme. Fungicide 24 was the best single product for ring spot and also reduced downy mildew and dark leaf spot. Total yield and mean head weight were increased by the Nativo 75WG/Rudis/Nativo 75WG programme and by fungicide 25a.

1.4 Spring onion: Evaluation of fungicides and biofungicides for control of downy mildew

A field trial was conducted in summer 2013 to evalute seven fungicides, three biofungicides and a fungicide + biofungicide mixture for control of downy mildew (*Peronospora destructor*) on spring onion cv. Slender Star. An untreated control and both spring onion (Invader + Amistar/Invader + Signum/Invader + Olympus) and bulb onion (Valbon + Olympus/Unicur + Dithane/Valbon + Dithane) grower standard programmes were included. Fungicides and the mixture were applied four times and biofungicides six times at 7-14 day intervals. Disease severity was moderate with 6% leaf area affected on untreated plants at 2 weeks after the final spray, rising to 36% at 4 weeks. The two grower standard programmes, each of which used six different active ingredients, were very effective, reducing downy mildew by ≥75%. Two novel fungicide products, coded 20 and 24, both significantly reduced downy mildew by >50%. Signum used alone was ineffective as were fungicides 22, 23, 25a and 41 and the fungicide + biofungicide mixture (22 + 105). None of the biofungicides (40, 47 and 188) reduced the disease. Persistene of control was greatest with the bulb onion standard programme, with <2% leaf area affected 4 weeks after the final spray.

1.5 Leek: Evaluation of insecticides and bio-insecticides for control of onion thrips

Two field trials were conducted in 2013 to evaluate the efficacy of insecticides (Trial 1) and bio-insecticides (Trial 2) for control of onion thrips (*Thrips tabaci*) on leek cv. Surfer. Insecticides were applied at 14 day intervals and bio-insecticides at 7 day intervals with four sprays of each. Damage by the pest was moderate with 20% leaf area affected on untreated plants. All four insecticides reduced damage with the standard product Tracer (spinosad) and coded insecticide 50 being the only 2 which reduced damage significantly, reducing the damage by around 50%. Bio-insecticide 62 gave a slight reduction in thrips damage when applied at 1,000 L/ha, but not at 200 L/ha. Leek moth caterpillar (*Acrolepiosis assectella*) also occurred and affected 60% of untreated plants. Damage by this pest was reduced by all four conventional insecticides, with Tracer and 50 the most effective, reducing the incidence of affected plants by 90%; the two bio-insecticides (62 and 130) at both application volumes gave a small reduction.

1.6 Lettuce: Evaluation of insecticides and bio-insecticides for control of currant-lettuce aphid and caterpillar

Six field trials (three for insecticides and three for bio-insecticides) were conducted in 2013 to evaluate the efficacy of products in an IPM programme for control of currant-lettuce aphid (*Nasonovia ribisnigri*) and caterpillars on lettuce cv. Saladin. Treatments for aphid control were applied once (insecticides) or twice (bio-insecticides) when a moderate infestation was present. Movento (spirotetramat) was included as a standard. Movento and insecticide 59 were the most effective conventional products; little efficacy on aphids was observed with any of four bio-insecticides (51, 62, 92 and 130). No caterpillars occurred in any of the field trials so treatments were tested on pot grown lettuce infested with a culture of silver Y moth (*Autographa gamma*). Treatments were applied once and plants assessed 7 days later. Tracer (spinosad) was included as a standard. Tracer and two conventional insecticides (48 and 50) resulted in 100% mortality of caterpillars. Four bio-insecticides (51, 68, 94, 130) all resulted in some caterpillar mortality and a reduction in feeding holes; bio-insecticide 68 was the most effective.

1.7 Brassica: Evaluation of insecticides and bio-insecticides against cabbage root fly, aphids and caterpillars

Two field trials were conducted simultaneously in 2013 to evaluate five insecticide programmes (Trial 1) and five bio-insecticide programmes (Trial 2) for control of cabbage root fly (*Delia radicum*), aphids (cabbage aphids – *Brevicoryne brassicae*) and caterpillars (small white butterfly – *Pieris rapae*) on Brussels sprout cv. Faunus. Insecticides were applied once and bio-insecticides three times at 7 day intervals. A standard programme of Tracer (spinosad) for cabbage root fly, Movento (spirotetromat) for aphids and Steward (indoxacarb) for caterpillars was included. The biopesticides trial used Dursban (chlorpyrifos) for cabbage root fly control in all programmes. Levels of pest infestation were high. All three insecticides tested (Tracer, 50 and 55) gave excellent control of CRF damage on roots; moderate control on stems. No bio-insecticides were tested. Movento and insecticides 59 and 60 gave good control of aphids, with Movento appearing the most effective (although there were no statistical differences). Bio-insecticides 62 and 130 gave reasonable control (but this was only statistically significant with 130) while 01 and 92 were ineffective. All three insecticides (Steward, 48 and 143) gave good control of caterpillars, with 143 the most effective. Bio-insecticides 64, 68 and 130 gave good control of caterpillars, whereas 93 was ineffective.

1.7a Brassica: Evaluation of bio-insecticides against cabbage root fly (2012)

A trial was conducted in winter 2012 to evaluate the efficacy of four bio-insecticides for control of cabbage root fly (*Delia radicum*) on cauliflower. Results were compared with an untreated control and with a standard insecticide, Tracer (spinosad). Bio-insecticide 130 was partially effective when applied either as a granule to the soil surface or as a drench (post transplanting), but was extremely phytotoxic when granules were incorporated and ineffective when drenched onto modules pre-transplanting. The other three bio-insecticides gave no control. Tracer gave good control both as a drench pre-transplanting and when incorporated at sowing (‘Phytodrip’ application).

1.8 Field vegetables: Evaluation of herbicides for crop safety and weed control

Field trials were conducted in 2013 on a light, sandy silt loam soil to evaluate three conventional hericides applied pre- or post weed emergence at a range of dose rates for weed control and crop safety in 15 crops. Additionally, volunteer potatoes were planted to determine if the herbicides suppressed their growth. Untreated control plots were included for comparison. The season was characterised by lower than average temperatures from March to June resulting in slow crop emergence and growth; and by heavy rainfall after application of the pre-weed-emergence herbicides. Product 164 applied pre-emergence has potential for use in drilled carrot, parsnip, leek and bulb onion. It controlled a wide weed spectrum including mayweeds and groundsel but not annual meadow grass. No crop was safe to post-emergence applications of this product. Product 165 applied pre-emergence has potential for bulb onion, broad bean, vining pea and dwarf French bean. Weed control was excellent on all species at 2.0 L/ha but at 1.0 L/ha it was less effective on small nettle and fat hen. Applied post-emergence, 165 did not control emerged weeds but was safer to the crops and has potential for use soon after planting, before weeds emerge, on cauliflower and courgette. Product 166 applied pre-emergence has potential for use in carrot, parsnip and coriander at 0.5 L/ha and to bulb onion, leek, dwarf French bean, broad bean and pea used at 0.25 L/ha. It did not control groundsel and annual meadow grass. Applied post-emergence, 166 suppressed volunteer potato foliage by up to 75% and has potential for use in carrot, parsnip, onion and leek. None of the three herbicides tested was safe to rocket.

1.9 Vegetables: Evaluation of bandsprayed residual herbicides for control of annual broad-leaf weeds

1.9a Cauliflower – site 1

A field trial was conducted in 2013 to evaluate a banded herbicide treatment for control of weeds and crop safety in a July planted crop of cauliflower cv. Diwan on sandy loam soil in Lincolnshire. Whole plots were treated once with either Rapsan 500SC (metazachlor) + Gamit 36CS (chlomazone) or coded 74 + Dual Gold (S-metolachlor) + Gamit 36CS + Kerb Flo (propyzamide). In the banded treatment, the first mixture was applied to crop rows and the second mixture between rows. An untreated was included. The weed population was very low and no firm conclusions could be drawn with regard to weed control. The second herbicide mixture applied over whole plots caused some phytotoxicity and reduced crop vigour. The banded treatment of Rapsan SC (metazachlor) applied to crop rows and 74 + Dual Gold (metolachlor) + Gamit 36CS (clomazone) + Kerb Flo (propyzamide) applied between rows did not cause damage or reduce vigour.

1.9b Cauliflower – site 2

The same treatments were evaluated in spring 2013 in cauliflower cv. Skywalker on a silt soil in Lincolnshire. The weed population was very high and was greatly reduced by all treatments; the banded herbicide treatment gave 94% control, equally effective as the best whole plot treatment. One herbicide mixture (coded 74 + Dual Gold + Gamit 36CS + Kerb Flo) appeared to cause slight phytotoxicity both when used over whole plots and as a band spray. There were no significant effects on crop vigour.

1.9c Leeks – site 1

A field trial was conducted in spring 2013 to evaluate a banded herbicide treatment for control of weeds and crop safety in leeks cv. Triton on a sandy loam soil in Lincolnshire. Whole plots were treated once with Wing P (dimethenamid-P + pendimethalin) at 2 and 4 L/ha and with Wing P at the high rate plus Defy (prosulfo-carb). One banded treatment consisted of Wing P (2 L/ha) applied to rows and Wing P (4 L/ha) + Defy applied between rows. A second banded treatment consisted of Wing P (2 L/ha) applied to rows and Stomp Aqua (pendimethalin) + Defy between rows. An untreated control was included. The first banded treatment of Wing P/Wing P + Defy gave the best overall control, reducing weeds by 82.5%. The high rate Wing P + Defy whole plot treatment and the second banded treatment (Wing P + Stomp Aqua) reduced weeds by 67.5 and 65% respectively. No phytotoxic symptoms were observed and no treatments reduced crop vigour.

1.9d Leeks – site 2

The same treatments were evaluated in spring 2013 in leeks cv. Galvani on a silt soil in Lincolnshire. The two banded spray treatments and the high rate Wing P whole plot treatment gave similar high levels (86-88%) of weed control. These three treatments gave slight crop phytotoxicity 1 month after spray application which was not evident two weeks later. No treatment reduced crop vigour.

1.10 Field vegetables: Electrical treatment for control of annual weeds

1.10a Cauliflower

A field trial was conducted in summer 2013 to evaluate electrical weeding used alone and one month after a herbicide spray for control of weeds and crop safety in cauliflower cv. Skywalker on a silt soil in Lincolnshire. The electrical treatments were compared with Rapsan 500SC (metazachlor) + Gamit 36CS (clomazone) herbicide treatment, mechanical weeding and the herbicide spray followed one month later by mechanical weeding. An untreated control was included. The combined treatments of herbicide followed by electrical or mechanical weeding gave similar high levels (86-88%) of weed control. Mechanical weeding alone and herbicide alone were comparable, with 54-56% control. The electrical treatment alone gave a 19% reduction in weeds; treatment efficacy was reduced due to a cloddy seedbed. No phytotoxicity symptoms were observed and no adverse effects on crop vigour.

1.10b Leeks

Similar treatments were evaluated in summer 2013 in drilled leeks cv. Galvani on a silt soil in Lincolnshire. The herbicide treatment in this trial was Wing P (dimethenamid-P + pendimethalm) at 2 L/ha. The combined treatments of herbicide followed by electrical or mechanical weeding gave similar moderate levels of weed control (56-63%), slightly better than the herbicide alone (54%). The electrical treatment alone (11% weed control) and mechanical treatment alone (19% weed control) were poor, probably due to a delay in treatment due to rainfall. No phytotoxicity symptoms and no differences in crop vigour were observed.

Soft fruit

2.1 Raspberry: Evaluation of fungicides for control of cane spot and spur blight

This work is in progress and will be reported in 2015.

2.2 Strawberry: Evaluation of fungicides and biofungicides for control of soft rots

A trial was conducted in summer 2013 to evaluate the efficacy of one fungicide, one biofungicide, two alternative products, three fungicide programmes and two fungicide + alternative products programmes for control of fruit soft rots (*Mucor* and *Rhizopus* spp.) in a tunnel crop of strawberry cv. Finesse. Treatments were compared with an untreated control. Products were applied on five occasions during fruit development and resultant mature fruit were assessed in post harvest tests. Over 40% of untreated fruit developed *Mucor* soft rot. Fungicide 37 and two programmes (Thianosan, Switch, Signum; Thianosan, Switch, fungicide 77) were consistently the best treatments, reducing the disease by 30-34%; the other treatments (fungicide 47, products 186 and 187 and three programmes) had no effect. Botrytis affected 24% of fruit from untreated plants in post harvest tests. This disease was reduced by the same three treatments and also by a programme of Thianosan, Switch and fungicide 25a.

2.3 Strawberry: Evaluation of fungicides and biofungicides for control of crown rot

A polytunnel trial was conducted in summer 2013 to evaluate three fungicides and two biofungicides, each applied by three application methods, for control of crown rot (*Phytophthora cactorum*) in strawberry cv. Elsanta grown in peat bags. Two crown rot infected plants were placed in each bag as a source of inoculum. By February 2014, crown rot symptoms had developed in only two plants. It was not possible therefore to draw any conclusions on treatment efficacy from this work.

2.4 Strawberry: Evaluation of insecticides for control of European tarnished plant bug

A caged trial in a glasshouse was conducted in summer 2013 to evaluate insecticide 59 applied alone and insecticide 149 applied alone and in mixtures with Chess (pymetrozine), Spruzit (pyrethrum) and Silwet L-77 (silicon wetter) for control of European tarnished plant bug (*Lygus rugulipennis*) on strawberry cv. Finesse. An untreated control and the standard treatment Chess were included; Spruzit alone was also tested. Each cage was artificially infested with adults of the pest and plants were sprayed 3 and 5 weeks later. Insecticide 59 greatly reduced numbers of adults and nymphs. Insecticide 149 alone reduced numbers of adults and reduced numbers of nymphs when in admixture with Chess, Spruzit and Silwet-L77. Chess or Spruzit used alone (at a low rate) did not reduce the pest.

2.5 Raspberry: Evaluation of insecticides and bio-insecticides for control of aphids

A field trial was conducted in summer 2013 to evaluate one insecticide and three bio-insecticides used in conjunction with macrobiologicals for control of large raspberry aphid (*Amphorophora idaei*) and potato aphid (*Microsiphum euphorbiae*) in a polytunnel crop of raspberry cv. Glen Ample. Treatments were compared with a water control and the standard insecticide Calypso (thiacloprid). The parasitoid Ervipar (*Aphidius ervi*) was released to suppress potato aphid and Spidex (*Phytoseiulus persimilis*) was used to suppress spider mites; endemic hoverflies were encouraged. Calypso and insecticide 50 gave best control of both aphid species. Biopesticide 62 was the best biopesticide and reduced both aphid species. Biopesticide 130 was very effective against large raspberry aphid but not potato aphid; this bio-insecticide resulted in fruit taint after 4 sprays. Both insecticides had a strong negative effect on released parasitoids and endemic hoverflies whereas none of the biopesticides did.

2.6 Blackcurrant: Evaluation of herbicides and bioherbicides for crop safety

A trial was conducted in spring 2013 on 1-year-old pot grown blackcurrants cvs Ben Gairn and Ben Tirran to determine the crop safety of five herbicides and two bioherbicides applied as directed sprays to the base of bushes around bud break (23 March and 21 April). Following the March application, Roundup, 72 and 151 caused damage to basal buds on Ben Gairn; damage was insignificant on the later variety Ben Tirran. The April application caused more damage to basal buds than the earlier spray, including bud death and leaf yellowing and scorch. No treatments were safe to buds of Ben Gairn at this timing but herbicide 135 and bioherbicide 109 resulted in least damage when applied to breaking buds of Ben Tirran and no damage was evident when whole plants were assessed 6 weeks after the April treatment.

2.7 Raspberry: Evaluation of herbicides and bioherbicides for crop safety

A field trial was conducted in spring 2013 to evaluate the efficacy and crop safety of two herbicides and two bioherbicides applied to the base of raspberry canes, cv. Glen Ample, for control of weeds and initial raspberry spawn growth. An untreated control and the grower standard treatment Shark (carfentrazone-ethyl) were included. Herbicide 124 and bioherbicide 109 showed the greatest control of weeds, including thistle, and appeared better than Shark. No phytotoxicity and no significant effect on spawn control were observed with these products although Shark showed a slight reduction in spawn cover. The lack of overall plant phytotoxicity was likely because the season was late so treatments did not come into contact with broken buds. Bioherbicide 116 gave no sustained weed control.

2.8 Soft fruit: Evaluation of herbicides and bioherbicides for control of three perennial weeds

A field trial was conducted in spring 2013 to evaluate the efficacy of two herbicides and two bioherbicides for control of the perennial weeds broad-leaved dock (*Rumex obtusifolius*) and stinging nettle (*Urtica dioica*). An untreated control and a grower standard Rosate 36 (glyphosate) were included. Each product was applied twice, on 7 and 22 May. At 56 days after the first application, docks were significantly reduced by the bioherbicide 109 and Rosate 36; the latter gave complete control from 28 days after treatment (DAT)1. Herbicide 124 and bioherbicide 116 were ineffective on docks. All products initially reduced nettles, up to 21 DAT1, but by 56 DAT1 re-growth had occurred in all plots, comparable to the untreated, except for Rosate 36 and bioherbicide 116.

Protected edibles

3.1. Tomato: Evaluation of fungicides and biofungicides for control of grey mould

A glasshouse trial was conducted in 2013 to evaluate four conventional fungicides and five biofungicides against grey mould (*Botrytis cinerea*) in tomato cv. Elegance grown on Maxifort rootstock. Treatments were compared with an untreated control and a standard fungicide programme of Rovral WG (iprodione) alternated with Signum (boscalid + pyraclostrobin) and Switch (cyprodinil + fludioxonil). Conventional and biofungicides were evaluated in separate, identical glasshouses to preclude possible interactions. Biofungicides were applied eight times at 7 day intervals over a 2 month period and fungicide six times at 14 day intervals, both from the first sign of natural leaf infection in early July; the exception was Prestop (*Gliocladium catenulatum*), which was applied every 3 weeks, as per label. Severe leaf botrytis and ghost spot developed and there was a high incidence of leaf dieback and stem lesions by the final assessment on 6 September. The standard fungicide programme and the four coded conventional fungicides (25a, 31, 77 and 118) all reduced leaf Botrytis with product 77 better than all other treatments; 25a, 77 and 118 also appeared to reduce stem lesions. None of the biofungicides (40, 105, 132, 178 and Prestop) reduced Botrytis at any assessment. No conventional fungicide and no biofungicide reduced ghost spot symptoms on fruit.

3.2. Cucumber: Evaluation of fungicides and biofungicides for control of Pythium root and stem base rot

A glasshouse inoculated trial was conducted in summer 2013 to evaluate 11 fungicides and nine biofungicides for control of Pythium root and stem base rot (*Pythium aphanidermatum*) in cucumber cv. Shakira grown in rockwool blocks. A water-only treatment and a standard fungicide Previcur Energy (propamocarb-HCI + fosetyl-Al) were included. Products were drenched into blocks at 65 ml/block. Fungicides were applied 2 days before and 10 days after inoculation; biofungicides at these times and additionally at seed sowing (2 weeks before inoculation). At 7 weeks after inoculation, stem base lesion severity was reduced by six of the fungicides (44, 46, 139, 169, 171, 183) and none of the biofungicides (38, 40, 43, 47, 98, 105, 121, 188 and 189). Fungicide 183 was best, with no stem lesions and no root discolouration. Fungicides 139 and 171 were phytotoxic at the rates used, resulting in stunting and chlorosis. Biofungicide 189 appeared to reduce the disease. Previcur Energy failed to reduce root discolouration or stem base lesion severity.

3.3. Cucumber: Evaluation of fungicides and biofungicides for control of black root rot

This work is in progress and will be reported in 2015.

3.4. Tomato: Evaluation of insecticides and bio-insecticides for control of spider mites and whitefly

A glasshouse trial was conducted in summer 2013 to evaluate the efficacy of three bio-insecticides against relatively high levels of spider mite (*Tetranychus urticae*) and whitefly (*Trialeurodes vaporariorum*) on tomato cv. Cheramy. Each treatment was applied twice at 7 day intervals and followed by two introductions of *Phytoseiulus persimilis* for spider mite and of *Encarsia formosa* for whitefly. Treatments were compared with Chess (pymetrozine) for spider mite and Borneo (etoxazole) for white fly each followed by the macrobiologicals; water only and macrobiologicals only treatments were included. At the start of the experiment the mean number of adult plus nymph spider mites was 1-8 per leaflet; the mean number of adult whiteflies was 3-13 per leaflet. All treatments reduced all stages of spider mite with Borneo and the three biopesticides (51, 62, 130) followed by *P. persimilus* giving high levels of control, better than *P. persimilis* only. Spider mite levels were greatly reduced in all treatments by treatment with sulphur for powdery mildew control 4 days after the second biopesticide application; however, whereas levels in the water treatment subsequently increased, the macrobiologicals maintained control in all other treatments. Whitefly adults were reduced by Chess and biopesticide 51, but whitefly scales were not reduced by any treatment. The sulphur spray did not reduce whitefly populations. The experiment provides evidence that Chess and biopesticide 51, 62 and 130 can reduce spider mite, and Borneo and biopesticide 51 can reduce whitefly, to levels sufficient for macrobiologicals to maintain control.

3.5. Pepper: Evauation of insecticides for control of aphids

3.5a Comparison of bio-insecticides

A glasshouse trial was conducted in late summer 2013 to evaluate three bio-insecticides against aphids (*Myzus persicae*) on pepper cv. Ferrari. Treatments were compared with the insecticide Pyrethrum 5EC (pyrethrum) and a water-only control. Treatments were applied three times at 7 day intervals. Aphid levels at the start of the experiment were 5-15 per leaf. The bio-insecticide 130 reduced aphids to around 2 per leaf whereas Pyrethrum and bio-insecticides 51 and 62 were ineffective.

3.5b Integration of bio-insecticides and macrobiologicals

A glasshouse trial was conducted in late summer 2013 to evaluate the bio-insecticide 130 against aphid (*Myzus persicae*) on pepper cv. Ferrari. Treatment was compared with the conventional insecticide Chess (pymetrozine) and a water-only control. Chess and 130 were each applied once followed one day later by introduction of the macrobiological *Aphidius colemani*; an *Aphidlus*-only treatment was also included. At the time of treatment there were 28-48 aphids/plant. Two weeks after application, both Chess and 130 followed by *A. colemani* had reduced aphid numbers compared with the water only treatment; *A. colemani* alone was ineffective at this time.

Top fruit

4.1 Apple: Evaluation of fungicides and biofungicides for control of powdery mildew

4.1a Fungicides

A trial was conducted in summer 2013 to evaluate the efficacy of six fungicide programmes and two fungicide products (88 and 118) in comparison with a standard fungicide Systhane 20EW (myclobutanil) for control of powdery mildew on apple trees cv. Cox. Five sprays were applied at 7-14 d intervals from the start of extension growth using a motorised knapsack sprayer. Four of the programmes comprised three fungicides from different fungicide groups; two programmes involved two fungicides. The severity of mildew was high. All treatments reduced mildew at all assessments. Fungicides 88 and 118 were both very effective, reducing mildew from 82% to 33 and 32% leaves affected respectively. The most effective programme used fungicides 32 and 159, reducing mildew to 30%. The standard fungicide Systhane 20EW gave relatively poor control (63% leaves affected), probably due to reduced sensitivity.

4.1b Fungicides and integrated fungicide/biofungicide programmes

A trial was conducted in summer 2013 to evaluate the efficacy of six biofungicides in comparison with a standard fungicide Systhane 20EW (myclobutanil) and an inorganic fungicide Kumulus DF (sulphur) for control of powdery mildew (*Podosphaera leucotricha*) on apple cv. MM106 grown in pots. A programme of two sprays of a conventional fungicide (32) followed by three sprays of a biofungicide (105); and a programme alternating one biofungicide (06) with another (105) were also tested. Untreated and water-only controls were included. Treatments were applied five times at 7 day intervals. Conditions were conducive to mildew and over 50% of leaves on untreated and water-treated plants were affected by secondary mildew. All treatments reduced the disease, with Systhane 20EW, Kumulus DF, biofungicide 90, and a programme based on conventional fungicide 32 and biofungicide 105 reducing it to <30%.

4.2 Pear: Evaluation of biofungicides for control of Botrytis rot in stored pear

An inoculated trial was conducted between September 2012 and March 2013 to evaluate four biofungicides against Botrytis rot (*Botrytis cinerea*) in cold-stored pears, cv. Conference. Treatments were compared with the fungicide Rovral WG (iprodione) and untreated controls. Treatments were applied as a dip immediately before transfer to a cold store (0°C). Spread of *B. cinerea* from inoculated to healthy fruit was good with 50% of fruit becoming affected in untreated crates. Botrytis rot was reduced by Rovral WG and the biofungicide 38 and not by other treatments (06, 99 and Nexy 1). Rovral WG (13% fruit rot) was better than biofungicide 38 (39% fruit rot).

Milestones

Milestone	Target month	Title	Status
P2.3	36	Disease and pest efficacy tests for Y3 completed	
		Brassica powdery mildew	Complete
		Brassica ring spot	Complete
		Leek rust	Complete
		Onion downy mildew	Complete
		Lettuce aphid	Complete
		Lettuce caterpillar	Complete
		Leek thrips and moth	Complete
		Raspberry cane diseases	In progress
		Strawberry crown rot	In progress
		Strawberry soft rots	Complete
		Strawberry European tarnished bug	Complete
		Cucumber Phomopsis	In progress
		Cucumber Pythium	Complete
		Tomato grey mould	Complete
		Pepper aphids	Complete
		Apple powdery mildew	Complete
		Pear botrytis rot in storage (2011/12)	Complete
P3.3	36	Disease and pest IPM work for Y3 completed	
		Brassica powdery mildew programmes	Complete
		Brassica ring spot programmes	Complete
		Brassica cabbage root fly, aphid and caterpillar programmes	Complete
		Raspberry aphid – biopesticides and natural enemies	Complete
		Tomato spider mites IPM	Complete
		Tomato whitefly IPM	Complete
		Pepper aphids IPM	Complete
		Apple powdery mildew programmes	Complete
P4.3	36	Herbicide efficacy and crop safety tests for Y3 completed	
		Vegetables herbicide crop safety	Complete
		Blackcurrant crop safety	Complete
		Raspberry crop safety	Complete
		Soft fruit – perennial weeds	Complete
P5.2	36	Sustainable weed control work for Y3 completed	
		Vegetables herbicide band spraying	Complete
		Vegetables electrical weed control	Complete

SCIENCE SECTION

Individual experiments are summarised below; more detailed reports are held by HDC. Unless stated otherwise:

- No problems were encountered during mixing or application of any of the products under test;
- No phytotoxicity or treatment-related crop vigour differences were observed;
- The results for the standard treatment were as expected and it can be considered a valid trial.
- Trials were carried out on young plants which were not taken to maturity and therefore no observations were made on yield.
- The terms fungicide, herbicide and insecticide used without a prefix refer to conventional pesticides; all biopesticides are prefixed with bio.
- Products currently approved for use on the test crop and included as standard treatments are shown <u>underlined</u> in the Tables.
- Results of treatments that are significantly ($p < 0.05$) better than the untreated control are shown in bold in tables.

1. Field vegetables

1.1 Assessment of the efficacy of fungicides and biofungicides against rust on leek

One replicated trial was conducted in 2013 on a hard standing at ADAS Boxworth to screen fungicides and biofungicides for the control of rust (*Puccinia allii*) on leeks cv. Darwin F1. The treatments were compared with an untreated control and an industry standard fungicide Amistar Top.

Fungicides were applied at two timimgs and sprays were allowed to dry before inoculation on the same day as the first spray. Dry spore inoculation was done initially on 19 June and repeated on 8 July. Biofungicides were first applied 7 days prior to the first inoculation and then at 7 day intervals up to 21 days after inoculation. Treatments and results are listed below.

Table 1.1.1. Fungicides and biofungicides evaluated for control of *Puccinia allii* on leeks 2013

Treatment number	SCEPTRE code/product	Rate of product	Active ingredient	Timing
1 + 10	Untreated			
Fungicides				
2	Amistar Top	1.0 L/ha	Azoxystrobin + difenconazole	Day 0, 14
3	SF2013-LEE-27	-	-	Day 0, 14
4	SF2013-LEE-10	-	-	Day 0, 14
5	Signum	1.0 kg/ha	Boscalid + pyraclostrobin	Day 0, 14
6	SF2013-LEE-25a	-	-	Day 0, 14
7	SF2013-LEE-24	-	-	Day 0, 14
8	SF2013-LEE-118	-		Day 0, 14
9	SF2013-LEE-31	-	-	Day 0, 14
Biofungicides				
11	SF2013-LEE-40	-	-	Day -7, 0, 7, 14, 21
12	SF2013-LEE-105	-	-	Day -7, 0, 7, 14, 21
13	Serenade ASO	10.0 L/ha	*Bacillus subtilis*	Day -7, 0, 7, 14, 21
Fungicide				
14	Amistar	1.0 L/ha	Azoxystrobin	Day -7, 0, 7, 14, 21

Results

Table 1.1.2. Effect of fungicides and biofungicides on leek rust at intervals after the first inoculation – ADAS Boxworth, 2013

Treatment	Product name or code	Severity (% leaf area affected)		
		5 weeks	6 weeks	8 weeks
1 + 10	Untreated	0.59	1.05	0.70
Fungicides				
2	Amistar Top	**0.06**	**0.09**	**0.16**
3	SF2013-LEE-27	**0.16**	**0.21**	**0.22**
4	SF2013-LEE-10	**0.20**	**0.26**	**0.17**
5	Signum	**0.09**	**0.21**	**0.16**
6	SF2013-LEE-25a	0.28	**0.50**	**0.21**
7	SF2013-LEE-24	**0.20**	**0.28**	**0.21**
8	SF2013-LEE-118	**0.04**	**0.04**	**0.23**
9	SF2013-LEE-31	**0.03**	**0.03**	**0.19**
Biofungicides				
11	SF2013-LEE-40	0.53	0.96	0.54
12	SF2013-LEE-105	0.40	0.59	**0.17**
13	Serenade ASO	0.43	0.96	**0.23**
Fungicide				
14	Amistar	**0.04**	**0.12**	**0.16**
Probability (F value)		0.01	<0.001	0.024
LSD vs. treatment (69 d.f.)		0.39	0.57	0.392
LSD vs. untreated (69 d.f.)		0.33	0.50	0.340

- Disease pressure was low.
- There were significant differences in % severity for many treatments when compared to the untreated with the best performers being 25a, 27, 118 and 31. Amistar Top, Amistar and Signum also appear to have good persistence over the course of the trial, and notably the biofungicides 105 and Serenade ASO become significant at 8 weeks post inoculation.

Discussion

Disease pressure was initially low, reaching more moderate levels towards the end of the trial. Although not a stern test of the products this data can be compared to similar practical cropping situations and was sufficient to quantify treatment efficacy. As plants grew larger during the course of the experiment there was continuing disease activity that maintained severity at about 1% leaf area affected in the untreated controls.

The biofungicides 40, 105 and Serenade ASO failed to reduce rust severity 6 weeks after the first inoculation, but by 8 weeks 105 and Serenade ASO had begun to give significant control of leek rust.

The most effective treatments gave >90% control at 6 weeks after treatment. The efficacy decreased subsequently with up to 75% control from the leading products after 8 weeks. The extended protection of c. 6 weeks from early sprays merits further evaluation to determine if economies can also be made with later treatments.

The leading fungicides over the whole trial were 25a, 27, 118 and 31. The top biofungicide was 105, which consistently outperformed Serenade ASO. In 2012 118 and 27 gave significant results, but 25a and 31 did not perform as well.

1.2 Assessment of the efficacy of fungicides and biofungicide programmes against powdery mildew in brassica crops

A replicated trial was conducted in 2013 in unheated polytunnels at ADAS Boxworth to screen fungicide and biofungicide programmes for the control of powdery mildew (*Erysiphe cruciferarum*) on Swede plants cv. Emily. The test treatments were compared with an untreated control and industry standard fungicides Nativo WG and Rudis.

Fungicides were applied and allowed to dry briefly before inoculation later on the same day and at day 14 after inoculation. Biofungicides were applied 7 days before inoculation, on the day of inoculation, 7, and 14 and 21 days after inoculation.

Table 1.2.1. Fungicide and biofungicide products used in programmes for powdery mildew control in brassica (swede) plants cv. Emily – ADAS Boxworth 2013

Treatment number	SCEPTRE code	Rate of product	Active ingredient	Timing (days)
1 + 9	Untreated	-	-	
Fungicides				
2	Rudis	0.4 L/ha	prothioconazole	0, 14
3	Nativo WG	0.3 kg/ha	tebuconazole + trifloxystrobin	0, 14
4	SF2013-SWE-24	-	-	0, 14
5	SF2013-SWE-28	-	-	0, 14
6	SF2013-SWE-89	-	-	0, 14
7	SF2013-SWE-88	-	-	0, 14
8	SF2013-SWE-10	-	-	0, 14
Biofungicides				
10	SF2013-SWE-90	-	-	-7, 0, 7, 14, 21
11	SF2013-SWE-90 + SF2013-40	-	-	-7, 0, 7, 14, 21
12	SF2013-SWE-11 + adjuvant	-		-7, 0, 7, 14, 21
Biofungicide/fungicide programmes				
13	SF2013-SWE-90 / Rudis	-	-	SF2013-SWE-90 at -7, 0, 7, 14 Rudis at 21
14	Rudis / SF2013-SWE-90	-	-	Rudis at 0 SF2013-SWE-90 at 7, 14, 21

Results

Table 1.2.2. Effect of fungicide and biofungicide programmes on powdery mildew (*Erysiphe cruciferarum*) severity at 6, 7 and 8 weeks after inoculation – ADAS Boxworth, 2013

Treatment	Product name or code	Severity (% leaf area affected)		
		6 weeks	7 weeks	8 weeks
1 + 9	Untreated	72.5	76.2	77.5
Fungicides				
2	Rudis	**0.5**	**13.8**	**35.0**
3	Nativo WG	**11.2**	**28.8**	**35.0**
4	SF2013-SWE-24	**4.0**	**12.5**	**31.2**
5	SF2013-SWE-28	**6.5**	**17.5**	**38.8**
6	SF2013-SWE-89	**7.5**	**17.5**	**40.0**
7	SF2013-SWE-88	**12.8**	**35.0**	**50.0**
8	SF2013-SWE-10	**27.5**	**33.8**	**42.5**
Biofungicides				
10	SF2013-SWE-90	**57.5**	72.5	75.0
11	SF2013-SWE-90 + SF2013-40	**56.2**	65.0	67.5
12	SF2013-SWE-11 + adjuvant	**51.2**	68.8	68.8
Biofungicide/fungicide programmes				
13	SF2013-SWE-90 / Rudis *	**3.0**	**5.0**	**10.0**
14	Rudis / SF2013-SWE-90**	**27.5**	**42.5**	**60.0**
Probability (F value)		<0.001	<0.001	<0.001
LSD vs. treatment (55 d.f.)		14.97	17.08	15.69
LSD vs. untreated (55 d.f.)		12.96	14.79	13.59

* Rudis applied once after 3 sprays of SWE-90, first spray at 5% disease severity.

** Rudis applied once at inoculation followed by SF2013-SWE-90 applied at days 7, 14 and 21.

- Disease pressure was high.
- Moderate phytotoxicity was first observed at the Day - 4 assessment on plots treated with biofungicide 11. This persisted into Day 14 of the trial. Affected plants had leaves with white spots or blotches typical of spray scorch, together with purple spotting which progressed to bright purple discolouration at the edges of leaves. A lighter leaf colour and slight yellowing and purpling were also observed in treatments 10 and 13, both treated with biofungicide 90. SF2013-SWE-90 was observed to cause similar phytotoxic effects in the 2012 trial.

- All the treatments gave significant control 6 weeks after inoculation but there were significant differences in efficacy between products. The best performers were the industry standard Rudis, fungicide 24 and biofungicide 90 when used in programme with Rudis at 5% disease severity.

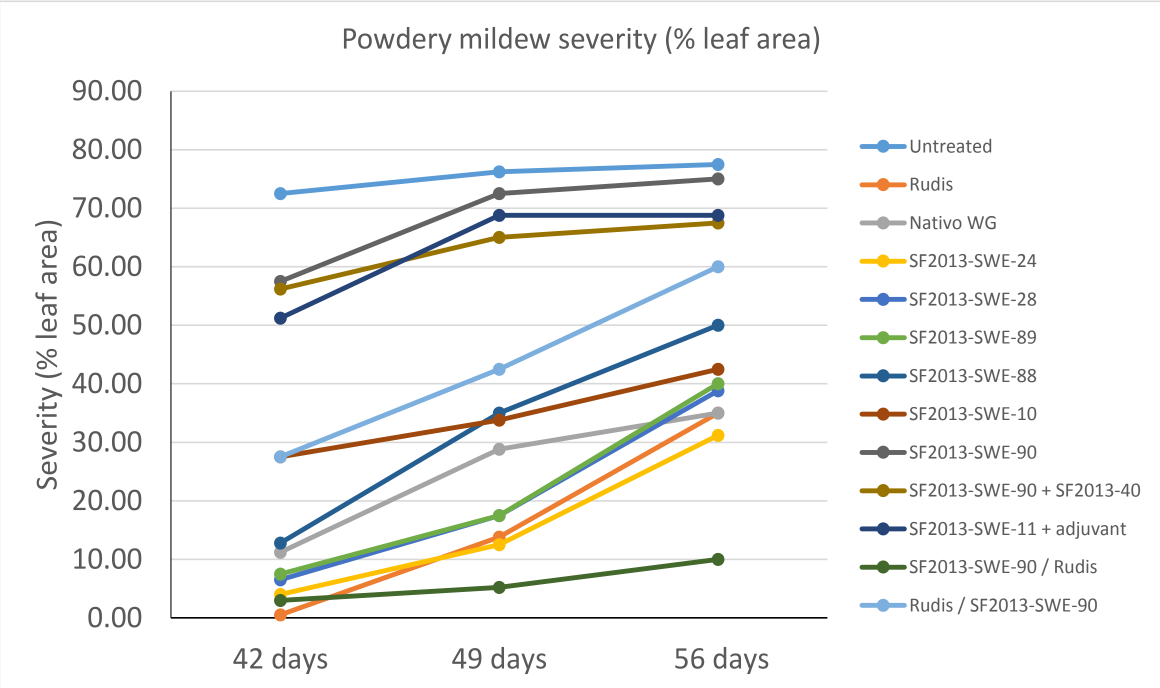

Figure 1.2.1. Brassica powdery mildew disease progress (days after inoculation)

Discussion

Disease pressure was initially moderate and eventually severe and this allowed a good assessment of disease control. Powdery mildew infection increased from point of inoculation up until 6 weeks, when disease levels began to plateau.

Up to 6 weeks after treatments were applied, all programmes significantly reduced severity of powdery mildew. After 8 weeks, several programmes still significantly reduced *Erysiphe cruciferarum* severity. Besides the industry standard (Rudis), fungicide 24 gave the best control from a single product (having also performed well in the 2012 trial), while products 28, 89, 88 and 10 also significantly reduced severity by over 40%. These products also showed a good level of persistence, but disease control faded quite sharply after 6 weeks.

Two treatment programmes combining both conventional fungicides and biofungicides were included in this trial, using Rudis and biofungicide product 90 in different combinations to investigate at what combinations and level of disease at which to switch from one to the other. Notably the treatment programme where sprays began with product 90 and switched to Rudis at day 14 was most effective at controlling powdery mildew over the whole trial. Biofungicide 90 performed poorly when used alone, and when used after Rudis in a treatment programme was only just significant. Using product 90 in a programme followed by Rudis was more effective than using Rudis alone to control powdery mildew.

1.3 Assessment of the efficacy of fungicide and biofungicide programmes against ring spot and other leaf diseases of cabbage

A replicated field experiment was conducted in 2013 at Spalding, Lincs to evaluate programmes of fungicides and biofungicides for the control of ring spot (*Mycosphaerella brassicicola*) and other foliar diseases on pointed cabbage plants cv. Caraflex. The test treatments were compared with an untreated control and three industry standard fungicide programmes, alternating Signum, Amistar or Nativo 75 WG with Rudis respectively.

Fungicides were applied and allowed to dry before inoculation by laying leaves naturally infected by ring spot on the soil surface within the plots. Inoculation was done twice on 5 September and 2 October. Treatments applied and spray timings are listed below:

Table 1.3.1. Products evaluated for ring spot control in brassica (pointed cabbage) cv. Caraflex in the field – 2013

	Product or SCEPTRE code	Rate of product	Active ingredient	Timing
1	Untreated			
Fungicides				
2	Amistar	1.0 L/ha	Azoxystrobin	2, 4, 6
3	Signum	1.0 L/ha	Boscalid + pyraclostrobin	2, 4, 6
4	Nativo 75WG	0.3 kg/ha	Tebuconazole + trifloxystrobin	2, 4, 6
5	SF2013-BRA-10	-	-	2, 4, 6
6	SF2013-BRA-24	-	-	2, 4, 6
7	SF2013-BRA-25a	-	-	2, 4, 6
8	Rudis	0.4 kg/ha	Prothioconazole	4
Biofungicides				
9	SF2013-BRA-105	-	-	2, 4, 6
10	SF2013-BRA-90	0.4 kg/ha	-	1, 2, 3, 4, 5, 6
11	Serenade ASO	10.0 L/ha	*Bacillus subtilis* QST 713	1, 2, 3, 4, 5, 6

Table 1.3.2. Detail of fungicide and biofungicide programmes evaluated for control of ring spot on cabbage – 2013

Treatment	Product and timing (T)					
	T1 27 Aug	T2 3 Sep	T3 12 Sep	T4 24 Sep	T5 9 Oct	T6 18 Oct
1.	-	-	-	-	-	-
Fungicides						
2.	-	Amistar	-	Rudis	-	Amistar
3.	-	Signum	-	Rudis	-	Signum
4.	-	Native 75WG	-	Rudis	-	Nativo 75WG
5.	-	10	-	10	-	10
6.	-	24	-	24	-	24
7.	-	25a	-	25a	-	25a
Biofungicide/fungicide programmes						
8.	-	105 + Amistar	-	105 + Rudis	-	105 + Amistar
9.	90	90	90	90	90	90
10.	Serenade ASO	Serenade ASO	Serenade ASO	Serenade ASO	Serenade ASO	Serenade ASO

Results

Table 1.3.3. Effect of fungicides and programmes of biofungicides and fungicides on ring spot (*Mycosphaerella brassicicola*) on cabbage - 2013

Treatment	Product name or code	Severity (% leaf area affected)		
		T4 24 Sep	T6 + 18 days 5 Nov	T6 + 34 days 21 Nov
1	Untreated	0.08	0.16	3.00
Fungicides				
2	Amistar / Rudis	0.02	0.01	**0.22**
3	Signum / Rudis	0.05	0.14	**0.15**
4	Nativo 75WG / Rudis	0	0	**0.20**
5	SF2013-BRA-10	0	0.04	**0.16**
6	SF2013-BRA-24	0.03	0.01	**0.10**
7	SF2013-BRA-25a	0.02	0.06	**0.20**
Biofungicide/fungicide programmes				
8	SF2013-BRA-105 + Amistar	0.02	0	**0.02**
9	SF2013-BRA-90	0.04	0.28	**1.42**
10	Serenade ASO	0.06	0.25	2.62
Probability (F value)		0.584	0.016	<.001
LSD (39 d.f.)		0.084	0.179	1.068
SED (39 d.f.)		0.041	0.087	0.521

- Disease levels were low initially, however in late November disease levels increased quite rapidly.
- Significant differences only became apparent in the trial under higher levels of disease pressure achieved in the trial's later stages. By the final assessment all fungicides, one biofungicide and the biofungicide and fungicide mixture had significantly reduced disease compared to the untreated.
- Ring spot affected 3.0% of the plant and 1.1% of the head area at the final assessment and all treatments except Serenade ASO gave significant control.
- Fungicide 24 was the best single product for ring spot and also reduced downy mildew and dark leaf spot. Several products were still providing significant control over 1 month after the last spray.

- The best performing treatment programme was biofungicide 105 admixed with Amistar alternating with 105 admixed with Rudis in a 3-spray programme.
- Downy mildew, *Alternaria* leaf spot, white blister, black rot (*Xanthomonas*) and light leaf spot were also recorded in the trial and significant control was observed for *Alternaria* and downy mildew. Treatments 4, 7, 8 and 10 had more severe downy mildew than in the untreated control (Table 1.3.4).
- Total yield and mean head weight were increased by fungicide 25 and the Nativo 75WG/Rudis/Nativo 75WG programme.

Table 1.3.4. Effect of fungicides and programmes of fungicides and biofungicides on brassica leaf diseases at 5 weeks after the final spray

Treatment	Product name or code	Severity (% leaf area affected) on 21 Nov		
		Downy mildew	Alternaria	Ring spot
1	Untreated	5.00	0.55	3.00
Fungicides				
2	Amistar / Rudis	5.00	**0.00**	**0.22**
3	Signum / Rudis	5.00	**0.05**	**0.15**
4	Nativo 75WG / Rudis	6.25	**0.00**	**0.20**
5	SF2013-BRA-10	4.50	**0.08**	**0.16**
6	SF2013-BRA-24	**1.80**	**0.01**	**0.10**
7	SF2013-BRA-25a	5.25	**0.03**	**0.20**
Biofungicide/fungicide programme				
8	SF2013-BRA-105 + Amistar	6.00	**0.03**	**0.02**
9	SF2013-BRA-90	**2.25**	0.48	**1.42**
10	Serenade ASO	5.50	0.58	2.62
Probability (F value)		<0.001	0.007	<0.001
LSD (39 d.f.)		1.975	0.390	1.068
SED (39 d.f.)		0.962	0.190	0.521

Phytotoxicity – At all assessments it was noted that biofungicide 90 exerted slight toxicity with foliage becoming a lighter colour and having an oily appearance. This product has caused similar symptoms previously in other SCEPTRE trials. These effects were much less noticeable by the final assessment.

1.4 Assessment of the efficacy of fungicides and biofungicides against downy mildew in spring onion

A replicated field experiment was conducted 2013 on a commercial farm in Warwickshire to evaluate fungicides, biofungicides and fungicide programmes for the control of downy mildew (*Peronospora destructor*) on spring onion plants cv. Slender Star. The results obtained were compared with an untreated control and an industry standard fungicide programme, involving sprays of Amistar, Invader, Signum and Olympus.

Inoculation took place on 6 September with the introduction of infected leaf material to the crop. *Peronospora destructor* spores were brushed across plants crop in damp conditions and infected leaf debris was scattered in the plot. Products and treatments applied are listed below:

Table 1.4.1. Named fungicides used for control of downy mildew in spring onion, cv. Slender Star - 2013

Product or Sceptre code	Abbreviation	Rate of use	Active ingredient(s)
Amistar	Ami	1 L/ha	azoxystrobin
Dithane	Dit	2.5 kg/ha	mancozeb
Invader	Inv	2 kg/ha	dimethomorph + mancozeb
Olympus	Oly	2.5 L/ha	azoxystrobin + chlorothalonil
Signum	Sig	1 L./ha	boscalid + pyraclostrobin
Unicur	Uni	1.25 L/ha	prothioconazole + fluoxastrobin
Valbon	Val	1.6 kg/ha	benthiavalicarb-isopropyl + mancozeb

Table 1.4.2. Treatments evaluated for control of downy mildew on onion cv. Slender Star – 2013

Treatment	Product and timing					
	T1 26 Jul	T2 7 Aug	T3 15 Aug	T4 22 Aug	T5 4 Sep	T6 18 Sep
1.	-	-	-	-	-	-
Fungicides						
2.	-	-	Inv+Ami	Inv+Sig	Inv+Oly	Inv+Ami
3.	-	-	Val+Oly	Uni+Dit	Val+Dit	Val+Oly
4.	-	-	23	23	23	23
5.	-	-	24	24	24	24
6.	-	-	25a	25a	25a	25a
7.	-	-	Signum	Signum	Signum	Signum
8.	-	-	41	41	41	41
9.	-	-	20	20	20	20
10.	-	-	22	22	22	22
Biofungicide + fungicide						
11.	-	-	105+22	105+22	105+22	105+22
Biofungicides						
12.	47	47	47	47	47	47
13.	40	40	40	40	40	40
14.	188	188	188	188	188	188

Treatments 2 and 3 are the spring onion and bulb onion grower standards respectively.

Results

Table 1.4.3. Effect of fungicide and biofungicide products on control of downy mildew in spring onion, cv. Slender star – 2013

Treatment	Product name or code	Severity (% leaf area affected)		
		5 Oct (17 DAT6)	9 Oct (21 DAT6)	17 Oct (29 DAT6)
1	Untreated	5.93	28.8	35.8
Fungicides				
2	Spring onion standard	**0.04**	**8.4**	**8.9**
3	Bulb onion standard	1.17	**4.2**	**1.4**
4	SF2013-SPO-23	6.72	21.1	34.9
5	SF2013-SPO-24	2.19	**9.6**	**14.6**
6	SF2013-SPO-25a	5.20	29.4	37.1
7	Signum	3.22	29.4	38.6
8	SF2013-SPO-41	4.63	23.9	36.8
9	SF2013-SPO-20	2.52	**12.6**	**16.0**
10	SF2013-SPO-22	4.11	24.9	29.5
Biofungicide + fungicide				
11	SF2013-SPO-105 + SF2013-SPO-22	5.61	21.9	32.1
Biofungicides				
12	SF2013-SPO-47	3.14	28.1	30.0
13	SF2013-SPO-40	5.66	25.6	27.0
14	SF2013-SPO-188	1.48	20.90	32.3
Probability (F value)		<0.001	<0.001	<0.001
LSD vs. treatment (47 d.f.)		5.173	12.64	17.070
LSD vs. untreated (47 d.f.)		4.224	10.32	13.940

- The crop was sown on 20 June 2013. Downy mildew was first seen in the crop in small patches in late September and overall levels were low initially. However, in October disease levels increased rapidly, reaching over 30% severity on untreated plots.
- The results obtained for the standard treatments were very effective, and were the best two treatments in the trial.
- Besides the two grower standard treatments, the most effective products/programmes were fungicides 20 and 24 which significantly reduced disease compared to the untreated at both the second and third assessments.

- None of the biofungicides reduced onion downy mildew.
- Addition of biofungicide 105 to fungicide 22 did not improve efficacy of the latter.

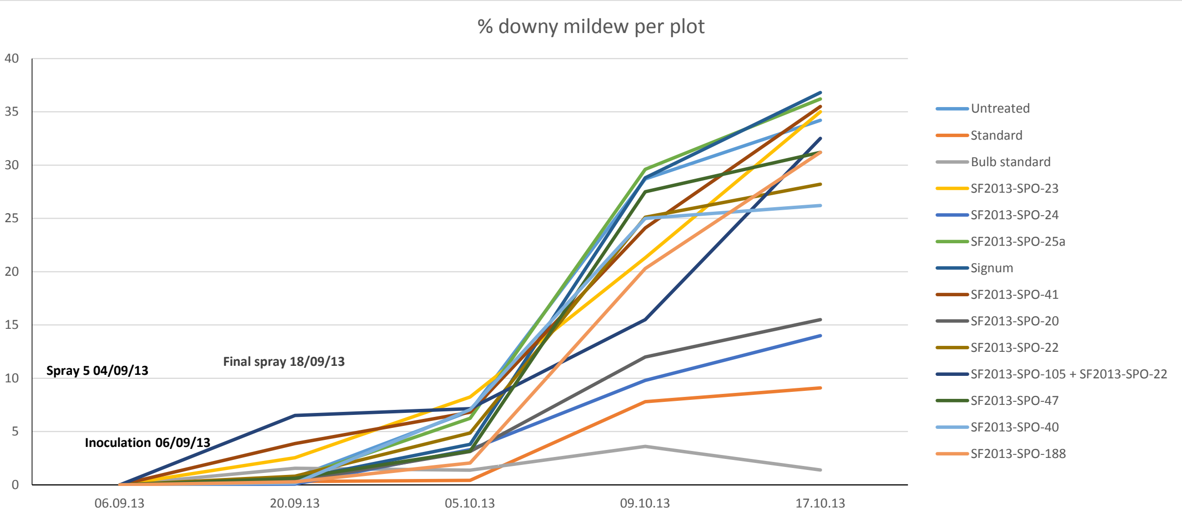

Figure 1.4.1. Onion downy mildew disease progress – 2013

Discussion

Disease was first recorded on 20 September, 14 days after inoculum was added to the trial. Inoculum was added to the trial in the form of chopped up infected leaves, and by brushing spores from infected leaves onto the trial plants. Downy mildew usually takes around 10-14 days to develop, and from this point onwards disease levels steadily rose. It therefore appears that the inoculation was successful, although the presence of small foci suggested there was also local background inoculum. The weather in late September and October was conducive for downy mildew and salad onions crops in other regions were severely affected at this stage.

Little leaf spot (*Botrytis)* was noticed in the field trial, although high levels of *Botrytis* were seen in a nearby commercial field, planted with variety Performer. The variety used in the trial, cv. Slender Star, may have had some resistance to *Botrytis.*

The final treatments were applied on 18 September and these were expected to give control for two weeks. The final assessment was later than the commercial harvest date and provided opportunity to evaluate the persistence of test treatments. None of the test treatments were as effective as the bulb onion standard treatment, which kept downy mildew levels at below 5% leaf area throughout the course of the trial. Even in the plots treated with the most effective treatments under test (fungicides 24 and 20) downy mildew was seen to increase steadily over the three assessment timings to 14.6 and 16% leaf area respectively by 17 October 2013. However, these products looked promising and may be useful as part of alternating programmes to control downy mildew in spring onions and other alliums. It will be necessary to look at treatments applied at shorter intervals and/or product mixtures in future studies.

It may be relevant that the effective standard programmes (i) included the protectant fungicides mancozeb and chlorothalonil; (ii) each spray included at least three and usually four different active ingredients all with activity against downy mildew.

1.5 Assessment of the efficacy of insecticides and bio-insecticides against thrips on leek

Two replicated trials (one for insecticides and one for bio-insecticides) were conducted in 2013 to evaluate the efficacy of insecticides for the control of onion thrips (*Thrips tabaci*) and leek moth (*Acrolepiosis assectella*) in leek. The results obtained were compared with untreated controls and the trial protocol was validated by inclusion of a standard treatment, Tracer (Spinosad), applied at the recommended rate.

Four applications of each treatment were made. Treatments applied are listed below:

Table 1.5.1. Detail of conventional insecticides (C) and bio-insecticides (B) evaluated for control of leek thrips

Treatment	SCEPTRE code	UK rate of product	Application timing
C1	Untreated	-	-
C2	Tracer	200 ml/ha	At first sign of pests
C3	SI2013-LEE-48	-	At first sign of pests
C4	SI2013-LEE-50	-	At first sign of pests
C5	SI2013-LEE-142	-	At first sign of pests
B1	Untreated		At first sign of pests
B2	SI2013-LEE-62 (200L water)	-	At first sign of pests
B3	SI2013-LEE-62 (1000L water)	-	At first sign of pests
B4	SI2013-LEE-130 (200L water)	-	At first sign of pests
B5	SI2013-LEE-130 (1000L water)	-	At first sign of pests

Results

Table 1.5.2. Effect of insecticides and bio-insecticides on damage to leeks by thrips and leek moth – 2013

Treatment	Mean % leaf area damaged by thrips	% plants damaged by leek moth
Insecticides		
Untreated	21.1	58.3
Tracer	**11.5**	**5.1**
SI2013-LEE-48	16.0	**23.1**
SI2013-LEE-50	**9.7**	**2.8**
SI2013-LEE-142	17.4	**25.9**
Probability (F value)	0.02	<.001
LSD (12 d.f.)	6.686	1.068
SED (12 d.f.)	3.069	0.521
Bio-insecticides		
Untreated	19.8	60.5
SI2013-LET-62 (200L water)	20.8	**20.7**
SI2013-LET-62 (1000L water)	15.0	**17.0**
SI2013-LET-130 (200L water)	20.7	**46.3**
SI2013-LET-130 (1000L water)	16.9	**28.7**
Probability (F value)	0.059	<0.001
LSD (20 d.f.)	4.367	7.59
SED (20 d.f.)	2.094	3.64

- The amount of pest damage was moderate.

Discussion

Thrips control

Conventional insecticides all reduced damage due thrips feeding, but this was only significant for Tracer and 50, which were similar in efficacy. Reduction in damage was small with both bio-insecticides. Only 62 applied in 1000 L/ha reduced damage significantly (at the 10% level). Bio-insecticides applied in 200 L/ha were not effective.

Leek moth control

Conventional insecticides all reduced damage due to leek moth. The standard treatment (Tracer) and insecticide 50 were the most effective of the 4 products tested. Reduction in damage was small but both bio-insecticides in either water volume showed some control of leek moth. Bio-insecticide 62 was the most effective bio-insecticide.

1.6 Assessment of the efficacy of insecticides and bio-insecticides against currant lettuce aphid and caterpillars on lettuce

Six replicated trials (three for insecticides and three for bio-insecticides) were conducted in 2013 to evaluate the efficacy of insecticides in an IPM programme for the control of currant-lettuce aphid and caterpillars on lettuce. The insecticides applied were compared with untreated controls and a standard treatment (Movento - spirotetramat (for aphid control) and Tracer – spinosad (for caterpillar control) applied at the recommended rate). In the aphid field trials, insecticides were applied once and bio-insecticides twice at 7 day intervals. No caterpillars were observed in the field trials so pot trials were conducted in the laboratory. In the caterpillar pot trials, both insecticides and bio-insecticides were applied once, immediately after inoculation with caterpillars.

Table 1.6.1. Detail of conventional insecticides (C) and bio-insecticides (B) evaluated for control of aphids and caterpillars on lettuce – 2013

Code	Aphid treatments	Caterpillar treatments
C1	Untreated	Untreated
C2	Movento (500 ml/ha)	Tracer (200 ml/ha)
C3	SI2013-LET-50	SI2013-LET-50
C4	SI2013-LET-59	SI2013-LET-48
C5	SI2013-LET-60	SI2013-LET-48
B1	Untreated	Untreated
B2	SI2013-LET-62	SI2013-LET-94
B3	SI2013-LET-130	SI2013-LET-130
B4	SI2013-LET-51	SI2013-LET-51
B5	SI2013-LET-92	SI2013-LET-68

Results

The data are summarised below. Numbers of aphids (currant-lettuce aphid – *Nasonovia ribisnigri*) were generally low and their distribution was uneven. Mean numbers of aphids per plot are shown (Tables 1.6.2 and 1.6.3). No caterpillars were observed on the plots but a laboratory culture of silver Y moth (*Autographa gamma*) was established and the caterpillar treatments were tested on pot-grown lettuce. Results are also presented in Tables 1.6.4 and 1.6.5.

Table 1.6.2. Effect of insecticides on wingless currant-lettuce aphid (*Nasonovia ribisnigri*) – 2013

Treatment	Mean number of aphids per plot					
	Trial 1		Trial 2		Trial 3	
	SQRT	Back trans	SQRT	Back trans	SQRT	Back trans
Untreated	1.466	2.150	0.712	0.507	0.636	0.405
Movento	**0.210**	0.004	**0.085**	0.007	0.207	0.043
SI2013-LET-50	**0.393**	0.154	**0.257**	0.066	0.619	0.384
SI2013-LET-59	**0.315**	0.099	**0.043**	0.002	0.248	0.062
SI2013-LET-60	**0.335**	0.112	**0.252**	0.063	1.021	1.043
Probability (F value)	<0.001		0.014		0.056	
LSD (12 d.f.)	0.483		0.368		0.580	
SED (12 d.f.)	0.222		0.169		0.266	

Table 1.6.3. Effect of bio-insecticides on currant-lettuce aphid (*Nasonovia ribisnigri*) – 2013

Treatment	Mean number of aphids per plot					
	Trial 1		Trial 2		Trial 3	
	SQRT	Back trans	SQRT	Back trans	SQRT	Back trans
Untreated	0.620	0.385	0.982	0.964	0.598	0.358
SI2013-LET-62	0.873	0.763	1.097	1.203	0.345	0.119
SI2013-LET-130	0.754	0.568	0.908	0.824	0.637	0.406
SI2013-LET-51	0.413	0.171	1.772	3.140	0.489	0.239
SI2013-LET-92	0.736	0.542	1.410	1.988	0.617	0.381
Probability (F value)	0.475		0.194		0.539	
LSD (20 d.f.)	0.536		0.811		0.403	
SED (20 d.f.)	0.257		0.389		0.193	

Table 1.6.4. Effect of insecticides on silver Y moth (*Autographa gamma*) caterpillars – 2013

Treatment	Mean % caterpillars surviving		Mean number of feeding holes	
	Fresh residue	Aged residue (7 days)	Fresh residue	Aged residue (7 days)
Untreated	66	70	58.5	Plants dead
Tracer	**0**	**0**	4.1	2.8
SI2013-LET-50	**0**	**0**	0.9	0.7
SI2013-LET-48	**0**	**0**	3.1	2.7

- Insecticide results were not analysed as no caterpillars survived on treated plants.

Table 1.6.5. Effect of bioinsecticides on silver Y moth (*Autographa gamma*) caterpillars – 2013

Treatment	Mean % caterpillars surviving		Mean number of feeding holes	
	Angular	Back trans	Log	Back trans
Untreated	60.1	75.2	4.511	91.1
SI2013-LET-94	**33.7**	30.8	**3.769**	43.3
SI2013-LET-130	**18.2**	9.8	**3.222**	25.1
SI2013-LET-51	**37.7**	37.5	**3.831**	46.1
SI2013-LET-68	**2.7**	0.2	**2.284**	9.8
Probability (F value)	<0.001		<0.001	
LSD (45 d.f.)	6.78		0.277	
SED (45 d.f.)	13.65		0.558	

Discussion

Aphids (currant-lettuce aphid)

Conventional insecticides were all effective to some degree in the first 2 trials but only Movento and 59 showed any efficacy in the third trial. Movento and 59 appeared to be the most effective of the 4 products tested. Little efficacy was observed with any of the bio-insecticides.

Caterpillars (silver Y moth)

All of the conventional insecticides tested (48, 50 and 140) were highly effective (100% mortality) and aged residues (1 week) of all test insecticides continued to be 100% effective. Based on the numbers of feeding holes insecticide 50 could be marginally the most effective treatment. All of the bio-insecticides were effective to some degree. Bio-insecticide 68 was the most effective followed by 130.

1.7(a) Assessment of the efficacy of several bioinsecticides against cabbage root fly in cauliflower (2012)

One replicated trial was conducted in 2012 to evaluate the efficacy of bio-insecticides for the control of cabbage root fly on cauliflower. The results obtained were compared with untreated controls and the trial protocol was validated by inclusion of the standard treatment 'Tracer' (spinosad) applied at the recommended rate. One application of each treatment was made.

Results

- Some phytotoxic symptoms or treatment related crop vigour differences were observed.
- The root damage score clearly shows the difference in treatment efficacy.
- There were significant efficacy effects for the standard treatment Tracer applied at sowing and pre-transplant and both formulations (granule and liquid) of SI2012-CAU-130 applied immediately after inoculation (8 days after transplanting) (Table 1.7.1a).
- Yield assessments were not made as this was a pot trial, but root weight was recorded and was increased relative to the untreated control in effective treatments.

Table 1.7.1a. Effect of bio-insecticides on number of cabbage root fly and root damage in cauliflower - 2012

Product or SCEPTRE code	Application timing	Number of pupae recovered		Root damage score
		Square root transformed	Back-transformed	
Untreated	Untreated	2.63	6.93	5.00
Tracer	Drench pre transplant	**0.15**	0.02	0.25
Tracer	Incorporation at sowing ("Phytodrip")	**0.00**	0.00	0.00
SI2012-CAU-65	Soil surface post transplanting (7days)	2.23	4.98	4.81
SI2012-CAU-65	Incorporation at sowing	**0.00**	0.00	5.00
SI2012-CAU-130	Soil surface post transplanting (7 days)	**0.32**	0.10	1.06
SI2012-CAU-130	Drench 7 days post transplant	**0.60**	0.36	1.13
SI2012-CAU-93	Drench pre transplant	**1.07**	1.13	5.00
SI2012-CAU-93	Drench 7 days post transplant	**1.20**	1.44	4.88
SI2012-CAU-57	Soil surface post transplanting (7 days)	**1.75**	3.05	5.00
SI2012-CAU-57	Incorporation at sowing	2.95	8.69	4.94
F value		25.80		Not analysed
P -value		<0.001		
Replicate		16		
d.f.		164		
s.e.d.		0.300		
l.s.d.		0.592		

Discussion

Of the test chemicals only bio-insecticide 130 showed any significant efficacy. It was partially effective when applied after egg inoculation as either a granular (to the soil surface) or liquid formulation (drench). However, the granular formulation incorporated into compost pre-sowing proved to be extremely phytotoxic and the liquid drenched on to modules pre-transplanting (SCEPTRE 2011) was ineffective. This suggests that both timing and dose are crucial. Too high a dose pre-germination (and probably to young seedlings) will be phytotoxic and applications at transplanting may not have the persistence to provide more than a few days control.

1.7 Assessment of the efficacy of insecticides and bio-insecticides against cabbage root fly, aphids and caterpillars on Brussels sprout

Two replicated trials (one for insecticides and one for bio-insecticides) were conducted in 2013 to evaluate the efficacy of insecticides in an IPM programme for the control of cabbage root fly (CRF), caterpillars and aphids on Brussels sprout. The results obtained were compared with untreated controls and the standard treatments Tracer (Spinosad) for cabbage root fly, Steward (indoxacarb) for caterpillars and Movento (spirotetramat) for aphids applied at recommended rates. The aim was to treat each plot for cabbage root fly, aphids and caterpillars.

Table 1.7.1. Insecticides and bio-insecticides examined in an IPM programme against cabbage root fly (CRF), aphids and caterpillars on Brussels sprouts – 2013

	Product, pest target and application timing						
	CRF	Aphids			Caterpillars		
	13 May	26 July	2 Aug	9 Aug	2 Aug	9 Aug	15 Aug
Insecticides							
1.	-	-	-	-	-	-	-
2.	Tracer	Movento	-	-	Steward	-	-
3.	Tracer	Movento	-	-	-	-	-
4.	Tracer	60	-	-	48	-	- (2 reps)
					143	-	- (2 reps)
5.	55	59	-	-	48	-	-
					143	-	-
6.	50	-	-	-	-	-	-
Bio-insecticides							
1.	Dursban	-	-	-	-	-	-
2.	Dursban	01	01	01	64	64	64 (2 reps)
					68	68	68 (2 reps)
					93	93	93 (2 reps)
3.	Dursban	92	92	92	64	64	64 (2 reps)
					68	68	68 (2 reps)
					93	93	93 (2 reps)
4.	Dursban	62	62	62	64	64	64 (2 reps)
					68	68	68 (2 reps)
					93	93	93 (2 reps)
5.	Dursban	130	130	130	130	130	130

Results

- The level of pest infestation was high for cabbage root fly. Hot dry weather during the summer encouraged infestation by foliar pests (aphids and caterpillars). Treatments to control aphids were started on 26 July followed by caterpillar treatments on 2 August

Table 1.7.2. Effect of insecticide treatments on cabbage root fly on Brussels sprouts, cv. Faunus – 2013

Treatment	Application timing	Root weight (g)	Root damage score	Stem damage score
1. Untreated	Untreated	10.2	1.07	2.07
2. Tracer	Drench pre transplant	**11.8**	**0.02**	1.20
3. SI2013-BRU-55	Seed treatment	**13.7**	**0.00**	1.45
4. SI2013-BRU-50	Drench pre transplant	11.3	**0.02**	1.25
Probability (F value)		0.002	<0.001	0.112
LSD (12 d.f.)		1.505	0.153	0.782
SED (12 d.f.)		0.691	0.070	0.359

Table 1.7.3. Effect of insecticide treatments on aphids on Brussels sprouts, cv. Faunus – 2013

Treatment	Application timing and target			Mean number of aphids	
	CRF (13 May)	Aphids (26 July)	Caterpillars (2 Aug)		
				SQRT	Back trans
1.	None	None	None	19.4	377.6
2.	Tracer	Movento	Steward	**3.0**	9.0
3.	Tracer	Movento	None	**4.5**	20.4
4.	Tracer	60	2 x 48	**7.5**	55.6
			2 x 143		
5.	55		2 x 48	**7.0**	48.6
			2 x 143		
6.	50	None		15.0	226.3
Probability (F value)				0.041	
LSD (18 d.f.)				11.12	
SED (18 d.f.)				5.29	

Table 1.7.4. Effect of insecticide treatments on caterpillars on Brussels sprouts cv. Faunus – 2013

Treatment	Application timing and target			% plants with caterpillars	
	CRF (13 May)	Aphids (26 July)	Caterpillars (2 Aug)		
				SQRT	Back trans
1.	None	None	None	7.59	57.5
2.	Tracer	Movento	Steward	**4.39**	19.3
3.	Tracer	Movento	None	8.79	77.3
4.	2 x Tracer	2 x 60	48	**2.71**	7.4
	2 x 55	2 x 59			
5.	2 x Tracer	2 x 60	143	**0.00**	0.0
	2 x 55	2 x 59			
6.	50	None	None	7.23	52.2
Probability (F value)				<0.001	
LSD (18 d.f.)				2.818	
SED (18 d.f.)				1.341	

Table 1.7.5. Effect of bio-insecticides on treatments on aphids on Brussels sprouts – 2013

	Target pest and application timing			Mean number of aphids	
	CRF	Aphids	Caterpillar		
	13 May	(26 Jul, 2 Aug, 9 Aug)	(2 Aug, 9 Aug, 15 Aug)		
				LOG	Back trans
1.	Dursban WG	None	None	5.79	320.5
2.	Dursban WG	SI2013-BRU-01	2 x SI2013-BRU-64	5.77	198.7
			2 x SI2013-BRU-68		
			2 x SI2013-BRU-93		
3.	Dursban WG	SI2013-BRU-92	2 x SI2013-BRU-64	5.29	94.9
			2 x SI2013-BRU-68		
			2 x SI2013-BRU-93		
4.	Dursban WG	SI2013-BRU-62	2 x SI2013-BRU-64	4.55	69.5
			2 x SI2013-BRU-68		
			2 x SI2013-BRU-93		
5.	Dursban WG	SI2013-BRU-130	None	4.24	325.9
Probability (F value)				0.079	
LSD (25 d.f.)				1.333	
SED (25 d.f.)				0.647	

Table 1.7.6. Effect of bio-insecticide treatments on caterpillars on Brussels sprouts – 2013

	Target pest and application timing			Mean number of aphids	
	CRF	Aphids	Caterpillar		
	13 May	(26 Jul, 2 Aug, 9 Aug)	(2 Aug, 9 Aug, 15 Aug)		
				ANG	Back trans
1.	Dursban WG	None	None	57.4	70.9
2.	Dursban WG	2 x SI2013-BRU-01 2 x SI2013-BRU-92 2 x SI2013-BRU-62	SI2013-BRU-64	**27.5**	21.3
3.	Dursban WG	2 x SI2013-BRU-01 2 x SI2013-BRU-92 2 x SI2013-BRU-62	SI2013-BRU-68	**9.9**	3.0
4.	Dursban WG	2 x SI2013-BRU-01 2 x SI2013-BRU-92 2 x SI2013-BRU-62	SI2013-BRU-93	50.1	58.9
5.	Dursban WG	SI2013-BRU-130	None	**13.4**	5.4
Probability (F value)				<0.001	
LSD (25 d.f.)				20.81	
SED (25 d.f.)				10.10	

Discussion

<u>Cabbage root fly</u>

All conventional insecticides tested (Tracer, 50 and 55) reduced cabbage root fly damage – almost completely in the root area and partially in the stem area. No bio-insecticides were tested.

<u>Aphids</u>

The majority were cabbage aphid (*Brevicoryne brassicae*). All conventional spray treatments (Movento, 59, and 60) provided good control; Movento appeared to be the most effective treatment but this was not statistically significant The bio-insecticides 62 and 130 provided reasonable control but this was only statistically significant (at the 10% level) with 130

<u>Caterpillars</u>

The majority were small white butterfly (*Pieris rapae*). All conventional spray treatments (Steward, 48 and 143) provided good control. Insecticide 143 was statistically the most effective treatment. The bio-insecticides 64, 68 and 130 provided good control. Bio-insecticide 68 appeared to be the most effective treatment but was not statistically better than 64 and 130.

1.8 Assessment of the selectivity and efficacy of three herbicides in 15 vegetable crops

In a field screening trial in 2013 three herbicides (SH2013-FVS-164, SH2013-FVS-165 and SH2013-FVS-166) were applied pre- or post-weed-emergence at a range of dose rates in 15 crops: drilled bulb onion, leek, carrot, parsnip, coriander, peas, dwarf French beans, broad beans, rocket (new), swede, spinach; transplanted celery, cauliflower, lettuce and courgette (new). Crop safety and weed species controlled in comparison with untreated plots were evaluated. ‘Volunteer’ potatoes were planted to see whether they might be suppressed by the herbicides. None of the products have any UK approvals yet.

Herbicide treatments

The herbicides were applied pre-emergence of the drilled crops/pre-transplanting. They were also applied at early post-weed-emergence stage after emergence of the drilled crops/after transplanting. Herbicides were applied at 2x ‘Normal’, Normal (shown below), ½ Normal dose rates in all crops. There were two replications.

Table 1.8.1. Detail of herbicides examined in 2013

SCEPTRE code	EU status	‘N’ dose rate product
SH2013-FVS-164	on approved list of active substances	0.05 L/ha
SH2013-FVS-165	on approved list of active substances	2.0 L/ha
SH2013-FVS-166	on approved list of active substances	0.5 L/ha

On the post-weed-emergence trial reduced doses of standard pre-emergence herbicides were applied overall on 20 April to carrot, parsnip, onion and leek plots so that these slow-emerging crops, that are uncompetitive at early stages, were not smothered by weeds: Wing-P 1.75 L/ha was applied to onion and leek; Stomp Aqua + Afalon (480 g/L formulation) (1.45 + 1.04) L/ha to carrot and parsnip.

Crops were assessed on several occasions for herbicide damage (crop scores, phytotoxicity symptoms, delayed maturity). Herbicide efficacy was also assessed (weed species present on herbicide treated plots compared with numbers of each weed species present on untreated control plots, overall weed control scores). Rainfall was frequent throughout the trial period except for the beginning of June and no irrigation was needed to increase herbicide effects.

Table 1.8.2. Detail of crops treated and dates of herbicide application – Lincs, 2013

Crop (variety)	Sowing/ transplant date	Herbicides applied pre-weed emergence	Herbicides applied post-weed emergence	Crop growth stage
'Volunteer' potatoes	15 April	20 April	25 May	2 shoots 20cm tall
Onion (Hystar)	15 April	20 April	25 May	1 L
Leek ((Striker)	15 April	20 April	25 May	½ -1 L
Carrot (Nairobi)	15 April	20 April	25 May	1-2 TL
Parsnip (Palace) primed seed	15 April	20 April	25 May	1 TL
Celery transplant (Tango)	13 May	11 May	3 June	Established 7 TL
Cauliflower transplant (Jerez)	13 May	11 May	3 June	Established 6 ½ TL
Iceberg lettuce transplant (Challenge)	13 May	11 May	3 June	Established 6 TL
Courgette (Mikinos)	13 May	11 May	3 June	Established 3 new L
Coriander (Filtro)	10 May	11 May	9 June	1 TL
Pea (Cabree)	10 May	11 May	3 June	2 node
Dwarf French Bean (Parker)	10 May	11 May	9 June	simple L
Swede (Tweed)	10 May	11 May	9 June	2-2 ½ TL
Rocket (wild rocket)	10 May	11 May	9 June	2 ½ TL
Spinach baby-leaf (Renegade)	10 May	11 May	3 June	2 expanded TL
Broad beans (Manita)	10 May	11 May	3 June	2 node

L – leaf; TL – true leaf.

Results

<u>Crop safety</u>

SH2013-FVS-164 pre-emergence of drilled crops/pre-transplanting: After application most crops emerged, were yellow and suffered severe stunting followed by plant death. Swede, rocket and spinach were the most sensitive crops. Phytotoxicity symptoms on peas and broad beans were "bonsai" effects (chlorotic, multiple tillers and tiny plants) typical of ALS inhibitor herbicides. The only crops that appeared safe to herbicide 164 pre-emergence were carrots and parsnips at 0.05 /ha, and to onion and leek at 0.025 L/ha. No adverse effects were observed on carrot or parsnip roots.

SH2013-FVS-164 post-emergence of drilled crops/post-transplanting: caused yellowing, severe stunting and distortion of the crop growing point. No crop was safe to post-emergence applications.

SH2013-FVS-165 pre-emergence of drilled crops/pre-transplanting: Phytotoxicity symptoms were reduction in emergence of sensitive crops, stunting and delayed maturity. The emergence of swede was reduced and rocket did not emerge after treatment, even at the lowest dose rates. In umbelliferous crops leaves became crinkled and stuck together - carrots and parsnips were very sensitive at all dose rates tested. It was not safe to lettuce transplants and stunting was severe even at 1.0 L/ha. In baby-leaf spinach leaf crinkling reduced quality. The following crops appeared safe to 1.0 L/ha: bulb onion (it was less safe to leek), broad bean, vining pea (a conventional-leaved, sensitive variety). The effects on dwarf French beans were less severe - 2.0 L/ha appeared safe.

SH2013-FVS-165 post-emergence of drilled crops/post-transplanting: had very little foliar activity and was less damaging to some crops than the pre-emergence applications, which reduced emergence. Bulb onion, leek, vining pea and cauliflower transplants were safe to 2.0 L/ha. At 1.0 L/ha it was safe to transplanted courgette and possibly iceberg lettuce.

SH2013-FVS-166 pre-emergence of drilled crops/pre-transplanting: Phytotoxicity symptoms were leaf bleaching followed by severe stunting, and delayed maturity in some sensitive crops. Even at low dose it was extremely damaging to rocket which failed to emerge and swede. All dose rates caused initial bleaching in spinach, quality was reduced and the baby-leaf crop would be unmarketable. Carrot and parsnip were the most tolerant crops - there was no bleaching even from 1.0 L/ha 2N dose. No adverse effects were observed on carrot or parsnip roots. Coriander was also safe to 0.5 L/ha. At 0.25 L/ha pre-emergence it was safe to bulb onion, leek, vining pea, dwarf French bean, broad bean and before transplanting, celery. Onion and leek emerged with severe bleaching but new growth was not affected. Vining peas also showed initial bleaching.

SH2013-FVS-166 post-emergence of drilled crops/post-transplanting: Bleaching was more severe and persistent at this timing and only a few crops were tolerant. It was very safe to carrots at 0.5 (and 1.0) L/ha where bleaching was negligible, in parsnip the large leaf caught more spray but 0.25 L/ha was safe and also to transplanted celery. In bulb onion and leek there were bleached stripes on the 1st leaf which was lost later, the new growth was not affected and the 0.25 L/ha dose appeared safe. It would not be suitable post-emergence for salad onions, coriander or baby-leaf spinach because leaf defects would reduce quality.

For crop safety there should be no, or negligible/transient damage at a recommended dose rate and no, or acceptable, effects at the ‘overlap’ double dose.

Table 1.8.3. Crop safety: Herbicides applied pre-emergence of drilled crops and pre-transplanting; or post-emergence of drilled crops and post-transplanting: √ safe; x not safe, N “normal” dose rate.

Herbicide ‘Normal’ dose/ha	Onion	Leek	Carrot	Parsnip	Coriander	Celery transplants	Cauliflower transplants	Lettuce transplants	Courgette transplants	Dwarf French Bean	Vining Pea	Swede	Rocket	Spinach	Broad Beans
Pre-emergence/pre-transplanting															
FVS-164 0.05 L	½ N	½ N	√	√	x	x	x	x	x	x	x	x	x	x	x
FVS-165 2.0 L	½ N	¼ N	x	x	x	x	√	x	½ N	√	½ N	x	x	xcr	½ N
FVS-166 0.5 L	½ N	½ N	√	√	√	√	√	½ N	½ N	½ N	½ N	x	x	xbl	½ N
Post-emergence/post transplanting															
FVS-164 0.05 L	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
FVS-165 2.0 L	√	√	x	x	xb k	x	√	½ N	½ N	x	√	x	x	xcr	x
FVS-166 0.5 L	½ N	½ N	√	½ N	xbl	½ N	x	x	x	x	x	x	x	xbl	x

bk black, cr crinkled leaves or bl bleaching unmarketable, quality defects.

Weed control

There were 16 main weed species on the trial area and populations on untreated plots ranged from 130/m^2 to 340/m^2. There were high populations of chickweed, annual meadow-grass, groundsel, small nettle and red dead-nettle and on the post-emergence area also field pansy, black-bindweed, with more mayweeds, shepherd’s purse, redshank, knotgrass, and poppy spp.

Table 1.8.4. Weed control pre- and post-weed-emergence applications: √ weed species controlled; x poor control or not controlled at the dose rate; () some control; √x variable; ** low population; $ limited data pre-emergence

Herbicide dose rate L/ha	Groundsel	Small nettle	Red dead-nettle	Chickweed	Annual Meadow-grass	Shepherd's purse	Fat-hen	Fig-leaved goosefoot	Redshank $	Knotgrass	Black bindweed $ **	Mayweeds ##	Ivy-leaved speedwell **	Field speedwell **	Field pansy $	Common poppy
Pre-weed-emergence																
FVS-164 2N	√	√	√	√	√#	√	√	√	-	√	-	√	√	√	-	√
FVS-164 N 0.05 L	√	√	√#	√	x	√	√	√	-	√	-	√	√	√	-	√
FVS-164 ½ N	√	√	√#	√	x	√	√	√	-	√	-	√ #	√	√	-	√x
FVS-165 2N	√	√	√	√	√	√	√	√	√	x	-	√	√	√	-	√
FVS-165 N 2.0 L	√	√	√	√	√	√	√	√	x	x	-	√	√	√	-	√
FVS-165 ½ N	√	√#	√	√	√	√	√#	√#	x	x	-	√	√	√	-	√x
FVS-166 2N	x	√	√	√	(x)	√	√	√	√	√	-	√	√	√	-	√
FVS-166 N 0.5 L	x	√	√	√	x	√	√x #	√x #	√	√	-	x	x	√	-	√
FVS-166 ½ N	x	√	√	x	x	√	x	x	x	x	-	x	x	√	-	√
Post-weed-emergence																
FVS-164 2N	√	√	√x	√	(x)	√	√	√	√x	√st	√	√	√	√	√	x
FVS-164 N 0.05 L	√	√	x	√	x	√	x	x	x	x	√	√x	√x	√	x	x
FVS-164 ½ N	√	√	x	√	x	√	x	x	x	x	√ x	x	x	√x	x	x
FVS-165 2N	√ s	√	√	√	√	x	xst	xst	x	x	x	x	√	√	x	x
FVS-165 N 2.0 L	x	√x	√	√	√x	x	x	x	x	x	x	x	√	√	x	x
FVS-165 ½ N	x	x	√	√	x	x	x	x	x	x	x	x	√x	√	x	x
FVS-166 2N	x	√	√	√	(x)	√	√	√	xst	√	√	√x	√	√	√	√
FVS-166 N 0.5 L	x	√	√	√	x	√	√x	√x	xst	x	√	x	√	√	√	√
FVS-166 ½ N	x	√	√	x	x	√	x	x	x	x	√ x	x	x	√	√	√

mainly pineapple weed, some scentless mayweed; # controlled in all crops except early sown crops; s small; st stunted

SH2013-FVS-164 and *SH2013-FVS-166* had residual soil and foliar activity. There was adequate soil moisture and the efficacy of both was better where applied pre-weed-emergence. Herbicide 165 was a very effective residual herbicide, but it had negligible foliar activity and control of emerged weeds was poor. It must be applied before weeds emerge.

SH2013-FVS-164 applied pre-weed-emergence at 0.05 L/ha (N dose) was effective on groundsel, mayweeds, small nettle, shepherds purse, fat-hen, fig-leaved goosefoot, speedwells and knotgrass. Weaknesses were on annual meadow-grass and on early sown crops, red dead-nettle and mayweeds (at 0.025 L/ha). Applied post-weed-emergence at 0.05 L/ha, it was less effective on several species and field pansy, common and long-headed poppies were resistant.

SH2013-FVS-165 applied pre-weed-emergence at 2.0 L/ha (N dose) gave excellent weed control of most species on the trial area, importantly annual meadow-grass, groundsel, mayweeds, small nettle, but it did not control knotgrass or redshank. In early sowings 1.0 L/ha did not control fat-hen, fig-leaved goosefoot or small nettle. Post-weed-emergence it had negligible foliar activity. After rainfall a few weeds at early growth stages were controlled: red dead-nettle, chickweed, annual meadow-grass and speedwells. The plots were very weedy.

SH2013-FVS-166 applied pre-weed-emergence at 0.5 L/ha (N dose) was very effective on small nettle, red dead-nettle, shepherds purse, field speedwell, poppies and Polygonums. It did not control groundsel, mayweeds or annual meadow-grass and control of *Chenopodium* spp. was variable. At 0.25 L/ha small nettle, red dead-nettle and shepherd's purse were controlled but chickweed remained. Post-weed-emergence it controlled a similar range of weed species, but efficacy on redshank and knotgrass was poor. At 0.5 L/ha it also killed black–bindweed and field pansy, which were not present on the pre-emergence trial area.

<u>"Volunteer" potatoes</u>

Pre-emergence applications of herbicides 164 and 166 and pre- and post-emergence applications of 165 did not suppress potato foliage.

Post-emergence application of 164 resulted in brown/black leaf damage, followed by leaf loss. However, 164 post-emergence was not safe to any crop in the trial.

Post-emergence application of herbicide 166 to potatoes caused severe bleaching followed by loss of leaves and some shoots. Forty days after application of the Normal dose at 0.5 L/ha the foliage was only 25% of the untreated potatoes. There was less damage from the 0.25 L/ha dose rate, where there was 50% foliage reduction. These treatments would be useful in carrot, parsnip, onion and leek. There was no effective control of potato flower and berry formation and it was not safe to peas post-emergence.

Discussion

From March to late June temperatures were much lower than average and emergence and growth of crops was very slow. There was heavy rainfall after application of the pre-weed-emergence herbicides which enhanced efficacy of the soil acting residual herbicides on weeds, but also tested crop safety. The trial was on a light, sandy silt loam soil - damage will be increased where crops are grown on a sands.

SH2013-FVS-164 and SH2013-FVS-166 had residual soil and foliar activity but with adequate soil moisture efficacy of both was better when applied pre-weed-emergence. SH2013-FVS-165 was a very effective residual herbicide, but it had negligible foliar activity. It must therefore be applied before weeds emerge and would be most useful applied soon after transplanting of cauliflower, courgette and possibly lettuce. A post-transplanting application would be preferred, because it avoids weeds growing within the row where the action of the transplanter pushes treated soil aside.

In summary:

- SH2013-FVS-164 at 0.05 L/ha applied pre-emergence has potential for use in drilled carrot, parsnip, and at 0.025 L/ha in leek and bulb onion. It controlled a wide weed spectrum including mayweeds and groundsel (frequent problems in commercial crops), small nettle, fat-hen and Polygonums. It did not control annual meadow-grass.
- SH2013-FVS-165 at 1.0 L/ha applied pre-emergence looked promising for bulb onion (leek was more sensitive), broad bean and vining pea (a higher dose may be safe in pea), and at 2.0 L/ha for dwarf French bean. Weed control with 2.0 L/ha was excellent on all species including annual meadow-grass, groundsel, mayweed, small nettle and fat-hen. At 1.0 l/ha it was less effective on small nettle and fat-hen. A tank-mix partner would be needed for knotgrass and redshank control.
- SH2013-FVS-165 has little foliar activity and does not control emerged weeds but post-emergence applications were safer to the crop. At 2.0 L/ha it was safe to onion, leek, vining pea. It has potential applied soon after planting, but before weeds emerge for cauliflower at 2.0 L/ha; courgette at 1.0 L/ha. Courgette currently has only two options for broad-leaved weed control – neither control groundsel, but 165 does. Application post-planting at 1.0 l/ha in iceberg and other lettuce types requires further investigation.
- SH2013-FVS-166 caused leaf-bleaching in some vegetables which may concern growers, but new growth is not usually affected – several crops (e.g. bulb onion and

leek) recover. Applied pre-emergence at 0.5 L/ha it has potential for use in carrot, parsnip and coriander. At 0.25 L/ha it was safe to bulb onion, leek, dwarf French bean, broad bean and pea. Leaf bleaching was more severe when applied post-emergence. However, it was very safe at 0.5 L/ha to carrot and safe at 0.25 L/ha to parsnip, celery, leek and bulb onion. A tank-mix partner or programme is needed to control groundsel and annual meadow-grass.

- SH2013-FVS-166 applied post-emergence is also of interest because it suppressed volunteer potato foliage and there is potential for use in carrot, parsnip, onion and leek. Split doses and the addition of wetters could be tested.
- Rocket was evaluated in this trial for the first time but no herbicide treatment was safe.

1.9(a) Precision application of residual herbicides to improve crop safety and weed control in cauliflower crops (Blankney)

A replicated trial was conducted in summer 2013 to evaluate the efficacy of banded herbicide treatments applied between and over cropped rows, for the control of weed population and crop safety in a cauliflower crop.

One application of each treatment was made on the 1 August 2013.

Table 1.9.1.

Product or SCEPTRE code	UK rate of product (L/ha)	Dosage rate a.s. (g/L)	Application timing
Whole plot treatment			
1. Untreated	-	-	-
2. Rapsan 500 SC + Gamit 36CS	1.50 + 0.25	500g/L metazachlor + 360 g/L clomazone	01 August 2013
3. SH2013-CAU-74 + Dual Gold + Gamit 36CS + Kerb Flo	4. 0 + 1.4 + 0.25 + 3.10	960g/L S-metolachlor + 360 g/L clomazone + 400 g/L propyzamide	01 August 2013
4. Rapsan 500 SC (in row)	1.50	500g/L metazachlor	01 August 2013
SH2013-CAU-74 + Dual Gold + Gamit 36CS + Kerb Flo (inter row)	4. 0 + 1.40 + 0.25 + 3.10	960g/L S-metolachlor + 360 g/L clomazone + 400 g/L propyzamide	01 August 2013

Results

Table 1.9.2. Effect of band spray herbicide treatment on mean percentage of weed cover per plot in cauliflower – site 1

Treatments	Mean % weed cover 14 DAT	Mean % weed cover 21 DAT	Mean % weed cover 28 DAT
1. Untreated	1	4.75	6.75
2. Rapsan 500 SC + Gamit 36CS	0	0.25	0.5
3. Wing P + Gamit 36CS+ Kerb Flo	0	0.25	0.5
4. Rapsan 500 SC (row) + Wing P + Dual Gold + Gamit 36CS + Kerb Flo (inter row)	0	1.0	1.0

Table 1.9.3. Mean crop phytotoxicity in cauliflower – site 1

Treatments	Phyto Score 14 DAT	Phyto Score 21 DAT	Phyto Score 28 DAT
1. Untreated	8.25	7.75	8.50
2. Rapsan 500 SC + Gamit 36CS	7.75	8.00	8.25
3. Wing P + Gamit 36CS+ Kerb Flo	5.00	6.75	7.00
4. Rapsan 500 SC (row) + Wing P + Dual Gold + Gamit 36CS + Kerb Flo (inter row)	8.25	8.00	8.25
F. pr	<0.001	<0.001	0.002
d.f	15	15	15
LSD	0.667	0.547	0.703

Table 1.9.4. Mean crop vigour in cauliflower – site 1

Treatments	Crop vigour score 14 DAT	Crop vigour score 21 DAT	Crop vigour score 28 DAT
1. Untreated	9.00	9.00	8.75
2. Rapsan 500 SC + Gamit 36CS	9.00	9.00	9.00
3. Wing P + Dual Gold +	5.00	5.00	5.25
4. Gamit 36CS + Kerb Flo			
Rapsan 500 SC (row) + Wing P + Dual Gold +Gamit 36CS + Kerb Flo (inter row)	9.00	9.00	8.75
F. pr	-	-	*<0.001*
d.f	-	-	*15*
LSD	-	-	*0.667*

- The weed population at this site was extremely low.

- All herbicide treatments controlled the weed present; however as the weed population was so low it is difficult to draw conclusions on how effective these treatments are just from this individual trial.
- Crop phytotoxicity was recorded by treatment two (Rapsan 500 SC + Gamit 36CS) which was significantly different (p=0.002) to the untreated control by the final assessment 28 DAT.
- A small amount of phytotoxicity was recorded on the crop by treatment three (Wing P + Dual Gold + Gamit 36CS + Kerb Flo).
- Crop vigour was reduced significantly (p=<0.001) by treatment three (Wing P + Dual Gold + Gamit 36CS + Kerb Flo).
- Pigeon damage was observed on a number of trial plots.

Discussion

- As this crop was sown so late in the growing season the weed burden may have been low due to the natural weed emergence patterns at this time of the season (i.e. most weeds would germinate in the spring or autumn and not mid-summer).
- The mixed rotation on the farm has significantly reduced the overall weed burden.

1.9(b) Precision application of residual herbicides to improve crop safety and weed control in cauliflower crops (Elsoms)

A replicated trial was conducted to evaluate the efficacy of banded herbicide treatments for both between and over cropped rows, for the control of weed populations and crop safety in a cauliflower crop. The same treatments were applied as in 1.9a, with all treatments applied once, on 28 May 2013.

Results

Table 1.9.5. Effect of band spray herbicide treatment on mean % weed cover in cauliflower – site 2

Treatments	Mean % Weed Control 21 DAT	Mean % Weed Control 28 DAT	Mean % Weed Control 35 DAT
1. Untreated	-	-	-
2. Rapsan 500 SC + Gamit 36CS	66.25	65.75	72.00
3. Wing P + Dual Gold + Gamit 36CS+ Kerb Flo	96.50	94.00	95.75
4. Rapsan 55 SC (row) + Wing P + Dual Gold + Gamit 36CS + Kerb Flo (inter row)	87.25	90.00	93.75
F. pr	-	-	<0.001
d.f	-	-	15
LSD	-	-	16.56

The graph below shows the final mean percentage weed control from the herbicide treatments at 35 DAT.

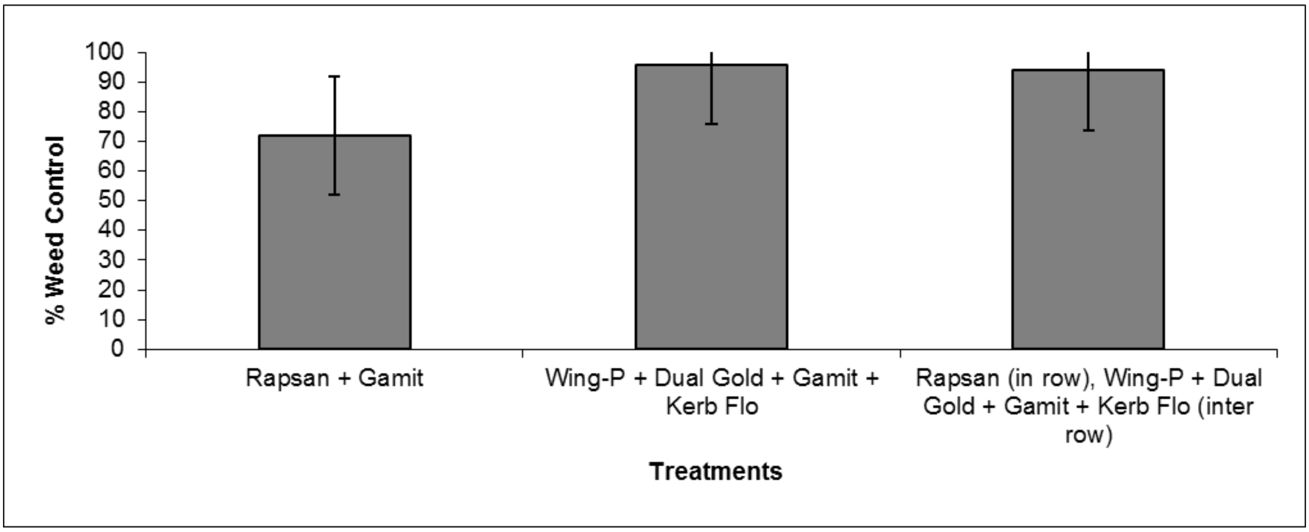

Figure 1.9.1. Effect of whole plot and band spray herbicide treatment on weed control in cauliflower – site 2

- The overall weed population was high on this site
- There were significant herbicide efficacy effects (p= <0.001) for treatments T3 and T4. T3 was Wing P + Dual Gold + Gamit 36CS + Kerb Flo and T4 was Rapsan (row), Wing

P + Dual Gold + Gamit 36CS + Kerb Flo (inter row), controlling the weed population by 95.75% and 93.25% respectively (Table 1.9.5).

- Some crop phytotoxicity was observed for the treatments three and four, but it was not significant compared to the untreated controls.
- It was noted that cauliflower plant size was generally smaller in treatments 3 and 4.

Discussion

- The treatment of Wing P + Dual Gold + Gamit 36CS + Kerb Flo, sprayed over the row gave a very high level of weed control (95.75%), which was significantly different to the untreated control.
- The band sprayed treatments of Rapsan (in row) and Wing P + Dual Gold + Gamit 36CS + Kerb Flo (inter row), also gave a very high level of weed control (93.75%) compared to the untreated control.
- The results of this trial indicate that the band sprayed herbicide treatment approach is as effective as an overall herbicide treatment.
- There was some pigeon damage noted on the crop during the trial period from 21 DAT. This issue made scoring phytotoxicity difficult.

1.9(c) Precision application of residual herbicides to improve crop safety and weed control in leeks (Besthorpe site)

A replicated trial was conducted in spring 2013 to evaluate the efficacy of band sprayed herbicide treatments for both between and over cropped rows for the control of weed populations in leeks at Besthorpe, Lincolnshire. Crop phytotoxicity was also assessed.

One spray application of each treatment was made. Treatments applied are listed below:

Table 1.9.6. Detail of residual herbicide treatments applied 25 May 2013 for control of weeds in leeks – site 1

Product or SCEPTRE code	UK rate of product	Dosage rate a.s.
Whole plot treatments		
1. Untreated	-	-
2. Wing P	2 L/ha	212.5 g/L dimethenamid-p + 250 g/L pendimethalin
3. Wing P	4 L/ha	212.5 g/L dimethenamid-p + 250 g/L pendimethalin
4. Wing P + Defy	4 L/ha + 4 L/ha	212.5 g/L dimethenamid-p + 250 g/L pendimethalin + 800 g/L prosulfocarb
In row treatment		
5. Wing P	2 L/ha	212.5 g/L dimethenamid-p + 250 g/L pendimethalin
Inter row treatment		
Wing P + Defy	4 L/ha + 4 L/ha	212.5 g/L dimethenamid-p + 250 g/L pendimethalin + 800 g/L prosulfocarb
In row treatment		
6. Wing P	2 L/ha	212.5 g/L dimethenamid-p + 250 g/L pendimethalin
Inter row treatment		
Stomp Aqua + Defy	2.9 L/ha + 4 L/ha	455 g/L pendimethalin + 800 g/L prosulfocarb

Results

- The best overall treatment was T5, Wing-P @ 2.0 L/ha (in row) and Wing-P @ 4 L/ha + Defy @ 4 L/ha (inter row), significantly (p=<0.001) reducing the weed population by 82.5% in contrast to the untreated plots (Table 1.9.7).
- Treatment 4, a mixture of Wing-P @ 4 0 L/ha + Defy @ 4.0 L/ha applied as an overall spray achieved a lower level of weed control at 67.5%.
- It was noted that there was generally poor or slow emergence of the leek crop due to the weather conditions and not due to treatment effects.

Table 1.9.7. Effect of residual herbicide treatments on weed control in leeks – site 1

Treatment	% Mean weed control 14 DAT	% Mean weed control 28 DAT	% Mean weed control 42 DAT	% Mean weed control 56 DAT
1. Untreated	-	-	-	-
2. Wing-P @ 2.0 L/ha	82.50	68.75	47.50	22.50
3. Wing-P @ 4.0 L/ha	92.75	94.50	80.00	46.25
4. Wing-P @ 4.0 L/ha + Defy @ 4.0 l/ha	98.25	97.00	87.00	67.50
5. Wing-P @2.0 L/ha (in row)	98.25	96.75	92.75	82.50
Wing-P @4 L/ha + Defy @ 4 L/ha- (inter row)				
6. Wing-P @2.0 L/ha (in row)	98	90.00	77.50	65.00
Stomp aqua @ 2.9 L/ha + Defy @ 4 L/ha - (inter row)				
F. pr	-	-	-	<0.001
d.f	-	-	-	23
LSD	-	-	-	21.25

The graph below represents the mean percentage weed control for the final assessment at 56 DAT.

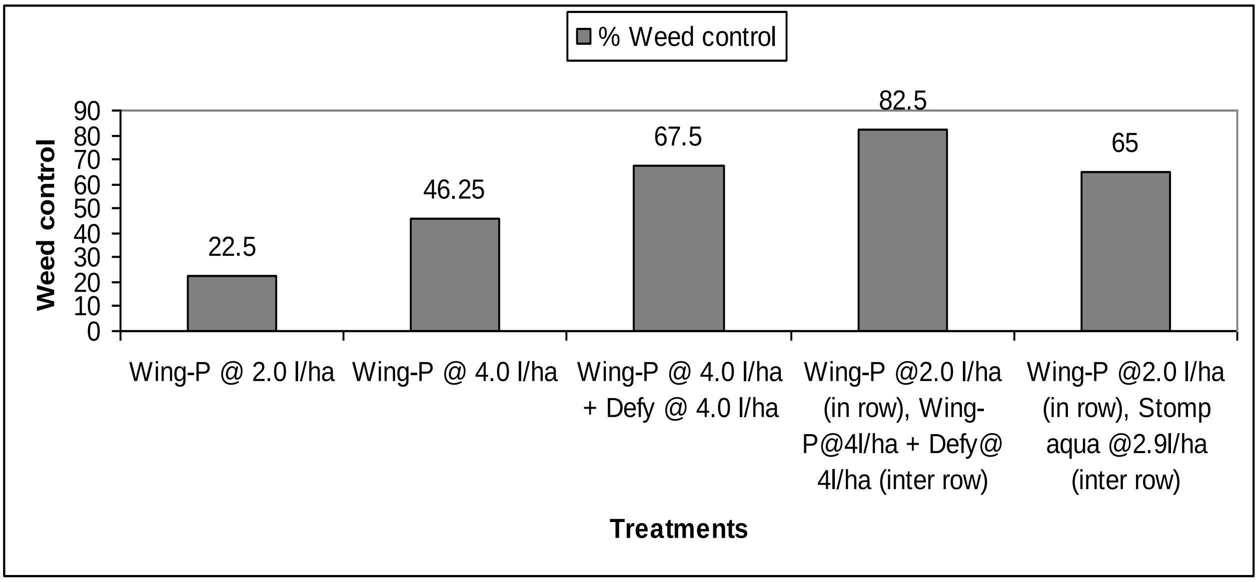

Figure 1.9.2. Effect of whole plot and band spray residual herbicide treatments on weed control in leeks – site 1

Discussion

- During the trial period there only slight phytotoxic symptoms were observed on the leeks 14 DAT. No phytotoxicity was noticed in subsequent assessments.

- The combination of in row and inter row spraying of residual herbicides has demonstrated a higher level of weed control within this trial compared to the untreated control. Treatment five was the most successful herbicide programme controlling the weed species by 82.5%.

1.9(d) Precision application of residual herbicides to improve crop safety and weed control in leeks (Moulton seas end)

A replicated field trial was conducted to evaluate the efficacy of banded herbicide treatments for both between and over cropped rows for the control of weed population and crop phytotoxicity levels in leeks. The results obtained were compared with untreated controls and the trial protocol was validated by inclusion of a standard treatment applied at recommended rates. The same treatments were applied as in 1.9c, with all treatments applied once on 30 April 2013.

Results

- Marginally, the most effective herbicide treatment was Wing-P @2.0 L/ha (in row), Stomp aqua @ 2.9 L/ha + Defy @ 4 L/ha (inter row), achieving 88.25% weed control compared to the untreated (Table 1.9.8).
- A treatment of Wing-P @ 4.0 L/ha + Defy @ 4.0 L/ha achieved 86.75% weed control and Wing-P @ 2.0 L/ha (in row) with Wing-P @ 4 L/ha + Defy @ 4 L/ha (inter row) achieved 85.75% weed control compared to the untreated controls.

Table 1.9.8. Effect of herbicide treatments on weed control in leeks – site 2

Treatment	% Av weed control 29/05/2013	% Av weed control 11/06/2013	% Av weed control 26/06/2013
1. Untreated	-	-	-
2. Wing-P @ 2.0 L/ha	18.75	32.50	26.25
3. Wing-P @ 4.0 L/ha	41.25	68.75	72.50
4. Wing-P @ 4.0 L/ha + Defy @ 4.0 L/ha	66.25	88.75	86.75
5. Wing-P @2.0 L/ha (in row) Wing-P @4 L/ha + Defy @ 4 L/ha - (inter row)	90.00	85.75	85.75
6. Wing-P @2.0 L/ha (in row) Stomp aqua @ 2.9 L/ha + Defy @ 4 L/ha - (inter row)	80.00	80.75	88.25
F. pr	-	-	< 0.001
d.f	-	-	23
LSD	-	-	21.26

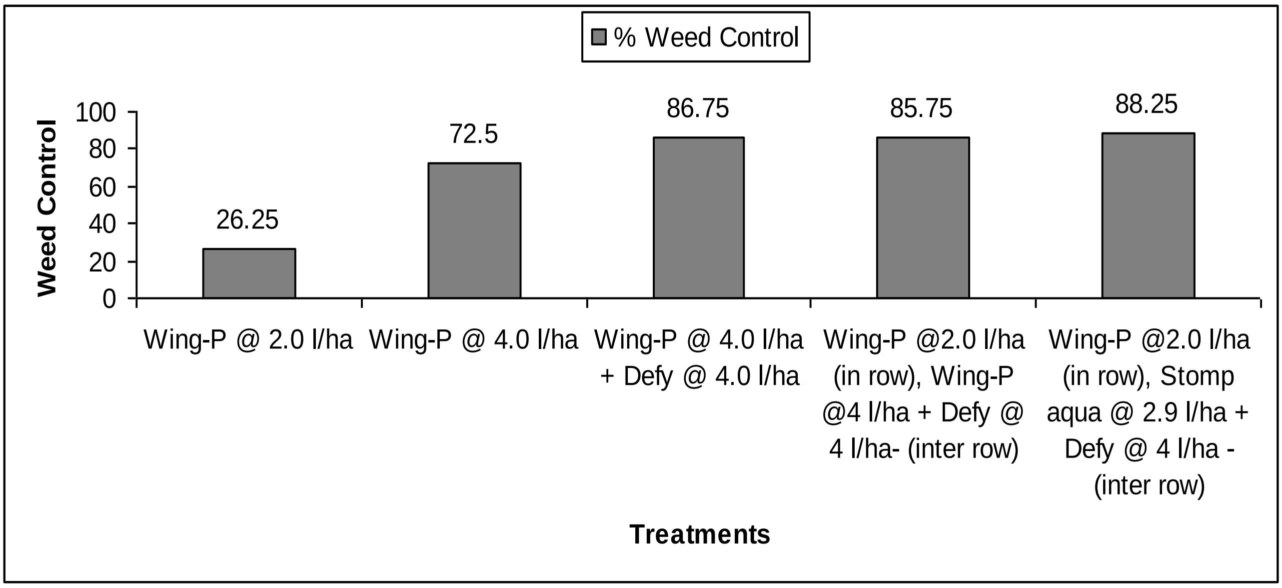

Figure 1.9.3. Effect of whole plot and band spray residual herbicide treatments on weed control in leeks – site 2

Table 1.9.9. Mean crop phytotoxicity on leeks – site 2

Treatments	28 DAT 29/05/2013	42 DAT 11/06/2013	56 DAT 26/06/2013
1. Untreated	9.00	9.00	9.00
2. Wing-P @ 2.0 L/ha	7.25	9.00	9.00
3. Wing-P @ 4.0 L/ha	7.25	9.00	9.00
4. Wing-P @ 4.0 L/ha + Defy @ 4.0 L/ha	4.25	9.00	9.00
5. Wing-P @ 2.0 L/ha (in row), Wing-P @ 4 L/ha + Defy @ 4 L/ha (inter row)	5.75	9.00	9.00
6. Wing-P @ 2 L/ha (in row), Stomp aqua @ 2.9 L/ha +Defy @ 4 L/ha (inter row)	5.75	9.00	9.00

- Some phytotoxic symptoms were recorded at 28 DAT, however symptoms had gone by 42 DAT (Table 1.9.9).
- Crop emergence was slow and poor in places which is likely to be due to the cold late spring of 2013 and not herbicide symptoms.

Discussion

- Due to the fact that the crop had slower emergence, the assessments dates were altered slightly from the initial protocol and began at 21 days after treatment (DAT).

- At 21 DAT there was some crop phytotoxicity assessed which later on was reduced and plants had a healthy re growth. The early crop phytotoxicity symptoms may also have been difficult to assess as crop plants were very small and weather conditions may also have not been favourable to young leek plants are the early assessment timings.
- Treatments four, five and six had the most promising results with 86.75%, 85.75% & and 88.25% weed control respectively.
- Overall, apart from the slow crop emergence, the final results of the trial give some very promising and effective weed control.

1.10(a) Assessment of the efficacy of electric weed control in cauliflowers (Elsoms)

A replicated trial was conducted in Elsoms, Spalding, to evaluate the efficacy of electric weed control in cauliflowers. The treatments included mechanical weeding, herbicide treatments and untreated controls.

One application of each treatment was made. The herbicides treatment dates were different than the electrical and mechanical weed control application dates. Treatments applied are listed below:

Table 1.10.1. Detail of herbicide (H), electrical (E) and mechanical (M) treatments applied for weed control in cauliflower – 2013

Treatment	Product or SCEPTRE code	UK rate of product	Application timing
1.	Untreated	-	-
2.	Rapsan 500 SC + Gamit	1.5 L/ha + 0.25 L/ha	28 May 2013 (H)
3.	Rapsan 500 SC + Gamit + electrical	1.5 L/ha + 0.25 L/ha	28 May 2013 (H) + 27 June 2013 (E)
4.	Rapsan 500 SC + Gamit + mechanical	1.5 L/ha + 0.25 L/ha	28 May 2013 (H) + 27 June 2013 (M)
5.	Electrical weed control	-	27 June 2013
6.	Mechanical weed control	-	27 June 2013

Results

Table 1.10.2. Effect of herbicide, electrical and mechanical treatments on weed control in cauliflower – 2013

Treatments	Mean % weed control 21 DAT	Mean % weed control 28 DAT	Mean % weed control 35 DAT (6 DAT electrical)	Mean % weed control 49 DAT (19 DAT electrical)
1. Untreated	-	-	-	-
2. Rapsan 500 SC + Gamit	70.00	75.66	70.00	53.75
3. Rapsan 500 SC + Gamit + Electrical weed control	60.25	65.00	97.75	88.00
4. Rapsan 500 SC + Gamit + Mechanical weed control	73.25	78.33	89.00	86.00
5. Electrical weeding alone	n/a	n/a	41.25	18.75
6. Mechanical weeding alone	n/a	n/a	70.75	56.25
F. pr	-	-	-	<0.001
d.f	-	-	-	14
LSD	-	-	-	34.71

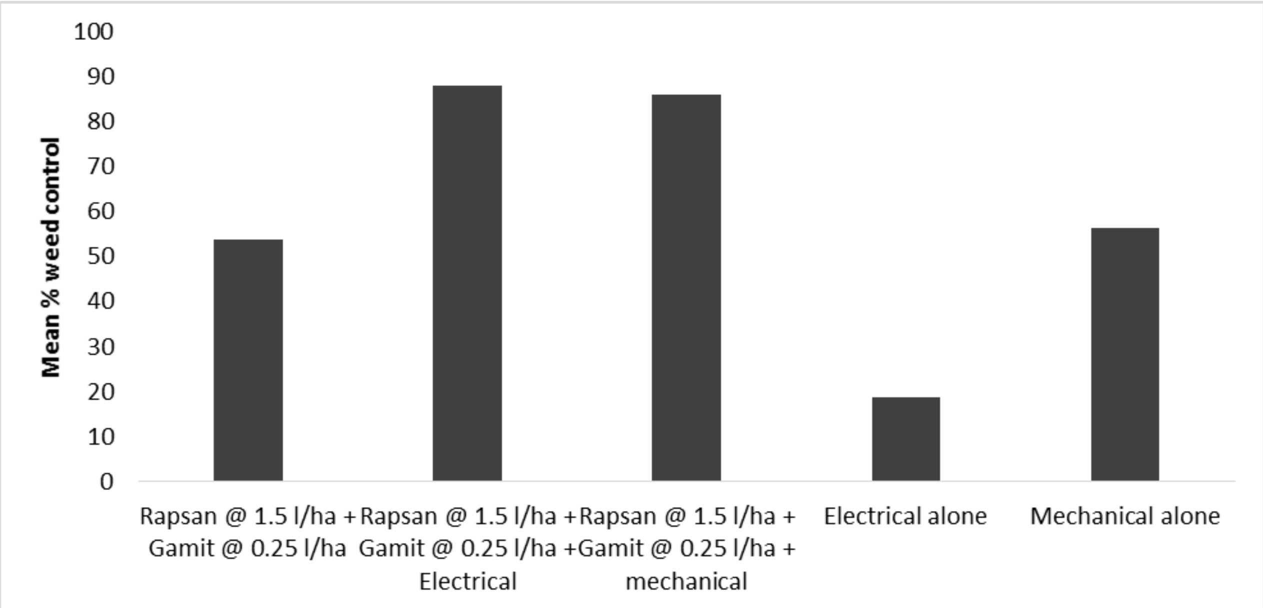

Figure 1.10.1. Effect of herbicide, electrical and mechanical treatments on weed control in cauliflower – 2013

- Electrical and mechanical weed control, were applied on the 27 June 2013, 28 days after herbicide application.
- No phytotoxic symptoms or treatment related crop vigour differences were observed at any of the assessment timings.

- There were significant efficacy effects (p= >0.001) for treatments T3 and T4, a combination of the standard commercial herbicide programme with electrical weed control (T3) or mechanical (T4) resulting and 88% and 86% control respectively (Table 1.10.2).
- Mechanical weeding alone achieved comparable levels of weed control compared to the standard herbicide programme of Rapsan 500 SC + Gamit 36CS, which were 53.75% and 56.25 % control respectively.

Discussion

- Combining a standard herbicide programme with electrical weed control gave effective weed control in cauliflowers.
- Combining a standard herbicide programme with mechanical weed control also gave effective weed control in cauliflowers.
- Both electrical and mechanical treatments alone were not adequate enough to control weeds in cauliflowers.
- The seedbed at the trials site was rougher than desired which proved unsuitable for the electric weeder. Some clods caused issues with earthing and also possibly hid small weeds during treatment.

1.10(b) Assessment of the electrical control efficacy in leeks (Moulton sea end)

A replicated field trial was conducted in spring 2013 to evaluate the efficacy and the benefits of electrical weed control in leeks. The results obtained were compared with mechanical and herbicide treatments and untreated controls.

One herbicide application of each treatment was made on the 30 April 2013. Electrical and mechanical controls were applied on the 25 May 2013. Treatments applied are listed below:

Table 1.10.3. Details of herbicide, electrical and mechanical treatments applied for weed control in leeks – 2013

Product or SCEPTRE code	UK rate of product	Application timing
1. Untreated	-	-
2. Wing P	2 L/ha	30 April 2013
3. Wing P + electrical	2 L/ha	30 April 2013 + 25 May 2013
4. Wing P + mechanical	2 L/ha	30 April 2013 + 25 May 2013
5. Electrical weeding	-	25 May 2013
6 Mechanical weeding	-	25 May 2013

Results

Table 1.10.4. Effect of herbicide, electrical and mechanical treatments on weed control in leeks – 2013

Treatments	Mean % Weed Control 28 DAT	Mean % Weed Control 42 DAT	Mean % Weed Control 56 DAT
1. Untreated	-	-	-
2. Wing P	18.75	58.75	53.75
3. Wing P + electrical	17.5	57.50	62.50
4. Wing P + mechanical	10.00	57.50	56.25
5. Electrical alone	n/a	n/a	11.25
6. Mechanical alone	n/a	n/a	18.75
F. pr	-	-	0.003
d.f	-	-	15
LSD	-	-	25.56

The graph below represents the mean percentage weed control at the final assessment date of 56 DAT.

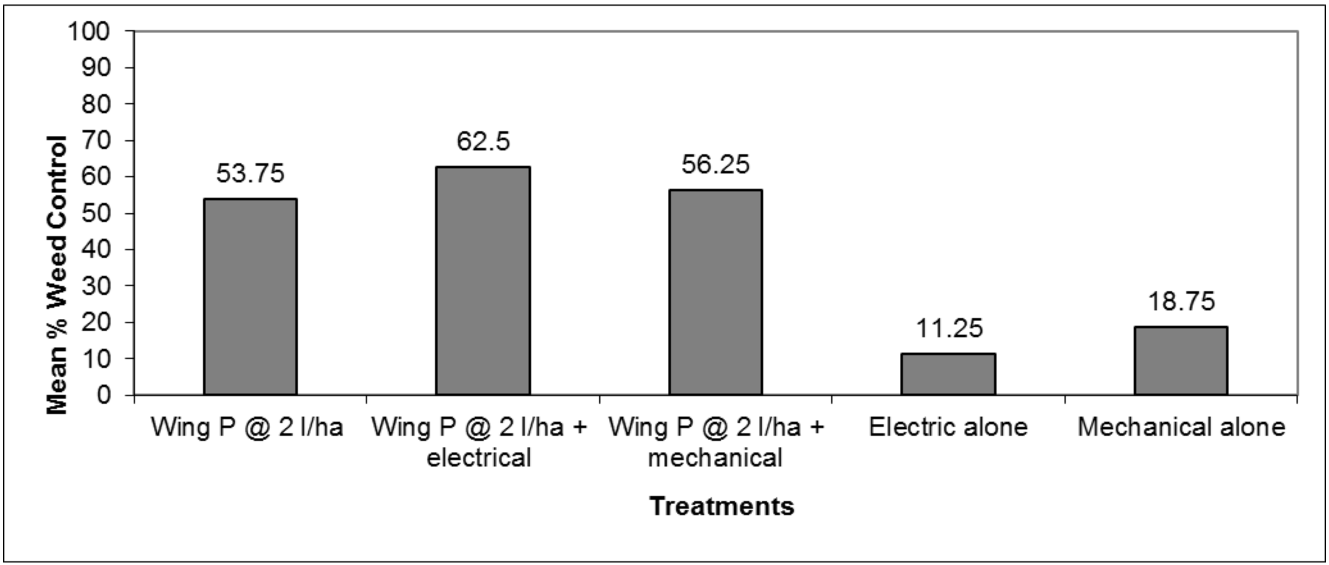

Figure 1.10.2. Effect of herbicide, electrical and mechanical treatments on weed control in leeks – 2013

- The combination of a standard commercial herbicide programme with electrical treatment (T3) significantly reduced the weed numbers (<0.003) compared to the untreated control, achieving 62.5 % weed control.
- The combination of a standard commercial herbicide programme with mechanical treatment (T4) significantly reduced the weed numbers (<0.003) compared to the untreated control, achieving 56.25 % weed control.
- Electrical or mechanical treatments alone did not significantly reduce the weed numbers compared to the untreated controls.

Discussion

- The combination of a standard commercial herbicide programme with electrical treatment would have good potential for effective weed control in leeks.
- This trial would need to be repeated to validate results as it only represents one field season and trial site.
- Electrical or mechanical treatments alone did not significantly reduce the weed numbers compared to the untreated controls and so they should be used in combination with other treatments (herbicides or other cultural methods) or be repeated on a number of different timings.
- Throughout the trial assessments, there was no phytotoxicity observed on the crop.
- Rainfall in mid May caused a delay to the electrical and mechanical weeding treatment. This gave rise to larger than desired weeds which were not controlled as effectively.

2. Soft fruit

2.1 Assessment of the efficacy of fungicides and biofungicides against spur blight and cane spot on raspberry canes

Work in progress. This experiment will be reported in next year's Annual Report.

2.2 Assessment of the efficacy of fungicide programmes against soft rots of strawberry fruit

One replicated trial was conducted in 2013 to evaluate the efficacy of fungicide products, programmes and alternative chemicals for the control of soft rots in strawberry. The results obtained were compared with untreated controls. There is no standard treatment for control of soft rots in strawberry.

Five applications of each programme/treatment were made. Chemicals applied are listed below:

Table 2.2.1. Detail of products used in spray programmes for control of soft rot in strawberry – 2013

Chemicals	Product or SCEPTRE code	UK rate of product / ha
1.	Untreated	-
2.	Untreated	-
3.	Signum	1.8 kg
4.	Switch	1.0 kg
5.	Thianosan	3.0 kg
6.	SF2013-STR-77	-
7.	SF2013-STR-25a	-
8.	SF2013-STR-47	-
9.	SF2013-STR-37	-
10.	SF2013-STR-186	-
11.	SF2013-STR-187	-

Programmes applied and treatment timings are given below.

Table 2.2.2. Programmes evaluated for control of soft rots on strawberry in 2013

Treatment / Programme		Product / Timing				
		1	2	3	4	5
		17 July	24 July	31 July	7 August	14 August
1.	-	-	-	-	-	-
2.	-	-	-	-	-	-
3.	P1	Thianosan	Switch	Signum	Switch	Signum
4.	P2	Thianosan	Switch	77	Switch	77
5.	P3	Thianosan	Switch	25a	Switch	25a
6.	P4	47	47	47	47	47
7.	P5	37	37	37	37	37
8.	P6	186	-	186	-	186
9.	P7	186 + Thianosan	Switch	186 + Signum	-	186
10.	P8	187	-	187	-	187
11.	P9	187 + Thianosan	Switch	187 + Signum	-	187

Results

- The incidence of soft rots was moderate-high.
- The results obtained were similar to previous trial results therefore this can be considered a valid trial.
- There were significant efficacy effects for treatments 3 (programme 1), 4 (programme 2) and 7 (programme 5). However, none of the treatments were completely effective in controlling soft rots.
- No significant differences in total crop yield or fruit number were observed between any of the treatments.

Table 2.2.3. Effect of various fungicides and programmes applied as five sprays from green fruit on *Mucor* rot (soft rots) incidence (in post-harvest tests following incubation at ambient temperature for 7 days), plot yield and fruit number in 2013. Data presented for *Mucor* are angular transformed, for yield log transformed and for fruit number square root transformed. Back transformed means in parenthesis.

Treatment	Programme	% Mucor fruit rot	Total yield Overall mean kg	Total fruit number Overall mean
1	-	37.8	0.854 (2.348)	14.7 (215.5)
2	-	44.4	1.181 (3.257)	16.9 (285.5)
3	P1	**26.5**	1.040 (2.829)	16.3 (264.6)
4	P2	**27.1**	1.138 (3.122)	16.9 (285.6)
5	P3	38.1	1.131 (3.099)	17.7 (313.1)
6	P4	38.7	1.070 (2.916)	16.9 (285.9)
7	P5	**28.0**	1.175 (3.240)	16.4 (269.7)
8	P6	34.8	0.770 (2.160)	14.6 (214.2)
9	P7	33.7	1.015 (2.759)	16.1 (257.7)
10	P8	39.8	1.119 (3.062)	17.8 (316.0)
11	P9	36.3	1.121 (3.068)	16.6 (274.6)
F Probability		0.020	0.859	0.731
SED (30df)		5.020	0.258	1.758
LSD (p= 0.05)		10.253	0.528	3.591

Discussion

Weather conditions were favourable for infection and development of *Mucor* soft rots on strawberry in August. The disease was present at low incidence at harvest but developed rapidly to high levels in untreated plots in the post-harvest tests. Treatments 3 (programme 1), 4 (programme 2) and 7 (programme 5) consistently gave the lowest incidence of *Mucor* (soft rots) in the post-harvest tests. However, none of the treatments were completely effective in controlling soft rots. Programmes 4, 6 and 8 were ineffective. A better understanding of the epidemiology of *Mucor* and *Rhizopus* is required in order to identify where fungicides or other control methods can be targeted. Research on this topic has started at EMR in 2013 as part of a Ph.D. study. No further work on soft rots within SCEPTRE is planned for 2014.

2.3 Assessment of the efficacy of fungicide and biofungicide products and application method against crown rot of strawberry

One replicated trial was conducted in 2013 to evaluate the efficacy of fungicide and biofungicides products applied as either pre-planting plant dips or post-planting drenches or post-planting sprays for the control of crown rot in strawberry. The results obtained were compared with untreated controls and the trial protocol was validated by inclusion of the standard treatment Paraat (dimethomorph) applied at recommended rates.

Fungicide treatments were applied once. Biofungicide treatments were applied three times at 14 day intervals. The treatments applied and standard rates are listed below: However, the rate differed according to the method of application (see following table).

Table 2.3.1. Detail of products evaluated for control of crown rot – 2013

Treatment	Product or SCEPTRE code	UK rate of product	Application timing
1	Untreated	-	-
2	Untreated		-
3	Paraat	1 g/L	See following Table
4	Fenomenal	0.75 g/L	
5	SF2013-STR24	2.5 L/ha	
6	SF2013-STR23	0.8 L/ha	
7	Prestop	5 g/ L	
8	SF2013-STR40		

Table 2.3.2. Treatment, application method, rate and application timing in 2013

Treatment	Product or SCEPTRE code	Dose rate of product	Application method	Application timing
1	Untreated	-	-	-
2	Untreated	-	-	-
3	Paraat	1.5 g/L	Pre-plant dip*	15 July
4	Paraat	0.75 g/L	Drench at planting	19 July
5	Paraat	3 kg/ha in 1000 L water	Post planting spray	2 August
6	Fenomenal	1.5 g/L	Pre-plant dip	15 July
7	Fenomenal	0.75 g/L	Drench at planting	19 July
8	Fenomenal	4.5 kg/ha in 1000 L water	Post planting spray	2 August
9	SF2013-STR24		Pre-plant dip	15 July
10	SF2013-STR24		Drench at planting	19 July
11	SF2013-STR24		Post planting spray	2 August
12	SF2013-STR23		Pre-plant dip	15 July
13	SF2013-STR23		Drench at planting	19 July
14	SF2013-STR23		Post planting spray	2 August
15	Prestop	5 g/ L	Pre-plant dip*	15 July, 2 August, 16 August
16	Prestop	5 g/L	Drench at planting	19 July, 2 August, 16 August
17	Prestop	5 g/L	Post planting spray	2 August, 16 August, 30 August
18	SF2013-STR40		Pre-plant dip	15 July, 2 August, 16 August
19	SF2013-STR40		Drench at planting	19 July, 2 August, 2 August
20	SF2013-STR40		Post planting spray	2 August, 16 August, 30 August

* Treatments outside the label method of application.

Results

- The incidence of crown rot in the trial in untreated plots was negligible at the first assessment despite the introduction of inoculated plants.
- No problems were encountered during mixing or application of any of the product formulations under test. No phytotoxic symptoms or treatment related crop vigour differences were observed at any of the assessment timings.
- No crown rot was recorded in the standard treatment Paraat but as the incidence of crown rot in the trial in untreated plots was negligible at present it cannot be considered a valid trial. Further assessments will be done in spring
- So far crown rot has failed to develop in the trial so it is not possible to draw any conclusions on efficacy from the trial
- No yield data was collected from the trial.

Discussion

We had originally planned to use either strawberry cv. Malling Pearl or Malling Opal in the trial both of which are very susceptible to crown rot and had performed well in previous crown rot trials. Unfortunately the planting material was not available. Elsanta, which is less susceptible to crown rot, was used as the alternative cultivar. Two crown rot-infected plants were introduced into each peat bag in each plot as inoculum. These plants had clear crown rot symptoms at the time they were introduced but, despite this, and the use of overhead irrigation to spread the disease, the problem failed to develop in the Elsanta plants. Crown rot symptoms were only seen in two plants in the entire trial at the assessment in late October. A final assessment of visual symptoms will be done in Spring 2014 together with an examination of the crowns on untreated plots. If there is no crown rot present then the trial will be repeated.

2.4 Assessment of the efficacy of insecticides against European tarnished plant bug on strawberry

One replicated cage trial was conducted in 2013 to evaluate the efficacy of insecticides for the control of European tarnished plant bug (*Lygus rugulipennis*) in strawberry. The results obtained were compared with untreated controls and the trial protocol was validated by inclusion of the standard treatment Chess applied at recommended rates.

Two applications of each treatment were made applied at a 14 day interval; on 20 Aug and 3 Sep 2013. Treatments applied are listed below:

Table 2.4.1. Detail of treatments evaluated for control of European tarnished plant bug on strawberry – 2013

Treatment	Product or Sceptre code	Active ingredients	Rate of product/ha	Application timing (days)
1	Untreated		-	-
2	Chess WG	Pymetrozine	400 g	0, 14
3	Spruzit	Pyrethrum	6.0 L	0, 14
4	SI2013-STR-59	-	200 ml	0, 14
5	SI2013-STR-149	-	250 g	0, 14
6	SI2013-STR-149 + Spruzit	-	250 g +6.0 L	0, 14
7	SI2013-STR-149 + Silwet L-77	-	125 g + 500 ml	0, 14
8	SI2013-STR-149 + Chess	-	250 g + 400 g	0, 14

‡Rates are full recommended rates, except for Spruzit, where 1/4 of the full recommended rate, was used as this is the rate used in normal commercial practice.

Results

- The numbers of the pest in the cages were high compared to levels commonly seen in the field.
- There were significant reductions in the number of nymphs for insecticide 59 and for 149 in admixture. There were additional benefits of mixing 149 with another treatment, perhaps due to the formulation rather than the chemical, as the added products were not significantly effective alone. Insecticide 59 was most effective at reducing the number of N1-N3 nymphs. There were also fewer adults in the cages with the following treatments: 59, 149, 149 + Spruzit, 149 + Silwet L-77 and 149 + Chess.
- Supplementary feeding of *Lygus* bugs with dead blowfly larvae, bee collected pollen and an alyssum plant improves the reproduction and survival of the *Lygus* in the trial.
- Fruit damage was shown to be related to number of *L. rugulipennis* nymphs, not adults.

Discussion

Insecticides 59 and 149 both gave better control of *L. rugulipennis* than Chess WG or Spruzit. Insecticide 149 performed better when in admixture than alone, although the added products may have acted as a spreader/wetter. Note that Spruzit was used at a quarter of the maximum dose recommended on the label for protected crops, as used in commercial practice. Both coded products should be taken forward for field-scale experiments.

2.5 Assessment of the efficacy of insecticides and bio-insecticides integrated with macrobiologicals against aphids on protected raspberry

Because of the complex nature of the data and statistical analyses, it is not possible to summarise in a simple table. Instead, a written summary of the main results is given below.

One replicated trial was conducted in 3 replicated polytunnels to evaluate the efficacy of 1 conventional and 3 bioinsecticides for the control of raspberry aphids and potato aphids in protected raspberry. The results obtained were compared with untreated controls and the trial protocol was validated by inclusion of the standard treatment Calypso applied at recommended rates

Four weekly applications of each treatment were made. Treatments applied are listed below:

Table 2.5.1. Detail of insecticides and bio-insecticides evaluated for control of aphids on protected raspberry – 2013

Treatment		Product or SCEPTRE code	UK rate of product	Application timing
1	-	Untreated (water)	-	4x weekly
2	C	Calypso	250 ml/ha	4 x weekly
3	C	SI2013-RAS-50		4x weekly
4	B	SI2013-RAS-130		4x weekly
5	B	SI2013-RAS-51		4x weekly
6	B	SI2013-RAS-62		4x weekly

B – bio-insecticide; C – conventional insecticide

Summary

- For controlling large raspberry aphid (a moderate infestation at the start of the trial which increased with time), Calypso and insecticide 50 were very effective. Of the bio-insecticides tested, product 130 was most effective, but gave tainted fruit (strong bitterness). The other bio-insecticides were less effective than 130. Bio-insecticide 62 became more effective after 4 consecutive weekly sprays.
- For controlling potato aphid (a heavy infestation at the start of the trial which declined with time), the two insecticides gave best control, particularly after week 2. Of the 3 bio-insecticides tested, none were significantly better than the water control, although product 62 initially reduced numbers below the water controls.
- The two released parasitoids helped to reduce aphids by up to 35% (in week 3), with no significant effect of treatments on % mummified total aphids.

- Hoverflies were the most abundant endemic natural enemies in all plots and were attracted by the added buckwheat tubs as a feeding source, but their specific impact on aphid numbers could not be quantified. The two conventionals caused more mortality of non-target invertebrates including hoverflies, particularly SI2013-RAS-50 in week 3 ($p<0.001$), when BCAs were actively flying during the spraying period.

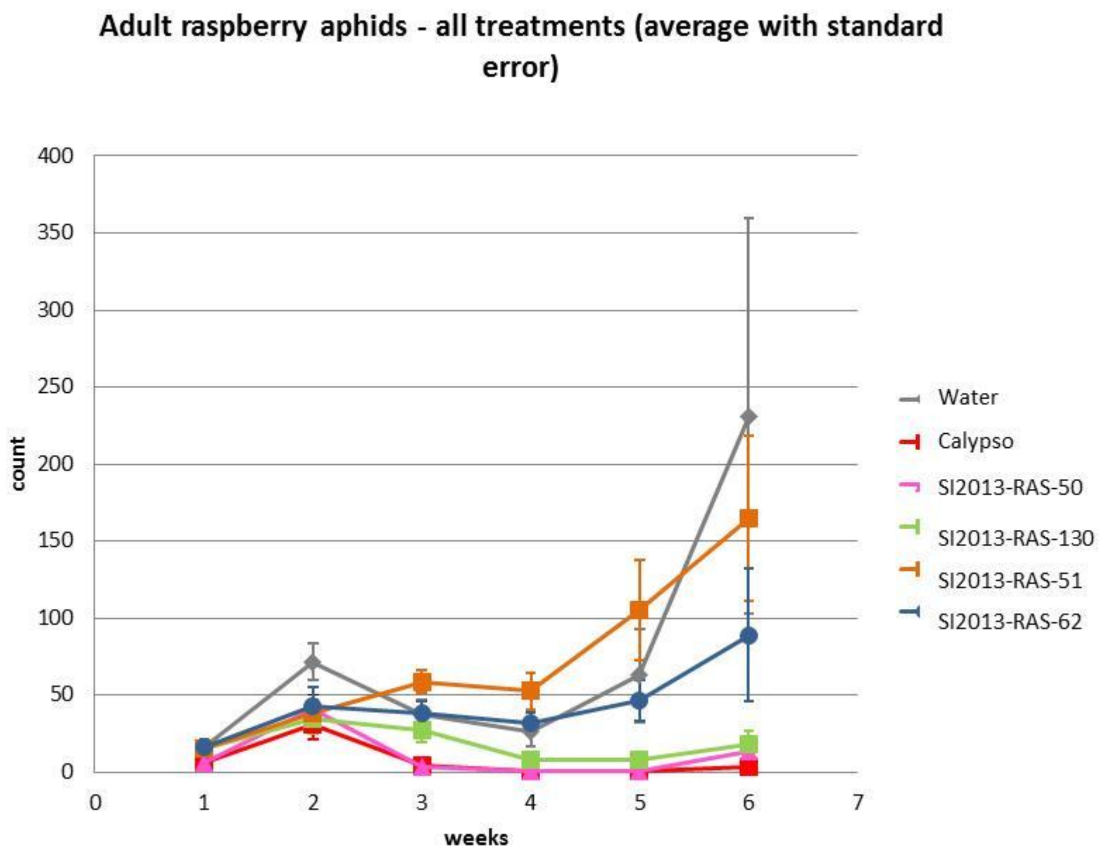

Fig 2.5.1. Means per week are total adult aphid numbers/ plot (sum of 4 canes sampled in each plot), with standard errors. *N.B.* Graphs are complementary to tables (see above) but use averages calculated from raw data (Excel), rather than transformed data from the GLM model. This shows actual aphid counts per plot (without transformation) and trends over time in a simpler way so the dynamics of treatment effects can be visualised clearly.

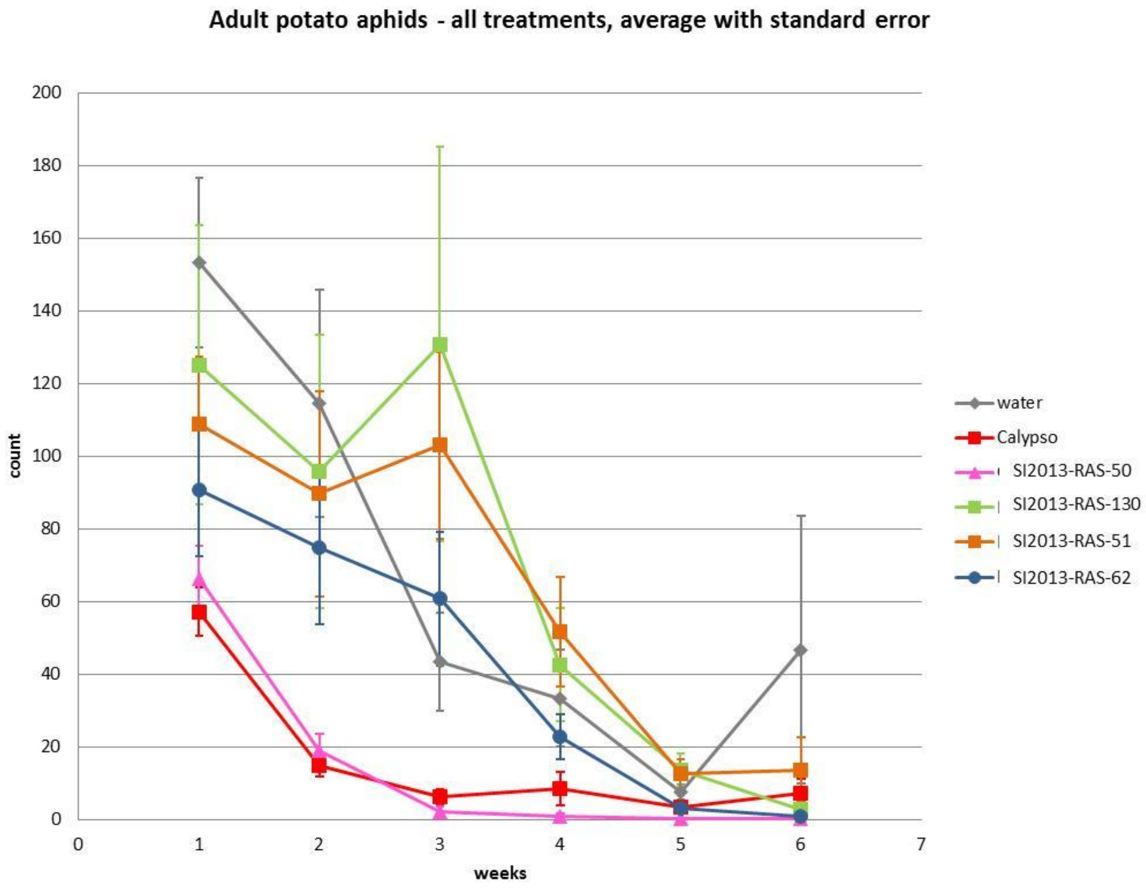

Fig 2.5.2. Means per week are total adult aphid numbers/ plot (sum of 4 canes samples in each plot), with standard errors. *N.B*. Graphs are complementary to tables (see above) but use averages calculated from raw data (Excel) rather than transformed data from the GLM model. This shows actual aphid counts per plot (without transformation) and trends over time in a simpler way so the dynamics of treatment effects can be visualised clearly.

2.6 Assessment of the crop safety of herbicides and bioherbicides to blackcurrant bushes

The trial was carried out on 1 year old pot grown blackcurrants cv. Ben Gairn and Ben Tirran. Treatments were applied as a directed spray to the lower 15 cm of the bushes just prior to and just after bud break on both varieties in March and April 2013.

Assessments were made 1, 2, 4 and 6 weeks after treatment application and then a final whole plant assessment was made in June assessing phytotoxicity on the upper leaves.

Several products caused significant scorch and death to leaves and buds on the spayed portion of branches particularly at the latter spray timing and on Ben Gairn but caused no adverse effects to the rest of the plant suggesting the potential for some of these products to be taken forward for off label approval as a directed spray into the base of the bush prior to bud break

Results

Table 2.6.1. Effect of herbicides (H) and bioherbicides (B) applied around bud break on growth of blackcurrant bushes – 2013

Treatment	Type	Average phytotoxicity score 0-9 scale (9 no effect – 0 death)			
		Ben Gairn		Ben Tirran	
		Treated buds 6 WAT	Whole plant June	Treated buds 6 WAT	Whole plant June
After March application					
1. Untreated	-	9.00	9.00	9.00	8.33
2. Roundup	H	**7.00**	**7.33**	7.67	8.00
3. SH2013-BLC-109	B	8.33	7.67	**7.33**	8.67
4. SH2013-BLC-72	H	**6.67**	**6.33**	**7.33**	**6.00**
5. SH2013-BLC-116	B	8.00	7.67	**7.33**	8.67
6. SH2013-BLC-135	H	8.00	7.67	7.67	9.00
7. SH2013-BLC-124	H	8.00	**7.33**	8.00	9.00
6. SH2013-BLC-151	H	**7.00**	7.67	7.67	9.00
P.value		<0.001	<0.001	<0.001	<0.001
LSD (58 df)		1.515	1.481	1.515	1.481
After April application					
1. Untreated	-	9.00	9.00	9.00	8.33
2. Roundup	H	**4.33**	**6.67**	**5.00**	8.00
3. SH2013-BLC-109	B	**4.00**	**6.67**	**7.33**	9.00
4. SH2013-BLC-72	H	**3.67**	**6.00**	**3.00**	**4.00**
5. SH2013-BLC-116	B	**4.00**	7.67	**6.67**	8.67
6. SH2013-BLC-135	H	**5.67**	7.33	**7.00**	9.00
7. SH2013-BLC-124	H	**3.67**	7.67	6.00	8.67
8. SH2013-BLC-151	H	**5.33**	8.00	6.67	8.33
P value		<0.001	<0.001	<0.001	<0.001
LSD (58 df)		1.515	1.481	1.515	1.481

WAT = Weeks after treatment

Values in bold are significantly different from the untreated.

Discussion

Following the March application, herbicides 72, Roundup and 151 caused the greatest level of damage to basal buds on Ben Gairn. Damage to Ben Tirran buds was generally less severe. After the April application all treatments caused significant effects to the basal buds of both varieties. Symptoms were again more severe in Ben Gairn and included bud death, delayed bud break and leaf scorch. Symptoms were less severe in Ben Tirran as this broke bud later and was therefore at a less advanced stage than Ben Gairn when treated. The most damage was caused by Roundup and herbicide 72.

Herbicide 72 and to a lesser extent Roundup caused some yellowing and leaf deformation over the whole plant from the March and April applications and herbicide 109 to Ben Gairn only from the April application. For the other treatments, foliage above the treated area generally grew away healthily and produced flowers and fruit suggesting the potential for some of these products to be used as a directed spray in March prior to bud break. For both varieties the least damage to buds in March was caused by conventional herbicides 124 and 135 and bioherbicides 109 and 116.

The young bushes used in this experiment are likely to have been more susceptible to damage than the mature field-grown bushes used in the previous year's experiments because a greater proportion of young wood was directly sprayed. In those experiments neither herbicide 72 nor bioherbicide 151 caused any significant phytotoxicity indicating that these treatments may still be safe provided bushes are well established.

2.7 Assessment of the crop safety of herbicides and bioherbicides to raspberry

The trial treatments were each applied as a three-spray programme in April and May 2013. All treatments reduced weed cover compared with untreated at assessments one to three weeks after treatment. Bioherbicide 109 and herbicide124 showed greatest control of weeds, including thistle, and had less weed cover than the industry standard treatment Shark. No whole plant phytotoxicity and no significant effects on spawn control were observed. This was likely because the season was very late so treatments did not come into contact with broken buds.

Results

Table 2.7.1. Effect of herbicides (H) and bioherbicides (B) on weed and spawn control in raspberry, cv. Glen Ample – 2013

Treatments	Type	Average % weed cover			Spawn phytotoxicity 0-9 score
		2WAT (T1)	1WAT (T2)	3WAT (T2)	1WAT(T2)
1. Untreated	-	8.5	10.8	28.8	9.0
2. Shark + Silwett	H	**4.8**	**4.5**	**11.4**	9.0
3. SH2013-RAS-109	B	**1.8**	**2.0**	**5.8**	9.0
4. SH2013-RAS-116	B	**2.3**	**2.5**	22.5	**6.3**
5. SH2013-RAS-124 + adjuvant	H	**2.1**	**0.8**	8.3	9.0
P Value		0.002	<0.001	0.034	0.028
LSD (11 df)		2.974	3.216	15.77	1.704

WAT – weeks after treatment.

Discussion

The treatments were applied twice in April. No phytotoxicity was observed on floricane from any of the treatments; it was however a very late season so the treatments did not come into contact with broken buds. A third spray was therefore applied to check crop phytotoxicity in May, unfortunately the trial area was subsequently oversprayed by the host grower so latter assessments had to be cancelled and therefore it was not possible to assess re-growth of thistles. All treatments reduced weed cover compared with the untreated control up to three weeks after the second treatment application. Products 109 and 124 showed greatest control of weeds including thistle and showed better control than the industry standard treatment Shark, therefore have some potential in this sector although it was not possible to check for subsequent re-growth. Bioherbicide 116 showed good early control of some annual weeds but this was not sustained and they rapidly re-grew. Because of the slow and protracted spawn emergence in 2013 spawn was very variable and tended to emerge between assessment dates. No significant effects were observed for spawn control, however the industry standard treatment Shark showed a slight reduction at some assessments and bioherbicide 116 showed some significant leaf yellowing to the spawn.

2.8 Assessment of the efficacy of herbicides and bioherbicides against three perennial weeds

A replicated field trial was conducted in spring 2013 to evaluate the efficacy of two bioherbicides and one conventional herbicide for control of perennial weed species that are commonly found in horticultural crops. The results obtained were compared with an untreated control and Rosate 36 (glyphosate).

The plots were marked out by identifying a representative patch of the target perennial weed species and marking a 0.25 m^2 quadrat area for that weed for each treatment, which was then replicated in a further three patches, on 25 April 2013. Due to the patchy nature of perennial weeds the replicate quadrats were not uniformly spaced as a traditional trial design, but were located approximately 2 m apart.

Table 2.8.1. Detail of herbicides and bioherbicides evaluated for control of perennial weeds – 2013

Treatment	Product or Sceptre code	Active ingredients	Rate of product	1st Application timing	2nd Application timing
1	Untreated	-	-	-	-
2	Rosate 36	Glyphosate	4.0 L/ha	7 May 2013	22 May 2013
3	SH2012-FVF-109		-	7 May 2013	22 May 2013
4	SH2012-FVF-116		-	7 May 2013	22 May 2013
5	SH2012-FVF-124 + adjuvant		-	7 May 2013	22 May 2013

There were two application timings of each treatment. Individual quadrats were examined six times at 7, 14, 21, 28, 42 and 56 days after treatment (DAT) and weeds assessed for vigour on a 0-10 scale.

Table 2.8.2. Effect of herbicides (H) and bioherbicides (B) on control of docks – 2013

Treatment	Type	Docks – Vigour score 21 DAT (0-10)	Docks – Vigour score 56 DAT (0-10)
1. Untreated Control	-	9.50	7.50
2. Rosate 36	H	**0.50**	**0.00**
3. SH2012-FVF-109	B	**1.25**	**2.00**
4. SH2012-FVF-116	B	**4.00**	7.75
5. SH2012-FVF-124 + adj	H	**0.75**	8.00
F. pr		<0.001	<0.001
d.f		19	19
LSD		1.70	2.92

The highest level of control for dock was from bioherbicide 109 which was shown to significantly (p = <0.001) reduce the weed vigour up to 56 DAT with a repeated application. Both products 116 and 124 showed some initial weed suppression with a much reduced weed vigour at 21 DAT, and high levels of plant scorching from 124. However by 56 DAT weed vigour was comparable to the untreated control plots as re-growth had occurred. Complete weed control was achieved by glyphosate, the standard treatment included for comparison, by 21 DAT.

Table 2.8.3. Effect of herbicides (H) and bioherbicides (B) on control of nettles – 2013

Treatment	Type	Nettles – Vigour score 21 DAT (0-10)	Nettles – Vigour score 56 DAT (0-10)
1. Untreated Control	-	10.00	7.75
2. Rosate 36	H	**5.00**	**3.25**
3. SH2012-FVF-109	B	**2.50**	8.00
4. SH2012-FVF-116	B	**0.25**	**5.00**
5. SH2012-FVF-124 + adj	H	**0.00**	7.75
F. pr		<0.001	0.145
d.f		19	19
LSD		1.84	4.53

At 21 DAT bioherbicide 109 and 116 and herbicide124 had reduced the nettle plant vigour significantly (p = <0.001) compared to the untreated controls. However by 56 DAT weed vigour was comparable to the untreated control plots as re-growth had occurred for all three treatments. Incomplete weed control was achieved by glyphosate, the standard treatment

included for comparison, by 21 and 56 DAT, but nettles are notoriously difficult to kill with glyphosate as re-growth can occur rapidly from the base of the plant.

Discussion

- Bioherbicide 109 is very promising for broad-leaved dock control.
- Conventional herbicide 124 was very promising for dock control up to 21 DAT but declined up to 56 DAT.
- Bioherbicide 116 was not adequate for broad-leaved dock control alone.
- All herbicides tested were effective at initially knocking back the nettles up to 21 DAT but the nettles recovered to be comparable to the untreated controls by 56 DAT.
- This trial should be repeated as field, year and external weather conditions may have had an effect on the weed growth and product performance as it was a cold spring in 2013.

3. Protected edibles

3.1 Assessment of the efficacy of fungicides and biofungicides against grey mould on protected tomato

One replicated trial was conducted in 2013 to evaluate the efficacy of 4 conventional fungicides and 5 biofungicides for the control of *Botrytis cinerea* (grey mould) in tomato cv. Elegance, grown on a Maxifort rootstock. The results obtained were compared with untreated controls and the trial protocol was validated by inclusion of a standard fungicide programme (Rovral/Switch/Signum) applied at label recommended rates.

The conventional fungicides and biofungicides were trialled in separate glasshouse sections in order to minimize any negative effects from conventional products on biopesticide products and *vice versa*. Eight applications of biofungicides were made at weekly intervals from 11 July to 29 August (except Prestop which was applied every 3 weeks as advised by the manufacturer) and 6 applications of conventional fungicides were made at two weekly intervals from 18 July to 26 September, commencing at the first sign of primary Botrytis infection.

Table 3.1.1. Detail of fungicides evaluated for control of grey mould on tomato – 2013

Trt No.	SCEPTRE code or product	Rate	Active Ingredient
1	Untreated Check	-	-
2	Rovral WG	67 g/100 L	Iprodione
	Switch	1.0 kg/ha	Cyprodinil + fludioxonil
	Signum	0.9 kg/ha	Pyraclostrobin + boscalid
3	SF2013-TOM-25a	-	-
4	SF2013-TOM-118	-	-
5	SF2013-TOM-31	-	-
6	SF2013-TOM-77	-	-

Table 3.1.2. Details of biofungicides evaluated for control of grey mould on tomato – 2013

Trt No.	SCEPTRE code or product	Rate	Active Ingredient
1	Untreated Check	-	-
2	Prestop	0.5 % w/w	*Gliocladium catenulatum*
3	SF2013-TOM-178	10	
4	SF2013-TOM-132	0.5	
5	SF2013-TOM-105	2.5	
6	SF2013-TOM-40	1	

Results

Table 3.1.3. Effect of fungicides on tomato grey mould – 2013

Treatment	Mean no. leaf lesions/plot 15 Aug	Leaf disease index (0-100) 10 Oct	Stem disease index (0-100) 23 Oct	Mean no. ghost spots/fruit 15 Aug
1. Untreated	30.8a	17.2a	21.2	7.7
2. Standard	**22.0**b	**8.4**b	19.0	6.1
3. SF2013-TOM-25a	**18.3**b	**4.6**c	11.2	7.3
4. SF2013-TOM-118	**10.0**cd	**4.5**c	12.1	6.4
5. SF2013-TOM-31	**14.5**bc	**4.4**c	20.7	5.4
6. SF2013-TOM-77	**6.0**d	**1.4**d	10.3	7.2
Significance	<0.001	<0.001	0.247	0.792
LSD (P = 0.05)	5.59	0.18	1.77	3.78

Sprays applied 18 July to 26 September 2013.

Means followed by the same letter do not differ significantly (P = 0.05).

Table 3.1.4. Effect of biofungicides on tomato grey mould – 2013

Treatment	Mean no. leaf lesions/plot		Mean no. stem lesions/plot	Mean no. fruit with ghost spots/fruit
	4 July	13 Aug	6 Sep	22 Aug
1. Untreated	6.3	52.5	3.0	15.3
2. Prestop	6.5	38.5	4.3	10.8
3. SF2013-TOM-178	7.5	38.0	3.8	13.0
4. SF2013-TOM-132	8.0	43.3	3.3	13.2
5. SF2013-TOM-105	6.8	51.3	5.5	11.8
6. SF2013-TOM-40	7.5	48.3	3.0	13.5
Significance	0.959	0.638	0.551	0.714
LSD (P = 0.05)	4.66	29.93	3.21	6.12

The amount of Botrytis leaf infection was low in both conventional and biofungicide trials when the spray programmes commenced. As the study progressed, infection levels increased in the conventional trial, becoming high in untreated plots towards the end of the trial. In comparison, the level of Botrytis leaf infection in the biofungicide trial developed much more rapidly, becoming extremely high by the end of the trial. Stem lesions in both trials were slow to develop and only occurred at the end of the trial. A number of plants died during the trial period but the majority of these deaths were not clearly attributable to Botrytis infection. Fruit infection symptoms (ghost spot) were also seen in both trials, with levels on some fruits extremely high.

There were significant positive efficacy effects against Botrytis for fungicides 25a, 118, 31 and 77. Fungicide 77 was significantly better than all other treatments.

No significant control of Botrytis was found with any of the biofungicides at any point during the trial. Prestop is already approved for use for control of Botrytis on tomatoes and both this treatment and one experimental product (178) appeared to have slightly lower levels of leaf Botrytis than the untreated control. However, these results were not significantly different in this trial.

Crop yield was not measured, but crop quality was monitored by assessing fruit for ghost spot symptoms caused by Botrytis. No significant differences were found in either trial in these assessments, although fruit from untreated plots in the conventional trial had the highest levels of ghost spot at all assessment timings.

Discussion

Products were first applied as protectant fungicides (i.e. before disease became well established) and as such the trial provided a fair test of the products. Botrytis developed initially as leaf lesions, then as fruit 'ghost spotting', with the anticipated stem lesions not developing until the very end of the trial and, even then, severe girdling lesions were not seen until very late. The presence of ghost spot on the fruit is a reflection of the high relative humidity levels maintained in the glasshouses to induce Botrytis infection.

All conventional treatments, including the standard programme, gave significant levels of control of Botrytis when comparing leaf disease index scores. All test treatments gave better leaf disease control than the standard programme (significant at one assessment timing only) and one fungicide (77) gave significantly better control of Botrytis than all other treatments at many of the assessment timings. Fungicides 25a, 118 and 31 all reduced Botrytis leaf lesion levels relative to levels in untreated plots.

Stem infection did not develop as early or as extensively in the trial as had been hoped and no significant differences were found between stem lesions severity scores at the end of the conventional trial. However, there does appear to be an effect on stem lesion severity as the untreated plots scored high and three of the experimental treatments had much lower stem lesion scores. The lack of significant difference here is likely to be due to high variation between plants in terms of the number of stem lesions seen. At trial termination the layered stem bundles in the best experimental treatment were visibly much cleaner than the untreated control.

No significant differences were found between treatments from ghost spot assessments, although this may be due to high variation amongst the fruit sample - some fruit were found to have more than 100 spots, where most had less than 10. Fruit from untreated plots did have the highest average levels of ghost spot at the end of the trial and fruit from plots treated with fungicide 77 the lowest. As inoculum from leaf lesions in untreated plots was so much higher than in the treated plots, this is perhaps not surprising. It is important to appreciate that as ghost spot is a reaction to germination of Botrytis spores in fruit surface tissues, therefore only products that act as spore germination inhibitors are likely to prevent this symptom when there are moderate - high levels of Botrytis spores are present in the environment.

Control of Botrytis by biofungicides was disappointing and no significant differences were found, even at early assessment timings when disease levels were low. Prestop, approved for use on tomato crops appears to have scored slightly better than the untreated plots in leaf lesion assessments and in fruit ghost spot assessments, but this data is not significant, perhaps due to variation within the plots. Disease levels in the biofungicide trial rose quickly, most probably due to the lack of control given by any of the products on trial and the subsequent increase in inoculum in the glasshouse. Once the disease became established, it was unlikely that any of the treatments could have prevented epidemic development of Botrytis, as they are ideally used as protectant rather than eradicant products.

3.2 Assessment of the efficacy of fungicides and biofungicides against Pythium root and stem base rot of protected cucumber

One replicated trial was conducted in 2013 to evaluate the efficacy of 12 conventional fungicides and 9 biofungicide for control of root and stem rot (*Pythium aphanidermatum*) in cucumber. The results obtained were compared with untreated controls and the trial included one approved product, although this is not necessarily considered a ‘standard’ treatment.

Two applications of each conventional fungicide treatment were made and three applications of each biofungicide treatment. Treatments applied are listed below:

Table 3.2.1. Detail of fungicides and biofungicides examined for control of Pythium root and stem base rot in cucumber, cv. Shakira – 2013

Product/ Sceptre code	Active ingredient(s)	Application timing		
		At sowing	Cotyledon stage	8 days after inoculation
Fungicides				
1. Untreated	-	-	-	-
2. SF2013-CUC-169	-	-	✓	✓
3. SF2013-CUC-44	-	-	✓	✓
4. Previcur Energy	Propamocarb + fosetyl-Al	-	✓	✓
5. SF2013-CUC-139	-	-	✓	✓
6. SF2013-CUC-46	-	-	✓	✓
7. SF2013-CUC-25a	-	-	✓	✓
8. SF2013-CUC-170	-	-	✓	✓
9. SF2013-CUC-145	-	-	✓	✓
10. SF2013-CUC-182	-	-	✓	✓
11. SF2013-CUC-183	-	-	✓	✓
12. SF2013-CUC-181	-	-	✓	✓
13. SF2013-CUC-171	-	-	✓	✓
Biofungicides				
14. SF2013-CUC-47	-	✓	✓	✓
15. SF2013-CUC-38	-	✓	✓	✓
16. SF2013-CUC-98	-	✓	✓	✓
17. SF2013-CUC-43	-	✓	✓	✓
18. SF2013-CUC-40	-	✓	✓	✓
19. SF2013-CUC-121	-	✓	✓	✓
20. SF2013-CUC-105	-	✓	✓	✓
21. SF2013-CUC-188	-	✓	✓	✓
22. SF2013-CUC-189	-	✓	✓	✓

Table 3.2.2. Effect of fungicides and biofungicides on control of Pythium root and stem base rot of cucumber, cv. Shakira, and plant damage – 2013

Product/Sceptre code	Root discolouration (0-3) 9 Oct	Stem base lesion severity (0-3) 9 Oct	Phytotoxicity (20 Sep)	
			% plants affected	Symptoms
Fungicides				
1. Untreated	1.37	1.72	0	
2. SF2013-CUC-169	1.06	**0.33**	0	
3. SF2013-CUC-44	**0.70**	**0.02**	0	
4. Previcur Energy	1.00	0.69	17	Small plants
5. SF2013-CUC-139	**0.08**	**0.00**	**50**	Stunting, Chlorosis
6. SF2013-CUC-46	**0.22**	**0.01**	6	1 plant stunted
7. SF2013-CUC-25a	1.00	1.29	**100**	Stunting, Chlorosis
8. SF2013-CUC-170	1.05	1.64	0	
9. SF2013-CUC-145	1.47	1.37	0	
10. SF2013-CUC-182	**0.89**	1.76	13	1 plant stunted
11. SF2013-CUC-183	**0.00**	**0.00**	25	Leaf mottle
12. SF2013-CUC-181	1.11	1.30	0	
13. SF2013-CUC-171	**0.68**	**0.17**	**83**	Stunting, chlorosis
Biofungicides				
14. SF2013-CUC-47	2.06	2.02	**100**	
15. SF2013-CUC-38	0.94	1.14	0	
16. SF2013-CUC-98	0.96	0.76	0	
17. SF2013-CUC-43	1.18	0.78	0	
18. SF2013-CUC-40	0.98	1.00	0	
19. SF2013-CUC-121	1.67	2.14	0	
20. SF2013-CUC-105	1.40	1.66	**33**	Small plants
21. SF2013-CUC-188	1.73	1.54	0	
22. SF2013-CUC-189	**0.79**	0.44	0	
LSD (P = 0.05)	0.203		31.6	
Probability	<0.001	<0.001	<0.001	

Root and stem rot disease levels were moderate by the end of the trial period. Very few plants had been killed by the infection, but distinct severe stem base lesions were seen and differences in root colour were evident.

Phytotoxic symptoms were observed with a number of the experimental treatments. Fungicides 139, 25a and 171 and biofungicides 47 and 105 all gave significant levels of phytotoxicity, assessed as the percentage of plants per plot that were affected. Symptoms varied between treatments, but stunting and chlorosis were the most predominant symptoms.

There were significant positive efficacy effects against the symptoms of *Pythium* root and stem rot for conventional treatments. Fungicide 183 had no root discolouration and no stem base lesions at the end of the trial, compared to the other treatments which gave significant control of disease, all of which had low levels of one or other symptom.

No significant control of *Pythium* root and stem rot was found with any of the biofungicides although one product (biofungicide 189) appears to have reduced the severity of symptoms, albeit not statistically significantly.

Discussion

In this small-scale screening trial, a large number of products were tested. Determining rates for these products where use as a drench is not an approved method was difficult. Where no specific rate was specified by the manufacturer the application rate was determined based on the reported commercial use of a product at 60 ml per 1000 plants where the label rate for foliar application on cucumbers is 1.0 L/ha.

An isolate of *Pythium aphanidermatum* was sourced via the industry and pathogenicity was confirmed on young cucumber plants before the trial started.

All products (unless otherwise directed by the manufacturer) were drenched onto the rockwool blocks at 10% of the block volume (65 ml). Biofungicides were first applied at sowing and then again at cotyledon stage to allow maximum protectant activity to be established. Conventional fungicides were first drenched onto blocks at cotyledon stage (48 hours before inoculation) to allow protectant activity. All applications were repeated ten days later to allow eradicant activity.

In a commercial crop environment, higher levels of plant wilting and death would be expected given the high inoculum levels present. As plants were contained within trays and only grown for a relatively short period, the amount of wilting and death seems to have been reduced. Plants reached at least 1 metre in height before the final assessments were carried out and the trial terminated. At this point, characteristic stem lesions could be seen and variations in root colour were evident. In the absence of high levels of plant death, these additional indicators of *Pythium* infection were assessed.

The untreated plots in general suffered from poorer root vigour, more root discolouration and increased stem lesion severity compared to effective treatments. Conventional fungicides 169, 44, 139, 46, 183 and 171 appear to have had good efficacy against *Pythium* root rot at the rates tested and will be further tested in larger scale trials in 2014. No significant effects were observed with any biofungicides, although product 189 does appear to have reduced levels of infection and is potentially worth including in future trials. The inert rockwool block growing medium used for commercial propagation of cucumbers in the UK (and used in this trial) may not be a suitable environment for some of the biofungicide products tested here and this may in some part explain the lack of efficacy seen with these products in this trial. Different formulations specifically designed for this, or similar, inert media may be necessary to optimise biofungicide activity and further discussion with manufacturers would be necessary in this regard.

Phytotoxicity caused by certain products was quite severe though where moderate-good efficacy was observed, these products may be included in future trials but at lower rates.

Overall, this screening trial has successfully identified a number of promising products to take forward into larger scale trials in 2014. It has also highlighted the difficulty of determining product rates for use as root drenches where no information regarding this use already exists.

3.3 Assessment of the efficacy of fungicides and biofungicides against black root rot in protected cucumber

Work in progress. This experiment will be reported in next year's Annual Report.

3.4 Assessment of the efficacy of insecticides and bioinsecticides integrated with macrobiologicals against spider mite and whitefly on protected tomato

A glasshouse trial was conducted in 2013 to evaluate the ability of three novel bio-insecticides against spider mites (*Tetranychus urticae*) and whitefly (*Trialeurodes vaporariorum*) on tomato cv. Cheramy. Bio-insecticides are usually applied at frequent intervals when pest levels are low. Previous SCEPTRE trials established that the products used here could work at low pest levels, however their performance against high levels of pests, and thus as a second line of defence to macrobiologicals, has yet to be determined.

Borneo and Chess were included as standard treatments for spider mites and whitefly respectively. Each treatment was applied twice at 7 day intervals followed by introduction twice of the macrobiologicals *Phytoseiulus persimilis* for spider mite and *Encarsia formosa* for whitefly at 11 and 18 days after the second application of treatments.

Table 3.4.1. Details of treatments applied to tomato – 2013

Treatment	Product or Sceptre code	Active ingredient(s)	Rate
1.	Water	-	-
2.	Chess (+ biocontrol)	Pymetrozine	60 g/100L
3.	Borneo (+ biocontrol)	Etoxazole	35 ml/100L
4.	Biocontrol only	*P. persimilis* + *Encarsia formosa*	$20/m^2$ + $10/m^2$
5.	S12013-TOM-130	-	-
6.	S12013-TOM-62	-	-
7.	S12013-TOM-51	-	-

Results and discussion

Spider mites

The results in Fig 3.4.1, show the numbers of spider mites recorded at the final assessment 25 days after the final spray.

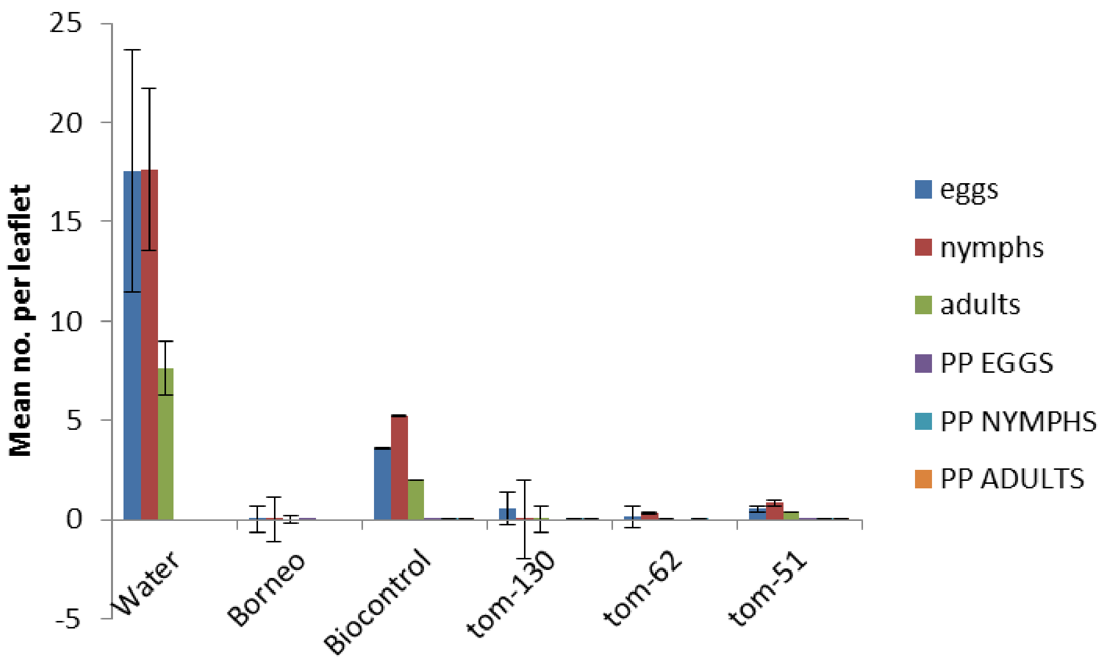

Fig. 3.4.1 Mean number of spider mites (eggs, nymphs and adults) and biocontrol *P. persimilis* (PP eggs, nymphs and adults) recorded following application of bio-

insecticides and a conventional insecticide (Borneo), and the addition of *P. persimilis* to all treatments except water control.

All treatments significantly reduced all stages of spider mites in comparison to the water control.

However the results in Figures 3.4.2 and 3.4.3 demonstrate that there was a general decline in spider mite populations that coincided with the application of sulphur (Microthiol Special) to control powdery mildew, particularly when comparing to pest population in the water control plots. Spider mite populations begin to recover within the control plots two weeks before the end of the trial. It is probable that sulphur had a temporary impact on the spider mite populations. Experimental treatments did reduce the pest levels, the sustained reduction observed after experimental treatment, sulphur application and biocontrol introduction may in part be attributed to predation.

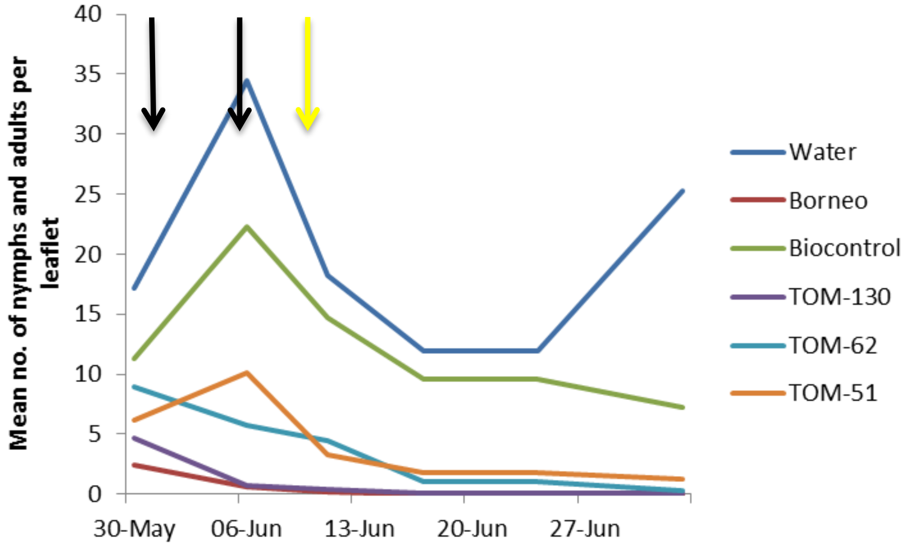

Fig 3.4.2. Mean numbers of nymph plus adult spider mites after two applications of treatments ( ) and biocontrol (*P. persimilis*) introduction (18 and 26 June). Sulphur applied ( ).

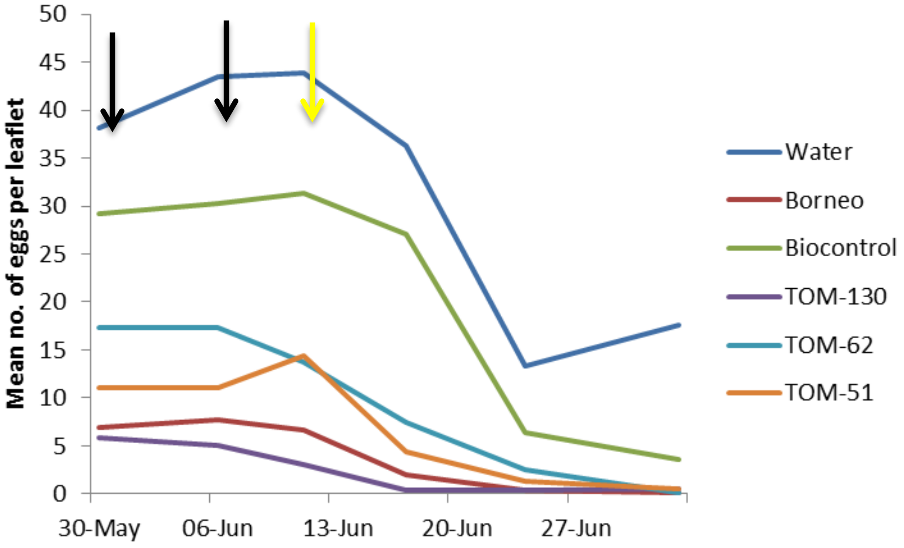

Fig 3.4.3. Mean numbers of spider mites eggs recorded after two applications of treatments (↓) and biocontrol (*P. persimilis*) introduction (18 and 26 June). Sulphur applied (↓).

Whitefly

Results are presented in Figs 3.4.4 - 3.4.6. At the final assessment the numbers of whitefly adults were significantly affected by treatment, with the standard (Chess) and bio-insecticide 51 having significantly lower numbers of adults compared to the control ($p<0.05$). Bio-insecticide also reduced numbers of adults but this was not statistically significant (Fig 3.4.4).

However, assessment of whitefly scales failed to establish a significant difference between treatments ($p>0.05$), including the standard Chess. Fig. 3.4.6 shows numbers of scales were increasing in the control but decreased after the second assessment, corresponding to an emerging population of adults within the trial. The data suggest that the synchronised population of whitefly was having an influence on the numbers of scales and emerging adults, overriding any treatment effects on numbers of scales.

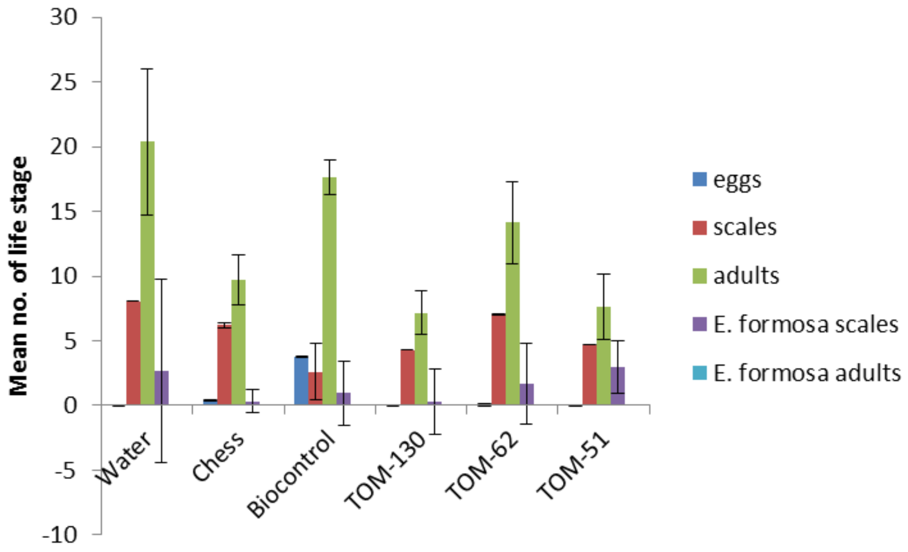

Fig. 3.4.4. Mean number of whitefly (eggs, nymphs and adults) and *E. formosa* (scales and adults) recorded following application of biopesticides and a standard insecticide (Chess) and the addition of *E. fomosa* to all treatments except the water control

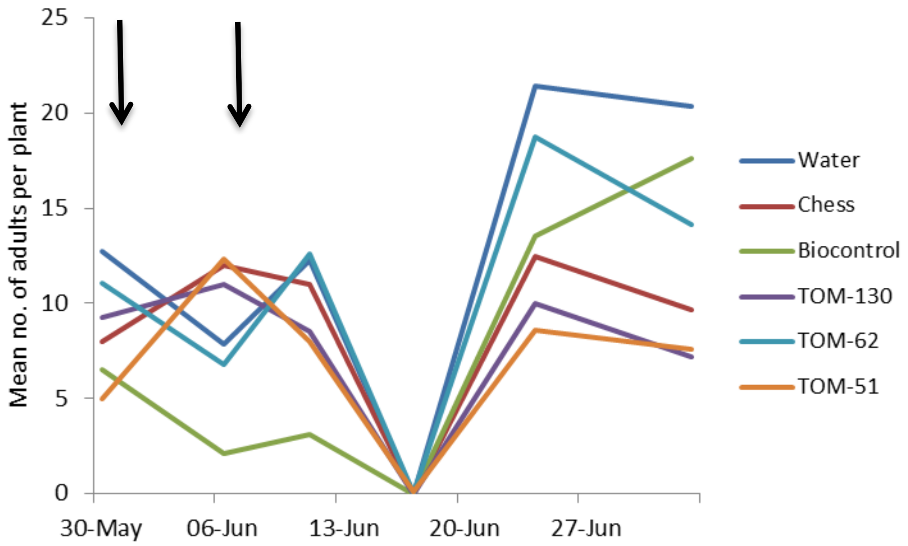

Fig. 3.4.5. Mean numbers of whitefly adults recorded after treatment application ↓ and release of *E. formosa* (18 and 26 June)

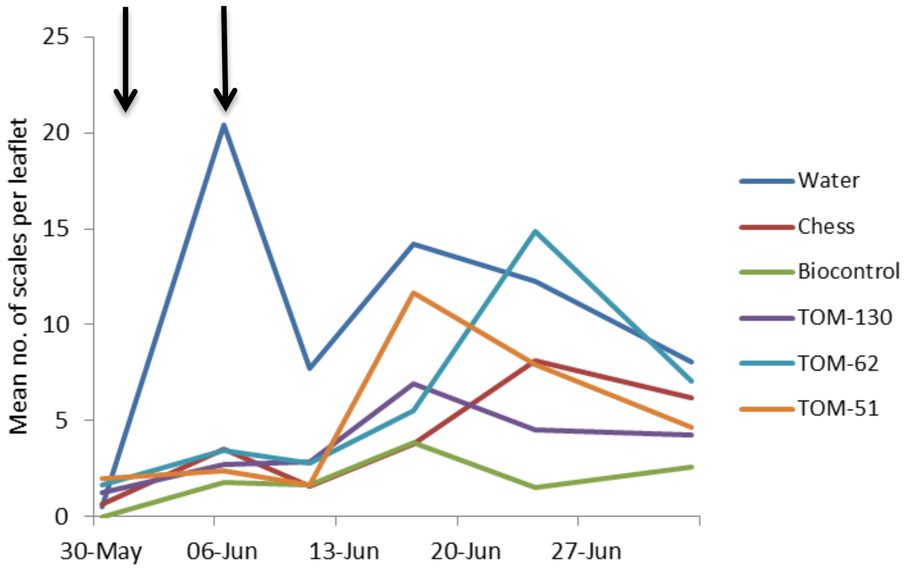

Fig. 3.4.6. Mean no. of whitefly scales recorded through trial after treatment application↓ and release of *E. formosa* (18 June)

3.5(a) Assessment of the efficacy of three bioinsecticides against aphid on protected pepper

A glasshouse trial was conducted in 2013 to evaluate the efficacy of three biopesticides against aphids on pepper, cv. Ferrari. Treatments were compared with the insecticide Pyrethrum 5EC and a water only control. Sprays were applied three times at 7 day intervals from 3 September. The aim of the trial was to screen novel biopesticides against high pest levels of two species of aphid; *Myzus persicae* and *Aulacorthum solani*.

High levels of *M. persicae* (5-15 adults/leaf) were established in plots. Aphids and mummies were recorded on two randomly selected leaves per plant, one day before application and at seven day intervals.

Table 3.5.1. Details of treatments to pepper for control of aphids – 2013

	Product or Sceptre code	Active	Rate
1.	Water		
2.	Pyrethrum 5EC	Pyrethrum	4 ml/l
3.	S12013-PEP-62		
4.	S12013-PEP-130		
5.	S12013-PEP-51		

Results and discussion

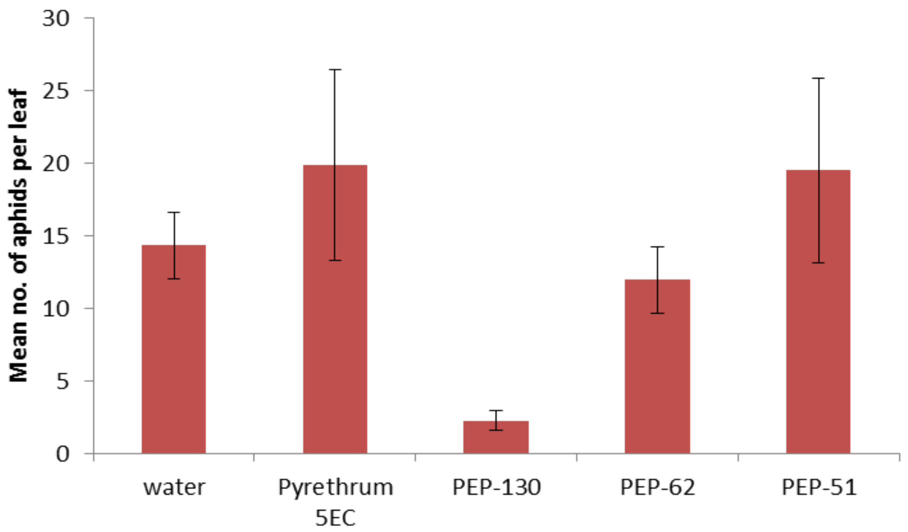

Fig 3.5.1. Mean numbers of *M. persicae* (± SE) per leaf after three applications of treatments

At the final assessment (22 September), bio-insecticide 130 had a significantly lower numbers of aphids compared to all other treatments ($p<0.05$) (Figure 3.5.1). This product was shown to be efficacious after just one application, at the assessment on 9 September (Figure 3.5.2).

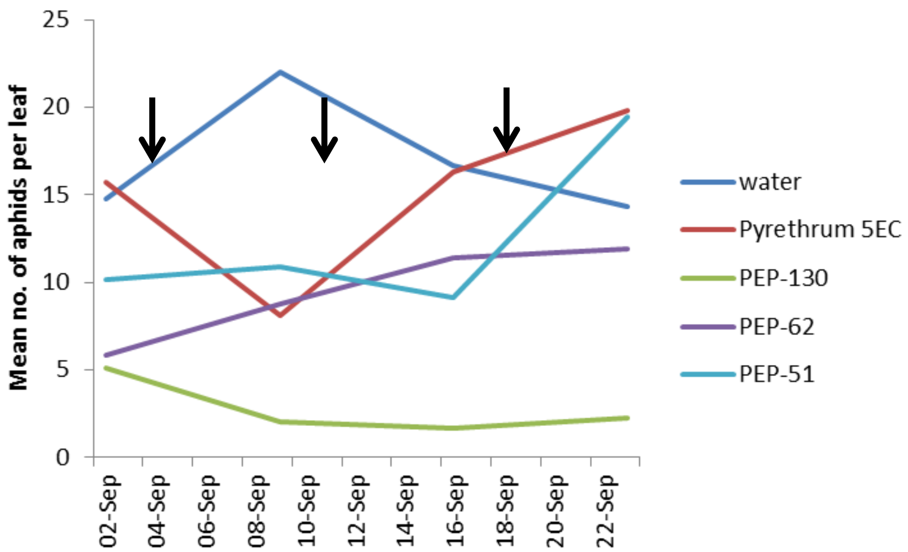

Fig 3.5.2. The mean numbers of aphids after three applications ↓ of bio-insecticide treatments and Pyrethrum.

The numbers of aphids recorded for the standard treatment (Pyrethrum 5EC) during the trial show an initial knockdown by this chemical but then a subsequent increase in the population despite further applications of the product, suggesting possible development of resistance within the aphid population. As a result, in a subsequent aphid/pepper trial (3.5b) the standard product was switched to Chess.

3.5(b) Assessment of the efficacy of a bio-insecticide and insecticide integrated with macrobiologicals against *Myzus persicae* on peppers

A glasshouse trial was conducted in 2013 to evaluate the ability of biopesticide 130 to act as a successful second line of defence against aphids (*Myzus persicae*) on peppers, cv. Ferrari. Treatment was compared with Chess and a water-only control. Each product was applied once, followed one day later by introduction of the parasite *Aphidius colemani*.

Table 3.5.2. Details of treatments applied to pepper for control of aphids – 2013

Treatment no.	Product or Sceptre code	Active	Rate
1.	Water	-	-
2.	Biocontrol	*Aphidius colemani*	$2/m^2$
3.	S12013-PEP-130	-	-
4.	Chess + biocontrol	Pymetrozine	$60g/100L + 2/m^2$

An initial screening of selected products against *M. persicae* on peppers established that bio-insecticide 130 produced a significant reduction in the pest population and this product was therefore taken to the next stage to determine its potential to act as a second line of defence.

Biopesticides are usually applied at frequent intervals when pest levels are low, however the efficacy against high levels of pests, and thus as a second line of defence to macrobiologicals had yet to be determined. In order to reliably replicate the situation where biocontrol agents are failing to regulate the pest populations the following trial established high pest levels in the absence of biocontrol agents.

Results and discussion

Aphid levels at the start of the experiment were 24-48 adults per plant. Biopesticide 130 and Chess (both supplemented with a biocontrol) offered a greater level of aphid control than use of the biocontrol only (Figure 3.5.1).

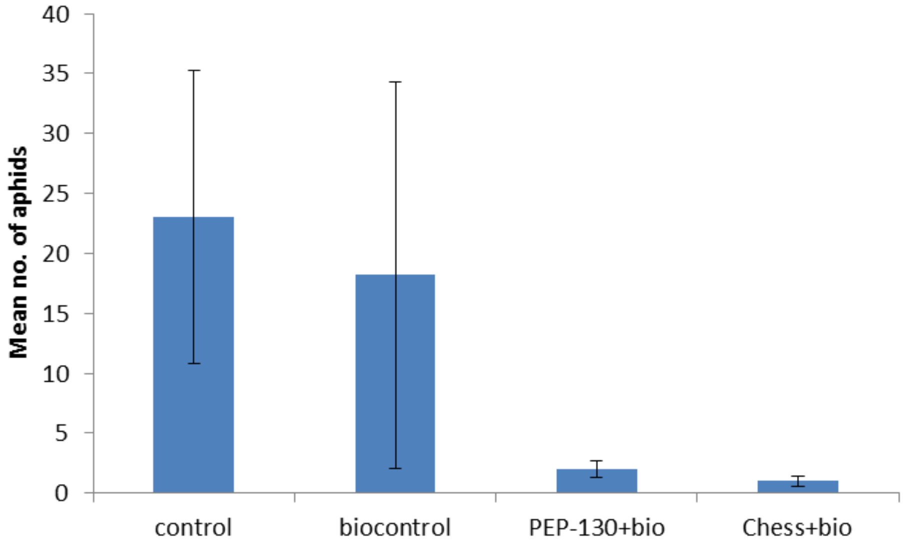

Fig. 3.5.1. Mean numbers of aphids per leaf two weeks after a single application of biopesticide 130 or Chess and introduction of biocontrol agents (*A. colemani*)

The results suggest that biopesticide 130 can provide the same level of aphid reduction within a high population situation, as the standard Chess, and can therefore potentially act as an efficient second line of defence. The biocontrol agent *A. colemani* used on its own against a high population of aphids was ineffective.

4. Top fruit

4.1(a) Assessment of the efficacy of fungicide programmes against powdery mildew on apple

One replicated trial was conducted in 2013 to evaluate the efficacy of fungicide programmes and products for the control of powdery mildew in apple. The results obtained were compared with an untreated control and the trial protocol was validated by inclusion of the standard treatment Systhane 20EW (myclobutanil) applied at recommended rates.

Five applications of each treatment were made at 7-14 day intervals. Products applied are listed below. Programmes applied and application timings are listed in Table 4.1.2.

Table 4.1.1. Detail of fungicides evaluated for control of apple powdery mildew – 2013

Treatment	Product or SCEPTRE code	UK rate of product/ha
1	Untreated	-
2	Systhane 20 EW	330 ml
3	SF2013-APL-32	-
4	SF2013-APL-128	-
5	SF2013-APL-17	-
6	SF2013-APL-25a	-
7	SF2013-APL-87	-
8	SF2013-APL-159	-
9	Cosine	0.5 L
10	Kumulus DF	5 kg
11	SF2013-APL-88	-
12	SF2013-APL-118	-

Table 4.1.2. Programmes evaluated for control of apple powdery mildew on apple trees in 2013

Treatment	Product and application timing				
	1 3 June	2 20 June	3 3 July	4 17 July	5 26 July
1	-	-	-	-	-
2	Systhane	Systhane	Systhane	Systhane	Systhane
3-P1	32	32	Cosine	87	32
4-P2	17	17	Cosine	87	17
5-P3	25a	25a	Cosine	87	25a
6-P4	128	128	Cosine	87	128
7-P5	32	32	159	159	32
8-P6	32	32	Kumulus DF	Kumulus DF	32
9	88	88	88	88	88
10	118	118	118	118	118

Results

Mean % mildewed leaves (mean of 7 assessments), mean russet score on fruit and mean % fruit drop (angular transformed) recorded on apple cv. Cox following five sprays of various treatments applied to apple trees post-blossom in 2013 are shown in Table 4.1.3.

Table 4.1.3. Effect of fungicide programmes on apple powdery mildew – 2013

Treatment	Overall mean % mildewed leaves	Mean russet score*	Mean % fruit drop
1. Untreated	82.4	119.5	42.9 (46.3)
2. Systhane 20EW (x 5)	**62.0**	110.8	34.1 (31.4)
3. P1: 32, 32, Cos, 87, 32	**37.0**	105.5	40.6 (42.3)
4. P2: 17, 17, Cos, 87, 17	**46.4**	133.3	35.6 (33.9)
5. P3: 25a, 25a, Cos, 87, 25a	**41.2**	127.0	38.2 (38.3)
6. P4: 128, 128, Cos, 87, 128	**44.1**	115.5	31.1 (26.7)
7. P5: 32, 32, 159, 159, 32	**30.1**	119.5	44.4 (49.0)
8. P6: 32, 32, Kum, Kum, 32	**41.5**	117.0	38.8 (39.2)
9. 88 (x 5)	**32.5**	112.5	35.2 (33.3)
10. 118 (x 5)	**32.1**	112.2	40.8 (42.8)
F Prob	<0.001	0.541	0.650
SED (27)	3.164	12.114	6.743
LSD (p=0.05)	6.491	24.855	13.836

*Russet score 0-4 where 0= no russet, 4= rough russet with cracking

- The incidence of powdery mildew in the orchard was high
- There were significant efficacy effects for all treatments compared to the untreated control at all assessment dates. Treatments 3-10 also had significantly less mildew overall compared to Systhane 20EW the standard treatment. The least mildew was recorded on plots treated with programme P5 or fungicide 88 or 118.

Discussion

Weather conditions during the trial were conducive to the development of powdery mildew on apple. The incidence of the powdery mildew was higher than normal. First treatments were applied soon after blossom at the start of the extension growth and the secondary mildew epidemic. Because of the high incidence of primary mildew on blossoms and shoots, powdery mildew was already established on the extension growth. Secondary mildew in untreated plots rapidly increased such that for most of the assessments 100% of the leaves were infected. Only limited control of mildew was achieved by the standard product Systhane 20EW. This is mostly likely due to the presence of mildew with reduced sensitivity to Systhane (and hence DMI fungicides) in the orchard. All treatments significantly reduced the incidence of powdery mildew compared to the untreated control at all assessment dates. Treatments 3-10 all significantly reduced the incidence of mildew compared to the standard treatment Systhane. The least mildew was recorded on plots treated with programme P5 or full programmes of fungicide 88 or 118. There was no effect of treatments on fruit quality, or fruit drop. Full season programmes (10-15 sprays) of the products will be evaluated in 2014.

4.1(b) Assessment of the efficacy of biofungicide programmes against powdery mildew on apple

One replicated trial was conducted in 2013 to evaluate the efficacy of several biofungicides applied alone or in programmes for the control of powdery mildew in apple. The results obtained were compared with untreated controls and the trial protocol was validated by inclusion of the standard treatment Systhane 20 EW (myclobutanil) applied at recommended rates.

Five spray applications were made for each programme. Products used in the programmes are listed below:

Programmes applied and application timing are in the following table

Table 4.1.4. Detail of biofungicides and fungicides evaluated for control of apple powdery mildew – 2013

Treatment		'roduct or SCEPTRE code	Rate of product /ha
1		Untreated	-
2		Water	-
3	F	Systhane 20 EW	330 ml
4	B	SF2013-APL105	-
5	B	SF2013-APL146	-
6	F	SF2013-APL160	-
7	B	SF2013-APL06	-
8	B	SF2013-APL157	-
9	B	SF2013-APL90	-
10	F	SF2013-APL32	-

B – biofungicide; F – conventional fungicide.

Table 4.1.5. Programmes of biofungicides evaluated for control of apple powdery mildew on potted apple trees in 2013

Treatment		Product / application timing				
		1 18 July	2 25 July	3 1 August	4 8 August	5 15 August
1.	-	-	-	-	-	-
2.	-	Water	Water	Water	Water	Water
3.	F	Systhane 20EW	Systhane	Systhane	Systhane	Systhane
4.	F	Kumulus DF	Potassium bicarbonate	Kumulus DF	Potassium bicarbonate	Kumulus DF
5.	F	Kumulus DF	Kumulus DF	Kumulus DF	Kumulus DF	Kumulus DF
6.	B	90	90	90	90	90
7.	B	06 + Silwet	06 + Silwet	06 + Silwet	06 + Silwet	06 + Silwet
8.	B	06	06	06	06	06
9.	B	105	105	105	105	105
10.	F and B	32	32	105	105	105
11.	B	06	105	06	105	06
12.	B	157 + Silwet	157 + Silwet	157 + Silwet	157 + Silwet	157 + Silwet

B – biofungicide; F – conventional fungicide.

Results

Table 4.1.6. Mean % mildewed leaves (angular transformed) recorded on apple cv. MM106 rootstock following five sprays of various biofungicide treatments and programmes at East Malling Research in 2013. Figures in parenthesis are back-transformed means

Treatment	Product	Mean % mildewed leaves 23 July	Mean % mildewed leaves 2 August	Mean % mildewed leaves 9 August	Mean % mildewed leaves 16 August	Mean % mildewed leaves 28 August	Overall mean % mildewed leaves
1	Untreated Check	39.4 (40.2)	50.5 (59.6)	62.1 (78.1)	56.6 (69.6)	54.3 (65.9)	52.6
2	Water	49.3 (57.4)	55.7 (68.2)	55.6 (68.0)	55.0 (67.2)	51.8 (61.7)	53.5
3	Systhane 20EW	33.8 (31.0)	**25.9** (19.1)	**22.5** (14.6)	**27.9** (21.8)	**21.1** (12.9)	**26.2**
4	Kumulus DF / Potassium bicarbonate	**31.3** (27.0)	**25.7** (18.7)	**33.9** (31.1)	**30.0** (25.1)	**38.4** (38.6)	**31.9**
5	Kumulus DF	**27.6** (21.5)	**26.0** (19.2)	**24.0** (16.6)	**21.6** (13.5)	**29.6** (24.4)	**25.8**
6	SF2013-APL-90	**27.2** (20.9)	**27.5** (21.3)	**25.9** (19.1)	**26.0** (19.2)	**38.7** (39.1)	**29.1**
7	SF2013-APL-06 + Silwet	33.4 (30.3)	**27.7** (21.7)	**28.1** (22.2)	**32.4** (28.7)	**42.2** (45.0)	**32.8**
8	SF2013-APL-06	35.7 (34.1)	**34.7** (32.5)	**42.3** (45.3)	**38.4** (38.6)	**32.8** (29.3)	**36.8**
9	SF2013-APL-105	34.7 (32.2)	**33.3** (30.2)	**28.3** (22.5)	**35.4** (33.6)	**27.7** (21.6)	**31.9**
10	SF2013-APL-32 / SF2013-APL-105	**25.7** (18.8)	**11.9** (4.2)	**16.3** (7.8)	**28.7** (23.0)	**32.6** (29.1)	**23.0**
11	SF2013-APL-06 / SF2013-APL-105	33.7 (30.7)	**32.5** (28.9)	**37.1** (36.4)	**36.0** (34.5)	**33.0** (29.7)	**34.5**
12	SF2013-APL-157 + Silwet	**22.9** (15.2)	**24.3** (16.9)	**32.2** (28.4)	**35.5** (33.7)	**41.9** (44.6)	**31.4**
F Prob		0.002	<0.001	<0.001	<0.001	<0.001	<0.001
SED (55)		5.57	4.087	3.626	4.326	4.012	2.724
LSD (p=0.05)		11.16	8.190	7.266	8.669	8.041	5.459

- The incidence of powdery mildew was moderate to high
- All treatments/programmes significantly reduced the incidence of powdery mildewed leaves compared to the untreated control. The least powdery mildew was recorded on trees treated with Systhane 20EW, Kumulus DF, biofungicide 90 and a programme based on fungicide 32 and biofungicide 105 (T10).

Discussion def

All treatments consistently reduced the incidence of powdery mildew on the potted trees. The most effective treatments were those with conventional fungicides (Systhane 20EW or Kumulus DF) or based on a programme of a fungicide (32) and biofungicide (105). As a number of the treatments were based on programmes there was a significant interaction of treatments with time. So for treatment 10 the incidence of mildew drops to <10% mildewed leaves by the third assessment following the first two treatments with a conventional fungicide but then increases to almost 30% by the final assessment at the end of August following the switch in the programme to the biofungicide. Kumulus DF applied alone as 5 sprays gave significantly better control of mildew than alternating Kumulus DF with potassium bicarbonate. There was also no improvement in control of mildew by the addition of a wetter (Silwet) to biofungicide 06. Alternating two biofungicides (06 and 105) did not improve control of powdery mildew compared to full programmes of the individual products. Although the biofungicides applied alone as full programmes significantly reduced the incidence of mildew compared to the untreated, the actual control of mildew achieved was still not good enough for these products to be used alone to give effective control in the orchard. Better results were obtained where the biofungicides were used as part of a programme with conventional fungicides. In 2014 the biofungicides evaluated here will be evaluated in programmes with conventional fungicides in a small plot orchard trial.

4.2 Assessment of the efficacy of biofungicide dips against Botrytis rot in cold-stored pears

One replicated trial was conducted in 2012-2013 to evaluate the efficacy of biofungicides for the control of *Botrytis cinerea* in stored pears cv. Conference. The results obtained were compared with untreated controls and the trial protocol was validated by inclusion of the standard treatment (Rovral WG) applied at the recommended rate.

One application of each treatment was made, applied as a dip treatment to crates of pears inoculated with *Botrytis cinerea*. After dipping the crates were allowed to drain and then placed in cold store at -1^{o}C until March 2013. Treatments applied are listed below:

Table 4.2.1. Details of treatment applied to crates of pear fruits in autumn 2012 prior to storage

Product or Sceptre code	Rate of use (product/L)	Active ingredient
1. Untreated	-	-
2. Untreated (uninoculated)	-	-
3. Rovral WG	1.3 g	iprodione
4. SF2012-PER-38	Low	-
5. SF2012-PER-38	High	-
6. SF2012-PER-99	Low	-
7. SF2012-PER-90	High	-
8. SF2012-PER-06	-	-
9. Nexy 1 + additive	0.33 g + 2.0 g	*Candida oleophilia* strain 0

Results

Table 4.2.2. Effect of pre-storage dip treatments on Botrytis rot in pear, cv. Conference – March 2013

Treatment	% *Botrytis* rot
1. Untreated	49.9 (58.5)
2. Untreated, uninoculated	9.9 (2.9)
3. Rovral WG	**13.1** (5.1)
4. SF2012-PER-38	42.8 (46.1)
5. SF2012-PER-38	**39.1** (39.8)
6. SF2012-PER-99	46.3 (52.3)
7. SF2012-PER-99	40.2 (41.7)
8. SF2012-PER-06	54.4 (66.2)
9 Nexy 1	46.2 (52.1)
F Prob	<0.001
SED (27 df)	5.28
LSD (p=0.05)	10.84

Figures in brackets are back-transformed means.

- The spread of *B. cinerea* from the inoculated fruit to the healthy fruit in store was good with more than 50 % of fruit infected in the untreated. However the inoculum spread did vary with 43-74 botrytis-rotted fruit in untreated crates of pears

- There were significant efficacy effects for treatments 3 (Rovral WG) and treatment 5 (SF2012-PER-38 at the higher rate)
-

Discussion

Only one of the biofungicides tested significantly reduced the *Botrytis* spread in cold-stored pears. Unfortunately the botrytis spread in the untreated was variable with two replicates at 43-46 % rotted pears and two replicates at 70-74% rotted pears. This variability obviously affected the statistical significance of the treatment effects. Treatment 7 (biofungicide 99 at the higher rate) was almost significant. As both biofungicides 38 and 99 gave better control at the higher rate it seems likely that there is scope for evaluating these products at higher doses although this could make their use very expensive. None of the products was as effective as the standard Rovral WG fungicide. Treatment 9 (Nexy 1) did not give as good control as in previous trials. Reasons for this are not clear but could be related to the way in which the trial was done. Normally pears would be treated with post-harvest treatments soon after picking when the fruit is still warm. Bins would then be put in store after drainage but there would be a short period when the biofungicide could begin action on the warm fruit. In this trial, pears were obtained from an outside farm and were cold-stored prior to use and hence were cold. Applying the biofungicides to the cold fruit may have limited their ability to act. Further work should be done to look at the effect of treating cold fruit on efficacy and also to examine efficacy at higher rates.

Technology transfer (1 October 2012 – 30 September 2013)

Articles

Atwood J (2013). Sceptre: progress in soft fruit. *HDC News* **191** pp.28-30.

Atwood R (2013). *HDC Field Vegetables Review 2013*, p 13.

Berrie A (2012). Sceptre targets tree fruit diseases. *HDC News* **186***,* p. 23.

Berrie A (2013). Mildew mitigation. *HDC News* **195**, 24-25.

Collier R & Gladders P (2013). SCEPTRE: progress in field vegetables. *HDC News* **193**, 19-21.

Croft P, Wright K & McPherson M (2013). SCEPTRE: progress in protected edibles. *HDC News* **194**, 28-30.

Knott, C (2013). Emerging weed controls, results from 2012 SCEPTRE trials. *HDC News* **189,** pp. 19-20

O'Neill TM (2013). Biopesticides that make the grade. *HDC News* **196**, 24-26.

Raffle S (2012). Controls for the next generation. *HDC Soft Fruit Review 2012*, p. 5

Raffle S (2012). New generation of active ingredients for tree fruit. *HDC Tree Fruit Review 2012*, p. 8

Richardson A (2013). Controlling weeds using electricity – the shocking truth! Brassica Growers Association Newsletter (March).

Tatnell LV, Atwood J, Sparkes JL, Richardson A & Jackson S (2013).The potential for electrical weed control in a range of horticultural crops. 16th European Weed Research Society Symposium, Samsun, Turkey, 24-27 June 2013, p 149 (abstract).

Presentations

Berrie A (2012). Evaluation of products for control of crown rot in strawberry, HDC/EMR Soft Fruit day, 21 November 2012.

Birch N (2013). Management of aphids on raspberry, Fruit for the Future, James Hutton Institute, Dundee, 18 July 2013.

Collier R (2013). IPM in outdoor lettuce: filling the gaps?!, AAB Conference - Advances in Biological Control and IPM, 16-17 October 2013.

McPherson M (2012). Sceptre – Control of powdery mildew, Cucumber Conference, 3 October 2012.

O'Neill T M (2013). New technologies for disease control, HDC / TGA Tomato Conference, 26 September 2013.

O'Neill T M (2013). Sceptre – filling crop protection gaps, BPOA meeting, 6 February 2013.

O'Neill T M (2012). Sceptre – An introduction to work on protected edible crops, 3 October 2012, Cucumber Conference.

Powell V (2012). Giving growers access to tested biocontrol tools through a Member State Programme – SCEPTRE, Annual Biocontrol Industry Meeting, Lucerne, Switzerland, 23 October 2012.

Tatnell L (2013). The potential for electrical weed control in a range of horticultural crops. 16th European Weed Research Society Symposium, Samsun, Turkey, 24-27 June 2013.

Tatnell L (2012). Evaluating Bioherbicides: current research, BCPC Weed Review, 24 October 2012.

Events

Field vegetable disease and weed control. ADAS Boxworth Open Day, 5 June 2013 (Lynn Tatnell, Jessica Sparkes, Angela Huckle, Sarah Mayne, Tim O'Neill)

Vegetable weed control Open Day, Elsoms Seeds Trial Ground, Spalding, 27 June 2013. (Cathy Knott, Andy Richardson, John Atwood, Angela Huckle).

Warwick Crop Centre Open afternoon, 18 September 2013 (Rosemary Collier)

Posters

Developing an IPM strategy for pests of lettuce, 14 November 2012, BLSA Conference (Rosemary Collier)

New fungicides and biofungicides for control of powdery mildew (*Erysiphe cruciferarum)* in Brassicas (Swede) (Sarah Mayne, Angela Huckle, Peter Gladders and Tim O'Neill).

New fungicides and biofungicides for control of ring spot (*Mycosphaerella brassicicola*) in Brassicas (spring greens) (Tim Boor, Angela Huckle, Peter Gladders and Tim O'Neill).

Website

sceptre.hdc.org.uk

Appendix 1 Crop protection targets (revised February 2014)

Summary of completed (Years 1 - 3) and planned work on disease targets

Year	Item	Disease type	FV	PE	SF	TF
1	1	Powdery mildew	-	Cucumber	-	Apple
	2	Downy mildew	Brassica	-	-	-
	3	Leaf/cane spots	Brassica (Alternaria)	-		-
	4	Botrytis	-	Tomato	-	Pear
	5	Fusarium wilts	Lit Review	-	-	-
	6	Pythium/ Phytophthora	-	-	-	-
	7	Other	-	-	Mucor/Rhizopus	-
2	1	Powdery mildew	Brassica	Cucumber	-	Apple
	2	Rust	Leek	-	-	-
	3	Leaf/cane spots	Brassica (Ring spot + Alternaria)	-	Raspberry cane	-
	4	Botrytis	-	Tomato	-	Pear
	5	Pythium/ Phytophthora	-	-	Strawberry crown rot	-
	6	Other	-	-	Mucor/Rhizopus	-
3	1	Powdery mildew	Brassica	-	-	Apple
	2	Rust	Leek	-		
	3	Downy mildew	Onion	-	-	-
	4	Leaf/cane spots	Brassica (Ring spot)	-	Raspberry cane	-
	5	Botrytis	-	Tomato	-	Pear
	6	Pythium/ Phytophthora	-	Cucumber	Strawberry crown rot	-
	7	Other	-	Cucumber Phomopsis	Mucor/Rhizopus	-
4	1	Powdery mildew	Brassica		Strawberry	Apple
	2	Downy mildew	Onion	-	-	-
	3	Leaf/cane spots	Brassica	-	Raspberry cane	-
	4	Rust	Leek	-	-	-
	5	Pythium/ Phytophthora	-	Cucumber	Strawberry crown rot	-
	6	Other	-	Phomopsis	-	-

Summary of planned work on pest targets

Year	Item	Pest type	FV	PE	SF
1	1	Aphid	B/L/C	-	Raspberry
	2	Cabbage root fly	Brassica	-	-
	3	Moth/butterfly caterpillar	Brassica	-	-
	4	Spider mite	-	Tomato	-
	5	Thrips	Allium	Pepper	-
	6	Capsid	-	-	Strawberry
	7	Whitefly	Brassica	Tomato	
2	1	Aphid	Lettuce	-	Raspberry
	2	Cabbage root fly	Brassica	-	-
	3	Moth/butterfly caterpillar	Lettuce		-
	4	Spider mites	-	Tomato	-
	5	Thrips	Allium	Pepper	-
	6	Capsid	-		Strawberry
	7	Whitefly	-	Tomato	
	8	IPM	Brassica	-	-
3	1	Aphid	Lettuce	-	Raspberry (IPM)
	2	Cabbage root fly	Brassica (part of 7; IPM)	-	-
	3	Moth/butterfly caterpillar	Lettuce	-	-
	4	Spider mites	-	-	-
	5	Thrips	Allium	-	-
	6	Capsid	-	-	Strawberry
	7	IPM	Brassica	Tomato/ pepper	-
4	1	Aphid	Lettuce	Pepper	Raspberry
	2	Moth/butterfly caterpillar	Lettuce	-	-
	3	Thrips	Allium	Pepper	-
	4	Capsid	-	-	Strawberry
	5	IPM	Brassica	-	-

L - lettuce; C - carrot; B - Brassica.

Summary of planned work on weeds targets

Year	Item	Work area	FV	SF
1	1	Residue studies	Several crops	-
	2	Annual broad leaf weeds	Many crops	Strawberry
	3	Perennial weeds	-	Bush & cane fruit
	4	Alleyways/runners	-	-
	5	Band spraying	-	-
	6	Non-herbicide methods	-	Test rig for electric weed control
2	1	Residue studies	-	-
	2	Annual broad leaf weeds	Many crops	Strawberry
	3	Perennial weeds	-	Bush & cane fruit
	4	Alleyways/runners	-	Strawberry
	5	Band spraying	Vegetables	-
	6	Non-herbicide methods	Several	Electric weed control
3	1	Residue studies	-	-
	2	Annual broad leaf weeds	Many crops	-
	3	Perennial weeds	-	Bush & cane fruit
	4	Alleyways/runners	-	-
	5	Band spraying	Vegetables	-
	6	Non-herbicide methods	Several	-
4	1	Residue studies	-	-
	2	Annual broad leaf weeds	Not yet known	Strawberry
	3	Perennial weeds	-	-
	4	Alleyways/runners	-	Strawberry
	5	Band spraying	Vegetables	-
	6	Non-herbicide methods	Several	Electric weed control