| | |
|---|---|
| **Project title:** | Sustainable Crop and Environment Protection – Target Research for Edibles (SCEPTRE) |
| **Project number:** | CP 77 |
| **HortLINK project:** | HL01109 |
| **Government sponsor:** | Defra |
| **Project chairman:** | Mrs Harriet Duncalfe, H&H Duncalfe Ltd |
| **Project co-ordinator:** | Dr Tim O'Neill, ADAS |
| **Annual report:** | Year 4, January 2015 |
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| **Collaborators:** | BASF<br>Bayer CropScience Ltd<br>Belchim Crop Protection Ltd<br>Berry Garden Growers Ltd<br>BerryWorld Ltd |

Dow AgroSciences Ltd
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Fresh Produce Consortium
H&H Duncalfe Ltd
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Koppert UK Ltd
Marks & Spencer plc
Stewarts of Tayside
Syngenta Crop Protection Ltd
Total World Fresh Ltd

| | |
|---|---|
| **Project Consultants:** | Dr Roma Gwynn, Biorationale<br>Mrs Vivian Powell, HDC |
| **Industry representatives:** | Ms Harriet Duncalfe, H&H Duncalfe Ltd, Wisbech, Cambs<br>Mr John Sedgwick, Agrimarc Ltd, March, Cambs<br>Mr Gary Taylor, Valley Grown Nursery, Nazeing, Essex |
| **Date project commenced:** | 1 October 2010 |
| **Expected completion date:** | 31 March 2015 |
| **Key words:** | biopesticides, conventional pesticides, crop protection, field vegetables, protected edible crops, soft fruit, top fruit, integrated disease management (IPM), alternative weed control strategies |

Intellectual Property Rights are invested in ADAS UK Ltd on behalf of the consortium members for LINK project number HL01109. The following are members of the Consortium for LINK project HL01109:

ADAS UK Ltd

Allium and Brassica Centre

BASF

Bayer CropScience Ltd

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Berry Garden Growers Ltd

BerryWorld Ltd

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Koppert UK Ltd

Marks & Spencer plc

Rationale Biopesticide Strategists

Stewarts of Tayside

Stockbridge Technology Centre

Syngenta Crop Protection Ltd

Total World Fresh Ltd

University of Warwick

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.

## *GROWER SUMMARY*

### Headline

- Potential new pesticide and/or biopesticide products have been identified to fill many of the crop protection gaps on edible crops arising from changing legislation.

### 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 on 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;
- assessment of pesticides to determine if they are endocrine disruptors;
- 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.
- establishment of a list of active substances within certain properties as candidates for substitution (the current draft list contains 77 candidates), as required under Regulation (EC) No. 1107/2009.

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 (except for bioherbicides);
- potential to reduce number of conventional pesticide applications in a programme through targeted use of biopesticides;
- 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 aimed 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, were evaluated.

A broad Consortium was 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 comprised three teams (diseases, pests and weeds) working across the major organizations currently delivering applied crop protection research in the UK.

## Summary

In Year 4, 48 conventional plant protection products based on chemical pesticides, 17 based on microorganisms, 8 based on botanical extracts and 1 other were screened against disease, pest and weed problems identified as high priority targets on edible crops. Thirty-four experiments were completed on 30 pests (Tables 1-3).

The numbers and types of products tested in each experiment are shown (Table 2) and the broad results are listed (Table 3). Novel products with good potential to fill crop protection gaps have been identified in all crop sectors (Tables 4-6). A summary of each experiment is given.

**Table 1.** Overview of experiments completed in 2014

| 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 | | |
| Cane diseases | | ✓ | | | |
| Crown rot | ✓ | | | | |
| Powdery mildew | ✓ | | | | |
| Aphid | | ✓ | | | |
| Capsid (Lygus) | ✓ | | | | |
| Runners | ✓ | | | | |
| Annual weeds | ✓ | | | | |
| Perennial weeds | | | ✓ | | |
| **Protected edibles** | Cucumber | Tomato | Pepper | | |
| Phomopsis | ✓ | | | | |
| Pythium | ✓ | | | | |
| WFT | | | ✓ | | |
| Aphid | | | ✓ | | |
| **Top fruit** | Apple | Pear | | | |
| Powdery mildew | ✓ | | | | |
| Botrytis | | ✓ | | | |

* broad beans, carrots, cauliflowers, celeriac, celery, coriander, courgette, drilled bulb onion, dwarf French bean, flat leaf parsley, leek, lettuce, mizuna, parsnip, rocket, spinach, swede.

**Table 2.** Overview of experiments in 2014 showing numbers and types of products tested individually

| Trial | Crop | Target | Novel products tested | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | micro-org | Botanical | Salt/ other | Tota l bio | Chemical | TOTAL products |
| 1.1 | Brassica | Powdery mildew | 0 | 0 | 0 | 0 | 5 | 5 |
| 1.2 | Brassica | Ring spot | 1 | 1 | 0 | 2 | 2 | 4 |
| 1.3 | Leek | Rust | 0 | 1 | 0 | 1 | 5 | 6 |
| 1.4 | Spring onion | Downy mildew | 0 | 0 | 0 | 0 | 5 | 5 |
| 1.5 | Leek | Onion thrips/Moth | 1 | 2 | 0 | 6 | 6 | 10 |
| 1.6 | Lettuce | Aphid | 1 | 2 | 0 | 3 | 3 | 6 |
| 1.6 | Lettuce | Caterpillar | NT | NT | NT | NT | NT | NT |
| 1.7a | Brassica (sprouts) | Aphids, caterpillar | 0 | 5 | 0 | 5 | 6 | 11 |
| 1.7b | Brassica (sprouts) | CRF | 2 | 1 | 0 | 3 | 4 | 7 |
| 1.8 | Courgette | Annual weeds | 0 | 0 | 0 | 0 | 5 | 5 |
| 1.9 | Umbellifers | Annual weeds | 0 | 0 | 0 | 0 | 3 | 3 |
| 1.10 | Field Vegetables | Annual weeds | 0 | 0 | 0 | 0 | 1 | 1 |
| 1.11 | Alliums | Annual weeds | 0 | 0 | 0 | 0 | 3 | 3 |
| 1.12a | Cauliflower | Electric weed control | N/A | N/A | N/A | N/A | N/A | N/A |
| 1.12b | Leek | Electric weed control | N/A | N/A | N/A | N/A | N/A | N/A |
| 2.1 | Raspberry | Cane diseases[b] | 4 | 1 | 0 | 5 | 6 | 11 |
| 2.2 | Strawberry | Crown rot | 2 | 0 | 0 | 0 | 3 | 5 |
| 2.3 | Strawberry | Powdery mildew (C) | - | - | - | - | 10 | 10 |
| 2.4 | Strawberry | Powdery mildew (B) | 6 | 4 | - | - | - | 10 |
| 2.5 | Raspberry | Aphid | 0 | 2 | 0 | 0 | 2 | 4 |
| 2.6 | Strawberry | Capsid (Lygus) | 0 | 0 | 0 | 0 | 2 | 2 |
| 2.7 | Strawberry | Herbicide crop safety | 0 | 0 | 0 | 0 | 1 | 1 |
| 2.8 | Strawberry | Runner control | 0 | 1 | 0 | 1 | 1 | 2 |
| 2.9 | Blackcurrant | Electric weed control | N/A | N/A | N/A | N/A | N/A | N/A |
| 3.1a | Cucumber | Phomopsis | 7 | 1 | 0 | 8 | 12 | 20 |
| 3.1b | Cucumber | Phomopsis | 2 | 0 | 0 | 2 | 8 | 10 |
| 3.2 | Cucumber | Pythium | 2 | 0 | 0 | 2 | 7 | 9 |
| 3.3 | Pepper | Aphid | 1 | 3 | 0 | 4 | 0 | 4 |
| 3.4 | Pepper | WFT | 1 | 2 | 0 | 3 | 1 | 4 |
| 4.1 | Apple | Powdery mildew – IPM | NA | NA | NA | NA | NA | NA |
| 4.2 | Apple | Powdery mildew - IPM | NA | NA | NA | NA | NA | NA |
| 4.3 | Pear | Botrytis (2013/14) | 6 | 0 | 0 | 6 | 0 | 6 |
| | Annual unique products for FV[c] | | 9 | 4 | 0 | 13 | 29 | 42 |
| | Annual unique products for PE | | 5 | 2 | 0 | 7 | 13 | 20 |
| | Annual unique products for SF | | 7 | 8 | 0 | 15 | 23 | 38 |
| | Annual unique products for TF | | 2 | 2 | 1 | 5 | 7 | 12 |
| | Annual unique products – herbicides | | 0 | 2 | 0 | 2 | 7 | 9 |
| | Annual unique products – fungicides | | 9 | 4 | 1 | 14 | 31 | 45 |
| | Annual unique products – insecticides | | 8 | 2 | 0 | 10 | 10 | 20 |
| | **TOTAL UNIQUE PRODUCTS Y4** | | 17 | 8 | 1 | 26 | 48 | 74 |

[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] – 2014

| Topic | | Number products demonstrating control* | | | Pest level on untreated |
|---|---|---|---|---|---|
| | | Pesticides | Bio-pesticides | Other method | |
| Field vegetables | | | | | |
| 1.1 | Brassica: Powdery mildew | 5 | NT | NT | Severe |
| 1.2 | Brassica: Ring spot | 2 | 2 | NT | Low/Mod |
| 1.3 | Leek: Rust | 5 | 1 | NT | Moderate |
| 1.4 | Spring onion: Downy mildew | 2 | NT | NT | Mod/Sev |
| 1.5 | Leek: Onion thrips | 6 | 4 | NT | Low |
| 1.5 | Leek: Moth | 6 | 4 | NT | Moderate |
| 1.6 | Lettuce: Aphid | 3 | 1 | NT | Moderate |
| 1.6 | Lettuce: Caterpillar | NT | NT | NT | Nil |
| 1.7a | Brassica (sprouts): aphids, caterpillar | 6 | 5 | NT | Low |
| 1.7b | Brassica (sprouts): cabbage root fly | 4 | 3 | NT | Severe |
| 1.8 | Courgette: Annual weeds | 4 | 0 | NT | Severe |
| 1.9 | Umbellifers: Annual weeds | 3 | 0 | NT | Severe |
| 1.10 | Field Vegetables: Annual weeds | 1 | 0 | NT | Severe |
| 1.11 | Alliums: Annual weeds | 2 | 0 | NT | Severe |
| 1.12a | Cauliflower: Band spray | NA | NA | NT | Moderate |
| 1.12b | Leek: Band spray + electric weed control | NA | NA | 1 | Severe |
| Soft fruit | | | | | |
| 2.1 | Raspberry: Cane diseases | - | - | - | In progress |
| 2.2 | Strawberry: Crown rot | | | | Moderate |
| 2.3 | Strawberry: Powdery mildew (C) | 10 | - | - | Mod/Sev |
| 2.4 | Strawberry: Powdery mildew (B) | - | 9 | - | Severe |
| 2.5 | Raspberry: Aphid | 2 | 2 | - | Moderate |
| 2.6 | Strawberry: Capsid (Lygus) | 2 | 0 | NT | Moderate |
| 2.7 | Strawberry: Herbicide crop safety | NA | NA | NA | NA |
| 2.8 | Strawberry: Runner control | 1 | 1 | 0 | Moderate |
| 2.9 | Blackcurrant: Weed control | NT | NT | 1 | Low |
| Protected edibles | | | | | |
| 3.1a | Cucumber: Phomopsis | NA | NA | NA | Very low |
| 3.1b | Cucumber: Phomopsis | 6 | 0 | NT | Moderate |
| 3.2 | Cucumber: Pythium | 5 | 0 | NT | Low |
| 3.3 | Pepper: Aphid | 2 | 2 | NT | Low/Mod |
| 3.4 | Pepper: WFT | 1 | 1 | NT | Moderate |
| Top fruit | | | | | |
| 4.1 | Apple: Powdery mildew (C) | 2 programmes | - | - | Severe |
| 4.2 | Apple: Powdery mildew (B) | 10 C/B programmes | | - | Severe |
| 4.3 | Pear: Botrytis (2013/14) | NT | 3 | NT | Moderate |

[a] Many experiments also tested treatment programmes using two or more products applied alternately or in mixture; results on such programmes are presented in the individual experiment reports and are not included here.

* 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.

Products causing significant crop damage excluded.

**Table 4.** Leading novel products (product name or code number in numerical order) identified for control of diseases: 2011-2014

| Target | Crop | Year | Exp ref. | Reference product | Leading 3 products | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Fungicides | | | Biofungicides | | |
| Field vegetables | | | | | | | | | | |
| Alternaria | Brassica | 2011 | 1.1 | Rudis | **Sig** | **Cas** | **28** | 06 | 43 | 47 |
| | Brassica | 2012 | 1.4 | Signum | * | * | * | 06 | 40 | 49 |
| Downy mildew | Brassica | 2011 | 1.2 | Folio Gold | Cas | Sig | **26** | **47** | **-** | - |
| | Onion | 2013 | 1.4 | Mixtures | **20** | **Cas** | **-** | - | - | - |
| | Onion | 2014 | 1.4 | Mixtures | **Cas** | 181 | **197** | * | * | * |
| Powdery mildew | Brassica | 2012 | 1.1 | Rudis | **Cas** | **28** | **89** | **90** | **134** | **136** |
| | Brassica | 2013 | 1.2 | Rudis | **Cas** | **28** | **89** | 11 | 90 | 90+40 |
| | Brassica | 2014 | 1.1 | Rudis | **Tal** | **25a** | **28** | * | * | * |
| Ring spot | Brassica | 2012 | 1.2 | Signum | **10** | **Cas** | **Nat** | Ser | 43 | 90 |
| | Brassica | 2013 | 1.3 | Ami/Rud | **10** | **Cas** | **25a** | 90 | - | - |
| | Brassica | 2014 | 1.2 | Ami/Rud | **Cas** | **25a** | **-** | 90 | Ser | - |
| Rust | Leek | 2012 | 1.3 | Amistar | **10** | **27** | **46** | * | * | * |
| | Leek | 2013 | 1.1 | Amistar Top | **Ami** | **31** | **118** | Ser | 105 | - |
| | Leek | 2014 | 1.3 | Ami/Rud/Nat | **Cas** | **31** | **118** | **105** | * | * |
| Soft fruit | | | | | | | | | | |
| Crown rot | Strawberry | 2012 | 2.3 | Paraat | **Cas** | - | - | **40** | **Pre** | - |
| Powdery mildew | Strawberry | 2014 | 2.3/4 | Systhane | **Tal** | **77** | **118** | **6** | **105** | **157** |
| 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 | Ser |
| | Tomato | 2012 | 3.2 | Signum | 08 | 25a | 118 | - | - | - |
| | Tomato | 2013 | 3.1 | Rov/Swi/Sig | **31** | **77** | **118** | - | - | - |
| Phomopsis | Cucumber | 2013 | 3.1a | - | **-** | **-** | **-** | - | - | - |
| | Cucumber | 2014 | 3.1b | - | 46 | 139 | 175 | - | - | - |
| Powdery mildew | Cucumber | 2011 | 3.1 | Systhane | **Tal** | **10** | **77** | **Ser** | **80** | **90** |
| | Cucumber | 2012 | 3.1 | Sys/Nim | **08** | **25a** | **77** | 90 | 105 | **154** |
| Pythium | Cucumber | 2013 | 3.2 | Previcur Energy | 46 | 139 | 183 | - | - | - |
| | Cucumber | 2014 | 3.2 | Previcur Energy | **46** | **139** | **183** | - | - | - |
| Top fruit | | | | | | | | | | |
| Botrytis | Pear | 2012 | 4.2 | Rovral WG | * | * | * | 178 | 98 | 99 |
| | Pear | 2013 | 4.2 | Rovral WG | * | * | * | 178 | - | - |
| | Pear | 2014 | 4.3 | Rovral WG | * | * | * | Nxy | 99 | 178 |
| Powdery mildew | Apple | 2011 | 4.1 | Systhane | **47** | **77** | **Cos** | **Ser** | **80** | **90** |
| | Apple | 2012 | 4.1 | Systhane | **25a** | **32** | **159** | **158** | **160** | **162** |
| | Apple | 2013 | 4.1 | Systhane | **Tal** | **118** | - | **90** | **105** | **157** |

* – 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; Tal – Talius; Thi – Thianosan DG; Cas – Cassiopeia; adj – adjuvant; Nxy – Nexy; - no (other) product gave control.

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; those shown in bold were equal to or better than the reference product, where one was included.  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: 2011-2014

| Target | Crop | Year | Exp ref. | Reference product | Leading 3 products | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Insecticides | | | Bioinsecticides | | |
| Field vegetables | | | | | | | | | | |
| Aphid | Brassica | 2011 | 1.4 | Movento | **50** | **59** | **60** | 62 | 92 | - |
| | Brassica | 2013 | 1.7 | Movento | 59 | 60 | - | 62 | 130 | - |
| | Brassica | 2014 | 1.7 | Movento | - | - | - | - | - | - |
| | Carrot | 2011 | 1.8 | Biscaya | **50** | **54** | **75** | - | - | - |
| | Lettuce | 2011 | 1.6 | Movento | 54 | - | - | - | - | - |
| | Lettuce | 2013 | 1.6 | Movento | **50** | **59** | **60** | - | - | - |
| | Lettuce | 2014 | 1.6 | Movento | **50** | **59** | 60 | 130 | - | - |
| Caterpillar | Brassica | 2013 | 1.7 | Steward | **48** | **143** | - | 64 | Lep | 130 |
| | Brassica | 2014 | 1.7 | Steward | - | - | - | - | - | - |
| | 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 | 1.7a | Tracer | * | * | * | 130 | - | - |
| | Brassica | 2013 | 1.7 | Tracer | **50** | 55 | - | * | * | * |
| | Brassica | 2014 | 1.7 | Tracer | **50** | **198** | **199** | 130 | - | - |
| Moth | Leek | 2012 | 1.7 | Tracer | **50** | - | - | 62 | 130 | - |
| | Leek | 2013 | 1.5 | Tracer | 48 | **50** | 142 | 62 | - | - |
| | Leek | 2014 | 1.5 | Tracer | **50** | **198** | **200** | **62** | **130** | - |
| Thrips | Leek | 2011 | 1.7 | Tracer | 48 | **50** | 54 | - | - | - |
| | Leek | 2013 | 1.5 | Tracer | 48 | **50** | 142 | 62 | 130 | - |
| | Leek | 2014 | 1.5 | Tracer | - | - | - | - | - | - |
| 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** | - |
| | Raspberry | 2014[†] | 2.5 | Calypso | **50** | **59** | - | **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** | - | * | * | * |
| | Strawberry | 2014 | 2.6 | Chess | **59** | **149** | - | * | * | * |
| Protected edibles | | | | | | | | | | |
| Aphid | Pepper | 2013 | 3.5 | Chess | * | * | * | **130** | - | - |
| | Pepper | 2014 | 3.3 | Chess | * | * | * | **62** | **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 | 2011 | 3.5 | - | 48 | 50 | 54 | 52 | 81 | 82 |
| | Pepper | 2012 | 3.5 | Pyrethrum | * | * | * | **01** | **62** | **Nat** |
| | Pepper | 2014 | 3.4 | Calypso | **200** | - | - | - | - | - |
| 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.

† - Tested in combination with macrobiologicals.

† - Bioinsecticides evaluated in combination with release of natural enemies.

**Table 6a.** Leading novel herbicide products[a] identified for crop safety to field vegetables, 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 | | | | 2014 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | pre | post | post | post | pre | pre | pre | post | pre | post |
| *Drilled* | | | | | | | | | | |
| Broad bean | 05 | | | (123) | | 165 | 166 | | | |
| Bulb onion | | 05 | 76 | (123) | 164 | 165 | 166 | 166 | | |
| Carrot | 05 | 05 | 76 | | 164 | | 166 | 166 | | |
| Coriander | 05 | 05 | 76 | | | | 166 | | | |
| Dwarf French bean | 05 | | | | 164 | 165 | 166 | | 190 | 190 |
| Leek | | 05 | 76 | (123) | 164 | 165 | 166 | 166 | | |
| Parsnip | 05 | 05 | 76 | | | | 166 | 166 | | |
| Pea | 05 | | | (123) | | 165 | 166 | | | |
| *Transplanted* | | | | | | | | | | |
| Cauliflower | 05 | | | | | 165 | 166 | | | |
| Celery | 05 | 05 | 76 | | | | 166 | 166 | | |
| Courgette | NT | NT | NT | NT | | 165 | 166 | | 190 | 190 |
| Lettuce | (05) | (05) | | (123) | | | 166 | | | |

NT not tested.

[a] 05 tested pre-and post-weed emergence in 2011; 123 (at low doses); 164, 165 and 166 tested pre- and post-weed emergence in 2013. 165 did not control emerged weeds. 76 (500 g/L formulation) was tested post-weed-emergence in 2012; it was tested further (400 g/L formulation, as 191) pre and post weed emergence of Umbelliferous crops in 2014 (see Table 6b).

Please see Sceptre Annual Reports for full details. A gap in the above table indicates the treatment was not safe to the test crop. Post-drilling/planting application of 164 was not safe to any of the listed crops.

For mizuna, rocket, swede and baby leaf spinach, no safe solutions were identified.

**Table 6b.** Leading novel herbicides identified for crop safety to courgette and six umbelliferous crops – 2014

| | 165 | 190 | | 191 | | Benfluralin |
|---|---|---|---|---|---|---|
| | Pre | Pre | Post | Pre | Post | Pre |
| Drilled | | | | | | |
| Carrot | | | | ✓ | ✓ | ✓ |
| Coriander | | | | ✓ | ✓ | |
| Flat leaf parsley | | | | ✓ | (✓) | |
| Parsnip | | | | ✓ | ✓ | ✓ |
| Transplanted | | | | | | |
| Celeriac | | | | ✓ | ✓ | ✓ |
| Celery | | | | (✓) | (✓) | ✓ |
| Courgette | ✓ | ✓ | ✓ | | | ✓ |

Pre – pre weed emergence; post – post weed emergence; ✓ - safe; (✓) slight damage.
See Science Section for range of weed species controlled by each herbicide. 165 and 190 not safe to umbellifers; 165 does not control emerged weeds.

**Table 6c**. Leading novel products (product name or code number in numerical order) identified for control of weeds: 2011-2014

| 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 | - | * | * | * |
| | Cauliflower | 2014 | 1.12a | Wing P + Butisan S + Gamit | E | - | - | * | * | * |
| | Leek | 2013 | 1.9 | Wing P + Defy | C | D | - | * | * | * |
| | Onion | 2012 | 1.10 | Stomp Aqua | WP | DG | - | * | * | * |
| | Onion | 2014 | 1.11 | Wing P | 165 | 191 | - | * | * | * |
| 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; E – Springbok over crop roots with Wing P + Dual Gold + Gamit 36CS between rows.

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

## Field vegetables

### 1.1 Brassica (swede): evaluation of fungicide and biofungicide programmes for control of powdery mildew (transplant field trial, Lincs; ADAS)

A field trial was conducted in Lincolnshire in summer 2014 to evaluate five fungicide and three integrated fungicide and biofungicide programmes for control of powdery mildew (*Erysiphe cruciferarum*) on swede cv. Emily. An untreated control and a grower standard, Rudis (prothioconazole), were included. Conventional fungicides (Talius, Rudis, Cassiopeia, 25a, 89) were applied three times at 20 day intervals. In the integrated programmes biofungicides were applied four times in alternation with Rudis at 10 day intervals resulting in seven sprays in total. Powdery mildew occurred naturally and was first observed on 14 July, the same day plants were also inoculated, and increased to affect 27% leaf area on untreated plants by 12 August. All treatments significantly reduced the disease. The programme Serenade ASO/Rudis had least disease (5.7% LAI) and appeared slightly better than Rudis alone (9.5% LAI). On 3 September, one week after the final spray, four programmes (Rudis; Serenade ASO/Rudis; biofungicide 11/Rudis and biofungicide 105/Rudis) had reduced powdery mildew to around 3% LAI compared with 14% on untreated plants. Programmes of three sprays of 28, Talius, 89 or 25a all reduced the disease to 5-9% LAI; only Cassiopeia was ineffective. No phytotoxic symptoms or vigour differences were observed.

### 1.2 Brassica (cabbage): evaluation of fungicide and biofungicide programmes for control of ring spot (transplant field trial, Lincs; ADAS)

A field trial was conducted in Lincolnshire in autumn 2014 to evaluate two conventional fungicides (Cassiopeia and 25a), two biofungicides (90 and Serenade ASO), three programmes of fungicides applied in alternation and one programme of fungicides and a biofungicide used as a mixture for control of ring spot (*Mycosphaerella brassicicola*) and other leaf diseases on cabbage cv. Caraflex. Conventional fungicides were applied as programmes of five sprays at 2-3 week intervals; biofungicides as programmes of nine sprays at 1-2 week intervals. An untreated control and a grower standard of Amistar (azoxystrobin) alternating with Rudis (prothioconazole) were included. Brassica leaf debris affected by ring spot was placed on the soil between plots on 27 August and 29 September 2014. Ring spot was confirmed on 14 October, 3 weeks before the final spray, and soon became widespread. On 11 November, ring spot affected 35% of untreated plants and was reduced by all treatments except Serenade ASO; the grower standard, a programme of Signum (boscalid + pyraclostrobin)/Rudis, a programme of Nativo 75WG (tebuconazole + trifloxystrobin)/Rudis and Cassiopeia were most effective, all reducing ring spot incidence fo 3%. Disease severity on untreated heads was low (1.3%) and was reduced by all treatments; most treatments reduced it to 0.1 – 0.2%. White blister (*Albugo candida*) affected 5% of untreated plants and was absent on plants treated with conventional fungicide Cassiopeia. No symptoms of phytotoxicity were observed with any of the treatments.

### 1.3 Leek: evaluation of fungicide and biofungicide programmes for control of rust (field trial, Lincs; ADAS)

A field trial was conducted in summer 2014 in Lincolnshire to evaluate the efficacy of conventional fungicide and biofungicide programmes for control of rust (*Puccinia allii*) on leek cv. Prelina. An untreated control and a grower standard programme alternating Amistar Top (azoxystrobin + difenoconazole), Rudis (prothioconazole) and Nativo 75 WG (trifloxystrobin + tebuconazole) were included. Conventional fungicides (except 47) were applied four times at 20 day intervals; 47 and biofungicide 105 were applied eight times at 10 day intervals, commencing 10 days before the first conventional fungicide spray application. A high incidence (100%) and moderate severity (4.2% LAI) developed on untreated plants. All treatments reduced both disease incidence and severity. The five best treatments had <0.1% leaf area infected at 2 weeks after the final spray compared with 4.2% on untreated plants; these were: grower standard, Rudis, 31, 118 and an alternating programme of Cassiopeia (dimethomorph + pyraclostrobin) and 31. Biofungicide 105 reduced the disease to 0.8%. No evidence of phytotoxicity or differences in crop vigour were observed. Fungicide 31 provides a new mode of action group for rust control and would be useful for resistance management, for use in conjunction with triazole and strobilurin fungicides currently used against leek rust.

### 1.4 Spring onion: evaluation of fungicide and biofungicide programmes for control of downy mildew (field trial, Warwicks; ADAS)

A field trial was conducted in summer 2014 to evaluate 10 programmes of conventional fungicides and two of conventional fungicides and biofungicides for control of downy mildew (*Peronospora destructor*) on spring onion cv. Photon. An untreated control and a grower standard were included; the latter comprised sprays of Invader (dimethomorph + mancozeb) + Amistar (azoxystrobin), Invader + Signum (boscalid + pyraclostrobin), Invader + Olympus (azoxystrobin + chlorothalonil) and Invader + Switch (cyprodinil + fludioxonil). Sprays were applied at 7 day intervals from 25 July (biofungicides) or 7 August (conventional fungicides). Programmes of conventional fungicides consisted of five spray applications; those utilising biofungicides had seven. Disease was severe with 37% leaf area affected on untreated plants at 4 days after the final spray timing, rising to 76% after 15 days. At 4 days after the final spray, disease severity was reduced by the grower standard (21% leaf area affected) and nine other programmes. A programme of 197 + Cassiopeia alternating with 197 + 23 was the most effective, with only 7% leaf area affected at 15 days after the final spray. A programme of biofungicide 40 (3 sprays) followed by Cassiopeia and finishing with biofungicide 40 significantly reduced downy mildew compared with the untreated. Only two treatments reduced downy mildew to a commercially acceptable level (<10% severity) at 4 days after the final spray; both utilised a mixture of two conventional fungicides at each application. No phytotoxicity was observed with any treatment.

### 1.5 Leek: evaluation of insecticides and bioinsecticides for control of thrips (field trial, Warwick Crop Centre)

One field trial was conducted in 2014 to evaluate the efficacy of six insecticides and four bioinsecticides for control of onion thrips (*Thrips tabaci*) on leek cv. Surfer. Insecticides were applied at 14 day intervals and bioinsecticides at 7 day intervals from the first sign of pests (early July) with 4 and 7 sprays respectively. Tracer (spinosad) was included as a standard. Damage by thrips was low with 11% leaf area affected on untreated plants. There were no differences between treatments. Leek moth caterpillar (*Acrolepiosis assectella*) also occurred and affected 87% of untreated plants. Damage by this pest was reduced by all treatments. Conventional insecticides 50, 198 and 200 were all more effective than the standard treatment, Tracer. Bioinsecticides 62 and 130 were more effective than bioinsecticide 61 and comparable to Tracer.

### 1.6 Lettuce: evaluation of insecticides and bioinsecticide for control of aphids and caterpillars (field trial, Warwick Crop Centre)

Two field trials were conducted in 2014 to evaluate the efficacy of three conventional insecticides and three bioinsecticides for control of currant-lettuce aphid (*Nasonovia ribisnigri*) and caterpillars on lettuce cv. Lobjoits Green Cos. Sprays of conventional insecticides were applied once (Trial 1) or twice (Trial 2) at 14 day intervals after aphid colonisation; sprays of bioinsecticides were applied twice (Trial 1) or three times (Trial 2) at 7 day intervals. Conventional insecticide 50 was applied as a spray and, in a separate treatment, as a pre-plant treatment dripped onto the peat blocks. Movento (spirotetramat) was included as a standard for aphid control. In Trial 1 there was a moderate infestation of aphids. At the first assessment one week after spray application, conventional insecticides Movento, 50 (spray), 50 (pre-plant), 59 and 60 and bioinsecticide 130 all reduced aphid numbers. Movento, 50 (spray) and 59 were the most effective. Seventeen days later Movento and bioinsecticide 130 still had lower numbers of aphids than the untreated control. In Trial 2 there was moderate infestation of aphids. The same pattern of control was observed although treatment differences were not quite significant at the 5% level. No caterpillars occurred.

**1.7a Brassicas: evaluation of insecticides and bioinsecticide for control of aphids and caterpillars (field trial, Warwick Crop Centre)**

Two field trials (one for conventional insecticides and one for bioinsecticides) were conducted in 2014 to evaluate products for control of cabbage aphid (*Brevicoryne brassicae*) and caterpillars on Brussels sprout cv. Faunus. Conventional insecticides were applied twice (16 day interval) and bioinsecticides three times (7 day intervals) from the first sign of pests. Movento (spirotetramat) and Steward (indoxacarb) were included as standards for aphids and caterpillars respectively. There was a moderate level of aphids and low levels of caterpillar (mostly small white butterfly, *Pieris rapae*) and whitefly (*Aleyrodes proletella*) on untreated controls. For both aphids and caterpillars, treatment differences were not quite significant at the 5% level. Conventional insecticides Movento and 59 and bioinsecticide 130 appeared to reduce aphid levels; conventional insecticides Steward, 48, 50, 67 and 200 and bioinsecticide 68 appeared to reduce caterpillars. All conventional insecticides (48, 50, 59, 67, 200) and none of the bioinsecticides reduced a low infestation of whitefly.

**1.7b Brassicas: evaluation of insecticides and bioinsecticides for control of cabbage root fly (field trial, Warwick Crop Centre)**

A field trial was conducted in summer 2014 to evaluate the efficacy of four conventional insecticides and three bioinsecticides for control of cabbage root fly (*Delia radicum*) on cauliflower cv. Skywalker. Results were compared with an untreated control and with a standard insecticide, Tracer (spinosad). Treatments were applied as a pre-plant drench and modules were planted in the field 1 day later. For bioinsecticide 94 only, a repeat drench application was made 2 weeks after planting. Cabbage root fly eggs were laid in high numbers by a field population of the pest. At 5 weeks after planting, all conventional insecticides (Tracer, 50, 198, 199, 200) and one bioinsecticide (130) had reduced root damage; three conventional insecticides (198, 199, 200) also reduced stem damage. Tracer, 198 and 199 resulted in increased root and foliage weight.

## 1.8 Courgette transplants: evaluation of herbicides for control of weeds and crop safety (field trial, Lincs; ABC)

A field trial was conducted in 2014 on a light, sandy silt loam soil in Lincolnshire to evaluate four novel herbicides (165, 190, 191, benfluralin) applied either alone or in mixture with registered herbicides for crop safety to transplants of courgette cv. Milos and weed control. The most effective and crop safe treatments applied within 7 days of transplanting (pre-weed emergence) were herbicides 165 at 2 L/ha and 190 at 35 g/ha. Herbicide 190 controlled a wide weed spectrum including groundsel, small nettle and redshank; herbicide 165 was excellent on annual meadow grass, groundsel, mayweed, small nettle and fat-hen. Herbicides 165, 190 and Gamit 36CS (clomazone) all controlled groundsel and are in different classes of chemistry and so are potentially useful to avoid herbicide resistance development in this weed. Gamit 36CS (EAMU for use on courgette) was useful in a programme following soil incorporation of benfluralin pre transplanting; it was safe in a tank mix with 165 or 190. Neither 165 or 190 controlled knotgrass. Herbicide 191 caused severe scorch and was not safe. Herbicides 165 and 190 are promising herbicides with potential for use on courgette. All treatments containing pendimethalin (Wing P, Stomp Aqua) applied over the top of courgettes remained weed-free but affected the growing point and killed the crop.

## 1.9 Umbelliferous crops: evaluation of herbicides for control of weeds and crop safety (field trial, Lincs; ABC)

A field trial was conducted in 2014 on a light, sandy silt loam soil in Lincolnshire to evaluate two herbicides 191 (a new alternative to linuron) and benfluralin applied alone and in programmes or in tank mixtures, for crop safety and weed control in six umbellifers (carrot cv. Nairobi, parsnip cv. Palace, coriander cv. Filtro, flat-leaf parsley cv. Rialto, celery cv. Plato and celeriac cv. Prinz). Benfluralin at 2.0 kg/ha was safe to carrots and parsnips when incorporated into the soil pre-sowing, and to celery and celeriac when soil-incorporated pre-transplanting. It gave good control of Polygonums, fat-hen and annual meadow-grass. Benfluralin did not control groundsel, shepherd's purse, mayweed and fool's parsley, but Gamit 36CS (not safe on parsnip) as a follow-up pre-emergence treatment was effective on these species. Linuron will be withdrawn 31 July 2016 and cannot be used after 31 July 2017. On carrot, the linuron alternative 191 caused no damage when applied pre-emergence at 2 L/ha alone or in tank-mix with Stomp Aqua (or Anthem) + Gamit 36CS; 191 was also safe applied at 1-2TL post-emergence (1.25 L/ha). On parsnip 191 applied pre-emergence at 2 L/ha alone or in tank-mix with with Stomp Aqua (or Anthem) were safe, but the addition of Goltix Flowable at 3 L/ha (to control groundsel) resulted in severe damage (1.5 L/ha was safer); 191 was also safe applied at 1TL post-emergence (1.25 L/ha). On coriander 191 was very safe applied pre-emergence at 1.25 L/ha alone, and early post-emergence at the same rate. On flat-leaved parsley 191 was safe applied pre-emergence at 1.25 L/ha but caused severe scorch and stunting when applied post-emergence, even as a split dose. In celery 191 applied soon after transplanting before weeds emerged in tank-mix with Gamit caused some transient scorch. The best treatment post-weed-emergence was with Defy + 191. Celeriac transplants were more tolerant of herbicides than celery. Here the best safe pre-weed-emergence treatment was with Stomp Aqua + Gamit 36CS + 191 although this also caused transient bleaching from Gamit and scorch from 191. Sencorex Flow at 0.233 L/ha applied when weeds were 1-2TL was promising and plots were weed-free until mid-September. Applied pre-weed-emergence alone 191 failed to control redshank or red dead-nettle, and groundsel control was incomplete and partners were needed. Post-weed-emergence 191 needs to be applied when weeds are small (<2 true leaves); applied at 1.25 L/ha post weed emergence it controlled small nettle, chickweed, annual meadow-grass, shepherd's purse, fat-hen, mayweed and field pennycress. Weaknesses were on red dead-nettle, field speedwell and Polygonums. For volunteer potato control in carrot and parsnip with a repeat treatment with a tank-mix of Defy + 191, the dose of 191 at 0.625L/ha was inadequate.

### 1.10 Field vegetables: evaluation of herbicides for crop safety and weed control (field trial, Lincs; ABC)

Field trials were conducted in 2014 on a silt loam soil to evaluate one conventional herbicide (190, a sulfonylurea) 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 herbicide suppressed their growth. Untreated control plots were included for comparison. The test herbicide has both soil residual and foliar activity. There were frequent and some very heavy showers in May, after application of the pre-emergency treatment, which would have both enhanced efficiency of residual activity and increased risk of crop damage due to herbicide leaching. Herbicide 190 was found to have good potential for use in courgettes transplants, drilled dwarf French beans and potatoes. The product caused severe damaged when used either pre-emergence / pre-transplanting or post-emergence/post-transplanting to broad beans, celery, coriander, leek, lettuce, onion, parsnip, pea, rocket, spinach or swede; cauliflower transplants survived probably because the planter pushed herbicide-treated soil aside in the row. Carrots suffered severe damage from 190 applied pre-emergence; 35 g/ha post-emergence may be safe. Herbicide 190 gave excellent control of groundsel both pre and post-emergence. Applied pre-emergence it was also very effective on small nettle, red dead nettle, chickweed, annual meadow-grass and redshank. It was less effective when applied post-emergence.

### 1.11 Alliums: evauation of herbicides for control of weeds and crop safety (field trial, Lincs; ABC)

A field trial was conducted in 2014 on a gravelly sand loam soil in Bedfordshire to evaluate three novel herbicides (165, 191, 196), applied alone or as components of spray programmes with registered herbicides, for weed control and crop safety to drilled bulb onion cv. Red Baron. The main weeds were volunteer oilseed rape, creeping buttercup, fat hen, small nettle and annual meadow grass. Herbicide 165 applied pre-emergence was safe to onion but poor on weed control. Herbicide 191 applied post-emergence, after Wing-P (pendimethalin + dimethenamid P) applied pre-emergence, gave both good weed control and was crop safe. Herbicide 196 applied post-emergence after use of Wing-P pre-emergence was an equally good programme. Herbicides 165 and 191 gave transient phytotoxicity symptoms.

### 1.12a Brussels sprouts: evaluation of herbicides for weed control and crop safety (field trial, Lincs; ABC)

A field trial was conducted in 2014 to evaluate a banded spray herbicide treatment for control of weeds and crop safety in a June-planted crop of Brussels sprouts cv. Victoria on a silt soil in Lincolnshire. Springbok (metazachlor + dimethenamid-P) was applied over crop rows and Wing P (dimethenamid-P + pendimethalin) + Dual Gold (metolachlor) + Gamit 36 CS (clomazone) was applied between crop rows in a single pass 4 days after planting. Treatment was compared with a commercial standard of Wing P applied pre-planting and Butisan S (metazachlor) + Gamit 36 CS applied over whole plots 4 days after planting. An untreated control was also included. Planned inter-row electrial weeding and cultivation to supplement the herbicide treatments were not applied due to rapid weed growth in warm wet weather, beyond the appropriate growth stages for treatment. The main weeds were black bindweed, fat hen, annual nettle and redshank. Both the commercial standard and the banded spray treatment gave good weed control compared with the untreated; there was no significant difference between the commercial standard and band spray. The two treatments both caused slight phytotoxicity but plants grew away satisfactorily.

### 1.12b Leeks: evaluation of herbicides and electrical treatment for weed control and crop safety (field trial, Lincs; ABC)

A field trial was conducted in 2014 to evaluate a banded spray herbicide treatment combined with inter-row electrical weeding for control of weeds and crop safety in an April planted crop of leeks cv. Pluston on a sandy clay loam soil in Lincolnshire. The experimental treatment consisted of a pre-emergence spray of Wing P (dimethenamid P + pendimethalin) over rows and Stomp Aqua (pendimethalin) + Defy (prosulfocarb) + Intruder (chlorpropham) between rows, followed by electrical weeding at two-true leaf stage and two subsequent herbicide sprays, Basagran (bentazone) + Tortril (ioxynil) + Starane 2 (fluroxypyr) and Basagran + Tortril. The commercial standard spray programme comprised a pre-emergence spray of Wing P and four post-emergence sprays: Stomp Aqua + Better DF (chloridazon) + Tortril; Defy + Better DF + Tortril; Tortril + Afalon (linuron) and Basagran + Tortril. No untreated was included. The main weeds were black bindweed, redshank, groundsel, creeping thistle, mayweed and nettle. Both treatments resulted in relatively poor control with 66-79% of plot areas covered by weeds at the final assessment; there was no difference between the two treatments at any of the assessments. None of the herbicide treatments caused phytotoxicity; the electrical weeder caused death of leek plants at a few points where rows were not straight.

## Soft fruit

### 2.1 Raspberry: evaluation of fungicides and biofungicides for control of spur blight (pot grown plant work, Kent; EMR)

An inoculated trial was established in autumn 2014 to evaluate the efficacy of Signum (pyraclostrobin + boscalid), Switch (cyprodonil + fludioxonil), six other conventional fungicides and five biofungicides for control of spur blight (*Didymella applanata*) on container-grown raspberry cvs Glen Ample and Octavia in Kent. An untreated control and a grower standard, Folicur (tebuconazole) were included. Conventional fungicides were applied once and biofungicides twice at the onset of leaf senescence and immediately prior to the introduction of infector plants into the trial. Plants will be assessed for cane lesions in spring 2015; results will be reported separately from this report, in summer 2015.

## 2.2 Strawberry: evaluation of fungicide and biofungicide products and application method for control of crown rot (polytunnel trial, Kent; EMR)

An inoculated trial was established in spring 2014 to evaluate the effect of plant protection product and application method on control of crown rot (*Phytophthora cactorum*) in strawberry cv. Malling Opal grown in peat bags in a polytunnel. Three conventional fungicides and two biofungicides were each examined as a pre-plant dip, a post-plant drench and a post-plant spray. Conventional fungicides were applied once and biofungicides three times at 14 day intervals. The biofungicide pre-plant dip treatments were followed by two drenches. An untreated control and a grower standard, Paraat (dimethomorph) were included. Visual symptoms suggestive of crown rot occurred in October and affected 38% of untreated plants. Levels of dead and dying plants in other treatments at this time ranged from 23% to 42%. None of the treatments reduced crown rot visual symptoms compared with the untreated control. Plants were dug up in December/January and examined for staining typical of *P. cactorum* infection within the crown. Results will be reported separately.

## 2.3 Strawberry: evaluation of fungicide products for control of powdery mildew (polytunnel trial, Kent; EMR)

A field trial was conducted in summer 2014 to evaluate the efficacy and crop safety of 10 conventional fungicides for control of powdery mildew (*Podosphaera aphanis*) on post-harvest re-growth of strawberry cv. Elsanta in a soil-grown polytunnel crop in Kent. An untreated control and a grower standard Systhane 20EW (myclobutanil) were included. Sprays were applied six times mostly at 7 day intervals. Powdery mildew was assessed 1 week after the fifth spray application. At this time the disease affected 24% leaf area on untreated plants. All treatments reduced mildew compared with the untreated control. Seven products (Talius, 17, 25a, 77, 118, 159 and 177) were more effective than Systhane 20EW. Systhane 20EW reduced mildew by 80% and fungicides Talius and 77 gave complete control. No phytotoxic symptoms or crop vigour differences were observed.

## 2.4 Strawberry: evaluation of biofungicide products for control of powdery mildew (polytunnel trial, Kent; EMR)

A field trial was conducted in summer 2014 to evaluate the efficacy and crop safety of 10 biofungicides for control of powdery mildew (*Podosphaera aphanis*) on newly planted strawberry cv. Elsanta in a soil-grown polytunnel crop in Kent. An untreated control and a grower standard, Systhane 20EW (myclobutanil) were included. Sprays were applied six times at 7 day intervals. Powdery mildew was assessed on 20

August, 1 week after the fourth spray application. At this time, powdery mildew affected 33% leaf area on untreated plants. All treatments reduced mildew compared with the untreated control. Biofungicides 6 and 105 were as effective as the standard fungicide Systhane 20EW; none were better. The level of control achieved by Systhane 20EW in this trial was relatively poor (around 50% reduction). No phytotoxic symptoms or crop vigour differences were observed. Biofungicide 105 reduced Mucor fruit rot at harvest (from 6.7% to 3.4%) whereas no product reduced this disease, or Botrytis fruit rot, in post-harvest tests. None of the treatments affected fruit yield.

### 2.5 Raspberry: evaluation of bioinsecticides and macrobiologicals for control of large raspberry aphid (polytunnel trial, Tayside; JHI)

A field trial was conducted in 2014 to evaluate two insecticides and two bioinsecticides used in conjunction with macrobiologicals for control of large raspberry aphid (*Amphorophora idaei*) and potato aphid (*Macrosiphum euphorblae*) in a polytunnel crop of raspberry cv. Glen Ample in Scotland. Treatments were compared with a water control and the standard insecticide Calypso (thiacloprid). There were moderate levels of both pests on untreated plants. All products (Calypso, 50, 59, 62, 130) reduced the level of potato aphid and all except insecticide 50 reduced large raspberry aphid. All products were compatible with introduced parasitoid wasps (*Aphidius ervi* and *Aphidus abdominalis*). When potato aphids were most abundant, conventional insecticide 50 and bioinsecticides 62 and 130 were as effective as Calypso. When large raspberry aphids were most abundant, conventional insecticide 59 was the best product, giving almost complete control of both adults and nymphs. Cane height was not affected by the treatments and all plots produced high quality fruit in large quantities.

### 2.6 Strawberry: evaluation of pesticides for control of European tarnished plant bug (*Lygus rugulipennis*) (field trial, Kent; EMR)

A field trial was conducted in summer 2014 to evaluate two conventional insecticides (59 and Steward) for control of European tarnished plant bug (*Lygus rugulipennis*) on strawberry cv. Flamenco. Steward was used at half rate in mixture with a wetter, Silwet-L77. An untreated control and two grower standard insecticides, Chess WG (pymetrozine) and Equity (chlorpyriphos), were included. Flowering plants were planted in strips on two sides of each plot to encourage *L. rugulipennis* into the area; weeds were also present surrounding the strips. Weeds were strimmed on 30 July 2014 and flowering plants on 5 August to encourage the pest to move onto the strawberry crop. High levels resulted. All treatments reduced the mean number of *L.*

*rugulipennis* nymphs, with Equity consistently the most effective (85% reduction). The coded insecticide 59 and Steward, reduced numbers of nymphs by 30-40%, comparable to Chess. Equity and Steward were the only products that reduced numbers of adults compared with the untreated. All treatments reduced fruit damage with Equity the most effective. Treatments may be more effective when applied to larger areas than the 25 m length x 1 bed plots as used in this work due to reduced immigration of adults. No symptoms of phytotoxicity were observed.

### 2.7 Strawberry: evaluation of herbicides for crop safety (polytunnel trial, Cambridgeshire; ADAS)

A field trial was conducted in summer 2014 to evaluate the crop safety of one conventional herbicide to protected strawberry cv. Elsanta grown in coir bags in Cambridgeshire. A grower standard treatment Dual Gold (S-metolachlor) and an untreated control were included. Herbicide 165 caused no phytotoxicity symptoms and had no effect on total or marketable fruit yield when applied over the crop either 1 day or 10 days after planting.

### 2.8 Strawberry: evaluation of herbicides for control of runners (field trial, Cambridgeshire; ADAS)

A field trial was conducted in autumn 2014 to evaluate the efficacy of herbicides for control of runners and weeds in alleyways of strawberry cv. Elsanta grown in the soil in Cambridgeshire. An untreated control and a grower standard Harvest (glufosinate ammonium) were included. Conventional herbicide 124 + adjuvant and bioherbicide 109 were each applied twice at a 14 day interval in September; Harvest was applied once. Conventional herbicide 124 + adjuvant was evaluated at two rates. At the final assessments 36% of untreated alleyway ground area was covered by runners and 12% by weeds. All treatments reduced alleyway ground area covered by runners compared with the untreated; products 109 and 124 (4-10% alleyway area covered) were as effective as the standard herbicide, Harvest (4%). All treatments also reduced weeds compared with the untreated and were equivalent to Harvest. Although not significantly different from the other herbicide treatments, Harvest appeared to give the best runner and weed control. The two rates of conventional herbicide 124 used in this experiment showed no difference in efficacy. Harvest resulted in almost complete scorch of green tissues and death of some runners; herbicides 109 and 124 significantly scorched foliage and reduced runner coverage but did not appear to kill runner crowns.

## 2.9 Blackcurrant: evaluation of an electrical treatment for control of perennial weeds (field trial, Norfolk; ADAS)

A field trial was conducted in spring 2014 to evaluate the efficacy of electrical weed control using a tractor-mounted, shielded high power electrode for control of perennial weed species in a blackcurrant crop in Norfolk. The main weed species were creeping thistle (*Cirsium arvense*) and stinging nettle (*Urtica dioica*). Three voltages (3.5, 6.5 and 7.5 KV) were compared using a single pass at 4.3 kph. The low and medium voltages (5.5 and 6.5 KV) controlled creeping thistle but did not affect stinging nettle. The high voltage controlled all weeds touched by the probe. Stinging nettles recovered around 6 weeks after treatment with re-growth from the base. There was no effect on weeds not directly touched by the probe. Leaf wilting and leaf and stem browning occurred where the probe touched young blackcurrant branches, at all voltages. At 6 weeks after treatment death of some individual branches was noted; the rest of the bushes were unaffected.

# Protected edibles

## 3.1. Cucumber: evaluation of fungicides and biofungicides for control of black root rot (rockwool crop trial, Yorkshire; STC)

### 3.1a 2013 trials

Two inoculated short-duration glasshouse trials were conducted in winter 2013 to evaluate the efficacy and crop safety of 12 conventional fungicides (Trial 1) and eight biofungicides (Trial 2) for control of black root rot (*Phomopsis sclerotioides*) in cucumber cv. Shakira grown in rockwool blocks in trays. Treatments were compared with an untreated control; currently there is no grower standard treatment or approved product for this disease. Limited information was available on appropriate rates of use for the products as drench treatments in a hydroponic crop. Conventional fungicides were applied twice, once before and once after inoculation; biofungicides were applied twice before and once after inoculation. The first application of biofungicides was at the cotyledon stage due to poor germination when applied at sowing. All treatments were applied as 65 ml drenches to the rockwool propagation block. Plants were inoculated by placing agar-bearing mycelium of *P. sclerotioides* onto roots. Minimal symptoms of black root rot had developed in either trial after 1 month so no conclusions could be drawn on product efficacy. Eight of the conventional fungicides and four of the biofungicides caused obvious phytotoxicity at the rates and timings used. The conventional fungicides were subsequently tested for inhibition of mycelial growth in agar plate tests. All of the products significantly reduced *P. sclerotioides* growth; eight products gave complete inhibition at 100 ppm ai; products 37 and 175 gave complete inhibition at 2 ppm ai.

**3.1b 2014 trial**

An inoculated long-duration glasshouse trial was conducted in summer 2014 to evaluate the efficacy and crop safety of eight conventional fungicides and two biofungicides for control of black root rot (*P. sclerotioides*) in cucumber cv. Shakira grown on rockwool slabs. The disease was established in a first crop (June – August) and a second crop (September – October) was then grown on the same slabs and re-inoculated with the pathogen 5 days after planting by application of 2 x 3 ml of dispersed mycelium to the base of each slab; the main disease assessment was on the second crop. Conventional fungicides and biofungicide 98 were applied four times to the first crop (at planting and then at 3 week intervals) and twice to the second crop (at 2 and 5 weeks after placement of plants on the slabs). Biofungicide 178 was applied seven times to the first crop (at planting and then at 10 day intervals) and four times to the second crop (2 weeks after planting and then at 10 day intervals). All products were applied as drenches to the rockwool block at 500 ml/plant. Symptoms typical of black root rot were seen on roots remaining in the slab at removal of the first crop. Wilt symptoms developed in the second crop 3 weeks after inoculation. Wilting was significantly reduced by conventional fungicides 37, 46, 139, 175 and 176; neither of the biofungicides nor conventional fungicides 10 and 47 reduced wilting. The effective conventional fungicide treatments also resulted in greater root vigour and reduced root rot symptoms. Two of these products (37 and 175) resulted in transient leaf phytotoxicity after the first application in the first crop; no phytoxicity was observed in the second crop.

### 3.2. Cucumber: evaluation of fungicides and biofungicides for control of Pythium root and stem base rot (rockwool crop trial, Yorkshire; STC)

A glasshouse trial was conducted in summer 2014 to evaluate seven conventional fungicides and two biofungicides for control of Pythium root and stem base rot (*Pythium aphanidermatum*) in cucumber cv. Shakira grown on rockwool slabs. A water-only treatment and a standard fungicide Previcur Energy (propamocarb-HCl + fosetyl-Al) were included. Products were drenched onto blocks at 500 ml/plant. Conventional fungicides and biofungicide 98 were applied four times to crop 1 and twice to crop 2 at 3 week intervals. Biofungicide 189 was applied seven times and four times to crops 1 and 2 respectively at 7-12 day intervals. Both the first and second crops were inoculated with *P. aphanidermatum*, 11 and six days after the first treatment application respectively. Pythium infection was confirmed in both crops although symptom severity was slight. Compared with the inoculated control, root discolouration was reduced by conventional fungicides 46 and 139 in crop 1 and by Previcur Energy in crop 2. Transient wilting in crop 1 was reduced by most of the conventional fungicides. Incidence of stem base rot was low and no plants died. Neither biofungicide reduced disease symptoms. Mild transient phytotoxicity symptoms occurred after the first application of Previcur Energy, 46, 47 and 139 in crop 1; however, plants grew out of these effects and no further symptoms occurred in either crop. There were no differences between treatments in fruit yield.

### 3.3. Pepper: evaluation of bioinsecticides for control of aphids (glasshouse trial, Yorkshire; STC)

A glasshouse trial was conducted in summer 2014 to evaluate the efficacy and crop safety of four bioinsecticides for control of foxglove aphid (*Aulacorthum solani*) on pepper cv. Ferrari. An untreated control and a standard insecticide Chess (pymetrozine) were included. Chess was applied three times and the bioinsecticides four times at 7 day intervals. The pest was introduced to each plant before treatments commenced; a natural infestation of *Myzus persicae* also occurred before treatments commenced. Low to moderate levels of aphids developed on untreated plants. Both aphid species were reduced by Chess and bioinsecticides 62 and 130. There was no evidence of phytotoxicity from any of the treatments.

### 3.4. Pepper: evaluation of conventional insecticides and bioinsecticides for control of western flower thrips in pepper (glasshouse trial, Yorkshire; STC)

A glasshouse trial was conducted in summer 2014 to evaluate the efficacy and crop safety of one conventional insecticide and three bioinsecticides for control of western flower thrips (WFT) (*Frankliniella occidentalis*) on pepper cv. Ferrari. An untreated control and a standard insecticide Calypso (thiacloprid) were included. Calypso was applied twice and all other products four times at 7 day intervals. WFT were introduced into each plot prior to the first spray applications and a moderate-high population developed on untreated plants. At 6 days after the final spray, numbers of WFT nymphs were reduced by conventional insecticide 200; Calypso, 130 and 209 were ineffective. A natural infestation of aphids (*Myzus persicae*) occurred and was reduced by Calypso, conventional insecticide 200 and bioinsecticides 62 and 130. None of the treatments caused phytotoxicity.

## Top fruit

### 4.1 Apple: evaluation of fungicide programmes for control of powdery mildew (field trial, Kent; EMR)

A field trial was conducted in 2014 to compare the efficacy of two fungicide programmes for control of powdery mildew (*Podosphaerea leucotricha*) on apple cvs Cox and Gala in an orchard in Kent. A standard fungicide programme based on Captan (captan), Cosine (cyflufenamid), Kumulus DF (sulphur), Stroby (kresoxim-methyl), Systhane 20EW (myclobutonil) and Topas (penconazole) was included. A common treatment of three sprays was applied up to blossom in all programmes for control of scab. Thereafter, from 30 April to 7 August, a series of 12 sprays was applied to the standard programme and the two experimental programmes. At the start of the trial the incidence of secondary mildew on extension growth was high (80% of leaves affected) on both cultivars. All three programmes steadily reduced mildew to around 10-20% leaves affected by 27 June. On cv Gala, Experimental programme 1, which included conventional fungicides Talius, 25a, 32 and 128, gave the best control, and the standard programme was the least effective, with 12% and 39% of leaves affected respectively at the final assessment. On cv. Cox the two experimental programmes (9-10% of leaves affected) appeared better than the standard programme (36% leaves affected). Experimental programme 1 reduced russet score on cv. Cox from 100 (standard programme) to 78. There were no phytotoxic effects observed on the trees or harvested fruits in any of the treatments.

### 4.2 Apple: evaluation of biofungicide and fungicide programmes for control of apple powdery mildew (field trial, Kent; EMR)

A field trial was conducted in 2014 to evaluate the efficacy of 10 fungicide and biofungicide programmes for control of powdery mildew (*Podosphaera leucotricha*) on apple cv. Cox in Kent. In each programme a series of 10 sprays was applied from the start of extension growth (22 May) until the end (28 July). An untreated control and a standard fungicide Systhane 20EW (myclobutanil) were included. In all programmes, conventional fungicides (two sprays) were used at the start to rapidly reduce the incidence of secondary mildew, and at the end (one spray) to reduce risk of infection of terminal buds. Biofungicides were used in the middle (sprays 3-9). Despite a pre-flowering fungicide programme, a high incidence of secondary mildew (80% of leaves) was present at the start of programmes. In all treatments the two sprays of conventional fungicide at the start reduced mildew to 20-40% leaves affected. In the eight programmes where biofungicides were used in the middle of the spray sequence, powdery mildew rapidly increased back to the starting level as programmes changed to biofungicides (7 sprays at 7 day intervals). Mildew incidence fell or remained the same following the final spray, which was a conventional fungicide. Best control was achieved with two 'managed disease programmes' where treatment switched to a conventional fungicide when mildew increased from the previous assessment. Managed programme A used 7 sprays of conventional fungicides and three of biofungicides; managed programme B used six and four respectively. Managed programmes A and B were more effective than the standard Systhane 20EW programme (35, 37 and 50% leaves affected respectively) and all three were better than the untreated (99% leaves affected). These three programmes, and also programmes using biofungicides 6 or 90, reduced fruit russet severity.

### 4.3 Stored pear: evaluation of biofungicides applied as post-harvest fruit dips for control of Botrytis rot (cold-store trial, Kent; EMR)

Two inoculated trials were conducted between September 2013 and April 2014 to evaluate biofungicide treatments for control of fruit rot (*Botrytis cinerea*) in stored pears cv. Conference. In Trial 1 fruit were stored in air at -1ºC; in Trial 2 they were stored in a controlled atmosphere (2% oxygen, 0% carbon dioxide) at -1ºC. Nine and three treatments were examined in Trials 1 and 2 respectively. Both trials included an inoculated untreated control dipped in water and a standard fungicide, Rovral WG (iprodione). In Trial 1, an uninoculated untreated control dipped in water was also included. Treatments were applied as a 1 minute dip, then allowed to drain before transfer to the stores within 30 minutes. Spread of Botrytis from inoculated to healthy fruit was good with 42% and 40% affected in Trials 1 and 2 respectively. In Trial 1 (air store), Botrytis rot was reduced by Rovral WG, Nexy and products 99 and 178. Rovral WG was the most effective (fruit rot incidence reduced to 20%). Biofungicide 178 was effective when used on ambient temperature fruit but not on cold fruit; Nexy was less effective on cold fruit. In Trial 2 (CA store), Rovral WG was again the most effective treatment (13% fruit affected) and biofungicide 178 also reduced the disease. Nexy and biofungicide 99 failed to reduce the disease in the CA storage trial. Possibly some of the biofungicides do not perform as well under CA storage conditions as in air due to the nature of the active substances.

## Milestones

| Milestone | Target month | Title | Status |
|---|---|---|---|
| 2.4 | 48 | Disease and pest efficacy tests for Y4 completed | |
| | | Leek rust | Complete |
| | | Leek thrips | Complete |
| | | Lettuce aphid | Complete |
| | | Lettuce caterpillar | Complete |
| | | Raspberry cane diseases | In progress |
| | | Strawberry crown rot | In progress |
| | | Strawberry powdery mildew | Complete |
| | | Strawberry *Lygus* sp. | Complete |
| | | Cucumber black root rot | Complete |
| | | Cucumber Pythium root rot | Complete |
| | | Pear Botrytis | Complete |
| 3.4 | 48 | Disease and pest IPM work for Y4 completed | |
| | | Brassica powdery mildew | Complete |
| | | Brassica ring spot | Complete |
| | | Spring onion downy mildew | Complete |
| | | Brassica insect pests | Complete |
| | | Raspberry aphids | Complete |
| | | Pepper aphids | Complete |
| | | Pepper WFT | Complete |
| | | Apple powdery mildew | Complete |
| 4.4 | 48 | Herbicide crop safety tests for Y4 completed | |
| | | Courgette | Complete |
| | | Umbelliferous crops | Complete |
| | | Field vegetables | Complete |
| | | Alliums | Complete |
| | | Strawberry | Complete |
| 5.3 | 48 | Sustainable weed control work for Y4 completed | |
| | | Vegetables – electric + herbicide | 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 chemical pesticides; all biopesticides are prefixed with 'bio';
- Products currently approved for use on the test crop and included as standard treatments are shown underlined 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 several conventional fungicides and biofungicides in programmes against powdery mildew in swede

A replicated field experiment was conducted between May and September 2014 at Spalding, Lincolnshire to evaluate nine programmes of conventional fungicides and/or biofungicides for the control of powdery mildew (*Erysiphe cruciferarum*) in swede cv. Emily. The results obtained were compared with an untreated control and the commercial standard treatment Rudis (prothioconazole) for which application was targeted at three 20 day intervals.

Four biofungicide applications were made at approximately 20 day intervals, in between Rudis applications. All the conventional fungicides were applied at the same 20 day interval and timings as Rudis, but without biofungicide applications in between (see Table 1.1.2).

The first biofungicide treatments were applied when the seedlings reached 4-6 leaves, when no powdery mildew was visible. The first conventional fungicides were applied 10 days after the biofungicides, when all treatments had a trace of visible infection. The fungicides were allowed to dry briefly and powdery mildew infected leaf pieces were tapped over the whole experiment later on the same day.

**Table 1.1.1.** Detail of conventional fungicide (C) and biofungicide (B) products used in programmes for control of powdery mildew in swede – 2014

| Product or SCEPTRE code | UK product rate | Active ingredients |
|---|---|---|
| Rudis (C) | 0.4 L/ha | prothioconazole |
| Cassiopeia (C) | - | - |
| SWE-28 (C) | - | - |
| SWE-89 (C) | - | - |
| Talius (C) | - | proquinazid |
| SWE-25a (C) | - | - |
| SWE-11 + Silwett L77 (B) | - | - |
| SWE-105 (B) | - | - |
| Serenade ASO (B) | 10 L/ha | *Bacillus subtilis* strain QST713 |

**Table 1.1.2.** Conventional fungicide and biofungicide programmes examined for control of powdery mildew in swede – 2014

| Treatment | Product and application timing | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1<br>4 Jul | 2<br>14 Jul | 3<br>24 Jul | 4<br>4 Aug | 5<br>12 Aug | 6<br>18 Aug | 7<br>27 Aug |
| 1. | - | - | - | - | - | - | - |
| 2. | - | Rudis | - | Rudis | - | Rudis | - |
| 3. | - | Cas | - | Cas | - | Cas | - |
| 4. | - | 28 | - | 28 | - | 28 | - |
| 5. | - | 89 | - | 89 | - | 89 | - |
| 6. | - | Talius | - | Talius | - | Talius | - |
| 7. | - | 25a | - | 25a | - | 25a | - |
| 8. | 11 | Rudis | 11 | Rudis | 11 | Rudis | 11 |
| 9. | 105 | Rudis | 105 | Rudis | 105 | Rudis | 105 |
| 10. | Ser | Rudis | Ser | Rudis | Ser | Rudis | Ser |

Cas – Cassiopeia; Ser – Serenade ASO

*Results*

- Disease levels were low initially but increased rapidly during the first month of the trial to a high incidence and severity.
- Natural powdery mildew infection was first observed on plants with ten true leaves on 14 July, when additional inoculum was added; the disease then increased rapidly to 27%

leaf coverage on untreated plants by 12 August (Table 1.1.3). Symptoms started to decrease after this as conditions became cooler and less favourable for powdery mildew. New leaves became less severely affected by powdery mildew.

- Significant differences (mainly p<0.001) in disease severity between the untreated and a number of the treatment programmes were seen for all assessments between 24 July and 15 September (Fig 1.1.1).
- At the 18 August assessment, two weeks after the second conventional fungicide applications and six days after the third biofungicide applications, significant reductions in disease were shown by conventional fungicides 28 and 89, Rudis, and the three treatments alternating biofungicide Serenade ASO, 11 or 105 with Rudis.
- The programme of Rudis in alternation with Serenade ASO was the most effective, maintaining leaf area affected below 7% through to the point of harvest. This programme comprised a total of seven applications, with the biological product Serenade ASO alternating with the standard, Rudis, to give spray intervals of approximately 10 days.
- Rudis alone and the biological treatments alternating with Rudis achieved the lowest levels of powdery mildew towards the end of trial. Conventional fungicides Talius, 28, 89 and 25a also gave significant control of powdery mildew compared with the untreated control at point of harvest when disease severity had fallen to 13.6% in the untreated plots (Table 1.13).

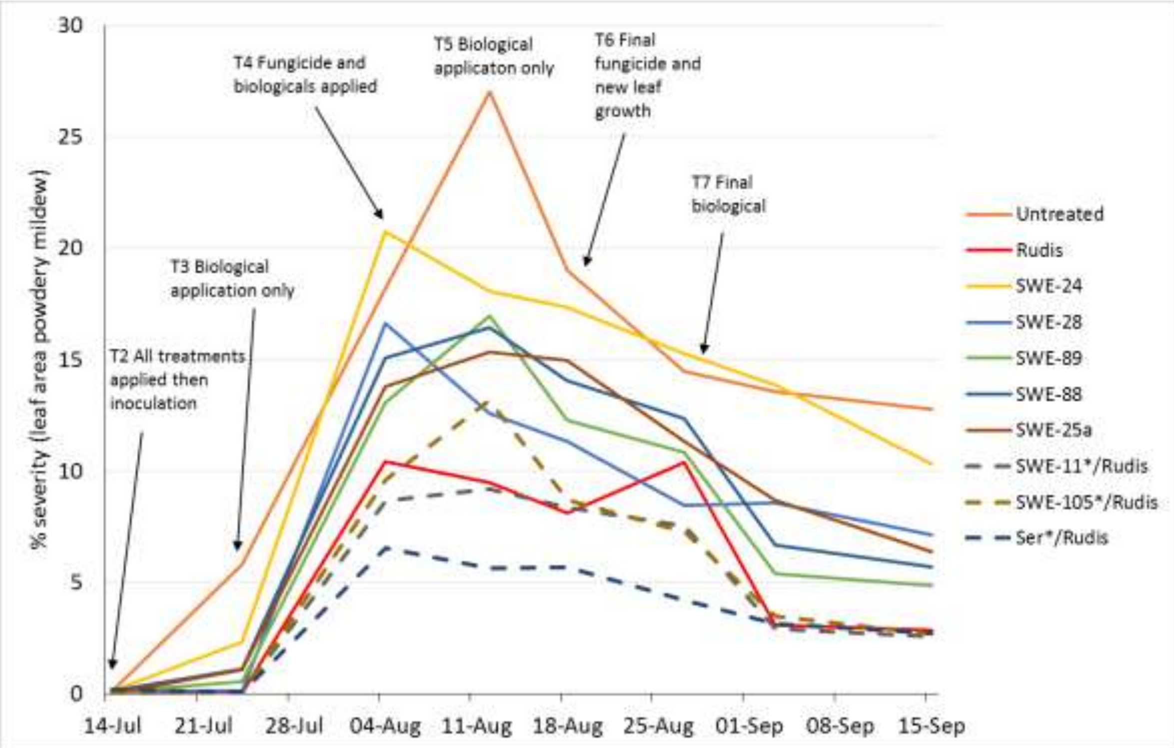


**Figure 1.1.1.** Disease progression through the course of the trial showing the timing of treatment applications and assessment dates. Treatments marked * were biofungicides.

**Table 1.1.3.** Powdery mildew assessments during peak severity immediately prior to application timings 5, 6 and 7 in August 2014

| Treatment | Product name or code | Powdery mildew severity (% leaf area) | | |
|---|---|---|---|---|
| | | 12 August | 18 August | 3 September |
| 1 | Untreated | 27.0 | 19.0 | **13.6** |
| 2 | <u>Rudis</u> | **9.5** | **8.1** | **3.1** |
| 3 | Cassiopeia | **18.1** | 17.3 | 13.9 |
| 4 | SWE 28 | **12.6** | **11.4** | **8.6** |
| 5 | SWE 89 | **17.0** | **12.3** | **5.4** |
| 6 | Talius | **16.4** | 14.1 | **6.7** |
| 7 | SWE 25a | **15.4** | 15.0 | **8.7** |
| 8 | SWE 11 + Adjuvant / Rudis | **9.2** | **8.4** | **2.9** |
| 9 | SWE 105 / Rudis | **13.2** | **8.7** | **3.5** |
| 10 | Serenade ASO / Rudis | **5.7** | **5.7** | **3.2** |
| Probability (F value) | | <0.001 | 0.003 | 0.001 |
| LSD vs. untreated (39 d.f.) | | 7.41 | 6.42 | 3.83 |

*Discussion*

Weather conditions during the trial were conducive to powdery mildew on swede, with higher than expected rainfall in August. Disease levels were moderate to severe throughout the trial and gave a stern test of efficacy for the treatments tested. Treatments selected for the programmes in the field trial were based on the best candidates tested in polytunnel screening trials carried out in 2012 and 2013 under the SCEPTRE project.

Of the single-product programmes, the commercial standard, Rudis, gave the best efficacy, but conventional fungicides 28 and 89 also gave significant control of powdery mildew throughout the course of the trial. Conventional products Talius, 25a, 28 and 89 gave a significant reduction in powdery mildew compared with the untreated at the point of harvest (only Cassiopeia gave no control at this final assessment).

Programmes alternating biofungicides with Rudis resulted in powdery mildew severity similar to the treatments with Rudis alone. Alternation of Rudis with Serenade ASO in a seven-spray programme (maintaining the same spray interval of Rudis) gave slightly lower powdery mildew severity, though not significantly different to Rudis alone. The swedes receiving the other biofungicide treatment combinations with Rudis (11 and 105), had a little higher mildew severity during late July and August than Serenade ASO, but also did not differ from Rudis used alone. By mid September when new growth had appeared and disease severity on Rudis treated plots had fallen below 5%, all programmes except Cassiopeia had less than the untreated.

In conclusion, the commercial standard, Rudis was shown to still give the best efficacy, but conventional fungicides 28 and 89 also gave significant and consistent control. Fungicides Talius, 25a, 28 and 89 gave a significant reduction in powdery mildew compared with the untreated at the point of harvest, and all contain actives in different fungicide groups to those in the industry standard and as such registration of these products for use against powdery mildew in brassicas would aid resistance management. There are indications that the biological treatment Serenade ASO could marginally increase the efficacy of conventional fungicide programmes when applied in addition to the conventional fungicide. However in the current experiment it was decided not to include a water only spray at timings 1, 3, 5. It would be useful to determine whether water application might cause a similar powdery mildew reduction as alternation with the biofungicide as powdery mildews generally require high humidity, but are not favoured by leaf wetness.

## 1.2 Assessment of the efficacy of several conventional fungicides and biofungicides in programmes against ring spot in brassicas

A replicated trial was conducted in 2014 in Lincolnshire to evaluate the efficacy of fungicide and biofungicides programmes for control of ring spot *Mycosphaerella brassicicola* in pointed cabbage cv. Caraflex. The results were compared with an untreated control and the trial protocol was validated by inclusion of a standard treatment (a programme of Amistar and Rudis) applied at recommended rates.

Five applications of conventional fungicides or mixed fungicide/biofungicides treatments were made in programmes. Nine applications were made of biofungicides.

**Table 1.2.1.** Detail of conventional fungicides (C) and biofungicides (B) included in programmes for control of brassica ring spot – 2014

| Product or SCEPTRE code | UK rate of product | Active ingredients |
|---|---|---|
| Amistar (C) | 1.0 L/ha | azoxystrobin |
| Nativo 75WG (C) | 0.3 kg/ha | tebuconazole + trifloxystrobin |
| Rudis (C) | 0.4 L/ha | prothioconazole |
| Cassiopeia (C) | - | - |
| BRA-25a (C) | - | - |
| BRA-90 (B) | - | - |
| BRA-105 (B) | - | - |
| Serenade ASO (B) | - | - |

**Table 1.2.2.** Detail of conventional fungicide and biofungicide programmes examined for control of brassica ring spot – 2014

| Treatment | Product and application riming | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1<br>4 Aug | 2<br>12 Aug | 3<br>20 Aug | 4<br>27 Aug | 5<br>9 Sep | 6<br>18 Sep | 7<br>2 Oct | 8<br>10 Oct | 9<br>31 Oct |
| 1. Untreated | - | - | - | - | - | - | - | - | - |
| 2. <u>Standard</u> | - | Ami | - | Rud | - | Ami | - | Rud | Ami |
| 3. | - | Sig | - | Rud | - | Sig | - | Rud | Sig |
| 4. | - | Nat | - | Rud | - | Nat | - | Rud | Nat |
| 5. | - | Cas | - | Cas | - | Cas | - | Cas | Cas |
| 6. | - | 25a | - | 25a | - | 25a | - | 25a | 25a |
| 7. | - | 25a | - | Cas | - | 25a | - | Cas | 25a |
| 8. | - | 105+<br>Ami | - | 105+<br>Rud | - | 105+<br>Ami | - | 105+<br>Rud | 105+<br>Rud |
| 9. | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 |
| 10. | Ser | Ser | Ser | Ser | Ser | Ser | Ser | Ser | Ser |

*Results*

**Table 1.2.3.** Effect of conventional fungicide and biofungicide programmes on ring spot on cabbage – 2014 (final spray 31 October)

| Treatment | % plants affected | | | % heads affected 18 Nov | % leaf area affected 18 Nov |
|---|---|---|---|---|---|
| | 14 Oct | 31 Oct | 11 Nov | | |
| 1. Untreated | 7.5 | 12.5 | 35.0 | 65.0 | 1.3 |
| 2. Amistar/Rudis | **0** | 7.5 | **2.5** | **17.5** | **0.2** |
| 3. Signum/Rudis | **0** | **0** | **2.5** | **22.5** | **0.1** |
| 4. Nativo/Rudis | 2.5 | **0** | **2.5** | **10.0** | **0.1** |
| 5. Cassiopeia | 2.5 | **0** | **2.5** | **10.0** | **0.1** |
| 6. BRA-25a | **0** | 2.5 | **12.5** | **22.5** | **0.2** |
| 7. Cas/BRA-25a | **0** | 7.5 | **10** | **30.0** | **0.1** |
| 8. BRA-105(B)+Ami/BRA-105+Rud | **0** | 2.5 | **7.5** | **22.5** | **0.1** |
| 9. BRA-90 (B) | 10.0 | 15.0 | **12.5** | 55.0 | **0.7** |
| 10. Serenade ASO (B) | 2.5 | 20.0 | 27.5 | 57.5 | **0.2** |
| F probability | 0.008 | 0.002 | <0.001 | <0.001 | <0.001 |
| LSD (27 df) | 5.654 | 10.10 | 13.71 | 24.95 | 0.49 |

- There was a moderate to high incidence of ring spot but the severity was low.
- There were significant efficacy effects for all treatments. An alternating programme of Nativo 75WG/Rudis and Cassiopeia were the best treatments, reducing the incidence of affected heads from 65% to ≤10%, and disease severity to 0.1%.

*Discussion*

At 11 days after the final spray, four treatment programmes reduced ring spot incidence to 2.5%. All treatments significantly reduced disease severity on the heads at the final assessment. Untreated heads had approaching >1% ring spot severity reduced to below 0.1% severity by five treatments.

Biofungicide 105 tank mixed with either Rudis or Amistar in a programme did not improve control by these conventional fungicides. The two biofungicides applied weekly (90 and Serenade ASO), significantly reduced ring spot levels in the trial at one or more assessments, but did not perform as well as the other treatments. Just over 50% of the heads treated with 90 or Serenade ASO were affected by ring spot 18 days after the last sprays and so persistence was lower than in all the other programmes as these had under 25% incidence.

White blister was seen at 5% incidence in the untreated and standard programme plots by the end of the trial, but was absent where Cassiopeia was used and so this would be worth further testing.

## 1.3 Assessment of the efficacy of several conventional fungicide and biofungicide programmes against rust in leeks

- A replicated field trial was conducted in 2014 at Mareham-Le-Fen, Lincolnshire to evaluate the efficacy of conventional fungicides and biofungicides in programmes for the control of rust (*Puccinia allii*) in leeks cv. Prelina. The results obtained were compared with a double replicated untreated control, and the trial protocol was validated by inclusion of a commercial standard comprising Amistar Top, Rudis and Nativo 75WG applied at recommended rates.
- The first biofungicide treatments were applied on 1 August when the crop reached 12 leaves, and no symptoms of rust were visible at this point. The first conventional fungicides were applied 10 days after the biofungicides. Inoculation was carried out once on 1 September after the second conventional fungicide application; fungicides were allowed to dry before inoculation later the same day.
- A programme of four applications of each of the conventional fungicide treatments was made (as for the growers' standard programme) and eight applications of the biofungicide products. Products and programmes are listed in Tables 1.3.1 and 1.3.2.

**Table 1.3.1.** Detail of conventional fungicides (C) and biofungicides (B) used in programmes for control of rust in leek – 2014

| Product or SCEPTRE code | UK rate of product | Active ingredients |
|---|---|---|
| Amistar Top (C) | 1.0 L/ha | azoxystrobin + difenoconazole |
| Rudis (C) | 0.4 L/ha | prothioconazole |
| Nativo 75WG (C) | 0.3 L/ha | trifloxystrobin + tebuconazole |
| Cassiopeia (C) | - | - |
| LEE-25a (C) | - | - |
| LEE-31 (C) | - | - |
| LEE-47 (C) | - | - |
| LEE-118 (C) | | |
| LEE-105 (B) | - | - |

**Table 1.3.2.** Conventional fungicide and biofungicide programmes examined for control of leek rust – 2014

| Treatment | Product and application timing | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| | 1 Aug | 11 Aug | 20 Aug | 1 Sep | 10 Sep | 22 Sep | 1 Oct | 14 Oct |
| 1. | - | - | - | - | - | - | - | - |
| 2. | - | Amistar Top | - | Rudis | - | Nativo | - | Rudis |
| 3. | - | Cas | - | 31 | - | Cas | - | 31 |
| 4. | - | 25a | - | 118 | - | 25a | - | 118 |
| 5. | - | Rudis | - | Rudis | - | Rudis | - | Rudis |
| 6. | - | 25a | - | 25a | - | 25a | - | 25a |
| 7. | - | Cas | - | Cas | - | Cas | - | Cas |
| 8. | - | 118 | - | 118 | - | 118 | - | 118 |
| 9. | - | 31 | - | 31 | - | 31 | - | 31 |
| 10. | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 |
| 11. | 105 | 105 | 105 | 105 | 105 | 105 | 105 | 105 |

*Results*

- Levels of leek rust were moderate. Disease was first noted in the trial on 10 September nine days after inoculation, at spray timing 5, and progressed to a peak of 4.2% leaf area affected and 100% incidence.

- All treatments significantly (p <0.001) reduced rust severity at all assessments. The best results at 14 days after the final application were gained with the grower standard programme of Amistar Top, Rudis and Nativo 75WG, and conventional fungicides Rudis, 118 and 31 all of which gave almost complete control. Although giving significant control, conventional fungicides 25a and 47 showed the lowest efficacy. Biofungicide 105 significantly reduced both disease incidence and severity, with similar activity to the two weaker fungicides (25a and 47).

**Table 1.3.3.** Effect of conventional fungicide and biofungicide programmes on leek rust – 2014

| Treatment | % plants affected | | % leaf area affected | |
|---|---|---|---|---|
| | 10 Sep<br>1 wk after T4 | 22 Oct<br>1 wk after T8 | 22 Sep<br>2 wk after T4 | 31 Oct<br>2 wk after T8 |
| 1. Untreated | 38.8 | 56.2 | 0.98 | 4.15 |
| 2. <u>Ami/Rud/Nat/Rud</u> | **2.5** | **0** | **0** | **0.03** |
| 3. Cassiopeia/LEE-31 | **0** | **2.5** | **0** | **0.05** |
| 4. LEE-25a/LEE-118 | **10.0** | **7.5** | **0.18** | **0.29** |
| 5. Rudis | **0** | **0** | **0** | **0.03** |
| 6. LEE-25a | **10.0** | **37.5** | **0.37** | **1.28** |
| 7. Cassiopeia | **5.0** | **7.5** | **0.01** | **0.46** |
| 8. LEE-118 | **2.5** | **2.5** | **0** | **0.06** |
| 9. LEE-31 | **0** | **0** | **0** | **0.06** |
| 10. LEE-47 | **12.5** | **32.5** | **0.56** | **1.26** |
| 11. LEE-105 (B) | **10.0** | **7.5** | **0.22** | **0.78** |
| F probability | <0.001 | <0.001 | <0.001 | <0.001 |
| LSD between treatments | 12.19 | 10.05 | 0.275 | 1.214 |
| LSD vs untreated | 10.56 | 8.70 | 0.238 | 1.051 |

*Discussion*

Weather conditions within the trial period were conducive to rust on leek, with higher than average rainfall in August increasing the length of leaf wetness periods to produce the symptoms in early September. However, September rainfall was below average, which may have hindered further cycles of rust infection. Subsequently, when rainfall and leaf wetness increased in October, rust levels also began to increase.

The incidence of leek rust was high overall, with untreated plots reaching 100% infection by the end of the trial, while maximum severity was moderate at 4.2% leaf area affected. All programmes effectively controlled rust and disease severity was significantly lower than the untreated control. Severity and incidence continued to increase over the course of the trial. The most effective treatments in reducing disease severity at 14 days after the final application were the grower standard programme followed by straight applications of 31, 118 and a programme of 31 with Cassiopeia. These all provided excellent control. A programme of 25a with 118 was also effective at controlling rust. Biofungicide 105 also reduced the disease. In terms of disease severity, conventional fungicides 25a and 47, whilst still significantly different from the untreated, were less effective than the standard treatment for the majority of the trial.

Conventional fungicide 31 contains an active in a different group to the standard products used for leek rust (triazoles and strobilurins), and would be useful to reduce risk of resistance development.

## 1.4 Assessment of the efficacy of several conventional fungicides and biofungicides in programmes against downy mildew in spring onion

A replicated field trial was conducted in 2014 in Worcestershire to evaluate the efficacy of conventional fungicides and biofungicides in programmes for control of downy mildew (*Peronospora destructor)* in spring onions cv. Photon. The results obtained were compared with a double replicated untreated control, and the trial protocol was validated by inclusion of a commercial standard treatment programme including Invader, Amistar, Signum, Olympus and Switch applied at recommended rates.

The first two biofungicide treatments were applied on 25 July and 1 August at 2 leaf stage, and no symptoms of downy mildew were visible at this point. The first conventional fungicides were applied 6 days after the second biofungicide applications.

Five application timings of the conventional fungicide treatments were made in total (including in the commercial programme) and seven applications of the biofungicide products (Table 1.4.2).

**Table 1.4.1.** Detail of conventional fungicides (C) and biofungicides (B) included in programmes evaluated for control of downy mildew on spring onions – 2014

| Product or SCEPTRE code | Rate of product | Active substance |
|---|---|---|
| Amistar (C) | 1 L/ha | azoxystrobin |
| Fubol Gold (C) | 1.9 kg/ha | metalaxyl-M + mancozeb |
| Invader (C) | 2 kg/ha | dimethomorph + mancozeb |
| Olympus (C) | 25 L/ha | azoxystrobin + chlorothalonil |
| Signum (C) | 1 kg/ha | boscalid + pyraclostrobin |
| Switch (C) | 1 kg/ha | cyprodinil + fludioxonil |
| SPO-23 (C) | - | - |
| Cassiopeia (C) | - | - |
| SPO-40 (B) | - | - |
| SPO-170 (C) | - | - |
| SPO-181 (C) | - | - |
| SPO-197 (C) | - | - |

**Table 1.4.2.** Conventional fungicide and biofungicide programmes evaluated for control of downy mildew on spring onion – 2014

| Treatment | Product and timing | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1<br>25 Jul | 2<br>1 Aug | 3<br>7 Aug | 4<br>15 Aug | 5<br>24 Aug | 6<br>2 Sep | 7<br>8 Sep |
| 1. | - | - | - | - | - | - | - |
| 2. | - | - | Inv + Ami | Inv _ Sig | Inv + Oly | Inv + Oly | Inv + Swi |
| 3. | - | - | Cas | Cas | Cas | Cas | Cas |
| 4. | - | - | 181 | 181 | 181 | 181 | 181 |
| 5. | - | - | 197 | 197 | 197 | 197 | 197 |
| 6. | - | - | 170 | 170 | 170 | 170 | 170 |
| 7. | - | - | 23 | 23 | 23 | 23 | 23 |
| 8. | - | - | Cas | 181 | Cas | 181 | Cas |
| 9. | - | - | Cas | 23 | Cas | 23 | Cas |
| 10. | - | - | 170 + FG | 170 + FG | 170 + FG | 170 + FG | 170 + FG |
| 11. | - | - | 170 + Ami | 170 + Sig | 170 + Oly | 170 + Oly | 170 + Swi |
| 12. | - | - | 197 + Ami | 197 + Sig | 197 + Oly | 197 + Oly | 197 + Swi |
| 13. | - | - | 197 + Cas | 197 + 23 | 197 + Cas | 197 + 23 | 197 + Cas |
| 14. | 40 | 40 | 40 | Cas | Cas | Cas | 40 |
| 15. | 40 | 40 | 40 | 181 | 181 | 181 | 40 |

*Results*

- Downy mildew levels were low initially but escalated rapidly to a high severity in September after the final spray was applied.
- Infection was first observed in the trial on 2 September at application timing 6 at low levels of 5.9% of plot area affected in the untreated. Infection occurred naturally as conditions during September were humid with heavy dews causing prolonged leaf wetness which encouraged the disease to infect and spread. Disease in the untreated plots escalated rapidly during the next three weeks to reach a mean severity of plot area affected of 76.2% to give a stern test of the products and programmes
- Significant differences (mainly $p < 0.001$) in severity of % plot area affected between the untreated and a number of the treatment programmes were seen between 12 and 23 September. Treatment 13 consisting of conventional fungicides 197+Cassiopeia/197+23 gave the greatest control of downy mildew maintaining severity below 7.2% to the final assessment 15 days after the last fungicide application. Fungicide 23 was ineffective applied as a single product treatment, whereas 197 alone was the most effective and persistent of the single product programmes.
- By the end of September, 15 days after last spray application, significant reductions in downy mildew severity compared with the untreated were also seen using the commercial standard programme (T2), 197 placed within the standard programme instead of Invader (T12), 170 tank mixed with Fubol Gold, and Cassiopeia applied in an alternating programme with 23.
- By the end of September, downy mildew affected to 76% plot area in the untreated, whereas in the best treatments (T12 and 13) it was only 16% and 7%, respectively. These two programmes used 197 in the tank mix at each of the five application timings. Plots where 197 was used alone for the same number of applications had 30%, still better than the untreated.
- At an earlier assessment, 4 days after final applications, more treatment programmes had given significant reductions in the severity of downy mildew, with Cassiopeia, 170 placed within the standard programme instead of Invader (T11) and a programme with 24 starting and finishing with biofungicide 40 (T14) giving control. These treatments had kept downy mildew to below 22% compared with 38% in the untreated. The later fall-off in efficacy indicates that these programmes lacked persistence.

**Table 1.4.3.** Effect of fungicide and biofungicide programmes on severity of downy mildew on spring onion – 2014

| Treatment | % plot area affected | | |
|---|---|---|---|
| | 12 Sep (4d after FS) | 19 Sep (11d after FS) | 23 Sep (15d after FS) |
| 1. Untreated | 37.8 | 65.0 | 76.2 |
| 2. Inv+Ami/Inv+Sig/Inv+Oly/Inv+Swi | **20.5** | **26.0** | **31.0** |
| 3. Cassiopeia | **21.2** | 53.8 | 68.8 |
| 4. SPO-181 | 31.2 | 61.2 | 70.0 |
| 5. SPO-197 | **13.2** | **28.8** | **30.0** |
| 6. SPO-170 | 33.8 | 63.8 | 68.8 |
| 7. SPO-23 | 36.8 | 65.0 | 76.2 |
| 8. Cas/SPO-181 | **12.0** | **38.8** | 66.2 |
| 9. Cas/SPO-23 | **21.2** | **46.2** | **55.0** |
| 10. SPO-170 + FG | **15.5** | **26.0** | **30.5** |
| 11. 170+Ami/170+Sig/170+Oly/170+Swi | **19.2** | **50.0** | 68.8 |
| 12. 197+Ami/197+Sig/197+Oly/197+Swi | **8.8** | **16.2** | **16.2** |
| 13. 197+Cas/197+23 | **4.2** | **7.2** | **7.2** |
| 14. SPO-40/Cas | **17.5** | **51.2** | 73.8 |
| 15. SPO-40/SPO-181 | 30.0 | 62.5 | 75.0 |
| Probability | <0.001 | <0.001 | <0.001 |
| LSD vs untreated | 11.98 | 17.87 | 17.60 |
| LSD between trts | 13.83 | 20.64 | 20.33 |

Final spray (FS) applied on 8 September.

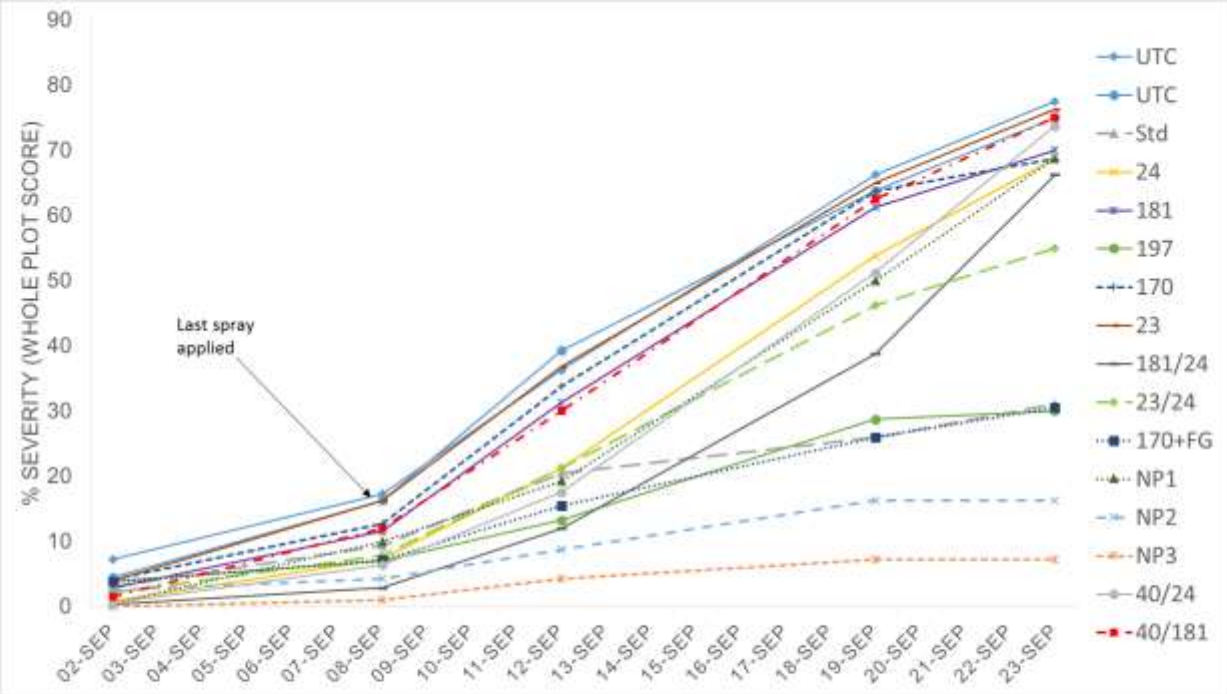


**Figure 1.4.1.** Downy mildew symptom progression in onions in 2014 from the point of visible infection. Novel programme NP1 is treatment 12, NP2 is treatment 13, NP3 is treatment no.14.

*Discussion*

Downy mildew developed very rapidly after the final fungicide application as climatic conditions at the chosen site were ideal for disease development, with high relative humidity and long periods of leaf wetness, and gave a stern test for the treatment programmes. Although there were significant differences in the results, quality requirements for spring onions are strict and only treatment 12 and 13 reduced the downy mildew to a commercially acceptable level (<10%) in the trial at four days after the final application, and only treatment 13 maintained this level of reduction up to 15 days after the final spray application. Both these treatments contained the new conventional fungicide 197 and so it would be a good addition to the current approved fungicides as it also appeared to give slightly better downy mildew control when included in the current commercial programme in place of Invader. In addition, the best programme in the trial contained a combination of new products 197, 23 and Cassiopeia which would be good candidates for approval on alliums to give growers a wider range of active ingredient modes of action options for downy mildew control.

Conventional fungicide 197 was the common product in the best performing treatments and was only available to be included in the trials for this final year, therefore it would be advantageous to test this product in further trials to confirm if control can be replicated in a different growing season. Also, the biofungicide 40 gave significant control of downy mildew compared to the untreated at 4 days after the final spray when used in a programme with Cassiopeia, allowing reduction in the number of conventional fungicides applied to just three. It would be useful to find the best way to combine this biofungicide with a reduced number of conventional fungicide applications, and gain longer persistence of control.

## 1.5 Assessment of the efficacy of insecticides and bioinsecticides against thrips on leeks

One replicated trial was conducted in 2014 to evaluate the efficacy of insecticides for the control of onion thrips and leek moth 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 recommended rates. Four applications of insecticides and seven applications of bioinsecticides were made. Treatments applied are listed in Table 1.5.1.

**Table 1.5.1.** Detail of conventional insecticides (C) and bioinsecticides (B) evaluated for control of leek thrips – 2014

| Treatment | SCEPTRE code | UK rate of product | Application timing |
|---|---|---|---|
| 1. | Untreated | - | - |
| 2. | Tracer | 200 ml/ha | At first sign of pests |
| 3. | LEE-48 (C) | | At first sign of pests |
| 4. | LEE-50 (C) | | At first sign of pests |
| 5. | LEE-198 (C) | | At first sign of pests |
| 6. | LEE-200 (C) | | At first sign of pests |
| 7. | LEE-75 (C) | | At first sign of pests |
| 8. | LEE-67 (C) | | At first sign of pests |
| 9. | LEE-62 (B) | | At first sign of pests |
| 10. | LEE-130 (B) | | At first sign of pests |
| 11. | LEE-61 (B) | | At first sign of pests |
| 12. | LEE-65 (B) | | At first sign of pests |

*Results*

**Table 1.5.2.** Effect of insecticides and bioinsecticides on damage to leeks by thrips and leek moth – 2014

| SCEPTRE code | Mean % leaf area damaged by thrips (leaves 1-8) | % plants undamaged by leek moth | |
|---|---|---|---|
| | | Ang trans | Back trans |
| 1. Untreated | 11.7 | 0.363 | 12.6 |
| 2. Tracer | 10.7 | **0.927** | 64.0 |
| 3. LEE-48 (C) | 13.1 | **0.696** | 41.1 |
| 4. LEE-50 (C) | 12.8 | **1.126** | 81.5 |
| 5. LEE-198 (C) | 9.8 | **1.227** | 88.6 |
| 6. LEE-200 (C) | 10.6 | **1.186** | 85.9 |
| 7. LEE-75 (C) | 11.6 | **0.607** | 32.5 |
| 8. LEE-67 (C) | 10.9 | **0.964** | 67.5 |
| 9. LEE-62 (B) | 11.0 | **0.803** | 51.7 |
| 10. LEE-130 (B) | 13.6 | **0.875** | 58.9 |
| 11. LEE-61 (B) | 13.7 | **0.548** | 27.1 |
| 12. LEE-65 (B) | 10.1 | **0.646** | 36.2 |
| F value | 1.668 | 21.395 | |
| p-value | 0.121 | <0.001 | |
| Replicate | 4 | 4 | |
| d.f. (within groups) | 36 | 36 | |
| s.e.d. | 1.477 | 0.083 | |
| l.s.d. (p<0.05; 2-tailed test) | 2.995 | 0.167 | |
| l.s.d. (p<0.05; 1-tailed test) | 2.493 | 0.139 | |

- The amount of thrips damage was low and the amount of leek moth damage was moderate.

*Discussion*

Thrips control

Thrips damage started to appear in early July so spraying was started. However, thrips numbers failed to build-up and damage remained at a low level on all plots throughout the trial period. Consequently no differences were seen between treatments.

Leek moth control

All of the treatments reduced leek moth damage compared with the untreated control. Conventional insecticides 50, 198 and 200 were all more effective than the standard treatment (Tracer). Of the bioinsecticides, 62 and 130 were more effective than 61 and comparable to Tracer.

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

Two replicated field trials were conducted in 2014 to evaluate the efficacy of insecticides for the control of currant-lettuce aphid on lettuce. The products were compared with untreated controls and a standard treatment Movento (spirotetramat) applied at the recommended rate. In Trial 1 insecticides were applied once and bioinsecticides twice and in Trial 2 insecticides were applied twice and bioinsecticides three times.

No caterpillar trials were possible due to a lack of infestation.

**Table 1.6.1.** Detail of conventional insecticides (C) and bioinsecticides (B) evaluated for control of aphid on lettuce - 2014

| Treatment | SCEPTRE code | UK rate of product | Application timing |
|---|---|---|---|
| 1. | Untreated | - | - |
| 2. | Movento | 500 ml/ha | After colonisation |
| 3. | LET-50 (C) | - | After colonisation |
| 4. | LET-59 (C) | - | After colonisation |
| 5. | LET-60 (C) | - | After colonisation |
| 6. | LET-50 (C) | - | Pre-planting |
| 7. | LET-62 (B) | - | After colonisation |
| 8. | LET-130 (B) | - | After colonisation |
| 9. | LET-51 (B) | - | After colonisation |

*Results*

Numbers of aphids (currant-lettuce aphid – *Nasonovia ribisnigri*) were generally moderate. Mean numbers of wingless aphids per plant are summarised in Table 1.6.2. No caterpillars (silver Y moth – *Autographa gamma*) were observed on the plots.

**Table 1.6.2.** Effect of insecticides and bioinsecticides on currant-lettuce aphid on lettuce – 2014

| SCEPTRE Code | | Mean number of wingless aphids per plot | | | | | |
|---|---|---|---|---|---|---|---|
| | | Trial 1 – count 1 | | Trial 1 – count 2 | | Trial 2 | |
| | | SQRT | Back trans. | SQRT | Back trans. | SQRT | Back trans. |
| 1. | Untreated | 25.81 | 666.0 | 41.56 | 1727.1 | 13.32 | 177.4 |
| 2. | Movento | **4.88** | 23.8 | **26.21** | 687.2 | 2.50 | 6.3 |
| 3. | LET-50 | **8.88** | 78.8 | 35.15 | 1235.4 | 4.92 | 24.2 |
| 4. | LET-59 | **6.27** | 39.4 | 33.08 | 1094.1 | 1.07 | 1.1 |
| 5. | LET-60 | **18.23** | 332.3 | 37.38 | 1397.1 | 5.76 | 33.2 |
| 6. | LET-50 (pre-planting) | **17.91** | 320.8 | 39.61 | 1569.0 | 4.76 | 22.7 |
| 7. | LET-62 (B) | 19.12 | 365.7 | 36.12 | 1304.7 | 7.45 | 55.5 |
| 8. | LET-130 (B) | **16.98** | 288.2 | **23.93** | 572.5 | 5.24 | 27.5 |
| 9. | LET-51 (B) | 24.50 | 600.3 | 38.03 | 1446.0 | 10.82 | 117.1 |
| F value | | 6.826 | | 2.036 | | 2.231 | |
| P -value | | <0.001 | | 0.080 | | 0.057 | |
| Replicate | | 4 | | 4 | | 4 | |
| d.f. (within groups) | | 27 | | 27 | | 27 | |
| s.e.d. | | 4.090 | | 5.886 | | 3.643 | |
| l.s.d. (p<0.05; 2-tailed test) | | 8.391 | | 12.077 | | 7.475 | |
| l.s.d. (p<0.05; 1-tailed test) | | 6.966 | | 10.025 | | 6.205 | |

*Discussion*

Aphids (currant-lettuce aphid – *Nasonovia ribisnigri*)

In Trial 1 conventional insecticides were all effective to some degree. At the first count Movento and 50 (spray) and 59 were the most effective treatments, but by the second count there was little difference between treatments and only Movento was effective. The only bioinsecticide to show any reduction in aphid numbers was 130. In Trial 2, although the analysis was not quite significant at the 5% level it is clear that the same pattern of control had occurred.

## 1.7a Assessment of the efficacy of insecticides and bioinsecticides against aphids and caterpillars on Brussels sprouts

Two replicated trials (one for insecticides and one for bioinsecticides) were conducted in 2014 to evaluate the efficacy of insecticides for the control of aphids and caterpillars on Brussels sprouts. The results obtained were compared with untreated controls and the trial protocol was validated by inclusion of the standard treatments Movento (spirotetramat) for aphids and Steward (indoxacarb) for caterpillars, applied at recommended rates.

**Table 1.7a.1.** Detail of conventional insecticides (C) and bioinsecticides (B) evaluated for control of aphid and caterpillar on Brussels sprouts – 2014

Trial 1 – Conventional insecticides

| Treatment | | UK rate of product | Application timing |
|---|---|---|---|
| 1. | Untreated | - | - |
| 2. | Movento | 500 ml/ha | First sign of pests |
| 3. | BRU-60 | | First sign of pests |
| 4. | BRU-59 | | First sign of pests |
| 5. | BRU-50 | | First sign of pests |
| 6. | Steward | 85 g/ha | First sign of pests |
| 7. | BRU-200 | | First sign of pests |
| 8. | BRU-143 | | First sign of pests |
| 9. | BRU-48 | | First sign of pests |

Trial 2 - Bioinsecticides

| Treatment | | Application timing |
|---|---|---|
| 1. | Untreated | |
| 2. | BRU-62 | First sign of pests |
| 3. | BRU-130 | First sign of pests |
| 4. | BRU-64 | First sign of pests |
| 5. | BRU-68 | First sign of pests |
| 6. | BRU-202 | First sign of pests |

*Results*

- Infestation by foliar pests (aphids and caterpillars) was moderate but despite hot dry weather did not appear until late in the season. Treatments were started on 31 July.
- None of the conventional insecticides and none of the bioinsecticides significantly reduced numbers of aphids or caterpillars.

**Table 1.7a.2.** Effect of conventional insecticides on aphids and caterpillars on Brussels sprouts - 2014

| Treatment | | Target | Mean number of aphids per plot | | % plants with caterpillars | Whitefly score |
|---|---|---|---|---|---|---|
| | | | SQRT | Back trans | | |
| 1. | Untreated | Aphid + Caterpillar | 25.74 | 662.4 | 25.0 | 2.29 |
| 2. | Movento | Aphid | 1.75 | 3.1 | 8.3 | **0.25** |
| 3. | BRU-60 | Aphid | 3.59 | 12.9 | 20.8 | **0.58** |
| 4. | BRU-59 | Aphid | 1.41 | 2.0 | 4.2 | **1.13** |
| 5. | BRU-50 | Aphid + Caterpillar | 3.08 | 9.5 | 12.5 | **0.46** |
| 6. | Steward | Caterpillar | 13.73 | 188.4 | 12.5 | **1.58** |
| 7. | BRU-200 | Aphid + Caterpillar | 3.33 | 11.1 | 4.2 | **0.83** |
| 8. | BRU-67 | Caterpillar | 10.63 | 112.9 | 0.0 | **1.38** |
| 9. | BRU-48 | Caterpillar | 41.71 | 1739.4 | 0.0 | **1.63** |
| F-value | | | 2.109 | | 2.209 | 6.895 |
| p-value | | | 0.070 | | 0.059 | <0.001 |
| Replicate | | | 4 | | 4 | 4 |
| d.f. (within groups) | | | 27 | | 27 | 27 |
| s.e.d. | | | 13.413 | | 8.410 | 0.355 |
| l.s.d. (p<0.05; 2-tailed test) | | | 27.521 | | 17.256 | 0.728 |
| l.s.d. (p<0.05; 1-tailed test) | | | 22.846 | | 14.325 | 0.604 |

**Table 1.7a.3.** Effect of bioinsecticides on aphids and caterpillar on Brussels sprouts - 2014

| Treatment | | Target | Mean number of aphids per plot | | % plants with caterpillars | Whitefly score |
|---|---|---|---|---|---|---|
| | | | SQRT | Back trans | | |
| 1. | Untreated | Aphid + Caterpillar | 27.38 | 749.9 | 29.2 | 2.75 |
| 2. | BRU-62 | Aphid + Caterpillar | 26.45 | 699.8 | 16.7 | 2.33 |
| 3. | BRU-130 | Aphid + Caterpillar | 10.74 | 115.3 | 16.7 | 1.83 |
| 4. | BRU-64 | Caterpillar | 34.80 | 1210.8 | 37.5 | 2.25 |
| 5. | BRU-68 | Caterpillar | 29.10 | 846.7 | 8.3 | 2.04 |
| 6. | BRU-202 | Caterpillar | 55.14 | 3040.9 | 16.7 | 2.21 |
| F-value | | | 1.139 | | 1.557 | 1.036 |
| p-value | | | 0.376 | | 0.222 | 0.427 |
| Replicate | | | 4 | | 4 | 4 |
| d.f. (within groups) | | | 18 | | 18 | 18 |
| s.e.d. | | | 19.152 | | 11.948 | 0.428 |
| l.s.d. (p<0.05; 2-tailed test) | | | 40.237 | | 25.101 | 0.899 |
| l.s.d. (p<0.05; 1-tailed test) | | | 33.211 | | 20.718 | 0.742 |

*Discussion*

Aphids

The majority were cabbage aphid (*Brevicoryne brassicae*). Of conventional spray treatments targeted at aphids, Movento and 59 appeared to provide good control. However the overall analysis was not significant at the 5% level. The analysis for the bioinsecticides was also not significant but there is an indication that aphid numbers had been reduced by insecticide130.

Caterpillars

The majority were small white butterfly (*Pieris rapae*). All conventional spray treatments targeted at caterpillars appeared to provide some control but the analysis was not quite significant at the 5% level. Conventional insecticides 48 and 67 eliminated caterpillars completely. The analysis for the bioinsecticides was also not significant but there was an indication that caterpillar numbers had been reduced by bioinsecticide 68.

Whitefly

Whitefly infestation was very low. However, there were still statistically significant differences between the conventional insecticides. All treatments reduced whitefly infestation. There was no evidence of effective whitefly control with any of the bioinsecticides.

## 1.7b Assessment of the efficacy of insecticides and bioinsecticides against cabbage root fly

One replicated trial was conducted in 2014 to evaluate the efficacy of insecticides and bioinsecticides 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. Carrot root fly eggs were laid in high numbers soon after transplanting following infestation by a field population of the pest.

**Table 1.7b.1.** Detail of conventional insecticides (C) and bioinsecticides (B) evaluated for control of cabbage root fly on cauliflower - 2014

| Treatment | UK rate of product | Application timing |
|---|---|---|
| 1. Untreated | | |
| 2. Tracer (C) | 12 ml/1000 plants | Pre-planting |
| 3. CAU-199 (C) | - | Pre-planting |
| 4. CAU-198 (C) | - | Pre-planting |
| 5. CAU-50 (C) | - | Pre-planting |
| 6. CAU-200 (C) | - | Pre-planting |
| 7. CAU-130 (B) | - | Pre-planting |
| 8. CAU-94 (B) | - | Pre- and post-planting |
| 9. CAU-65 (B) | - | Pre-planting |

*Results*

- The level of pest infestation was high for cabbage root fly.
- All conventional insecticides tested reduced cabbage root fly damage in the root area and there was little difference between treatments.
- Damage in the stem area was only significantly reduced by conventional insecticides 198, 199 and 200.
- Root and foliage weight were increased, compared with the untreated control, by Tracer, 198 and 199.
- Of the bioinsecticides tested, only product 130 was effective by any measure (root damage score).

**Table 1.7b.2.** Effect of conventional insecticides and bioinsecticides on cabbage root fly damage to cauliflower at 5 weeks after planting - 2014

| SCEPTRE code | Application timing | Root weight (g) | Foliage weight (g) | Root damage score | Stem damage score |
|---|---|---|---|---|---|
| 1. Untreated | Untreated | 11.31 | 205.0 | 1.77 | 1.83 |
| 2. Tracer | Pre-transplant | **17.23** | **308.1** | **0.67** | 1.33 |
| 3. CAU-199 | Pre-transplant | **16.33** | **306.7** | **0.69** | **1.06** |
| 4. CAU-198 | Pre-transplant | **18.58** | **325.8** | **0.46** | **0.96** |
| 5. CAU-50 | Pre-transplant | 12.97 | 248.8 | **0.76** | 1.31 |
| 6. CAU-200 | Pre-transplant | 10.69 | 242.7 | **0.79** | **1.27** |
| *7.* CAU-130 (Bio) | Pre-transplant | 14.12 | 255.6 | **1.44** | 1.80 |
| 8. CAU-94 (Bio) | Pre-transplant + post-transplant | 11.31 | 248.0 | 1.79 | 1.71 |
| 9. CAU-65 (Bio) | Pre-transplant | 11.56 | 228.4 | 1.77 | 1.98 |
| F value | | 3.786 | 2.945 | 15.242 | 2.388 |
| p-value | | 0.002 | 0.009 | <0.001 | 0.029 |
| Replicate | | 4 | 4 | 4 | 4 |
| d.f. (within groups) | | 33 | 33 | 33 | 33 |
| s.e.d. | | 2.255 | 40.246 | 0.190 | 0.314 |
| l.s.d. (p<0.05; 2-tailed test) | | 4.587 | 81.882 | 0.387 | 0.638 |
| l.s.d. (p<0.05; 1-tailed test) | | 3.816 | 68.111 | 0.322 | 0.531 |

## 1.8 Assessment of the efficacy and crop safety of some conventional herbicides for control of annual weeds in courgette

In a field screening trial in 2014, new active substances and tank-mixes were examined in comparison with untreated plants for their phytotoxicity to courgette (*Cucurbita pepo*) transplants cv. Milos grown outdoors, for control of weed species and where they would best fit in a weed control programme.  The data may also be relevant to drilled courgettes, squash and other cucurbits.

**Table 1.8.1.** Detail of herbicide treatments used on courgette – 2014 (& = followed by; + = tank mix)

| Herbicide treatment | g a.s./ha | L or kg product/ha |
|---|---|---|
| 0. Untreated | - | - |
| *Pre-transplanting soil incorporated Roterra T0* | | |
| 1. Benfluralin *T0* & Gamit *T1* | 1200 & 90 | 2.0 kg & 0.25 L |
| *Pre-transplanting T1* | | |
| 2. Stomp Aqua + Gamit + FVS-191 | 1046 + 90 + 800 | 2.3 L + 0.25 L + 2.0 L |
| 3. Wing-P (dimethenamid-P/pendimethalin) | 425/500 | 2.0 L |
| *Soon after planting within 7d and before weed emergenceT2 (&+ 14d)* | | |
| 4. FVS-165 | 600 | 1.0 L |
| 5. FVS-165 | 1200 | 2.0 L |
| 6. FVS-165 + Gamit | 600 + 90 | 1.0 L + 0.25 L |
| 7. FVS-165 + Stomp Aqua | 600 + 1046 | 1.0 L+ 2.3 L |
| 8. Stomp Aqua + Gamit | 1046 + 90 | 2.3 L + 0.25 L |
| 9. Stomp Aqua + Gamit + FVS-191 | 1046 + 90 + 500 | 2.3 L + 0.25 L + 1.25 L |
| 10. FVS-191 | 500 | 1.25 L |
| 11. Wing-P | 425/500 | 2.0 L |
| 12. Wing-P & FVS-190 | 265.6/312.5 & 26.25 | 1.25 L & 35 g |
| 13. FVS-190 | 39.38 | 52.54 g |
| 14. FVS-190 | 26.25 | 35 g |
| 15. FVS-190+ Gamit | 26.25 + 90 | 35 g + 0.25 L |
| *Post-weed-emergence 4-5 TL before flower T3* | | |
| 16. FVS-190 | 39.38 | 52.54 g |
| 17. FVS-190 | 26.25 | 35 g |

Rainfall was frequent throughout the trial period and 180% above average in May - no irrigation was needed to increase herbicide effects.

**Table 1.8.2.** Approval status (August 2014) of herbicide products used on courgettes - 2014

| Active substance (a. s.) | Product, SCEPTRE code, formulation | Company | EU status | UK Approval Status |
|---|---|---|---|---|
| propyzamide | Kerb Flo<br>400 g/L SC | Dow | on approved list of active substances | EAMU courgette, squash, pumpkin, marrow |
| isoxaben | Flexidor 125<br>125g/L SC | Landseer | on approved list of active substances | EAMU courgette, squash, pumpkin, marrow |
| clomazone | Gamit 36 CS<br>360 g/L CS | Belchim | on approved list of active substances | EAMU UK post transplanting. latest BBCH 12 (2TL unfolded) |
| pendimethalin | Stomp Aqua<br>455 g/L CS | BASF | on approved list of active substances | On-label and EAMUs for several vegetable crops, **not courgette** |
| dimethenamid-P /pendimethalin | Wing-P<br>212.5/ 250 g/L EC | BASF | on approved list of active substances | EAMUs for salad onion, cauliflower etc. **not courgette** |
| - | FVS-191<br>400 g/L SC | - | on approved list of active substances | - |
| benfluralin | 600 g/kg WG | - | pending | - |
| - | FVS-165<br>600 g/L SC | - | on approved list of active substances | - |
| - | FVS-190<br>75% WG | - | on approved list of active substances southern zone | - |

**Table 1.8.3.** Dates of herbicide application to courgette – 2014

| Transplant date | Timing | Herbicide treatment | Date applied | Crop growth stage (true leaves TL) |
|---|---|---|---|---|
| | T0 | 1 | 21 May | Pre-planting, incorporated with Roterra |
| | T1 | & 1, 2, 3 | 21 May | Pre-planting |
| 23 May 1TL | | | | |
| | T2 | 4 - 15 | 26 May | Soon after planting, crop 1½ TL |
| | T3 | 16, 17 | 12 June | Large weeds, crop 4-5 TL before flower bud |
| | | & 12 | 12 June | Post-weed-emergence |

*Results*

Crop safety

No quality defects from any herbicide treatment were observed on courgette fruit.

*Pre-transplanting soil incorporated T0*

Benfluralin at 2.0 kg/ha was applied and soil-incorporated with a Roterra at a depth of c. 5cm. Gamit 0.25 L/ha was then applied to the soil surface before planting T1. No herbicide effects were observed on the courgettes at any growth stage.

*Pre-transplanting T1*

Stomp Aqua + Gamit + FVS-191 (2.3 + 0.25 + 2.0) L/ha: there were slight effects initially from Gamit – bleaching on leaf margins of plants, and a growth check (typical of pendimethalin) – courgettes were stunted and GS delayed compared with untreated plants. On 16 June the leaves were curled down. There was recovery by early harvest stage mid-July. Wing-P 2.0 L/ha also caused stunting and slight delay but the dose of pendimethalin was lower and effects were less than from Stomp Aqua.

*Soon after planting within 7 d and before weed emergenceT2 (&+ 14d)*

All treatments (7, 8, 9, 11, 12) containing pendimethalin (Stomp Aqua and Wing-P) applied over the top of courgettes affected the growing point, the 1$^{st}$ leaf curled down followed by very severe stunting and crop death. Treatment 9, a tank-mix of Stomp Aqua + Gamit + FVS-191: in addition the latter caused scorch and the courgettes died 23 DAT. The treatments might have been safe if applied between the crop rows.

FVS-191 1.25 L/ha (treatment 10, a linuron alternative) was not safe, causing severe scorch and a growth check. The new leaves were not damaged. The crop recovered and harvest stage was not delayed.

The safest treatments were with FVS-165 and FVS-190 – neither delayed maturity and GS were the same as untreated courgettes. The addition of Gamit caused slight bleaching on courgette leaf margins.

FVS-165 is a residual soil acting herbicide with very little foliar activity. In this trial there was no damage from the 1.0 L/ha or 2.0 L/ha dose.

FVS-190 at 35 g/ha caused only slight transient yellowing 13 DAT, more for the higher dose rate 52.5 g/ha, but the courgettes soon recovered.

*Post-weed-emergence 4-5 TL before flowering T3*

FVS-190 was applied at 35 g/ha or 52.5 g/ha when plants were at a late GS 4TL on 12 June, a hot sunny day when temperatures reached 22ºC later. Both dose rates caused yellowing of leaves, stunting and delayed flowering compared with untreated courgettes and effects were more severe from the higher dose.

Weed control

Weed populations were extremely high on untreated plots: 462/m$^2$ by the 8 June. There were 10 weed species, predominantly small nettle and red dead-nettle and high populations of groundsel, mayweeds, chickweed, shepherd's purse, annual meadow-grass with a few redshank, fat-hen and late-emerging field speedwell. Plot cover at harvest stage was 100% on untreated plots, where small nettle formed a canopy above the crop and other weed species. Courgettes were effective in suppressing some weeds.

*Pre-transplanting soil incorporated T0*

Benfluralin at 2.0 kg/ha at T0 followed by Gamit at T1, small nettle and a few groundsel remained and more emerged later. Percent weed cover was high for this treatment 1.

*Pre-transplanting T1*

Stomp Aqua + Gamit + FVS-191 (2.3 + 0.25 + 2.0) L/ha treatment 2 was weed free on 8 June but a few groundsel and small nettle emerged later. Weeds were in the crop row where the planter pushed treated soil aside and small nettle would have interfered with harvesting.

Wing-P 2.0L/ha plots were almost weed-free, and there were none in the row – possibly because dimethenamid-P is soluble and it had spread into the row after heavy rain.

Efficacy was good and % weed cover very low for both of these treatments.

*Soon after planting 2d and before weed emergenceT2 (&+ 14d)*

There were no weeds on plots treated soon after transplanting with the exception of FVS-191 at low dose 1.25 L/ha (treatment 10) which gave poor control.

All treatments (7, 8, 9, 11, 12) containing pendimethalin *(Stomp Aqua and Wing-P)* applied over the top of courgettes remained weed-free but they had killed the crop.

FVS-190 and FVS-165 applied pre-weed-emergence need soil moisture for good efficacy and there was heavy rainfall after application. FVS-165 and FVS-190 were the best safe herbicide treatments. Both gave excellent weed control of most species, importantly annual meadow-grass, groundsel, mayweeds and small nettle. In other trials FVS-165 did not control knotgrass or redshank, FVS-190 controlled redshank but not knotgrass. Percent weed cover very low on FVS-165 (4, 5, 6) mainly small nettle and FVS-190 (13, 14, 15) with only a few stunted annual meadow-grass. FVS-165 at 1.0 L/ha gave good control of groundsel and there was none where Gamit was added. Treatment 13 FVS-190 at 52.5 g/ha or 35 g/ha alone (14) or with Gamit (15) left a few stunted annual meadow-grass which died later on treatments 13 and 15. FVS-190 as a residual herbicide was more persistent than FVS-165.

*Post-weed-emergence 4-5 TL before flowering T3*

FVS-190 at 52.5 g/ha (T16) or 35 g/ha (T17) were applied on 12 June. High populations of red dead-nettle, groundsel, mayweed, chickweed and shepherd's purse were controlled, but some small nettle remained and efficacy on annual meadow-grass, field speedwell and fat-hen was poor. The highest % weed cover on the trial was for FVS-190 at 35 g/ha (T17). The courgette leaves sheltered weeds including nettle (not counted) from spray and these would have interfered with harvesting.

**Table 1.8.4.** Summary of weed species controlled in courgettes - 2014

| Herbicide dose rate/ha | Groundsel | Small nettle | Red dead-nettle | Chickweed | Annual Meadow-grass | Shepherd's purse | Fat-hen | Fig-leaved goosefoot | Redshank | Knotgrass | Mayweed | Field speedwell ** | Fool's parsley |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Pre-planting soil incorporated* | | | | | | | | | | | | | |
| Benfluralin (2.0 kg) | X | √ | √ | √ | √ | X | √ | √ | √ | √ | X | √ | - |
| *Pre-weed-emergence* | | | | | | | | | | | | | |
| FVS-190 (52.5 g) | √ | √ | √ | √ | √ | √ | √ | - | √ | - | √ | √ | - |
| FVS-190 (35 g) | √ | √ | √ | √ | Xst | √ | √ | - | √ | X | √ | √ | - |
| FVS-165 (2.0 L) | √ | √ | √ | √ | √ | √ | √ | √ | X | X | √ | √ | - |
| FVS-165 (1.0 L) | √ | √ | √ | √ | √ | √ | √X | √X | X | X | √ | √ | - |
| FVS-191 (1.25 L) | X | √ | X | √ | √ | √ | √ | √ | X | X | √ | X | - |
| *Post-weed-emergence* | | | | | | | | | | | | | |
| FVS-190 (52.5 g) | √ | √ | √ | √ | X | √ | X | - | - | - | √ | X | √ |
| FVS-190 (35 g) | √ | X | √X | √ | X | √ | X | - | - | - | √ | X | √ |

Gamit controls groundsel, fool's parsley, shepherd's purse, red dead-nettle, but redshank is moderately susceptible. √ - controlled; X – not controlled, st – stunted; - weed species not present.

*Discussion*

The only herbicides approved (EAMUs) for courgettes are for Kerb Flo (propyzamide) and Flexidor 125 (isoxaben) – neither control groundsel. Clomazone controls groundsel and now has an EAMU as Gamit 36SC for courgette. There are potential herbicide solutions for weed control in outdoor courgette transplants and possibly squash and other cucurbits. These herbicides could also be evaluated on crops grown from seed. The variety Milos was tested in this trial – other varieties need to be assessed.

The best herbicide application timing is soon after transplanting but before weeds emerge (i.e. 2 days after planting and within 7 days). The best safe effective treatments were with FVS-165 at 2.0 L/ha and FVS-190 at 35 g/ha product applied soon after planting. FVS-190 was more persistent than FVS-165. However, there may be issues where sensitive crops follow FVS-190, but the low doses may reduce the risks.

FVS-190, a sulfonylurea, has soil residual and foliar activity, but with adequate rainfall it performed better pre-weed-emergence. It controlled a wide weed spectrum including groundsel (a frequent problem in vegetables), small nettle (a deterrent to hand-harvesting) and redshank. Post-weed-emergence it had weaknesses on annual meadow-grass, fat-hen and field speedwell. The addition of a wetter for courgettes is not recommended (USA) because it is too damaging.

FVS-165 has only residual soil activity and must be applied pre-weed-emergence soon after transplanting. Weed control with 2.0 L/ha was excellent on all species including annual meadow-grass, groundsel, mayweed, small nettle and fat-hen. It does not control knotgrass or redshank and at 1.0 L/ha it was less effective on small nettle and fat-hen.

Groundsel has become a frequent problem in vegetable crops and there is often more than one flush. Several different herbicides are needed to avoid the risk of herbicide resistance developing. FVS-165, FVS-190 and Gamit, an isoxazolidinone, control groundsel and are from different classes of chemistry.

Programmes and tank-mixes

In the trial, Gamit 36CS was useful in a programme following benfluralin. It was safe in tank-mix with FVS-165 or FVS-190. Slight bleaching on courgette leaf margins was seen but the effect soon grew out.

FVS-190 does not control knotgrass: FVS-165 does not control redshank or knotgrass and a programme with a product containing pendimethalin (Stomp Aqua or Wing-P) applied before transplanting would be needed but they are less safe and neither is available for courgettes. Benfluralin soil incorporated pre-planting would also be useful for control of Polygonums.

FVS-190 and FVS-165 are on the EU list of authorised active substances but not yet registered in the UK for any crop and it could take some time before they are available to growers. FVS-190 is authorised in the USA for asparagus (including fern stage), cucurbits, snap beans, sweet corn, peppers, maize and several other crops. Metabolism and residues data for would be needed for UK on-label approvals or EAMUs and may be available from the USA.

## 1.9 Assessment of the efficacy and crop safety of some conventional herbicides for control of annual weeds in six umbelliferous crops

In previous trials benfluralin and an alternative to linuron were identified with potential for use in umbelliferous crops. In 2014 they were evaluated in field trials alone, in programmes and in tank-mixes to provide information about their phytotoxicity to carrot, parsnip, coriander, flat-leaved parsley, celery and celeriac, and on weed species controlled. Treatments were compared with untreated crops.

**Table 1.9.1.** Approval status (2014) of herbicides used on umbelliferous crops

| a.s. | Product | Company | EU status | UK Approval Status |
|---|---|---|---|---|
| pendimethalin | Stomp Aqua 455 g/L CS | BASF | on approved list of active substances | UK approval carrots, parsnips, celeriac, celery, parsley, coriander |
| pendimethalin | Anthem 400 SC 400 g/L | Makhteshim | on approved list of active substances | UK approval carrots, parsnips, celeriac, celery |
| - | FVS-191 | - | on approved list of active substances | - |
| benfluralin | 600 g/kg WDG | Dow | on approved list of active substances | - |
| metribuzin | Sencorex WG 70% w/w WDG | Interfarm | on approved list of active substances | EAMU for carrots, (parsnip but not safe) |
| metribuzin | Sencorex Flow 600 g /L SC | Interfarm | on approved list of active substances | Pending for carrots |
| clomazone | Gamit 360 CS, 36 g/L CS | Belchim | on approved list of active substances | UK approval carrots, celeriac, celery |
| prosulfocarb | Defy 800 g/L SC | Syngenta | on approved list of active substances | EAMU carrots, parsnips, celeriac, celery |
| metamitron | Goltix Flowable 700g/L SC | Makhteshim | on approved list of active substances | EAMU parsnips (pre-em) |

Rainfall was frequent throughout the trial period and 180% above average in May - no irrigation was needed to increase residual herbicide effects.

*Results*

## a) Carrots

**Table 1.9.2.** Detail of herbicide treatments to carrots (& = followed by; + = tank mix)

| Herbicide | g a.s./ha | L or kg product/ha |
|---|---|---|
| Pre-sowing soil incorporated with shallow bedformer T0 11 April | | |
| 1. Benfluralin & Gamit pre-emergence T1 | 1200 & 72 | 2.0 kg & 0.2 L |
| Pre-emergenceT119 April | | |
| 0. untreated | - | - |
| 2. FVS-191 | 800 | 2.0 L |
| 3. FVS-191 + Gamit | 800 + 72 | 2.0 L + 0.2 L |
| 4. FVS-191 + Stomp Aqua + Gamit | 800 + 705 + 72 | 2.0 L + 1.55 L + 0.2 L |
| 5. FVS-191 + Anthem + Gamit | 800 +1320 + 72 | 2.0 L + 3.3 L + 0.2 L |
| 6. Anthem + Gamit + Sencorex Flow | 1320 + 72 + 175 | 3.3 L + 0.2 L + 0.292 L |
| Post-emergence 1-2 TL T2 17 May (& +14 days) 26 May | | |
| 7. FVS-191 | 500 | 1.25 L |
| 8. FVS-191 & FVS-191 | 250 & 250 | 0.625 L & 0.625 L |
| 9. Stomp Aqua + FVS-191 | 200 + 500 | 0.44 L + 1.25 L |
| 10. Stomp Aqua + FVS-191 | 200 + 250 | 0.44 L + 0.625 L |
| Post-emergence 2-3TL T3 21 May (& + 14 days) 31 May | | |
| 11. Defy + FVS-191 & Defy + FVS-191 | 2000 + 250 & 2000 + 250 | 2.5 L + 0.625 L & 2.5 L + 0.625 L |
| 12A, B, C. Sencorex Flow + FVS-191 | 140 + 250 | 0.233 L + 0.625 L |
| 12B. & Sencorex Flow + FVS-191 | &140 + 250 | & 0.233 L + 0.625 L |

**Table 1.9.3.** Dates of herbicide application to carrot, cv. Nairobi - 2014

| Sowing date | Timing | Herbicide treatment | Date applied | Crop growth stage (cot cotyledon; true leaves TL) |
|---|---|---|---|---|
| 15 April | T0 | 1 | 11 April | Pre-sowing incorporated shallow bed-former 10 cm |
| | T1 | 1 2 3 4 5 6 | 19 April | Pre-emergence |
| | T2 | 7 8 9 10 | 17 May | 5% cot: 50% 1TL; 45% 2TL |
| | | & 8 | 26 May | 2-2½ TL |
| | T3 | 11 12 | 21 May | 10% 1½ TL: 80% 2TL; 10% 2½ TL |
| | | & 11 12B | 31 May | 3TL |

Crop safety – Carrots

*Pre-sowing soil incorporated T0*

There were no phytotoxic effects from benfluralin or bleaching from Gamit applied at T1

*Pre-emergenceT1*

There was no damage observed from FVS-191 at 2.0 L/ha where applied alone or in tank-mix with Gamit, Stomp Aqua or Anthem.

Anthem + Gamit + Sencorex Flow (3.3 + 0.2 + 0.292 L/ha) caused stunting and the carrot growth stage was delayed compared with untreated carrots. These effects persisted but the carrots recovered a month later.

*Post-emergence 1-2 TL T2*

The temperature reached 22ºC on 17 and 26 May, but the only herbicide effect was slight transient chlorosis (yellowing) from FVS-191 1.25 L/ha.

*Post-emergence T3*

Treatment 11 with a repeat dose of Defy + FVS-191 caused scorch to carrot leaves - about 3% of the plant, but no leaf loss, also slight stunting and delay compared with the untreated carrots. These effects grew out later.

Sencorex Flow + FVS-191 as a single treatment caused some scorch (2% of the plant) and stunting. The repeat dose 12 B was only just acceptable but the carrots recovered by 2 July.

<u>Weed control – Carrots</u>

There were 390 weeds /$m^2$ on untreated plots, with very high populations of small nettle, red dead-nettle, groundsel, shepherd's purse, fat-hen and lower populations of annual meadow-grass, mayweed, redshank and chickweed. The weed distribution was uneven.

*Pre-sowing and soil incorporated with a bed-former T0*

Benfluralin 2.0 kg/ha followed by Gamit pre-emergence controlled complementary weed spectra and initially there were no weeds on these plots. A few small nettle, groundsel and shepherd's purse emerged later.

*Pre-emergenceT1*

FVS-191 at 2.0 L/ha (treatment 2) controlled fat-hen, shepherd's purse, chickweed, and importantly, mayweed. It had poor efficacy on red dead-nettle, redshank and was less effective on groundsel than in previous trials. Tank-mix partner Gamit (3) improved control of red dead-nettle and groundsel and products containing pendimethalin Stomp Aqua (4), Anthem (5) controlled redshank, although the lower dose of pendimethalin left a few.

Anthem + Gamit + Sencorex Flow (3.3 + 0.2 + 0.292) L/ha gave complete control of all weed species and plots were weed-free for 74 DAT1.

*Post-emergence T2*

The carrots emerged 20 days after drilling (too deep) and some rows emerged later than this. Many weeds had emerged earlier and on 17 May GS were: groundsel 2TL, small nettle 2-4TL, red dead-nettle 2TL; fat-hen 2-4TL, redshank 2-3TL, chickweed 8TL, shepherd's purse 2-4TL. Treatments 7-10 were not effective because some weeds were too large by the time the crop had reached 1-2 TL, and the dose rates too low. However, FVS-191 at a total dose of 1.25 L/ha had good efficacy on small nettle, shepherd's purse, chickweed, mayweed and fat-hen. Red dead-nettle was stunted and there was little effect on groundsel or on an uneven population of redshank. The addition of the low dose of pendimethalin (9, 10) appeared to improve red dead-nettle control.

*Post-emergence T3*

On 21 May 80% of carrots were at 2TL stage. The tank-mix of Defy +FVS-191 as a repeat dose was more effective than FVS-191 alone particularly on red dead-nettle, but it did not control groundsel. It failed to suppress the very large potato plants (2-3 shoots, flower buds, height 30cm), with only 27% leaf area scorch.

Sencorex + FVS-191 (treatment 12) gave complete control of large weeds of all species: groundsel 4TL, chickweed small plant, small nettle 4-6TL, red dead-nettle 4TL, annual meadow-grass tillering, shepherd's purse 4TL, fat-hen 4TL, redshank 3TL and mayweed 5TL.

### b) Parsnips

**Table 1.9.4.** Details of herbicide treatments to parsnips – 2014 (& = followed by; + = tank mix)

| Herbicide | g a.s./ha | L or kg product/ha |
|---|---|---|
| Pre-sowing soil incorporated with shallow bedformer T0 | | |
| 1. Benfluralin | 1200 | 2.0 kg |
| Pre-emergenceT1 | | |
| 0. Untreated | - | - |
| 2. FVS-191 | 800 | 2.0L |
| 3. FVS-191 + Stomp Aqua | 800 + 705 | 2.0L + 1.55L |
| 4. FVS-191 + Anthem + Goltix Flowable | 800 + 1320 + 2100 | 2.0L + 3.3L + 3.0L |
| 5. FVS-191 + Anthem + Goltix Flowable | 800 + 1320 + 1050 | 2.0L + 3.3L + 1.5L |
| 6. Anthem & FVS-191 at 2TL | 1320 & 500 at 2TL | 3.3L & 1.25L |

| | | |
|---|---|---|
| Post-emergence 2 TL T2 (&+ 14 days) | | |
| 7. FVS-191 | 500 | 1.25L |
| 8. FVS-191 & FVS-191 | 250 & 250 | 0.625L & 0.625L |
| 9. Stomp Aqua + FVS-191 | 200 + 500 | 0.44L + 1.25L |
| 10. Stomp Aqua + FVS-191 | 200 + 250 | 0.44L + 0.625L |
| Post-emergence 3 true leavesT3 & + 14 days | | |
| 0. Untreated | - | - |
| 11. Defy + FVS-191 & Defy + FVS-191 | 1600 + 250 & 1600 + 250 | 2.0L + 0.625L & 2.0L + 0.625L |

**Table 1.9.5.** Dates of herbicide application to parsnip, cv. Palace

| Sowing date | Timing | Herbicide treatment | Date applied | Crop growth stage (cot cotyledon; true leaves TL) |
|---|---|---|---|---|
| 15 April | T0 | 1 | 11 April | Pre-sowing incorporated shallow bed-former 10 cm |
| | T1 | 2 3 4 5 6 | 19 April | Pre-emergence |
| | T2 | & 6 7 8 9 10 | 21 May | Post-emergence 90% 1TL:10% 1½ TL |
| | | & 8 | 31 May | Post-emergence 90% 2TL: 10% 2½ TL |
| | T3 | 11 | 31 May | Post-emergence 90% 2TL: 10% 2½ TL |
| | | & 11 | 6 June | Post-emergence 90% 3TL: 10% 3½ TL |

Crop safety - Parsnips

Treatment 1 with benfluralin 2.0 kg/ha soil incorporated with a bed-former was safe to parsnip.

*Pre-emergence*

FVS-191 at 2.0 L/ha alone (2), FVS-191 + Stomp Aqua (3) and (6) Anthem at high dose followed by FVS-191 were safe to the crop.

Tank-mixes FVS-191 + Anthem + Goltix Flowable (2.0 + 3.3 + 3.0 L/ha) (4) and FVS-191 + Anthem + Goltix Flowable (2.0 + 3.3 + 1.5) L/ha (5) included Goltix (metamitron) to control groundsel but it caused damage. Parsnips were chlorotic and Goltix Flowable at 3.0 L/ha caused some plant death reducing population by 31%, at 1.5 L/ha there was no plant loss. Treatments 4 and 5 delayed maturity and growth stages were not as advanced as untreated parsnips. Stunting persisted until 11 June but treatment 5 had recovered by 8 July when roots began to expand.

*Post-emergence T2*

Treatments of FVS-191 and Stomp Aqua + FVS-191 at low doses (7-10) were applied when parsnips were 90% 1TL: 10% 1½ TL. There was no damage from any herbicide.

*Post-emergence T3*

Defy + FVS-191 (2.0 + 0.625) L/ha & Defy + FVS-191 (2.0 + 0.625) L/ha only caused slight scorch to leaf margins, observed after the second application under hot conditions on 6 June.

<u>Weed control - Parsnips</u>

On untreated plots there were 358 weeds/m$^2$. There were high populations of small nettle, red dead-nettle, groundsel, shepherd's purse and annual meadow-grass. Other species included redshank. The weed distribution was uneven.

*Pre-sowing soil incorporated T0*

Benfluralin 2.0 kg/ha did not control shepherd's purse, groundsel or mayweed but achieved good control of small nettle, red dead-nettle, annual meadow-grass, and redshank. Weed cover was high

*Pre-emergence T1*

FVS-191 at 2.0 L/ha had poor efficacy on red dead-nettle and redshank, gave 59% control of groundsel numbers. It controlled small nettle, shepherd's purse, mayweed, annual meadow-grass and chickweed.

FVS-191 + Stomp Aqua tank-mix (treatment 3) and Anthem 3.3 L/ha (6) controlled all species except groundsel. A follow-up post-emergence application (6) had little effect on groundsel at 5TL - too large for control with the low dose FVS-191 1.25 L/ha post-emergence.

Goltix was added to control groundsel and treatment 4 FVS-191 + Anthem + Goltix Flow (2.0 + 3.3 + 3.0) L/ha and treatment 5 FVS-191 + Anthem + Goltix Flow (2.0 + 3.3 + 1.5) L/ha were weed-free until after 8 July 50 DAT1. However 3.0 L/ha of Goltix Flow caused severe damage to parsnip.

*Post-emergence T2*

Parsnip emergence was late, 28 days after drilling (too deep), and uneven. Weed growth stages were very advanced: groundsel 5TL, small nettle 4-8TL, red dead-nettle 6TL, redshank 3-5TL, shepherd's purse 6TL, annual meadow-grass tillering, fat-hen 6-8TL, chickweed small plant, mayweed 6-8TL. These were all too large for control with low doses of FVS-191 alone or in tank-mix with Stomp Aqua. The weeds were more vigorous on treatment 7 than 8. Where the tank-mix with Stomp Aqua was applied redshank were stunted but plot cover was still high, it also stunted red dead-nettle compared with untreated plots.

*Post-emergence T3*

All weeds were at large plant stage by 31 May and GS of parsnips was only 90% 2TL: 10% 2½ TL.

Treatment 11 Defy + FVS-191 (2.0 + 0.625) L/ha scorched small nettle, annual meadow-grass, redshank and red dead-nettle, the latter was killed by the second dose. There was little effect on large groundsel. It killed shepherd's purse, chickweed and the few fat-hen. "Volunteer" potatoes had 3 shoots, 35 cm tall were too large to be suppressed - 25% of leaf area was scorched.

**c) Coriander and Flat-leaved Parsley**

**Table 1.9.6.** Detail of herbicide treatments on coriander and flat leaf parsley – 2014 (& = followed by; + = tank mix)

| Herbicide | g a.s./ha | L product/ha |
|---|---|---|
| Pre-emergenceT1 | | |
| 0. Untreated | - | - |
| 1. FVS-191 | 500 | 1.25L |
| 2. FVS-191 + Stomp Aqua | 500 + 1001 | 1.25L + 2.2L |
| 3. FVS-191 + Stomp Aqua pre & FVS-191 post 2-4TL | 500 + 1001 & 500 | 1.25L + 2.2L & 1.25L |
| Post-emergence 2 TL- 4TL T2 (&+ 10 days) | | |
| 4. FVS-191 & FVS-191 | 250 & 250 | 0.625L & 0.625L |
| 5. FVS-191 | 500 | 1.25L |

**Table 1.9.7.** Dates of herbicide treatment applied to coriander cv. Filtro and flat leaf parsley cv. Rialto - 2014

| Sowing date | Timing | Herbicide treatment | Date applied | Crop growth stage (cot cotyledon; true leaves TL) |
|---|---|---|---|---|
| 23 April | T1 | 1 2 3 | 23 April | Pre-emergence |
| | T2 | 3 4 5 | 19 May | Post-emergence 90% 1TL: 5% 1½ TL: 5% 2TL |
| | | & 4 | 31 May | Post-emergence 3TL |
| 23 April | T1 | 1 2 3 | 23 April | Pre-emergence |
| | T2 | 3 4 5 | 31 May | Post-emergence 70% 2TL: 30% 1½ TL |
| | | & 4 | 6 June | Post-emergence 2½ TL |

<u>Crop safety – Coriander</u>

Coriander was sown on 23 April and emerged 7 May.

FVS-191 at 1.25 L/ha was very safe to coriander applied pre-emergence alone, or in tank-mix with Stomp Aqua. FVS-191 at 1.25 L/ha was also safe when applied early post-emergence to coriander at an early growth stage (90% 1TL: 5% 1½ TL: 5% 2TL) as a single or as a split dose.

No herbicide damage was observed and there were no effects that might reduce quality of the crop.

Weed control – Coriander

Weed populations were high 248/$m^2$ on untreated plots, mainly red dead-nettle, small nettle and groundsel. Coriander emerged much earlier than flat-leaved parsley, growth was vigorous and it suppressed some weeds.

*Pre-emergence*

FVS-191 at 1.25 L/ha alone gave 92% control of small nettle numbers, 74% control of groundsel and was effective on other species including mayweed, shepherd's purse, chickweed and low numbers of fat-hen. It had little effect on red dead-nettle or redshank.

FVS-191 + Stomp Aqua (1.25 + 2.2) L/ha (T3) controlled redshank and all other species - only groundsel escaped control. The follow-up post-emergence application of FVS-191 1.25 L/ha to groundsel up to 2TL, did not control the larger plants, but this was the best treatment.

*Post-emergence*

Treatments 4 and 5 were applied early, when coriander was at GS 90% at 1TL : 10% at cotyledon stage, but by this time several weeds were at advanced growth stages. FVS-191 had little effect on the large groundsel (4TL) but it scorched and stunted red dead-nettle (cot-2TL) at an earlier growth stage and killed small nettle (2-4TL). The 1.25 L/ha dose and the second follow-up dose killed shepherd's purse (4-6TL) and some mayweed but redshank (2-3TL) remained. Post-emergence application of FVS-191 at 1.25 L/ha alone, or as a split dose, had poor efficacy overall and weed control was unacceptable.

Crop safety – Flat-leaved Parsley

Flat-leaved parsley was sown on 23 April and did not emerge until 14 May.

FVS-191 at low dose 1.25 L/ha applied pre-emergence alone and in tank-mix with Stomp Aqua were safe to the crop. There were no herbicide effects that might reduce quality.

Post-emergence treatments with FVS-191 (&3, and 4, 5) were applied on 31 May when the parsley was at GS 70% 2TL: 30% 1½ TL, earlier than the 2-4TL suggested, because weeds were at advanced growth stages. These treatments caused scorch and leaf loss. The growing point of most parsley was not damaged but there was severe stunting and some plant death – about 10%. The follow-up split dose to treatment 4 applied in hot sunny weather on 6 June increased damage.

Weed control – Flat-leaved Parsley

Weed populations were high 284 /$m^2$ on untreated plots, mainly red dead-nettle, small nettle and groundsel.

*Pre-emergence*

FVS-191 at 1.25 L/ha alone gave 68% control of small nettle numbers, only 61% control of groundsel but was effective on other species including mayweed, shepherd's purse and chickweed. It had little effect on red dead-nettle or redshank. FVS-191 + Stomp Aqua (1.25 + 2.2) L/ha controlled redshank and all other species - only groundsel remained. FVS-191 1.25 L/ha post-emergence (follow-up treatment 3) had no effect on the large groundsel plants.

*Post-emergence*

Weeds were large and some only suffered scorch and stunting from the low doses of FVS-191.

The parsley on treatments 4 and 5 was smothered by weeds.

**d) Celery**

**Table 1.9.8.** Detail of herbicide treatments applied to celery – 2014 (& = followed by; + = tank mix)

| Herbicide | g a.s./ha | L or kg product/ha |
|---|---|---|
| Pre-planting soil incorporated with Roterra T0 | | |
| 0. Untreated | - | - |
| 1. Benfluralin T0 & Gamit T1post plant | 1200 & 72 | 2.0kg & 0.2L |
| Soon after planting 5-10d T1 | | |
| 2. Stomp Aqua + Gamit | 1046 + 72 | 2.3L + 0.2L |
| 3. Stomp Aqua + Gamit + FVS-191 | 1046 + 72 + 500 | 2.3L + 0.2L +1.25L |
| Post-weed-emergence T2 (& + 10d) | | |
| 0. Untreated | - | - |
| 4. FVS-191 | 500 | 1.25L |
| 5. FVS-191 & FVS-191 | 250 & 250 | 0.625L & 0.625L |
| 6. Defy + FVS-191 & FVS-191 | 1600 + 250 & 250 | 2.0L + 0.625L & 0.625L |

**Table 1.9.9.** Dates of herbicide application – celery, cv. Plato

| Transplanted date | Timing | Herbicide treatment | Date applied | Crop growth stage true leaves TL |
|---|---|---|---|---|
| 14 May 5TL | T0 | 1 | 10 May | Pre-sowing incorporated Roterra |
| | T1 | & 1 2 3 | 16 May | Soon after planting 5TL |
| | T2 | 4 5 6 | 31 May | Post weed emergence 6½ TL |
| | | & 5 & 6 | 6 June | Post weed emergence 7½ TL |

<u>Crop safety – Celery</u>

*Pre-transplanting soil incorporated T0*

Benfluralin 2.0 kg/ha was soil-incorporated with a Roterra at a depth of 5 cm, and Gamit 0.2 L/ha was then applied to the soil surface after planting T1. The only phytotoxic effect was slight transient bleaching on celery leaf margins from Gamit.

*Soon after planting and before weed emergenceT1*

Stomp Aqua + Gamit (2.3 + 0.2) L/ha was also very safe with similar bleaching from Gamit.

Stomp Aqua + Gamit + FVS-191 (2.3 + 0.2 + 1.25) L/ha. There were slight effects initially from Gamit, but the scorch 30%, mainly on older celery leaves, caused by FVS-191 was severe and there was some leaf loss. New leaves that developed were not affected. Celery plants began to recover 28 DAT1.

*Post-weed-emergence T2*

FVS-191 was applied at 1.25 L/ha (treatment 4) as a single or a split dose (treatment 5). There was more severe scorch from the single dose. The damage to pale-leaved celery was greater than to dark-leaved celeriac.

Defy + FVS-191(2.0 + 0.625) L/ha followed by FVS-191 at 0.625 L/ha (treatment 6): the addition of Defy increased damage but improved efficacy on some species. Treatments 4, 5 and 6 all caused leaf loss, but untreated plants also lose older leaves eventually as the celery develops. Under good growing conditions, the celery recovered. Harvest stage was estimated early August.

<u>Weed control - Celery</u>

Weed populations were high 240 weeds/$m^2$ on untreated plots. There were 10 weed species predominantly red dead-nettle, small nettle, groundsel and a few field speedwell, mayweeds, chickweed, shepherd’s purse and some annual meadow-grass. There was a late emergence of field speedwell - a total of 17/$m^2$.

*Pre-transplanting soil incorporated T0*

Benfluralin 2.0 kg/ha at T0 followed by Gamit 0.2L/ha soon after planting T1: control of the high population of red dead-nettle and other species was excellent but some small nettle and groundsel remained.

*Soon after planting and before weed emergenceT1*

Treatments 2 and 3 were both effective on the high populations of small nettle, red dead-nettle and field speedwell and 32 days after application only groundsel remained. There were fewer groundsel where FVS-191 was added - Stomp Aqua + Gamit + FVS-191 (2.3 + 0.2 + 1.25) L/ha and this was the best treatment pre-weed-emergence.

*Post-weed-emergence T2*

Herbicides were applied early when weeds were small: groundsel mainly 1 TL a few 2TL, redshank 1TL small nettle, red dead-nettle cot-2TL.

FVS-191 at 1.25 L/ha (treatment 4) as a single or a split dose (treatment 5): control of groundsel was poor but redshank was scorched. The follow up dose applied under hot conditions on 6 June had more effect on red dead-nettle. Neither controlled field speedwell, which is resistant to FVS-191. Efficacy on small nettle, mayweed, shepherd's purse and annual meadow-grass was excellent. Overall the split doses (treatment 5) gave slightly better weed control than 4 where remaining weeds were more vigorous but both were inadequate and these plots were very weedy.

Defy + FVS-191(2.0 + 0.625 L/ha) followed by FVS-191 at 0.625 L/ha (6) was the best treatment post-weed-emergence. Red dead-nettle and field speedwell were killed but a few stunted groundsel remained.

### e) Celeriac

**Table 1.9.10.** Detail of herbicide treatments applied to celeriac – 2014 (& = followed by; + = tank mix)

| Herbicide | g a.s./ha | L or kg product/ha |
|---|---|---|
| Pre-sowing soil incorporated with Roterra T0 | | |
| 1. Benfluralin T0 & Gamit T1 post plant | 1200 & 72 | 2.0kg & 0.2L |
| Soon after planting 5-10d T1 | | |
| 2. Stomp Aqua + Gamit | 1046 + 72 | 2.3L + 0.2L |
| 3. Stomp Aqua + Gamit + FVS-191 | 1046 + 72 + 500 | 2.3L + 0.2L + 1.25L |
| 4. Stomp Aqua + Gamit + Sencorex Flow | 1046 + 72 + 175 | 2.3L + 0.2L + 0.292L |
| Post-weed-emergence T2 (& + 14d) | | |
| 0. Untreated | - | - |
| 5. FVS-191 & FVS-191 | 250 & 250 | 0.625L & 0.625L |

| | | |
|---|---|---|
| 6. FVS-191 | 500 | 1.25L |
| 7. Sencorex Flow | 175 | 0.292L |
| 8. Sencorex Flow | 350 | 0.583L |
| 9. Sencorex Flow + FVS-191 & Sencorex Flow + FVS-191 | 140 + 250 & 140 + 250 | 0.233L + 0.625L & 0.233L + 0.625L |
| Post-weed-emergence late T3 large weeds | | |
| 10. Sencorex Flow | 350 | 0.583L |

**Table 1.9.11.** Details of herbicide treatment to celeriac, cv. Prinz - 2014

| Transplanting date | Timing | Herbicide treatment | Date applied | Crop growth stage (true leaves TL) |
|---|---|---|---|---|
| 14 May | T0 | 1 | 10 May | Pre-sowing incorporated Roterra |
| | T1 | & 1 2 3 4 | 16 May | Soon after planting 5TL |
| | T2 | 5 6 7 8 9 | 31 May | Post weed emergence 6½ TL |
| | | & 5 & 9 | 6 June | Post weed emergence 7½ TL |
| | T3 | 10 | 12 June | Post weed emergence 8½ TL |

<u>Crop safety – Celeriac</u>

There were phytotoxic effects from several treatments of scorch and leaf loss, mainly of the older leaves, but untreated plants also lose older leaves as the celeriac develops. Stem bulb diameter was measured on a few treatments to give an indication of recovery from herbicide damage.

*Pre-transplanting soil incorporated T0*

Benfluralin 2.0 kg/ha was soil-incorporated with a Roterra at a depth of 5 cm, and Gamit 0.2 L/ha was applied after planting at T1. No herbicide effects from benfluralin were observed on the celeriac at any growth stage, but there was slight transient bleaching from Gamit.

*Soon after planting and before weed emergenceT1*

Stomp Aqua + Gamit (2.3 + 0.2 L/ha): there was only slight bleaching on leaf margins from Gamit.

Stomp Aqua + Gamit + FVS-191 (2.3 + 0.25 + 2.0 L/ha): there was more phytotoxicity – 5% bleaching on leaf margins of plants from Gamit and also scorch caused by FVS-191. The damage was less than in celery and the effects grew out later - 40 DAT1.

Stomp Aqua + Gamit + Sencorex Flow (2.3 + 0.2 + 0.292 L/ha): this tank-mix caused initial bleaching, very severe damage in the form of scorch to 50% of the plant on 6 June, followed by severe stunting and leaf loss a result of Sencorex damage. The celeriac began to recover and new leaves were not affected, but bulb development was delayed (19 July). The damage from the tank-mix (with Gamit) was far greater than treatment 7 where the same dose of Sencorex Flow (0.292 L/ha) was applied alone. The celeriac on treatment 4 did not recover until about 4 August.

*Post-weed-emergence T2 31 May (& 6 June)*

FVS-191: caused chlorosis (yellowing). On 6 June, 6 DAT2 the higher dose 1.25 L/ha treatment 6 caused more chlorosis on the first new leaves than the first split dose 0.625

L/ha, treatment 5. There was scorch from both treatments 5 and 6, but the celeriac soon recovered, and there was little difference in crop safety between them.

Sencorex Flow: damage was slower to develop but caused severe scorch and leaf loss, followed by stunting. The worst damage was from treatment 8 with 0.583 L/ha (equivalent to Sencorex WG 0.5 kg/ha) where there was some plant loss, severe stunting and delay in stem bulb development. On 5 September celeriac had suffered about 10% plant loss and bulbs were smaller than treatment 2 – this would have resulted in yield reduction.

Celeriac treated with 0.292 L/ha (treatment 7) recovered by 19 July (49 DAT2).

Sencorex Flow + FVS-191 (0.233 + 0.625 L/ha) repeat dose also caused severe scorch due to both components but less stunting. The single dose was probably safe. Later assessments showed that treatment 9 had recovered by 5 September.

*Post-weed-emergence late T3*

Sencorex Flow 0.583 L/ha (10) applied to a more mature crop had less effect than treatment 8, there was scorch and 3 leaves were lost but the celeriac was not stunted and stem bulb development did not appear to be affected.

<u>Weed control – Celeriac</u>

There were170 weeds/$m^2$ on the trial site, predominantly red dead-nettle, small nettle and groundsel. There was also a late flush of field speedwell 19/$m^2$.

*Pre-transplanting T0*

Benfluralin, soil incorporated at 5 cm depth with a Roterra followed by Gamit post-transplanting was effective 27 DAT on 6 June. Gamit controlled species that are resistant to benfluralin (groundsel, shepherd's purse and mayweed); benfluralin controlled red dead-nettle, annual meadow-grass and weeds present in low numbers – fat-hen, knotgrass and redshank. It was the least persistent treatment and by 18 June more small nettle and groundsel emerged on these plots.

*Soon after planting T1*

There was rainfall after application of residual treatments 2, 3 and 4 and these all performed well. Only a few groundsel remained on treatments 2 with Stomp Aqua + Gamit and there were fewer on treatment 3, Stomp Aqua + Gamit + FVS-191. All other species were controlled. The tank-mix with Sencorex Flow controlled all weeds but was not safe to the crop.

*Post-weed-emergence T2*

Weeds were at early growth stages: groundsel mainly 1 TL a few 2TL, redshank 1TL; small nettle, red dead-nettle cotyledon-2TL; field speedwell 2TL.

FVS-191 dose rates were low and there was little difference between the full (6) and the split dose (5). Treatments 5 and 6 achieved complete control of small nettle, good control of the high numbers of red dead-nettle at cotyledon GS. Only small groundsel (1TL) was controlled and it had no effect on the high number of field speedwell, which is resistant, or on the low population of knotgrass. Speedwell over-ran plots.

Sencorex Flow at 0.292 L/ha (7) and 0.583 L/ha (8), and treatment 9 repeat dose, Sencorex Flow + FVS-191 (0.233 + 0.625) L/ha (even as a single treatment) gave complete control of all weeds species present, including small knotgrass. These plots were still weed-free on 5 September.

*Post-weed-emergence late T3*

Weed counts were made on treatment 10 plots on 12 June before application of Sencorex Flow at high dose of 0.583 L/ha. It was applied when many species were at small plant stage. It controlled nettle, mayweeds, field speedwell, leaving only a few stunted red dead-nettle, groundsel and annual meadow-grass.

Knotgrass numbers were very low on untreated plots. FVS-191 (T5 and 6) had no effect on knotgrass and it was too advanced for control with the late Sencorex (T10). On 1 July there was negligible weed cover from knotgrass on any plots, but by 5 September it had over-run treatments 5 and 6 and there was some cover on treatment 10. There was no knotgrass on any other treated plot.

**Table 1.9.12.** Summary of weed control from herbicides FVS-191 and Benfluralin - 2014

√ weed species controlled; x poor control or not controlled at the dose rate; √x variable; s small

| Herbicide dose rate/ha | Groundsel | Small nettle | Red dead-nettle | Chickweed | Annual Meadow-grass | Shepherd's purse | Fat-hen ## | Redshank | Knotgrass | Mayweed | Field speedwell | Ivy-leaved speedwell | Fool's parsley | Black bindweed | Green nightshade | Field pansy | Field pennycress |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Pre-sowing/planting soil incorporated* | | | | | | | | | | | | | | | | | |
| Benfluralin 2.0 kg | X | √ | √ | √ | √ | X | √ | √ | √ | X | √ | √ | X | √ | - | √ | - |
| *Pre-weed-emergence* | | | | | | | | | | | | | | | | | |
| FVS-191 2.5 L | √ | √ | X | √ | √ | √ | √ | X | X | √ | X | X | - | √ | √ | √ | - |
| FVS-191 2.0 L | X | X √ | X | √ | √ | √ | √ | X | X | √ | X | X | - | X | √ | - | - |
| FVS-191 1.25 L | X | X √ | X | √ | √ | √ | √ | X | X | √ | X | X | X | X | √ | X | - |
| *Post-weed-emergence* | | | | | | | | | | | | | | | | | |
| FVS-191 1.25 L | √ | √ | X | √ | √ | √ | √ | X | - | √ | X | X | X | X | - | - | √ |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | s | | | | | | | | | | | | | | | | |
| FVS-191 0.625L | X | √ | X | √s | √ | √ | √ | X | X | X | X | X | X | X | - | - | √ |

## and fig-leaved goosefoot; FVS-191 at 1.25 L/ha pre-emergence gave 50-70% control of groundsel in trials.

FVS-191 needs to be applied when weeds are small <2TL

Gamit controls groundsel, fool's parsley, shepherd's purse, red dead-nettle and redshank is moderately susceptible.

*Discussion*

Residues data are being generated for FVS-191 for many of the umbelliferous crops. For benfluralin the company is investigating whether metabolism data covers root crops. Residues data will also be needed.

<u>FVS-191</u>

Linuron has not been supported and will be withdrawn. The potential alternative, FVS-191 is from the same class of chemistry as linuron. The dose rates evaluated in this trial were those likely to be approved for umbelliferous crops, and are lower than those anticipated in previous HDC/SCEPTRE trials.

The maximum dose likely to be permitted for FVS-191 pre-emergence/pre-transplanting is 2.0 L/ha (800 g a.s.). The maximum doses likely to be permitted for FVS-191 post-emergence or post-transplanting are 1.25 L/ha (500 g a.s.) or a split dose. These doses are too low for control of some species. FVS-191 has residual and foliar activity. Where it is used in the programme – pre- or post-weed-emergence needs to be considered carefully.

FVS-191 applied pre-weed emergence in a tank-mix with Gamit 36CS appeared to cause more scorch in some crops (celery, celeriac) than where it was applied alone.

FVS-191 applied in hot sunny weather post-weed emergence had more effect on weeds but caused damage to celery and parsley.

<u>Weeds</u>

Weed populations were very high on untreated plots in all the trials: 358/m$^2$ on parsnips; 390/m$^2$ carrots; 248/m$^2$ coriander; 284/m$^2$ flat-leaved parsley; 240/m$^2$ celery, 170/m$^2$ celeriac. Post-weed-emergence herbicides were applied when weeds were at early growth stages (cotyledon to 2TL) in celery and celeriac, but very advanced in parsnip and flat-leaved parsley. Weed susceptibility to benfluralin and FVS-191 are given in the Table above but more information will eventually be available from the companies. Neither product is approved yet.

<u>Weather</u>

There were periods of heavy rain in the third week of April, and rainfall was 180% higher than average in May. This ensured good activity of residual pre-emergence herbicides but also a risk of crop damage after herbicide leaching. Temperatures were higher than average in May, June and July and herbicides applied post-weed-emergence on 19 May, 26 May, 6 June and 12 June increased risk of scorch.

**a) Carrots**

Soil incorporated benfluralin product at 2.0 kg/ha followed by Gamit 0.2 L/ha at T1 controlled complementary weed spectra and this was an effective programme for carrots. The depth and method of incorporation needs to be considered – the depth of working of a bed-former in commercial crops is deeper than used in the trial and the benfluralin would be too dispersed and diluted for good efficacy. Benfluralin controlled redshank and knotgrass, although there were very few in these trials. It would be useful on other Polygonum spp.. It also works in a dry season.

There was no damage from pre-emergence applications of FVS-191 at 2.0 L/ha (800g a.s.), and only slight chlorosis from FVS-191 at 1.25 L/ha (500g a.s.) applied post-emergence even in hot sunny weather. Post-emergence tank-mixes of FVS-191 with Defy or Sencorex Flow were more phytotoxic, causing crop scorch and stunting, and care should be taken with the latter.

FVS-191 will be needed as a linuron alternative, pre-emergence it controls mayweed and gives some control of groundsel, but there are gaps in the weed spectrum and tank-mix partners are needed. The best safe and effective pre-emergence treatments for carrots were 3-way tank-mixes FVS-191 + Stomp Aqua + Gamit (2.0 + 1.55 + 0.2) L/ha or FVS-191 + Anthem + Gamit (2.0 + 3.3 + 0.2) L/ha.

Sencorex WG was evaluated pre-emergence in previous HDC carrot trials (FV 236b) on sand soils in a tank-mix at 0.25 kg/ha a low dose. It appeared safe at some sites but where the seedbed was loose and puffy, the herbicide leached after rain and reduced plant population. In 2014 a pre-emergence tank-mix Anthem + Gamit + Sencorex Flow (3.3 + 0.2 + 0.292) L/ha was evaluated (Sencorex Flow 0.292 L/ha was equivalent to 0.25 kg/ha of the WG formulation). The tank-mix gave excellent weed control including groundsel and mayweed and plots were weed free, but it caused severe stunting on the sandy silt loam after heavy rain. It would be risky on a sand soil particularly if the seedbed had not settled.

Post-emergence weed control with FVS-191 at 1.25 L/ha alone or with low dose Stomp Aqua was disappointing.

Volunteer potato plants were very large by the time the 2-3TL carrot growth stage was reached. Potatoes were not suppressed and Defy + FVS-191 (2.5 + 0.625) L/ha as a repeat dose only gave 27% potato leaf scorch, although control of other weeds was improved. At 0.625 L/ha FVS-191 had negligible effect in SCEPTRE 2012 trial and in company trials. It may be worth testing again on a smaller target. However, herbicide FVS-166 in the same class of active substances as diflufenican, evaluated SCEPTRE 2013 was very safe to carrots, looked promising for potato control, but did not control groundsel or annual meadow-grass.

Excellent control of large weeds was achieved with Sencorex Flow + FVS-191 (0.233 +0.625) L/ha – a useful but potentially damaging "fire engine" treatment. This could be a replacement for Sencorex WG + linuron.

**b) Parsnip**

Benfluralin 2.0 kg/ha applied pre-sowing and soil-incorporated appears very safe to parsnips but there are gaps in the weed spectrum and a pre-emergence treatment will also be needed, possibly Stomp Aqua + FVS-191 (Gamit is not safe to parsnips). The method of incorporation needs to be considered. Benfluralin controlled redshank and would be useful on other Polygonums. It also works in a dry season.

FVS-191 is needed as an alternative to linuron. FVS-191 applied pre-emergence was safe to parsnips at 2.0 L/ha (800g a.s.). It had weaknesses on red dead-nettle, redshank and gave only partial control of groundsel at this dose rate, but it controlled mayweeds. Parsnips were also safe to a tank-mix of FVS-191 + Stomp Aqua or Anthem at high dose, redshank was controlled but groundsel remained.

Control of groundsel is difficult in parsnip and Goltix WG was evaluated in HDC project FV 236b. It was effective on groundsel but it was advised that on very light soil the maximum dose of Goltix WG should not exceed 2.0 kg/ha. In this trial 2014, pre-emergence applications of FVS-191 + Anthem + Goltix Flowable (2.0 + 3.3 + 3.0) L/ha (4) and FVS-191 + Anthem + Goltix Flowable (2.0 + 3.3 + 1.5) L/ha (5) were evaluated on a sandy silt loam soil. Goltix is very soluble and leached after heavy rainfall. Goltix Flowable at 3.0 L/ha (treatment 4) reduced parsnip population by 31%. Gaps in rows would result in uneven size grades. Goltix Flowable at 3.0 L/ha on sands in a wet season would be risky. Goltix Flowable at 1.5 L/ha in tank-mix FVS-191 + Anthem + Goltix Flowable (2.0 + 3.3 + 1.5) L/ha (5) also has potential to cause damage and caused persistent stunting for 80 DAT1, but groundsel was controlled and parsnips remained weed free. Control of groundsel will continue to be very difficult in parsnip and several options are needed to avoid herbicide resistance.

FVS-191 applied post-emergence at 1.25 L/ha (500 g a.s.) when parsnips were only at 1TL was safe to the crop but weed control with the low doses of FVS-191 was poor. Parsnip seed was sown deep and parsnips did not emerge until 27 days later. The weed population was very high and most were at 5-8TL when post-emergence spray was applied. However in the celery trial weeds were small and control was also unacceptable with FVS-191 at low doses. FVS-191 needs a partner.

Defy + FVS-191 (2.0 + 0.625) L/ha as a repeat dose had little effect on the large ‘volunteer’ potatoes. It may be worth testing again on smaller potato plants. FVS-166, in the same class of active substances as diflufenican, evaluated SCEPTRE 2013 was safe to parsnips may be more promising for potato control and could be evaluated in tank-mix with Defy.

**c) Coriander and Flat-leaved parsley**

Coriander and flat-leaved parsley are contrasting herb types. Coriander emerged in 14 days, growth was vigorous and it suppressed some weeds. Flat-leaved parsley emerged unevenly after 21 days and growth was slower. Coriander is usually herbicide-tolerant, flat-leaved parsley is more sensitive to herbicides.

The maximum doses likely to be permitted for FVS-191 in herbs are 1.25 L/ha pre-emergence and 1.25 L/ha post-emergence before 6TL. These doses are too low for control of some species (see Table Weed Control Summary).

Both coriander and parsley are very dependent on linuron. FVS-191 is needed as an alternative and it was safe to both crops when applied pre-emergence alone at 1.25 L/ha, or in tank-mix with Stomp Aqua. FVS-191 achieved c. 70% control of groundsel. The post-emergence application of FVS-191 in coriander at 1TL was safe and it removed some groundsel. FVS-191 caused severe damage to flat-leaved parsley, applied when 70% were at 2TL but groundsel was too advanced for control.

A pre-emergence treatment is therefore essential in both crops and the addition of Gamit in a tank-mix (if safe) would reduce groundsel numbers. The best control was from treatment 3, but the post-emergence follow-up with FVS-191 caused damage to flat-leaved parsley at 2TL, although it might be safer applied at a later growth stage.

Groundsel is a toxic contaminant in coriander and parsley. It cannot be removed after machine harvesting and must be hand-weeded. There is nil-tolerance of groundsel contaminant in herbs for processing. Several options are needed to avoid development of herbicide resistance.

**e) Celery**

Celery is very dependent on linuron particularly for use post-weed-emergence, because most of the crop is grown organic soil. In future FVS-191 as a linuron alternative will be vital for this crop.

FVS-191 doses likely to be approved after planting are low 1.25 L/ha (500g a.s.) possibly the maximum permitted and where this is used in the programme – pre- or post-weed-emergence needs to be considered carefully and will depend on soil type.

In this trial the most effective treatment applied soon after planting but before weeds emerged was Stomp Aqua + Gamit + FVS-191 (2.3 + 0.25 + 1.25) L/ha. The FVS-191 added to the groundsel control by Gamit but the tank-mix caused severe scorch (more than in celeriac). Stomp + Gamit was safer to the crop.

FVS-191, like linuron, causes scorch to celery if applied in hot weather.

FVS-191 post-weed-emergence - weed control was poor even on small weeds (groundsel mainly 1 TL a few 2TL, redshank 1TL, small nettle). It controlled red dead-nettle at cotyledon stage. Field speedwell is known to be resistant to FVS-191 even at high dose rates.

Benfluralin, soil incorporated, a residual herbicide, is safe to celery and could be useful on Polygonums but there were only a few in this trial. It may have poor efficacy on organic soils.

The most effective treatment was the programme of Defy + FVS-191 (2.0 + 0.625 L/ha) followed by FVS-191 at 0.625 L/ha (treatment 6), but it caused scorch.

**e) Celeriac**

The best timing for herbicide application in celeriac is soon after planting (i.e. 2 days after planting and within 7 days) and before weed emergence. If herbicides are applied before transplanting, the action of the machine pushes treated soil aside, weeds emerge within the crop row and must be hand-weeded.

Benfluralin has potential for use in celeriac - applied before planting and soil-incorporated, it controls weeds within the row. It could be useful on Polygonums.

FVS-191 was safe pre- or post-weed emergence in celeriac transplants and it would be a useful alternative to linuron.

Stomp Aqua + Gamit tank-mix applied pre-weed emergence two days after planting forms the basis for a weed control programme. Stomp Aqua + Gamit + FVS-191 (2.3 + 0.2 + 1.25 L/ha) was safe and effective.

FVS-191 applied post-weed-emergence, at a dose of 1.25 L/ha (likely to be authorised after transplanting) was too low for good weed control. A tank-mix with Defy at 2.0 L/ha (see celery trial treatment 6) would be more effective and likely to be safe. The current celeriac EAMU for Defy is for application within 14 days of transplanting, but a shorter Harvest Interval may be needed so it can be applied to emerged weeds. Residues data can now be extrapolated from carrots to celeriac. There is potential for the EAMU for Defy in carrots to be extended to celeriac. UK celeriac is harvested in November.

Sencorex Flow (and FVS-191) caused more scorch to celeriac than carrots – the celeriac leaves catch more spray.

Sencorex Flow gave the best weed control. It was too damaging applied in tank-mix soon after planting. Sencorex Flow applied post-weed-emergence gave excellent control of all weed species and plots 7, 8, 9 were still weed-free on 5 September. Sencorex Flow at 0.292 L/ha (7) (equivalent to 0.25 kg/ha Sencorex WG) caused severe scorch but recovered 28 days after treatment. Sencorex Flow at 0.233 L/ha would be effective and damage acceptable. The single dose of treatment 9 Sencorex Flow + FVS-191 (0.233 + 0.625 L/ha) was effective and possibly safe.

Sencorex Flow at 0.583 L/ha treatment 10 was safer than 8. It was applied later to large weeds and a more mature and vigorous crop caused scorch and loss of 3 older leaves but did not cause stunting, plant loss, or reduce stem bulb development. However, it was less effective on large weeds and those in the row sheltered by the crop. It could be useful as a top-up treatment in mid-July.

Initial scorch may be acceptable if it avoids hand-weeding within the row later. For carrots there is an EAMU for Sencorex WG (Sencorex Flow is still pending) with a 28 day Harvest Interval; an EAMU for celeriac is needed.

## 1.10 Assessment of the selectivity and efficacy of a novel herbicide in 15 vegetable crops

In a field screening trial in 2014 novel herbicide FVS-190, a sulfonylurea, was 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, swede, spinach; transplanted celery, cauliflower, lettuce and courgette. 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.

*Herbicide treatments*

The herbicide was applied pre-emergence of the drilled crops/pre-transplanting. It was also applied at early post-weed-emergence stage after emergence of the drilled crops/after transplanting. It was applied at 2x 'Normal', Normal, ½ Normal dose rates in all crops. The 'Normal' dose rates at both timings suggested for this trial was 70 g product/ha. There were two replications. Herbicide 190 is on the approved list of active substances for the EU south zone; it is not yet registered on any crop in the UK.

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, 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 1.10.1.** Detail of crops treated and dates of herbicide application – Lincs, 2014

| Crop (variety) | Sowing/ transplant date | Herbicide applied pre-weed emergence | Herbicide applied post-weed emergence | Crop growth stage (leaf L; true leaves TL) |
|---|---|---|---|---|
| 'Volunteer' potatoes Maris Piper | 9 April | 18 April | 15 May | 1 shoot 20cm tall |
| Onion (Hysky) | 8 April | 18 April | 15 May | 1 L |
| Leek ((Striker) | 8 April | 18 April | 15 May | 1 L |
| Carrot (Nairobi) | 8 April | 18 April | 15 May | 1-2 TL |
| Parsnip (Palace) | 8 April | 18 April | 15 May | 1 TL |
| Coriander (Filtro) | 13 May | 13 May | 6 June | 1 TL |
| Swede (Tweed) | 13 May | 13 May | 6 June | 1-2 TL |
| Rocket (wild rocket) | 13 May | 13 May | 6 June | 2 TL |
| Spinach baby-leaf (Renegade) | 13 May | 13 May | 1 June | 2 expanded TL |
| Dwarf French Bean (Parker) | 13 May | 13 May | 1 June | simple L |
| Pea (Cabree) | 13 May | 13 May | 1 June | 2 node |
| Broad beans (Manita) | 13 May | 13 May | 1 June | 1-2 node |
| Cauliflower transplant (Jerez) | 14 May | 13 May | 1 June | Established 6 ½ TL |
| Celery transplant (Plato) | 14 May | 13 May | 1 June | Established 7 TL |
| Lettuce transplant (Challenge) | 14 May | 13 May | 1 June | Established 6 TL |

| | | | | |
|---|---|---|---|---|
| Courgette transplant (Milos) | 14 May | 13 May | 1 June | Established 3 TL |

L – leaf; TL – true leaf

*Results*

Crop safety

*FVS-190 pre-emergence of drilled crops/pre-transplanting*

FVS-190 appeared to be safe to drilled dwarf French bean, courgette transplants and potatoes on the silt loam soil, at the dose rates shown in Table 1.10.2. Damage might be increased where crops are grown on a sand soil. There were no herbicide effects that reduced produce quality, but the highest dose rate 140 g/ha may delay maturity.

After application most of the less tolerant crops emerged, were yellow and suffered severe stunting with no further growth, followed by plant death. The most sensitive crops were swede, rocket, spinach and lettuce. Carrot, parsnip, celery transplants, coriander, onion and leek were also sensitive. Vining pea and broad bean were slightly less sensitive but emergence and growth was uneven. At 35 g/ha the cauliflower transplants survived, probably because the planter pushed the herbicide-treated soil aside in the row.

*FVS-190 post-emergence of drilled crops/post-transplanting*

FVS-190 also appeared to be safe to drilled dwarf French bean, courgette transplants and potatoes on the silt loam soil, at the post-emergence timing and at the dose rates shown in Table 1.10.2. There was some transient yellowing at the higher dose rates. There were no herbicide effects on the produce (pods, flowers, fruit, tubers) from these crops.

FVS-190 at 35 g/ha may be safe to carrots probably because the finely divided leaf caught less spray – parsnips were killed within days of application. Initially carrots became yellow and stunted they regained green colour but at 140 g/ha there was plant loss and the roots were tiny compared with the untreated crop. On 24 July root diameter of carrots on plots treated with FVS-190 35 g/ha was similar to untreated carrots but there was a slight constriction on the upper root – a potential quality defect.

In other vegetables FVS-190 caused yellowing, severe stunting, as well as crinkling and distortion of the crop growing point which was most marked in cauliflower. All crops were sensitive including broad beans, cauliflower, celery and peas. The damage to broad beans was severe: brown/blackened leaves and growing point. Phytotoxicity symptoms on peas were “bonsai” effects (chlorotic, multiple tillers and tiny plants) typical of sulfonylurea herbicide.

**Table 1.10.2.** Crop safety: Herbicide applied pre-emergence of drilled crops and pre-transplanting, and post-emergence of drilled crops and post-transplanting: √ safe; x not safe, (carrots marginal, possible root defect), N "normal"

| Herbicide 'Normal' dose/ha (70 g/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-190 | X | X | X | X | X | X | X | X | √ | √ | X | X | X | X | X |
| *Post-emergence/post transplanting* | | | | | | | | | | | | | | | |
| FVS-190 | X | X | (√ ½ N) | X | X | X | X | X | √ | √ | X | X | X | X | X |

FVS-190 applied pre- and post-emergence was also very safe to potato (Maris Piper) even at 140 g/ha.

<u>Weed Control</u>

Summaries of weed species controlled are shown in Table 1.10.3.

The weed spectrum was not as wide as in previous trials on a sandy silt loam area on this field - the area in 2014 was on a silt loam soil. On the pre-weed-emergence area there were eight weed species with very high populations of small nettle and red dead-nettle, and also groundsel, chickweed, annual meadow-grass and field speedwell. Weed populations on untreated plots ranged from 159/m$^2$ on the early sown crops to 190/m$^2$ on the later ones. On the post-weed-emergence area there were 13 weed species. On untreated plots there were up to 210 weeds/m$^2$ predominantly small nettle, red dead-nettle and groundsel, with some field speedwell, chickweed, annual meadow-grass. There were low populations of mayweed, shepherd's purse, redshank, knotgrass and fat-hen.

*Pre-weed-emergence application.* FVS-190 has residual soil and foliar activity. Soil moisture was adequate and FVS-190 was very effective and the later drilled plots remained almost weed-free for 6 weeks. Applied <u>before</u> transplanting, the action of the machine pushed treated soil aside and weeds emerged within the crop row, but between the rows there were very few weeds. At all dose rates tested FVS-190 gave excellent control of groundsel and chickweed. It controlled high populations of small and red dead-nettle with the exception of the early drillings where 35 g/ha was less effective on small nettle. Annual meadow-grass was controlled at 70 g/ha, but a few remained stunted at 35 g/ha. Numbers of knotgrass were low, FVS-190 at 70 g/ha appeared to be ineffective pre-emergence.

*Post-weed-emergence application*. Weeds susceptible to FVS-190 treated post-emergence became very stunted and tolerant crops (courgette) smothered them. However other vegetables in this trial were soon killed by FVS-190 and offered no competition. In this trial a wetter was not added (for reasons of crop safety) and control of emerged weeds was poor. All dose rates controlled fool's parsley as well as shepherd's purse and mayweeds, although numbers were low. FVS-190 was more effective on red dead-nettle than small nettle, treated when the largest were at 4TL, 70 g/ha was inadequate. FVS-190 at 35 g/ha failed to control annual meadow-grass. The highest dose rate 140 g/ha had a weakness on field speedwell. On untreated plots some weed species were present in low numbers (knotgrass, fat-hen) – where they were also present on post-emergence treated plots this indicated they are not susceptible to FVS-190. However, fat-hen was controlled pre-emergence.

**Table 1.10.3.** 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; √x* variable, not controlled in early sowings; - not present on untreated

| Herbicide<br>dose rate/ha<br>N = 70 g/ha | Groundsel | Small nettle | Red dead-nettle | Field speedwell | Chickweed | Annual Meadow-grass | Fool's parsley | Shepherd's purse | Fat-hen | Redshank ** | Knotgrass ** | Mayweed# ** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Pre-weed-emergence* | | | | | | | | | | | | |
| FVS-190 2N | √ | √ | √ | √ | √ | √ | - | - | - | √ | √ | - |
| FVS-190 N | √ | √ | √ | √X* | √ | √ | - | - | - | √ | X | - |
| FVS-190 ½ N | √ | √X* | √ | √X* | √ | Xst | - | - | - | √ | X | - |
| *Post-weed-emergence* | | | | | | | | | | | | |
| FVS-190 2N | √ | √ | √ | X | √ | √ | √ | √ | X | √X | √ | √ |
| FVS-190 N | √ | X | Xst | X | √ | √ | √ | √ | X | X | X | √ |
| FVS-190 ½ N | √ | X | X | X | √ | X | √ | √ | X | X | X | √ |

st stunted; # pineapple weed

<u>"Volunteer" potatoes</u>

FVS-190 applied pre-emergence had no effect on 'volunteer' potato foliage and post-emergence application caused only a slight transient yellowing to the terminal shoot. It was clear that FVS-190 would not control "volunteers" in other crops even at the highest dose rate, but it could have potential as a herbicide for the potato crop.

*Discussion*

FVS-190 offers potential solutions for weed control in courgettes, squash and other cucurbits, dwarf French beans and potatoes. It may be safe to a major crop, maize and to sweet corn. In the USA it is authorised for asparagus at several timings including fern stage, curcubits, peppers and several other crops. FVS-190 is on the EU list (southern zone) of authorised actives but not yet registered in the UK. Metabolism and residues data for vegetable crops may be available from the USA and these would be needed for UK on-label approvals or Extensions of Authorisation for Minor Use (EAMUs).

There was rainfall after applications of the herbicide pre-weed-emergence. There were frequent showers some of them very heavy and rainfall in May was 180% higher than average. Rain enhanced efficacy of the soil acting residual herbicide, but increased the risk of herbicide damage to crops as a result of herbicide leaching and tested crop safety. FVS-190 was evaluated on a silt loam soil and damage may be increased where crops are grown on a sand soil.

FVS-190 has soil residual and foliar activity. It controlled a wide weed spectrum including groundsel (a frequent problem in commercial vegetable crops), small nettle (a deterrent to hand-harvesting), redshank and red dead-nettle. Applied post-emergence it did not appear to control fat-hen or knotgrass although numbers were low and a programme or pre-emergence tank-mix partner would be needed. Efficacy of FVS-190 was better where it was applied pre-weed-emergence than post. In some crops a wetter is added to improve efficacy on emerged weeds, but this would be too damaging to many vegetables except perhaps sweetcorn, and is not advised in the USA for courgette or asparagus.

In summary

- An EAMU for use in courgette would be very useful. The best timing would be soon after post-transplanting, within two days but before weeds emerge. If herbicides are applied before transplanting, the action of the machine pushes treated soil aside and weeds emerge within the crop row. The emergence of small nettle within the row of courgettes would be a deterrent to pickers. FVS-190 could also be evaluated in drilled courgette, squash and other cucurbits.
- There is also potential for FVS-190 use in asparagus particularly at fern stage where currently there are no safe herbicide options.
- FVS-190 was safe at 140 g/ha to Maris Piper potatoes. There is potential for use in the potato crop but none for suppression of potato volunteers.
- Several vegetable crops were very sensitive to FVS-190 and risk of damage from drift or to following crops need to be considered.

## 1.11 Assessment of the efficacy and crop safety of three herbicides in bulb onion

One replicated trial was conducted in drilled bulb onions to evaluate the efficacy of three predominately residual herbicides for the control of broad leaf weeds in Alliums. The results obtained were compared with an untreated control and the trial protocol was validated by inclusion of a standard treatment (Wing P, pendimethalin + dimethenamid P) applied at recommended rates.

**Table 1.11.1.** Details of herbicide treatments on drilled bulb onion - 2014

| Treatment | SCEPTRE code or product | UK rate of product | Application timing |
|---|---|---|---|
| 1 | Untreated | - | - |
| 2 | Wing-P | 2 L/ha | A1 |
| 3 | Wing-P | 2 L/ha | A1 |
| | FVS 196 | - | A2 |
| 4 | FVS 165 | - | A1 |
| 5 | Wing-P + | 2 L/ha | A1 |
| | FVS 165 | - | A1 |
| 6 | Wing-P | 2 L/ha | A1 |
| | FVS 191 | 0.625 L/ha | A2, A3 |
| 7 | Wing-P | 2 L/ha | A1 |
| | FVS 191 | - | A2 |
| 8 | Wing-P | 2 L/ha | A1 |
| | FVS 165 | - | A2 |
| 9 | Wing-P + | 2 L/ha | A1 |
| | Stomp Aqua | 0.5 L/ha | |
| | Better DF + | 0.3 Kg/ha | A2 |
| | Totril | 0.1 L/ha | |
| | FVS 196 | - | A3 |
| 10 | Wing-P + | 2 L/ha | A1 |
| | Stomp Aqua | 0.5 L/ha | |
| | Better DF + | 0.3 Kg/ha | A2 |
| | Totril | 0.1 L/ha | |
| | FVS 191 | - | A3 |
| 11 | Wing-P + | 2 L/ha | A1 |
| | Stomp Aqua | 0.5 L/ha | |
| | Better DF + | 0.3 Kg/ha | A2 |
| | Totril | 0.1 Kg/ha | |
| | FVS 191 | - | A3 |
| 12 | Wing-P + | 2 L/ha | A1 |

| | | | |
|---|---|---|---|
| | Stomp Aqua + | 0.5 L/ha | A2 |
| | Better DF | 0.3 Kg/ha | |
| | Totril | 0.1 L/ha | A2 |
| | FVS 165 | - | A3 |
| 13 | Wing-P + | 2 L/ha | A1 |
| | Stomp Aqua | 0.5 L/ha | |
| | Better DF | 0.3 Kg/ha | A2 |
| | Totril | 0.1 L/ha | |
| | FVS 191 | - | A3, A4 |
| 14 | Wing-P + | 2 L/ha | A1 |
| | Stomp Aqua | 0.5 L/ha | |
| | Better DF + | 0.3 Kg/ha | A2, A3 |
| | Totril + | 0.1 L/ha | |
| | FVS 191 | - | A4, A5 |
| | Defy | 1 L/ha | A4 |
| | Defy | 2 L/ha | A5 |

**Table 1.11.2.** Effect of herbicide programmes on weed control and crop growth in bulb onion – 2014

| Treatment number and application timing(s) | | | | | | Weed level (% plot area) 17 Jun | Onion crop | | |
|---|---|---|---|---|---|---|---|---|---|
| | A1 | A2 | A3 | A4 | A5 | | Seedlings (no./m$^2$) 6 May | Phytotoxicity (%) 17 Jun | Plant vigour (%) 17 Jun |
| 1. | - | - | - | - | - | 100.0 a | 44.5 | 3.8 | 92.4 d |
| 2. | W | - | - | - | - | 23.4 b | 40.3 | 2.8 | 99.7 ab |
| 3. | W | 196 | - | - | - | 11.8 c | 42.3 | 2.5 | 100.0 a |
| 4. | 165 | - | - | - | - | 69.1 a | 39.5 | 4.3 | 90.6 d |
| 5. | W+165 | - | - | - | - | 11.2 c | 42.5 | 2.3 | 98.7 abc |
| 6. | W | 191 | 191 | - | - | 7.5 cd | 42.8 | 6.5 | 98.7 abc |
| 7. | W | 191* | - | - | - | 7.5 cd | 42.3 | 2.0 | 99.7 ab |
| 8. | W | 165 | - | - | - | 22.5 b | 39.0 | 3.3 | 97.2 bcd |
| 9. | W | M | 196 | - | - | 9.1 cd | 42.8 | 2.3 | 100.0 a |
| 10. | W | M | 191 | - | - | 7.6 cd | 39.3 | 2.0 | 100.0 a |
| 11. | W | M | 191* | - | - | 5.0 d | 42.5 | 2.3 | 100.0 a |
| 12. | W | M | 165 | - | - | 9.4 cd | 44.8 | 2.8 | 98.7 abc |
| 13. | W | M | 191 | 191 | - | 5.6 d | 42.8 | 2.3 | 100.0 a |
| 14. | W | M | M | D+191 | D+191 | 5.6 d | 42.0 | 7.0 | 92.7 cd |
| F Probability | | | | | | <0.001 | 0.903 | 0.163 | <0.001 |

| | | | | |
|---|---|---|---|---|
| LSD | 0.257 t | 7.166 | 3.784 | 9.410 t |
| SD | 0.180 | 5.01 | 2.65 | 6.58 |
| CV | 15.7 | 11.96 | 81.0 | 7.85 |

A1 – 27 March (pre-emergence), A2 – 28 April, A3 – 6 May, A4 – 20 May, A5 – 3 June.

W – Wing P, M – Stomp Aqua + Better DF + Totril, D – Defy.

t – means reported in transformed data units.

Means followed by a common suffix do not differ significantly (P = 0.05).

* Applied at a high rate.

The amount of weed was moderate.

- Mild phytotoxic symptoms were observed at most of the assessment timings from most of the treatments. It should be noted that 14 days after application all phytotoxic symptoms on the crop had disappeared with no statistical difference to the untreated control (with the exception of treatment 6 and 14).
- All treatments significantly reduced weed cover compared with the untreated control. Treatments 6, 7, 9, 10, 12 were statistically identical. Treatments 11, 13 and 14 were the best, reducing weed cover to less than 6%.

*Discussion*

There were no differences in plant establishment with any of the pre-emergence treatments, and no treatment throughout the trial result in any crop death. The variety used (Red Baron) is no more, or less, sensitive to herbicides than other Rijnsburger types.

Weeds had started to emerge by the first post-emergence application on 28 April (BBCH10) and broadleaf weed populations were assessed on a percentage of the plot affected by weed.

Herbicides 191 and 165 produced phytotoxic effects on the crop significantly more than seen in commercial practice and the untreated control. There were also some cumulative phytotoxic effects from repeat applications. It should be noted however that phytotoxic symptoms subsided after 14 days, from which point there was no difference between these treatments and the control.

Herbicide 196 showed reasonable crop safety and weed control. This product would benefit from further testing with a view for an EAMU application.

In this trial herbicide 165 was safe to onion, but poor on weed control when applied at pre-emergence.

By the end of the trial at crop stage BBCH 15 (5 true leaves), treatments 6 and 7 (containing 191) gave the best combination of weed control and crop safety and would benefit from further testing with a view for approval or EAMU.

## 1.12a Assessment of the efficacy and crop safety of precision application of residual and contact herbicides with electric weed control on Brussels sprouts

A replicated trial was conducted to evaluate the efficacy and crop safety of residual herbicides using banded treatments in conjunction with electrical weeding for the control of weed population in Brussels sprouts. The results obtained were compared with untreated controls and standard herbicide treatments.

**Table 1.12a.1.** Detail of herbicide treatments on Brussels sprouts - 2014

| Treatment<br>Product | | Rate of product | Dose rate a.s. | Application timing |
|---|---|---|---|---|
| 1. Commercial standard | | | | |
| Wing P | | 4 L/ha | 212.5 g/L dimethenamid-P + 250 g/L pendimethalin | Pre-planting |
| Butisan S + | | 1.5 L/ha | 500 g/L metazachlor | Post-planting |
| Gamit 36 CS | | 0.25 L/ha | 360 g/L chlomazone | |
| (+ inter-row cultivation as required) | | | | |
| 2. Banded spray + electrical | | | | |
| In row: | Springbok | 2.5 L/ha | 250 g/L metazachlor + 200 g/L dimethenamid-P | Post-planting |
| Inter-row: | Wing P + | 4 L/ha | 212.5 g/L dimethenamid-P + 250 g/L pendimethalin | Post-planting |
| | Dual Gold + | 1.4 L/ha | 960 g/L metolachlor | |
| | Gamit 36 CS | 0.25 L/ha | 360 g/L chlomazone | |
| 3. Untreated control | | - | - | - |

Unfortunately, due to the wet and warm weather conditions, the weed population exceeded the appropriate growth stage for cultivation and electrical weed applications. In order to avoid damaging the trial, electrical weeding and inter – row cultivations were not applied.

*Results*

Weed cover

- The band spraying herbicide programme and commercial standard programme significantly reduced weed population in relation to the untreated controls.

- Weed control from the inter-row band spraying treatment appeared the most effective treatment.

**Table 1.12a.2.** Effect of herbicide treatments on weed control in Brussels sprouts - 2014

| Treatment | | Mean % weed cover | | |
|---|---|---|---|---|
| | | 27/06/2014 | 04/07/2014 | 19/08/2014 |
| 1. Commercial standard treatment | | 1 | 0.5 | 3.5 |
| 2. Band sprays | Row | 1.3 | 0.8 | 3 |
| | Inter-row | 0.5 | 0 | 1.5 |
| 3. Untreated control | | 1.3 | 5.3 | 63.8 |
| F pr | | 0.459 | <.001 | <.001 |
| d.f | | 15 | 15 | 15 |
| LSD | | 1.134 | 1.441 | 4.237 |

<u>Crop phytotoxicity</u>

- Some phytotoxicity symptoms were recorded in the commercial treatment at the first assessment, however the crop recovered.
- Phytotoxicity symptoms were recorded in the banded spray treatment on the 1st assessment and then plants recovered. Phytotoxicity did not affect crop vigour.

**Table 1.12a.3.** Effect of herbicide treatments on crop health – Brussels sprouts

| Treatment | Mean crop phytotoxicity (0 for healthy – 100 for dead plants) | | |
|---|---|---|---|
| | 27/06/2014 | 04/07/2014 | 19/08/2014 |
| 1. Untreated | 5 | 3.8 | 0.3 |
| 2. Commercial standard | 7.5 | 3.8 | 3.8 |
| 3. Banded spray | 3 | 0 | 0 |
| F pr | 0.195 | 0.044 | <.001 |
| d.f | 11 | 11 | 11 |
| LSD | 5.142 | 3.265 | 0.653 |

*Discussion*

- The banded spray treatment appeared slightly more effective than commercial standard, but there were no statistically significant differences between them.
- Some crop phytotoxicity was recorded, but crop vigour was not affected.
- Due to wet and warm conditions, weeds grew rapidly inhibiting the use of the electric weeder and inter row cultivations.

## 1.12b Assessment of the efficacy and crop safety of precision application of residual and contact herbicides with electrical weed control in leeks

A replicated trial was conducted to evaluate the efficacy and crop safety of residual herbicides using banded treatments in conjunction with electrical weeding for the control of weed population in leeks. The results obtained were compared with standard herbicide treatments.

**Table 1.12b.1.** Detail of herbicide treatments

| Treatment | Product | UK rate of product | Dosage rate a.s. | Application timing |
|---|---|---|---|---|
| 1. | Commercial standard | | | |
| | Wing P | 2 L/ha | 212.5 g/L dimethenamid-p + 250 g/L pendimethalin | Pre-emergence |
| | Stomp Aqua + Better DF + Totril | 2 L/ha + 0.25 kg/ha + 0.1 L/ha | 455 g/L pendimethalin + 65% w/w chloridazon + 225 g/L ioxynil | At post crook |
| | Defy + Better DF + Totril | 2 L/ha + 0.25 kg/ha + 0.2 L/ha | 800g/L prosulfocarb + 65% w/w chloridazon + 225 g/L ioxynil | 1 – 2 true leaf |
| | Totril + Afalon | 0.2 L/ha + 0.2 L/ha | 225 g/L ioxynil + 450 g/L linuron SC | 2 true leaf + |
| | Basagran + Totril | 0.4 kg/ha + 0.4 L/ha | 87% w/w bentazone + 225 g/L ioxynil | 2 true leaf + |
| 2 | Banded spray + electrical | | | |
| | <u>In – row</u> | | | |
| | Wing P | 2 L/ha | 212.5 g/L dimethenamid-p + 250 g/L pendimethalin | Pre-emergence |
| | <u>Inter - row</u> | | | |
| | Stomp Aqua + Defy + Intruder | 2.9 L/ha + 4 L/ha + 0.75 L/ha | 455 g/L pendimethalin + 800 g/L prosulfocarb + 400 g/L chlorpropham | Pre-emergence |
| | - | - | - | Majority of 2 true leaf stage |
| | Basagran + Totril + Starane 2 | 0.35 kg/ha + 0.35 L/ha + 0.3 L/ha | 87% w/w bentazone + 225 g/L ioxynil + 288 g/litre fluroxypyr | 2 true leaf + |
| | Basagran + Totril | 0.4 kg/ha + 0.4 L/ha | 87% w/w bentazone + 225 g/L ioxynil | 2 true leaf + |

*Results*

<u>Weed control</u>

- The main weeds were black bindweed, redshank, groundsel, creeping thistle, mayweed and nettle.
- There were no statistically significant differences in weed cover between the banded spray + electrical weeder and the commercial standard programme after the pre-em applications (Table 1.12b.2), or at the final assessment (Table 1.12b.3).

**Table 1.12b.2.** Effect of herbicide treatments on weed control – early assessments

| Treatment | | % Mean weed cover after pre-em sprays | % Mean weed cover after electrical weeder/1-2 lvs Commercial applications |
|---|---|---|---|
| 1. Commercial standard | | 26.7 | 30.0 |
| 2. Banded spray | Row | 20.0 | 43.3 |
| | Inter-row | 9.2 | 9.5 |
| F pr | | 0.146 | 0.057 |
| d.f | | 17 | 17 |
| L.S.D | | 17.99 | 27.46 |

**Table 1.12b.3.** Effect of herbicide treatments on weed control – final assessment (19 September 2014)

| Treatment | % Mean weed cover Whole Plot | % Mean weed cover In-row | % Mean weed cover Inter-row |
|---|---|---|---|
| 1. Commercial standard | 66.3 | 55.0 | 59.2 |
| 2. Banded spray | 79.2 | 67.5 | 67.5 |
| F pr | 0.223 | 0.473 | 0.533 |
| d.f | 11 | 11 | 11 |
| L.S.D | 22 | 37.37 | 28.79 |

<u>Crop phytotoxicity</u>

- No herbicide treatment caused crop phytotoxicity.
- Due to tracking issues, the electrical weeder accidentally had contact with the crop in a few points along a row and resulted in crop death at the point where contact had been made.
- There were no crop safety symptoms throughout the trial apart from the areas where electrical weeder touched the crop.

*Discussion*

- The commercial standard herbicide programme and the banded spray + electrical weeder treatments were equally effective.
- No phytotoxic symptoms were observed.
- The electrical weeder requires straight rows to avoid crop contact which could be detrimental for the crop safety.

# 2. Soft fruit

## 2.1 Assessment of the efficacy of several fungicides and biofungicides against spur blight in raspberry

One replicated trial was established in autumn 2014 to evaluate the efficacy of several fungicides and biofungicides for the control of spur blight (*Didymella applanata*) in raspberry. Assessments are still pending at the point of writing this report and are expected to be carried out in spring 2015.

An untreated control and the standard treatment, Folicur (tebuconazole), have been included in the trial to benchmark the efficacy achieved by the test fungicides and biofungicides.

Inoculated spreader plants were introduced into the trial immediately after application of the treatments. Biofungicides were applied twice (31st October and 7th November) and conventional fungicides once (7th November).

**Table 2.1.1.** Conventional fungicide (C) and biofungicide (B) treatments evaluated for control of spur blight – 2014/15

| Treatment | UK rate of product | Dosage rate a.s. | Application timing |
|---|---|---|---|
| 1. Untreated | - | - | - |
| 2. Folicur (C) | 0.8 L | 0.21 L | 07/11 |
| 3. Signum (C) | | 0.60 kg | 07/11 |
| 4. Switch (C) | | 0.625 kg | 07/11 |
| 6. RAS-32 (C) | | | 07/11 |
| 7. RAS-77 (C) | | | 07/11 |
| 8. RAS-17 (C) | | | 07/11 |
| 9. RAS-25a (C) | | | 07/11 |
| 10. RAS-39 (C) | | | 07/11 |
| 11. RAS-37 (C) | | | 07/11 |
| 12. RAS-105 (B) | | | 31/10, 07/11 |
| 13. Serenade ASO (B) | | | 31/10, 07/11 |

| | |
|---|---|
| 14. RAS-40 (B) | 31/10, 07/11 |
| 15. RAS-43 (B) | 31/10, 07/11 |
| 16. RAS-99 (B) | 31/10, 07/11 |

*Results*

Disease symptoms were not evident on trial plants up to the time of writing this report therefore it is too early to report (January 2015) relative product efficacy. Disease symptoms will become evident in the spring as lesions on the canes and reduced vigour of the lateral shoots associated with the diseased nodes.

## 2.2 Assessment of products and application method for control of crown rot in strawberry

One replicated trial was conducted in 2014 to evaluate the efficacy of conventional fungicide and biofungicides applied as either pre-planting plant dips, post-planting drenches or post-planting sprays for the control of crown rot (*Phytophthora cactorum*) 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. Plants were grown in peat bags in a polytunnel and two infector plants were added to each bag.

Conventional fungicides were applied once and biofungicides three times at 14 day intervals. The product applied and standard rates are listed in Table 2.2.1. The rates differed according to the method of application (Table 2.2.2).

**Table 2.2.1.** Details of conventional fungicides (C) and biofungicides (B) examined for control of strawberry crown rot

| Treatment | UK rate of product | Dosage rate a.s. |
|---|---|---|
| 1. Untreated | - | - |
| 2. Untreated | - | - |
| 3. Paraat (C) | 1 g/L | 0.375 g |
| 4. STR-44 (C) | - | - |
| 5. Cassiopeia (C) | - | - |
| 6. STR-23 (C) | - | - |
| 7. STR-98 (B) | - | - |
| 8. STR-40 (B) | - | - |

**Table 2.2.2.** Detail of treatment, rate and application method and timing in 2014

| Treatment | Dose rate of product | Application method | Application timing |
|---|---|---|---|
| 1. Untreated | - | - | - |
| 2. Untreated | - | - | - |
| 3. Paraat | 1.5 g/L | Pre-plant dip | 20 May |
| 4. Paraat | 0.75 g/L | Drench at planting | 28 May |
| 5. Paraat | 3 kg/ha in 1000 L water | Post planting spray | 9 June |
| 6. STR-44 | - | Pre-plant dip | 20 May |
| 7. STR-44 | - | Drench at planting | 28 May |
| 8. STR-44 | - | Post planting spray | 9 June |
| 9. Cassiopeia | - | Pre-plant dip | 20 May |
| 10. Cassiopeia | - | Drench at planting | 28 May |
| 11. Cassiopeia | - | Post planting spray | 9 June |
| 12. STR-23 | - | Pre-plant dip | 20 May |
| 13. STR-23 | - | Drench at planting | 28 May |
| 14. STR-23 | - | Post planting spray | 9 June |
| 15. STR-98 | - | Pre-plant dip + drenches | 20 May<br>16 June<br>30 June |
| 16. STR-98 | - | Drench at planting + drenches | 28 May<br>16 June<br>30 June |
| 17. STR-98 | - | Post planting sprays | 9 June<br>23 June<br>7 July |
| 18. STR-40 | - | Pre-plant dip + drenches | 20 May<br>16 June<br>30 June |
| 19. STR-40 | - | Drench at planting + drenches | 28 May<br>16 June<br>30 June |
| 20. STR-40 | - | Post planting sprays | 9 June<br>23 June<br>7 July |

*Results*

- The incidence of crown rot in the trial in untreated plots was negligible in visual inspections up to the end of September despite the introduction of inoculated infector plants. However, by mid-October an average of 37-39% plants showed visual symptoms of crown rot (dead or wilting) in untreated plots
- Based on visual symptoms crown rot was recorded in all plots, including the standard treatment Paraat, at around 30% infected plants. There were no significant differences.

The trial will be further assessed by digging up all plants, cutting the crowns and assessing for internal crown rot symptoms. This assessment is in progress.

- It is not possible to draw any conclusions on efficacy of application method from the trial at this stage.

**Table 2.2.3.** Mean % plants with crown rot based on visual symptoms (angular transformed), recorded on strawberry cv. Malling Opal following various treatments at East Malling Research in 2014. Figures in parenthesis are back-transformed means

| Treatment | Product | Mean % crown rot plants |
|---|---|---|
| 1. Untreated | - | 37.1 (36.4) |
| 2. Untreated | - | 39.0 (39.5) |
| 3. Paraat Pre-plant dip | Paraat | 34.8 (32.6) |
| 4. Paraat Drench | Paraat | 29.8 (24.6) |
| 5. Paraat Spray | Paraat | 35.8 (34.2) |
| 6. STR-44 Pre-plant dip | - | 24.4 (17.1) |
| 7. STR-44 Drench | - | 29.3 (23.9) |
| 8. STR-44 Spray | - | 30.5 (25.7) |
| 9. Cas Pre-plant dip | - | 33.7 (30.8) |
| 10. Cas Drench | - | 36.6 (35.6) |
| 11. Cas Spray | - | 22.8 (15.1) |
| 12. STR-23 Pre-plant dip | - | 33.4 (30.3) |
| 13. STR-23 Drench | - | 37.5 (37.1) |
| 14. STR-23 Spray | - | 36.4 (35.2) |
| 15. STR-98 Pre-plant dip | - | 42.3 (45.2) |
| 16. STR-98 Drench | - | 33.7 (30.8) |
| 17. STR-98 Spray | - | 38.2 (38.3) |
| 18. STR-40 Pre-plant dip | - | 34.5 (32.1) |
| 19. STR-40 Drench | - | 26.1 (19.4) |
| 20. STR-40 Spray | - | 42.7 (46.0) |
| | | |
| F Prob | | 0.154 |
| SED (57) | | 6.42 |
| LSD (p=0.05) | | 12.85 |

*Discussion*

The cultivar Malling Opal was obtained for the trial which was a repeat of the 2013 trial where crown rot failed to develop. Unfortunately, around 20% of the plants received were already infected with crown rot. 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. There were problems encountered with the trickle irrigation to the bags such that some bags dried out despite additional watering. In addition the overhead irrigation, installed to aid inoculum spread, was limited in the water delivered, such that bags furthest from the tap received less water. All these factors contributed to the slow development of the disease and variability in the visual assessment data. All the plants in the trial will be dug up and assessed for internal crown rot. Data from one replicate already assessed for internal crown rot indicates that crown rot incidence based on visual assessment differs from that based on actual rot symptoms.

## 2.3 Assessment of the efficacy of conventional fungicides for control of powdery mildew on strawberry

One replicated trial was conducted in 2014 to evaluate the efficacy of 10 conventional fungicide products for the control of powdery mildew (*Podosphaera aphanis*) in strawberry. The products evaluated 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.

**Table 2.3.1.** Detail of conventional fungicide treatments examined for control of powdery mildew on strawberry - 2014

| Treatment | UK rate of product / ha | Dosage rate a.s. | Application timing |
|---|---|---|---|
| 1. Untreated | - | - | - |
| 2. Systhane 20EW | 0.45 L | 90 g | 23/7, 6/8, 13/8, 20/8, 27/8, 3/9 |
| 3. STR-177 | - | - | 23/7, 6/8, 13/8, 20/8, 27/8, 3/9 |
| 4. STR-37 | - | - | 23/7, 6/8, 13/8, 20/8, 27/8, 3/9 |
| 5. STR-87 | - | - | 23/7, 6/8, 13/8, 20/8, 27/8, 3/9 |
| 6. STR-77 | - | - | 23/7, 6/8, 13/8, 20/8, 27/8, 3/9 |
| 7. STR-25a | - | - | 23/7, 6/8, 13/8, 20/8, 27/8, 3/9 |
| 8. STR-159 | - | - | 23/7, 6/8, 13/8, 20/8, 27/8, 3/9 |
| 9. STR-47 | - | - | 23/7, 6/8, 13/8, 20/8, 27/8, 3/9 |
| 10. STR-17 | - | - | 23/7, 6/8, 13/8, 20/8, 27/8, 3/9 |
| 11. Talius | - | - | 23/7, 6/8, 13/8, 20/8, 27/8, 3/9 |
| 12. STR-118 | - | - | 23/7, 6/8, 13/8, 20/8, 27/8, 3/9 |

*Results*

**Table 2.3.2.** Mean % leaf area mildewed (angular transformed) recorded on strawberry cv. Elsanta following six sprays of various conventional fungicides applied post-harvest to leaf regrowth after mowing-off at East Malling Research in 2014. Figures in brackets are back transformed data. Assessed 3 September 2014, 1 week after the fifth spray.

| Treatment | Overall mean % leaf area mildewed |
|---|---|
| 1. Untreated | 29.5 (24.3) |
| 2. Systhane 20EW | **12.8** (4.9) |
| 3. STR-177 | **7.7** (1.8) |
| 4. STR-37 | **15.9** (7.6) |
| 5. STR-87 | **12.5** (4.7) |
| 6. STR-77 | **0** |
| 7. STR-25a | **5.4** (0.9) |
| 8. STR-159 | **2.7** (0.2) |
| 9. STR-47 | **17.1** (8.6) |
| 10. STR-17 | **5.2** (0.8) |
| 11. Talius | **0** |
| 12. STR-118 | **0.5** (0) |
| | |
| F Prob | <0.001 |
| SED (33) | 2.05 |
| LSD (p=0.05) | 4.17 |

- The incidence of powdery mildew on plant regrowth after mowing off was moderate to high
- All treatments significantly reduced the incidence of powdery mildew compared to the untreated control. The most effective fungicides were Talius, 177, 77, 25a, 159, 17 and 118.

*Discussion*

The incidence of powdery mildew on regrowth after mowing off post-harvest is generally high and difficult to control because of rapid leaf development and favourable warm humid conditions in the post-harvest period. All treatments were effective in reducing powdery mildew compared to the untreated control. The fungicides Talius, 177, 77, 25a, 159, 17 and 118 were more effective than the standard product Systhane 20EW. All of these products are suitable for consideration for future trials or for EAMUs.

## 2.4 Assessment of the efficacy of biofungicides for control of powdery mildew on strawberry

One replicated trial was conducted in 2014 to evaluate the efficacy of ten biofungicides for the control of powdery mildew (*Podosphaera aphanis*) in protected strawberries. 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.

**Table 2.4.1.** Detail of biofungicide treatments examined for control of powdery mildew on strawberry

| Treatment | UK rate of product / ha | Dosage rate a.s. | Application timing |
|---|---|---|---|
| 1. Untreated | - | - | - |
| 2. Systhane 20EW | 450 ml | 90 g | 22/7, 31/7, 7/8, 14/8, 21/8, 28/8 |
| 3. STR-188 | - | - | 22/7, 31/7, 7/8, 14/8, 21/8, 28/8 |
| 4. Serenade ASO | 10 L | 1.34 L | 22/7, 31/7, 7/8, 14/8, 21/8, 28/8 |
| 5. STR-06 | - | - | 22/7, 31/7, 7/8, 14/8, 21/8, 28/8 |
| 6. STR-203 | - | - | 22/7, 31/7, 7/8, 14/8, 21/8, 28/8 |
| 7. STR-105 | - | - | 22/7, 31/7, 7/8, 14/8, 21/8, 28/8 |
| 8. STR-90 | - | - | 22/7, 31/7, 7/8, 14/8, 21/8, 28/8 |
| 9. STR-40 | - | - | 22/7, 31/7, 7/8, 14/8, 21/8, 28/8 |
| 10. STR-43 | - | - | 22/7, 31/7, 7/8, 14/8, 21/8, 28/8 |
| 11. STR-157 | - | - | 22/7, 31/7, 7/8, 14/8, 21/8, 28/8 |
| 12. STR-187 | - | - | 22/7, 31/7, 7/8, 14/8, 21/8, 28/8 |

*Results*

- The incidence of powdery mildew on leaves on untreated plots was moderate at 33% leaf area mildewed.

**Table 2.4.2.** Mean % leaf area mildewed (angular transformed) recorded on strawberry cv. Elsanta following six sprays of various biofungicides applied from beginning of leaf growth after planting at East Malling Research in 2014. Figures in brackets are back transformed data. Assessed 20 August 2014, 1 week after the fourth spray application.

| Treatment | Overall mean % leaf area mildewed |
|---|---|
| 1. Untreated | 35.1 (33.0) |
| 2. Systhane 20EW | **18.3** (9.9) |
| 3. STR-188 | **22.0** (14.0) |
| 4. Serenade ASO | **25.0** (17.9) |
| 5. STR-06 | **17.1** (8.7) |
| 6. STR-203 | **25.1** (18.0) |
| 7. STR-105 | **18.4** (10.0) |
| 8. STR-90 | **25.6** (18.6) |
| 9. STR-40 | **24.3** (16.9) |
| 10. STR-43 | **27.6** (21.5) |
| 11. STR-157 | **20.7** (12.5) |
| 12. STR-187 | **22.3** (14.4) |
| | |
| F Prob | <0.001 |
| SED (44) | 1.97 |
| LSD (p=0.05) | 3.97 |

- All treatments significantly reduced the incidence of powdery mildew compared to the untreated control. The most effective products 6, 105, 157, 187 and 188 and Systhane 20EW. Products 6 and 105 were as effective as the standard treatment Systhane 20EW.
- The results obtained for the standard treatment were poorer than expected compared to the fungicide trial (on re-growth) where Systhane 20EW was also used as the standard with a mean leaf area mildewed of 4.9% (24% on untreated).
- No significant differences in total crop yield in kg/plot or total fruit number were observed between any of the treatments.

*Discussion*

Powdery mildew is a significant problem on strawberry plants, especially on 60-day plants planted in mid- summer when conditions generally favour powdery mildew development and spread. The incidence of powdery mildew on plants treated with the standard product

Systhane 20EW was higher than expected but as this product has been frequently used on strawberries over a number of seasons it is possible that, as with apple powdery mildew, reduced sensitivity may be an issue. Disease pressure may also be a factor: the levels of powdery mildew generally were much higher than in the fungicide trial. All the biofungicides reduced mildew significantly compared to the untreated control. Biofungicides 06 and 105 were almost as effective as Systhane 20EW and are worth considering for EAMUs.

## 2.5. Assessment of the efficacy of conventional insecticides and bioinsecticides combined with macrobiologicals for control of aphids on raspberry

One replicated trial was conducted to evaluate the efficacy of two biopesticides and two conventional insecticides for the control of large raspberry aphid (*Ampharophora idaei*) and potato aphid (*Macrosiphum euphorbiae*) in protected raspberry cv. Glen Ample. The results obtained were compared with untreated controls and the trial protocol was validated by inclusion of the standard treatment Calypso (thiacloprid) applied at recommended rates.

**Table 2.5.1.** Detail of conventional insecticides (C), bioinsecticides (B) and biocontrols used for control of aphids in raspberry - 2014

| Treatment<br>SCEPTRE code | UK rate of product | Dosage rate a.s. | Application timing |
|---|---|---|---|
| 1. Water | 1000 l/ha | N/A | Wks 2,3,4,5 |
| 2. Calypso (C) | 250 ml ai/ha | 0.08 ml/l | Wks 2,3,5 |
| 3. RAS-59 (C) | - | - | Wks 2,4 |
| 4. RAS-50 (C) | - | - | Wks 2,3 |
| 5. RAS-62 (B) | - | - | Wks 2,3,4,5 |
| 6. RAS-130 (B) | - | - | Wks 2,4 |
| Biocontrol inundative release of ERVIPAR (*Aphidius ervi*; Koppert) | 500x2/tunnel | | 3 weeks pre-spray & wks 2,3,4,5,6 |
| Biocontrol inundative release of APHILIN (*Aphelinus abdominalis*; Koppert) | 500x2/tunnel | | 3 weeks pre-spray & wks 2,3,4,5,6 |

[c] Week 1 was pre-spray, weeks 2-6 were post-spray; wks – weeks.

*Results*

**Table 2.5.2.** Efficacy of conventional insecticides (C) and bioinsecticides (B), used in conjunction with parasitoid wasps, compared with untreated control, against aphids on protected raspberry – 2014

| Treatment | Spray timing (week) | | | | % reduction of: | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Potato aphid (wk 2) | | Large raspberry aphid (wk 6) | |
| | 2 | 3 | 4 | 5 | Adults | Nymphs | Adults | Nymphs |
| 1. Water control | | | | | - | - | - | - |
| 2. Calypso (C) | ✓ | ✓ | - | ✓ | **50** | 0 | **46** | **71** |
| 3. RAS-59 (C) | ✓ | - | ✓ | - | 32 | **77** | **100** | **97** |
| 4. RAS-50 (C) | ✓ | ✓ | - | - | **63** | **54** | 0 | 6 |
| 5. RAS-62 (B) | ✓ | ✓ | ✓ | ✓ | **46** | **47** | **66** | 41 |
| 6. RAS-130 (B) | ✓ | - | ✓ | - | **39** | **51** | **46** | **73** |

Significant reductions (P <0.05) are shown in bold.

Note that lack of efficacy of RAS-50 against large raspberry aphid is probably associated with spray timing.

- The amount of large raspberry aphid and potato aphid was moderate in 2014, due to an early but milder summer than in 2013.
- There were significant (*P* = 0.026) efficacy effects against early attack of potato aphid apterous adults (week 2) compared with water controls for most treatments (130, 50, 62, Calypso) but 59 was not significantly effective. At week 2, all treatments including 59 significantly (P= 0.006) reduced potato aphid alates and all but Calypso significantly (*P* = 0.002) reduced potato aphid nymphs.
- All treatments except bioinsecticide 50 significantly (*P* <0.001) reduced large raspberry aphid adults (week 6). All treatments other than 50 and 62 significantly reduced large raspberry aphid nymphs (week 6) compared with untreated controls.
- Treatments had no significant effect on aphid parasitism by *Aphidius ervi* (week 2) and there was insufficient data to assess the impact of treatments on *A. abdominalis*. By week 6 there was a significant treatment effect on parasitism by *A. ervi* (*P* =0.002), probably reflecting aphid abundance and ability by parasitoid wasps to find hosts, rather than direct non-target toxicity of the treatments *per se*. As an improved procedure over 2013, parasitoids were released on non-sprayed rows in each tunnel to reduce direct exposure to sprays and released on non-spray days. Overall % parasitism varied

across weeks from 7%-17% for *A. ervi* and 0.6%- 2% for *A. abdominalis.* This was higher than the % parasitism rates obtained in 2013, especially for *A. ervi*.

- Cane height (plant vigour) was not significantly affected by the treatments applied ($P$=0.131). All treated plots produced high quality fruit in large quantities.

*Discussion*

- The experiment was successful in demonstrating efficacy of two biopesticides and two conventional insecticides against potato aphid (earlier attack, peaking at week 2) and large raspberry aphid (later attack, peaking at week 6).
- All the tested treatments were compatible with release of two species of parasitoid wasps (biocontrol agents), which helped to suppress aphid populations before, during and after the experiment. Careful placement of BCAs outside of spray zones is important to increase their effectiveness and reduce non-target effects of sprays.
- In 2014 we attempted to reduce spray frequencies by (a) discussing recommendations again with suppliers (b) noting recommended spray intervals and pre-harvest intervals for the products (on similar crops) (c) trying to reduce operator costs for chemicals and labour. In general this worked well, although optimising timing of some treatments with restricted numbers of applications/season is complex when two aphid species with different attack times and population dynamics are involved. Use of combined sprays with BCAs appears to give greater flexibility to alter spray dates and intervals because lower aphid numbers can be suppressed by natural enemies in between spray treatments.
- At week 2, when potato aphids were most abundant, treatments 50, 62 and 130 were as effective as Calypso, the industry standard (adults). Against potato aphid nymphs, treatments 50, 59, 62 and 130 were also effective (better than Calypso). At week 2 large raspberry aphids were relatively low and still increasing, so only Calypso gave significant control of this pest species.
- At week 6, potato aphids were in decline and numbers were too low to show strong treatment effects. This decline was likely to be due to (a) natural population dynamics of this species on protected raspberry (b) biocontrol by released parasitoids and endemic natural enemies (ladybirds, hoverflies, spiders, symphilids etc). In contrast, large raspberry aphids were at their peak at week 6 and treatments 130, 59, 62 and Calypso showed significant reductions in aphids (adults) after treatment. Treatment 59 was the most effective treatment against LRA adults at this date, but both biopesticides gave useful levels of control (46-66% reductions for treatments 130 and 62 respectively). Treatment 50 was ineffective by week 6, probably because it was only applied at weeks 2 and 3 and was not persistent enough to reduce LRA by week 6. A similar pattern was

seen at week 6 against LRA nymphs; again treatment 59 was very effective, both biopesticides 130 and 62 were moderately effective, but treatment 50 was ineffective.

- Further work is needed to optimise (a) spray timings (b) additional parasitoid species suited to polytunnel conditions (c) canopy structure for increased spray penetration as foliage matures during the season.

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

One replicated trial was conducted in 2014 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 treatments Chess WG (Pymetrozine) and Equity (Chlorpyrifos) applied at recommended rates. Two applications of each treatment were made applied at a 14 day interval; on 7 and 21 August 2014.

**Table 2.6.1.** Detail of insecticides evaluated against European tarnished plant bug - 2014

| Treatment | Product/SCEPTRE code | Active substance | Rate of product/ha | Application timing (days) |
|---|---|---|---|---|
| 1 | Untreated | | - | - |
| 2 | Chess WG | Pymetrozine | 400 g | 0, 14 |
| 3 | Equity | Chlorpyrifos | 1.0 L | 0, 14 |
| 4 | STR-59 | - | - | 0, 14 |
| 5 | Steward* + Silwet L-77 | - | - | 0, 14 |

‡Rates are full recommended rates, * half recommended rate.

*Results*

- The numbers of the pest in the plot were high due to early flower plantings surrounding the crop.
- There were significant reductions in the number of nymphs for the commercial standard chlorpyrifos, Steward + Silwet L-77 and insecticide 59.

**Table 2.6.2.** Efficacy of insecticide treatments against European tarnished plant bug on strawberry – 2014

| Treatment | Mean total numbers of *Lygus* (mean of all assessments; square root transformed data) | | Mean fruit damage score (0 – nil; 3 – severe) | |
|---|---|---|---|---|
| | Nymphs | Adults | 5 Sep | 22 Sep |
| 1. Untreated | 3.66 | 1.62 | **2.1** | 1.8 |
| 2. Chess WG | **2.68** | 1.57 | **1.7** | **1.3** |
| 3. Equity | **0.62** | **0.88** | **1.2** | **0.5** |
| 4. STR-59 | **2.53** | 1.25 | **1.5** | **1.2** |
| 5. Steward + Silwett L77 | **2.17** | **1.06** | **1.5** | **0.7** |
| F probability | <0.001 | 0.036 | 0.002 | <0.001 |
| LSD | 0.641 | 0.519 | 15.13 | 13.20 |

*Discussion*

The coded products 59 and Steward + Silwet L-77 both gave some level of control of *L. rugulipennis* and reduced numbers of nymphs 30 and 40% respectively, similar to Chess. Both products were less effective than Equity which reduced numbers by 85%. Note that Steward was used at a half of the maximum dose recommended on the label for protected crops, as used in commercial practice due to the addition of Silwet L-77. Selective treatments are likely to be more effective when applied to larger scale areas; there may be substantive immigration of *Lygus* adults into and between experimental plots after treatment. This is likely to be the reason why selective treatments appeared to work less well in the open field plots than they did in the cage experiments in previous years.

## 2.7 Assessment of the crop safety of a herbicide for control of annual weeds in strawberry

A replicated trial was conducted on newly planted strawberries cv. Elsanta (A+ 15mm cold stored runners) to evaluate the crop safety of a new herbicide (165) for use over the crop after planting. The results obtained were compared with an untreated control and the trial protocol was validated by inclusion of the standard treatment Dual Gold (S-metolachlor) applied at recommended rates.

**Table 2.7.1.** Detail of herbicide treatments evaluated for crop safety - 2014

| Treatment | UK rate of product | Dosage rate a.s. | Application timing |
|---|---|---|---|
| 1. Untreated | | - | - |
| 2. STR-165 | - | - | 1 day after planting |
| 3. Dual Gold* | 0.7 L/ha | 960 g/l S-metolachlor | 1 day after planting |
| 4. STR-165 | - | - | 10 days after planting |
| 5. Dual Gold* | 0.7 L/ha | 960 g/l S-metolachlor | 10 days after planting |

* Dual Gold (S-metolachlor) is only permitted for use on outdoor crops.

*Results*

**Table 2.7.2.** Effect of herbicide treatments on growth and yield of strawberry - 2014

| Treatment | Phytotoxicity score (0 dead-9 fine) | Total marketable yield (g/plant) | Total waste yield (g/plant) | Mean berry weight (g) |
|---|---|---|---|---|
| Main trial | | | | |
| 1. Untreated control | 9 | 118.0 | 38.3 | 14.6 |
| 2. STR-165 (1 day after planting) | 9 | 105.5 | 40.4 | 15.2 |
| 4. STR-165 (10 days after planting) | 9 | 106.2 | 36.1 | 15.3 |
| P. Value (6 df) | NS | NS | NS | NS |
| LSD | - | 26.16 | 7.01 | 1.04 |
| Extra trial | | | | |
| 1. Untreated control | 9 | 53.9 | 38.7 | 3.6 |
| 3. Dual Gold (1 day after planting) | 9 | 73.3 | 23.3 | 4.1 |
| 5. Dual Gold (10 days after planting) | 9 | 62.4 | 25.5 | 4.0 |
| P. Value (6 df) | NS | NS | NS | NS |
| LSD | - | 25.72 | 20.78 | 1.01 |

- An incorrect sample of Dual Gold was supplied for this trial therefore data for the main experiment only details the results for the 165 and untreated control. A separate pot trial was carried out to demonstrate the crop safety of the standard treatment Dual Gold 2 weeks later. Spare plants from the original trial had been kept in the cold store during this time and were used for this second screen but vigour was not as good as in the first planting and yield and berry size was low.

- No significant differences in total crop yield and marketable yield were observed between any of the treatment. The yields achieved were comparable with the untreated. Overall the yields were low compared with what would be expected from a planting of A+ runners in May. This was likely due to some irrigation issues at the beginning of the trial and powdery mildew coming in at the end.

*Discussion*

This trial confirmed the crop safety of herbicide 165 both as an over the crop treatment straight after planting and 10 days after planting.

## 2.8 Assessment of a conventional herbicide (C) and a bioherbicide (B) for control of strawberry runners and weeds

One replicated trial was conducted on strawberry cv. Elsanta to evaluate the efficacy of one conventional herbicide (124) and one bioherbicide (109) for the control of strawberry runners and weeds in strawberry alleyways. The results obtained were compared with untreated controls and the trial protocol was validated by inclusion of the standard treatment Harvest (glufosinate-ammonium) applied at recommended rates.

**Table 2.8.1.** Detail of herbicide treatments examined for control of strawberry runners and weeds – 2014

| Treatment | UK rate of product | Dosage rate a.s. | Application timing |
|---|---|---|---|
| 1. Untreated | - | - | - |
| 2. STR-124 (C) Low rate | - | - | 2/9, 16/9 |
| 3. STR-124 (C) High rate | - | - | 2/9, 16/9 |
| 4. STR-109 (B) | - | - | 2/9, 16/9 |
| 5. Harvest (C) | 5 L/ha | 150 g/L (13.52% w/w) glufosinate-ammonium | 2/9 |

*Results*

**Table 2.8.2.** Effect of herbicides on runner control in strawberry cv. Elsanta, and weed control in alleyways

| | % runner cover | | | % weed cover | | | Runner health score at 6 wks (0-9 scale) |
|---|---|---|---|---|---|---|---|
| | Pre-treatment | At 6 wks* | At 8 wks* | Pre-treatment | At 4 wks* | At 6 wks* | |
| 1. Untreated control | 18.3 | 29.1 | 36.4 | 5.8 | 12.4 | 12.4 | 9.0 |
| 2. STR-124 (low rate) | 23.8 | **2.6** | **6.3** | 7.5 | **2.4** | **3.3** | **4.3** |
| 3. STR-124 (high rate) | 23.0 | **0.7** | **3.8** | 7.8 | **4.6** | **6.6** | **3.8** |
| 4. STR-109 | 16.3 | **6.9** | **10.5** | 5.3 | **2.4** | **4.2** | **2.0** |
| 5. Harvest | 16.3 | **2.7** | **3.8** | 7.4 | **0.2** | **1.7** | **0.5** |
| P. value (11 df) | NS | 0.005 | <0.001 | NS | 0.010 | 0.010 | <0.001 |
| Covariate P. value (11 df) | - | 0.013 | <0.001 | - | 0.810 | 0.387 | - |
| LSD | 17.61 | 14.30 | 11.03 | 3.80 | 6.27 | 5.52 | 2.29 |

*Covariate adjusted means.

- The quantity of runners in the alleyways was moderate and measures were taken to ensure a similar number of runners in each plot. The pre-treatment assessment was used as a covariate in analysis to account for initial differences in ground cover by runners.
- Conventional herbicide 124 at both high and low rates and bioherbicide 109 showed a significant runner reduction compared with the untreated control. Both rates of 124 showed as good runner control in terms of coverage as the industry standard Harvest. The runner damage score was highest with Harvest, killing more runners, this suggests runners treated with 124 or 109 may recover.
- Harvest resulted in almost complete scorch of green tissues and death of some runners; herbicides 109 and 124 also significantly scorched foliage and reduced runner coverage but did not appear to kill runner crowns, suggesting they may recover.
- Conventional herbicide 124 and bioherbicide 109 reduced ground area covered by weeds from 12% to 5% or less at 4 weeks after treatment. Harvest appeared the best treatment with less than 1% weed cover.

- There was no difference between the two rates of conventional herbicide 124 examined in either runner control or weed control.

*Discussion*

Pot experiments carried out in previous years indicated that for both conventional herbicide 124 and bioherbicide 109, two applications would be required to control strawberry runners, so this was the approach used in this field experiment.

Good but not complete runner control was achieved with all the herbicides tested. All significantly reduced runners compared with the untreated and were not significantly different from the industry standard Harvest. Harvest and 124 at the higher rate tended to show best control.

Good levels of weed control were achieved by all treatments compared with the untreated control up to a month after treatment. Treatment effects were slightly less clear at 6 weeks as large populations of volunteer cereals germinated in all plots after treatment. This was not unexpected as the treatments are not thought to have a residual activity.

Products 109 and 124 therefore both show potential in strawberry for this use. However it should be noted that for both products two applications were used to achieve a similar result to one application of Harvest.

## 2.9 Assessment of the efficacy of an electrical treatment for perennial weed control in blackcurrant

A field trial was conducted in spring 2014 to evaluate the efficacy of electrical weed control using a shielded high power electrode applied to perennial weed species in blackcurrants. The main two weed species investigated were creeping thistle (*Cirsium arvense*) and common nettle (*Urtica dioica*). In addition, crop safety of the electrical weeding design against blackcurrants was tested.

**Table 2.9.1.** Detail of electrical treatments examined - 2014

| Treatment | Voltage | Speed of travel (kph) | Application timing |
|---|---|---|---|
| 1 | Untreated control | - | - |
| 1 | 5500 | 4.3 | 16 May 2014 |
| 2 | 6500 | 4.3 | 16 May 2014 |
| 3 | 7500 | 4.3 | 16 May 2014 |

*Results*

The trial comprised two rows of established blackcurrant bushes separated in three equal parts, 20 m long, which represented three different voltages 5500, 6500 and 7500 for the electrical weeder. The natural weed population was very low which made it difficult to assess in replicated blocks, so individual weeds were tagged for observations instead. Phytotoxicity symptoms and weed control efficacy were assessed visually.

Electrical weed control

Treatment application 16/05/2014

Low voltage (5500 volts) controlled thistle but did not affect the nettles. Other weeds such as willowherb turned to brown, dried up and died slowly. Similar results were observed with the medium voltage (6500 volts). The highest voltage (7500 volts) controlled creeping thistles and any weed which was touched by the electric probe. Nettles were temporarily controlled but they recovered six weeks after treatment with regrowth at the base, so they would require a repeated treatment of electrical weeding for a higher level of control.

Ineffective control of weeds was observed that were shorter than the electrical probe's height or weeds that were not directly touched by the electric weeder. The height of the probe should be adjustable in future trials.

Crop damage was similar at all voltages. Both woody and soft basal shoots were assessed. In early assessments only local damage was noticed, where the electric weeder had direct contact. Early damage symptoms such as wilted brown leaves and stem browning, were noticed in the young shoots. By the end of the trial (6 WAT), some old woody parts turned completely brown and dry.

*Discussion*

- The overall weed numbers were very low at this particular field site making assessment difficult.
- Creeping thistles were controlled by all three electrical voltages.

- Nettles were controlled only at the higher voltage and only temporarily. At 6 weeks after treatment there was regrowth at the base of the stems. A second electrical weeder application would have been essential.
- There was ineffective control of weeds that were shorter than the probe's height or weeds that were not directly touched by the electrical weeder probe.
- All three voltages produced the same level of damage to blackcurrant bushes.
- Initially, phytotoxicity was shown as a local symptom either on leaves or young shoots. By the final assessment, phytotoxicity was observed over the whole blackcurrant branch, but did not seem to effect the rest of the bush.

# 3. Protected edibles

## 3.1a Assessment of the efficacy of conventional fungicides and biofungicides for control of black root rot in cucumber - 2013

Two inoculated trials were conducted in 2013 to evaluate the efficacy of 11 conventional fungicides and nine biopesticides applied as drench treatments for the control of black root rot in cucumber (*Phomopsis sclerotioides*). The results obtained were compared with untreated controls. Disease development was poor, and consequently plate testing of conventional products was performed to assess activity against the fungus.

**Table 3.1a.1.** Detail of fungicides and biofungicides examined for control of cucumber black root rot – 2013

| Treatment | | Application date |
|---|---|---|
| 1 | Water control | 22/11, 2/12, 17/1, 27/1, 6/2 |
| Conventional products | | |
| 2 | CUC-139 | 22/11, 2/12 |
| 3 | CUC-176 | 22/11, 2/12 |
| 4 | CUC-46 | 22/11, 2/12 |
| 5 | CUC-173 | 22/11, 2/12 |
| 6 | CUC-185 | 22/11, 2/12 |
| 7 | CUC-39 | 22/11, 2/12 |
| 8 | CUC-25a | 22/11, 2/12 |
| 9 | CUC-175 | 22/11, 2/12 |
| 10 | CUC-152 | 22/11, 2/12 |
| 11 | CUC-37 | 22/11, 2/12 |
| 12 | CUC-10 | 22/11, 2/12 |

| | | |
|---|---|---|
| 13 | CUC-47 | 17/1, 27/1, 6/2 |
| Biopesticide Products | | |
| 14 | CUC-178 | 17/1, 27/1, 6/2 |
| 15 | CUC-98 | 17/1, 27/1, 6/2 |
| 16 | CUC-40 | 17/1, 27/1, 6/2 |
| 17 | CUC-99 | 17/1, 27/1, 6/2 |
| 18 | CUC-121 | 17/1, 27/1, 6/2 |
| 19 | CUC-105 | 17/1, 27/1, 6/2 |
| 20 | CUC-188 | 17/1, 27/1, 6/2 |
| 21 | CUC-189 | 17/1, 27/1, 6/2 |

*Results*

Root and stem rot disease levels were minimal at the end of the trial, 4 weeks after inoculation. However, *in vitro* fungal inhibition tests showed significant activity of conventional fungicides against *P. sclerotioides* mycelial growth (Table 3.1a.2). Little information was available on safe rates of product use when applied as drench treatments to hydroponic cucumber (see discussion). Eight of the conventional fungicides and four of the biofungicides caused obvious crop damage at the rates and timings chosen.

**Table 3.1a.2.** Inhibition of mycelial growth of *Phomopsis sclerotioides* on agar by conventional fungicides – 2014

| Treatment | % inhibition compared with unamended agar | | |
|---|---|---|---|
| | 2 ppm | 20 ppm | 100 ppm |
| 1. Untreated | 0 | 0 | 0 |
| 2. CUC-139 | 98 | 83 | 96 |
| 3. CUC-176 | 82 | 61 | 100 |
| 4. CUC-195 | 97 | 100 | 100 |
| 5. CUC-192 | 19 | 34 | 51 |
| 6. CUC-194 | 28 | 74 | 86 |
| 7. CUC-37 | 100 | 100 | 100 |
| 8. CUC-185 | 38 | 47 | 69 |
| 9. CUC-39 | 64 | 94 | 100 |
| 10. CUC-175 | 100 | 100 | 100 |
| 11. CUC-152 | 71 | 100 | 100 |
| 12. CUC-10 | 38 | 96 | 100 |
| F probability | <0.001 | <0.001 | <0.001 |

| | | | |
|---|---|---|---|
| LSD | 21.6 | 18.6 | 4.7 |

Significant phytotoxic effects were observed in the crop trials with conventional fungicides 25a, 37, 39, 139, 152, 173, 185 and biofungicides 178, 47 and 105. Symptoms varied between treatments, but stunting and chlorosis were the predominant symptoms. It is, however, important to note that applications were made to very young plants and it is possible that older, more mature, plants may be less sensitive to these treatments.

*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 on cucumber 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.

The strain of *P. sclerotioides* 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). Biopesticide products were first applied at sowing and then again at cotyledon stage to allow maximum protectant activity to be established. Conventional products 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.

Little pathogen development was seen in either crop. Plants were contained within trays and cultivated for a relatively short period. *P. sclerotioides* is a slow-growing fungus that can take substantial time to become established; this probably explains the minimal symptoms seen within the crop when the final assessments were made at 8 weeks after inoculation. This perhaps limits the value of such screening tests against this particular pathogen and greater reliance on *in vitro* tests may be necessary.

A number of conventional fungicides (10, 39, 192, 194) exhibited dose-dependent inhibitory effects against fungal growth in agar plate based assays.

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

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

## 3.1b Assessment of the efficacy and crop safety of conventional fungicides and biofungicides for control of black root rot in cucumber - 2014

One replicated trial was conducted in 2014 to evaluate the efficacy of 10 conventional fungicides and two biofungicides for the control of black root rot (*Phomopsis sclerotioides*) in rockwool-grown cucumber. Disease development in the initial crop was poor, and a second crop was therefore grown on the same rockwool slabs. Both crops were inoculated with *P. sclerotioides* on agar plugs, inserted two per rockwool slab after the first treatment applications.

The results obtained were compared with untreated controls. There were no approved products for control of this disease.

In the first crop, conventional fungicides and biofungicide 98 were applied four times and biofungicide 178 was applied seven times. In the second crop, conventional fungicides and biofungicide 98 were applied twice and biofungicide 178 was applied four times. All products were applied as a 500 ml drench to the rockwool propagation block.

**Table 3.1b.1.** Details of conventional fungicides (C) and biofungicides (B) evaluated for control of cucumber black root rot - 2014

| Treatment and SCEPTRE code | Application timing | |
|---|---|---|
| | Crop 1 | Crop 2 |
| 1. Uninoculated control | | |
| 2. Inoculated control | | |
| 3. CUC-176 (C) | 11/6, 1/7, 21/7, 11/8 | 19/9, 10/10 |
| 4. CUC-139 (C) | 11/6, 1/7, 21/7, 11/8 | 19/9, 10/10 |
| 5. CUC-25a (C) | 11/6, 1/7, 21/7, 11/8 | 19/9, 10/10 |
| 6. CUC-37 (C) | 11/6, 1/7, 21/7, 11/8 | 19/9, 10/10 |
| 7. CUC-46 (C) | 11/6, 1/7, 21/7, 11/8 | 19/9, 10/10 |
| 8. CUC-175 (C) | 11/6, 1/7, 21/7, 11/8 | 19/9, 10/10 |
| 9. CUC-10 (C) | 11/6, 1/7, 21/7, 11/8 | 19/9, 10/10 |
| 10. CUC-47 (C) | 11/6, 1/7, 21/7, 11/8 | 19/9, 10/10 |
| 11. CUC-98 (B) | 11/6, 1/7, 21/7, 11/8 | 19/9, 10/10 |
| 12. CUC-178 (B) | 11/6, 24/6 1/7, 11/7, 21/7, 1/8, 11/8 | 19/9, 29/9, 10/10, 20/10 |

*Results*

Results are shown (Table 3.1b.2) for disease assessments in crop 2 (wilting, stem base lesion and *Phomopsis sclerotioides* root infection).

- The level of infection was low in crop 1 and minimal symptoms were seen by the end of the trial period. A repeat crop was therefore planted on the same rockwool slabs, to simulate what happens in commercial practice. The level of infection was moderate to high in crop 2.
- Transient phytotoxicity symptoms were observed in association with the first treatment application in crop 1. Symptoms included chlorosis and stunting. Plants recovered and no phytotoxicity effects were seen after further treatments in crop 1 or crop 2. Foliar damage was most severe with 25a, moderate with 37 and 175, and mild with 176, 139, and 46. Transient stunting was seen with products 139 and 175.
- No standard treatment was included in this trial as none are currently available. However, the inoculated, untreated plants succumbed to disease while the uninoculated plants were largely unaffected. This can therefore be considered a valid trial.
- There were significant efficacy effects for conventional fungicides 37, 46, 139, 175 and 176, with disease symptoms reduced by 77–93% in crop 2, compared to the untreated control.
- Fruit number and weight were assessed in crop 1. No difference in yield was observed between treatments.

**Table 3.1b.2.** Efficacy of conventional fungicides and biofungicides against black root rot (*P. sclerotioides*) in rockwool-grown cucumber – 2014 (crop 2)

| Treatment and SCEPTRE code | Mean severity of plant wilting (0 – 4) | Mean severity of stem base lesions (0 – 5) | Mean severity of *Phomopsis* on roots (0 – 4) |
|---|---|---|---|
| 1. Uninoculated control | **0.3** | **0.2** | **0** |
| 2. Inoculated control | 2.5 | 2.1 | 1.2 |
| 3. CUC-176 (C) | **0.3** | **0.3** | **0.1** |
| 4. CUC-139 (C) | **0.2** | **0.3** | **0.1** |
| 5. CUC-25a (C) | **0.8** | **1.9** | 1.7 |
| 6. CUC-37 (C) | **0.7** | **0.3** | **0** |
| 7. CUC-46 (C) | **0.2** | **0.7** | **0.1** |
| 8. CUC-175 (C) | **0.3** | **0** | **0** |
| 9. CUC-10 (C) | 2.2 | 2.6 | 2.4 |
| 10. CUC-47 (C) | 1.7 | 2.1 | 2.0 |
| 11. CUC-98 (B) | 2.5 | 2.1 | 2.2 |

| | | | |
|---|---|---|---|
| 12. CUC-178 (B) | 2.3 | 1.9 | 1.6 |
| F probability | <0.001 | <0.001 | <0.001 |
| LSD | 0.83 | 0.66 | 0.08 |

*Discussion*

Twelve fungicides (10 conventional and two biological) were assessed for efficacy against *Phomopsis sclerotioides* in this trial. Products were drenched onto the rockwool blocks in 500 ml volumes to allow penetration to the rockwool slabs.

In crop 1, biopesticide and conventional products were applied as protectants at the same time as blocks were planted onto rockwool slabs. This was approximately nine days prior to inoculation with *Phomopsis sclerotioides.* Despite conditions conducive to pathogen infection and growth, disease symptoms developed slowly and no significant wilting or other above-ground symptoms were observed during the life of the first crop. Plants grew very vigorously immediately after planting, and it is possible that this limited the ability of the pathogen to infect the crop. However, significant differences were observed between treatments when roots in the propagation blocks were examined at the end of the life of the crop, and black banding patterns characteristic of *P. sclerotioides* infection were seen on the roots. At this stage, it was not possible to assess the roots in the rockwool slabs as these were required for replanting.

A second cucumber crop was therefore planted onto the same rockwool slabs, initially to determine whether test treatments had eradicated the pathogen from the slabs. However, no disease symptoms were observed after two weeks, and a programme of treatment and inoculation was again applied. Inoculation was performed 5 days after the first drench of conventional and biological treatments was applied. Wilting symptoms began to develop three weeks after inoculation, and this was considered to be largely due to the earlier latent infection in the slabs, especially as characteristic symptoms had been seen on the roots at the base of the rockwool blocks. Clear differences rapidly became apparent between the effective and non-effective treatments. A significant reduction in wilting was achieved with fungicides 37, 46, 137, 139, and 175, and this was reflected in the greater root vigour and reduced root disease symptoms seen with these treatments. Two of these products (37 and 175) produced moderate foliar phytotoxicity symptoms; however, these were transient and only occurred after the first application in crop 1. Plants in crop 2 were more mature at the first treatment application, which may explain the lack of phytotoxicity symptoms.

Drench dosage was estimated using manufacturer recommendations or, where these were unavailable, a drench rate of 60 ml/1000 plants for 1 L/ha. It may be possible to reduce application rates for the efficacious products and reduce the phytotoxic effects.

Neither of the biofungicides used in this trial were effective in preventing symptoms of *P. sclerotioides* infection. It should be noted that the inert rockwool substrate and high pathogen loads used in this study may limit the effectiveness of biological treatments. Alternative product formulations may be necessary in order to sustain biological treatments in the absence of a host. In a commercial environment, where pathogens appear more progressively, biological products may be more effective. Further work is needed to evaluate this.

Overall, this screening trial successfully identified a number of highly effective conventional fungicides that can be considered for future EAMU applications against *Phomopsis sclerotioides*.

## 3.2 Assessment of the efficacy of conventional fungicides and biofungicides for control of Pythium root and stem base rot in cucumber

One replicated trial was conducted in 2014 to evaluate the efficacy of 10 conventional fungicides and two biofungicides for control of root and stem base rot of cucurbits caused by *Pythium aphanidermatum* in rockwool-grown cucumber. Disease development in the initial crop was poor, and a second crop was therefore grown on the same rockwool slabs.

The results obtained were compared with untreated controls and with an approved standard product, Previcur Energy (propamocarb hydrochloride + fosetyl aluminium) used at the label rates.

In the first crop, conventional fungicides and treatment 11 were applied four times and treatment 12 was applied seven times. In the second crop, conventional fungicides and treatment 11 were applied twice and treatment 12 was applied four times.

**Table 3.2.1.** Detail of conventional fungicides (C) and biofungicides (B) examined for control of Pythium root and stem base rot in cucumber – 2014

| Treatment | Application timing | |
|---|---|---|
| | Crop 1 | Crop 2 |
| 1. Uninoculated control | | |
| 2. Inoculated control | | |
| 3. CUC-169 (C) | 12/6, 2/7, 22/7, 12/8 | 19/9, 10/10 |
| 4. CUC-44 (C) | 12/6, 2/7, 22/7, 12/8 | 19/9, 10/10 |
| 5. Previcur Energy (C) | 12/6, 2/7, 22/7, 12/8 | 19/9, 10/10 |
| 6. CUC-139 (C) | 12/6, 2/7, 22/7, 12/8 | 19/9, 10/10 |
| 7. CUC-46 (C) | 12/6, 2/7, 22/7, 12/8 | 19/9, 10/10 |
| 8. CUC-145 (C) | 12/6, 2/7, 22/7, 12/8 | 19/9, 10/10 |
| 9. CUC-183 (C) | 12/6, 2/7, 22/7, 12/8 | 19/9, 10/10 |
| 10. CUC-47 (C) | 12/6, 2/7, 22/7, 12/8 | 19/9, 10/10 |
| 11. CUC-98 (B) | 12/6, 2/7, 22/7, 12/8 | 19/9, 10/10 |
| 12. CUC-179 (B) | 12/6, 24/6, 2/7, 11/7, 22/7, 1/8, 12/8 | 19/9, 29/9, 10/10, 20/10 |

*Results*

Results are shown for two disease assessments in crop 1 and two disease assessments in crop 2 (wilting and root colour).

- The quantity of *Pythium* symptoms was low in crop 1 and, with the exception of the first wilting assessment, little difference was seen between treatments throughout the trial.
- Transient mild phytotoxicity symptoms were observed after the first treatment application in crop 1 with Previcur Energy, 139, 46, and 47. These symptoms manifested as chlorosis of the edge or main body of the leaves. Plants recovered and no phytotoxicity effects were seen after further treatments in crop 1 or crop 2.
- Results obtained for the standard, Previcur Energy, treatment were inconsistent. In addition, disease symptoms were apparent in the uninoculated plots, particularly in the second crop. Therefore, caution must be employed when interpreting the results of this trial.
- Fruit number and weight was assessed in crop 1. No difference in yield was observed between treatments.

**Table 3.2.2.** Effect of conventional fungicides and biofungicides on Pythium root rot in cucumber – 2014

| Treatment | Crop 1 | | Crop 2 | |
|---|---|---|---|---|
| | Mean severity of wilting (0-4) 7 Jul | Mean severity root colour (0-4) 21 Aug | Mean severity of wilting (0-4) 21 Oct | Mean root colour (0-4) 6 Nov |
| 1. Uninoculated control | **0.1** | **0.6** | 0.1 | **0.7** |
| 2. Inoculated control | 0.9 | 1.2 | 0.3 | 1.1 |
| 3. CUC-169 (C) | **0.2** | 1.4 | 0.1 | 1.3 |
| 4. CUC-44 (C) | **0.2** | 1.3 | 0.3 | 0.8 |
| 5. Previcur Energy (C) | **0.1** | 1.1 | 0.2 | **0.6** |
| 6. CUC-139 (C) | **<0.1** | **0.3** | 0.2 | 1.0 |
| 7. CUC-46 (C) | **<0.1** | **0.6** | 0.0 | 1.0 |
| 8. CUC-145 (C) | **0.7** | 1.5 | 0.1 | 1.2 |
| 9. CUC-183 (C) | **<0.1** | 0.8 | 0.1 | 1.0 |
| 10. CUC-47 (C) | 1.0 | 1.5 | 0.5 | 0.9 |
| 11. CUC-98 (B) | 0.7 | 1.7 | 0.3 | 1.2 |
| 12. CUC-179 (B) | 0.7 | 1.4 | 0.2 | 1.2 |
| F. probability | <0.001 | <0.001 | 0.121 | 0.023 |
| LSD | 1.54 | 0.54 | 1.87 | 0.08 |

Values in bold are significantly reduced compared with the inoculated control (T2). All data are reported in transformed units except crop 1 root colour severity.

*Discussion*

Twelve products (10 conventional and two biological) were assessed for efficacy against *Pythium*. Products were drenched onto the rockwool blocks in 500 ml volumes to allow penetration to the rockwool slabs. Drench dosage was estimated using manufacturer recommendations or, where these were unavailable, a drench rate of 60 ml/1000 plants for 1 l/ha.

In crop 1, biofungicides and conventional fungicides were applied as protectants at the same time as blocks were planted onto rockwool slabs, 11 days prior to inoculation with *Pythium aphanidermatum.* Transient wilting symptoms developed in the crop within 2 weeks, with significant differences apparent between the inoculated and uninoculated controls. Plots treated with conventional fungicides 44, 46, 139, 169 and 183 exhibited significantly less wilting than the inoculated untreated control. Most plants recovered from this initial wilting event. A destructive root assessment was performed at the end of the crop life. The roots of plants treated with products 139 and 46 had significantly less browning than inoculated untreated controls. No difference was seen in root vigour between treatments. Roots were also assessed for presence of oospores, but there was no significant difference between treatments. It should be noted that oospores were present in roots from one uninoculated plot, suggesting that the pathogen had spread between plots. There are a number of possible explanations that would account for such pathogen dispersal, including sciarid flies, zoospore movement in water, and water splash.

A second cucumber crop was planted onto the same rockwool slabs, initially to determine whether test treatments had eradicated the pathogen from the slabs. However, no disease symptoms were observed after two weeks, and a programme of treatment and inoculation was again applied. Inoculation was performed 5 days after the first drench of conventional and biological treatments. Symptoms were minimal throughout the life of the crop, and no consistent differences were observed between treatments for any of the assessment parameters.

In summary, although disease expression was generally low and infection spread to uninoculated plots, there is some evidence to suggest that conventional fungicides 46 and 139 may reduce symptoms caused by *Pythium aphanidermatum*. Further work will be required to help identify alternative products for the control of this important oomycete pathogen.

## 3.3 Assessment of the efficacy of several insecticides and bioinsecticides against aphids in peppers

One replicated trial was conducted in August/September 2014 to evaluate the efficacy of conventional insecticides and bioinsecticides for the control of aphids (*Aulacorthum solani)* in peppers. The results obtained were compared with untreated controls and the trial protocol was validated by inclusion of a standard treatment Chess (pymetrozine) applied at recommended rates. Four applications of each treatment were made, except Chess which was applied three times.

**Table 3.3.1.** Detail of conventional insecticides (C) and bioinsecticides (B) evaluated for control of aphids in peppers – 2014

| Treatment | Rate of product used | Application timing |
|---|---|---|
| 1. Untreated | - | - |
| 2. Chess (C) | 60g/100L | 7/8, 14/8, 21/8 |
| 3. PEP-62 (B) | | 7/8, 14/8, 21/8, 28/8 |
| 4. PEP-130 (B) | | 7/8, 14/8, 21/8, 28/8 |
| 5. PEP-51 (B) | | 7/8, 14/8, 21/8, 28/8 |
| 6. PEP-208 (B) | | 7/8, 14/8, 21/8, 28/8 |

*Results*

**Table 3.3.1.** Effect of conventional insecticides (C) and bioinsecticides (B) on control of aphids in pepper – 2014

| Treatment | Mean number of *Aulacorthum solani*/plot | | Mean number of *Myzus persicae*/plot | |
|---|---|---|---|---|
| | Pre-spray | 6 d after spray 2 | Pre-spray | 6 d after spray 2 |
| 1. Untreated | 15.8 | 7.8 | 32.8 | 220.6 |
| 2. Chess (C) | 20.8 | **0** | 34.2 | **1.0** |
| 3. PEP-62 (B) | 23.2 | **0.6** | 36.6 | **1.2** |
| 4. PEP-130 (B) | 15.2 | **1.7** | 17.8 | **6.8** |
| 5. PEP-51 (B) | 13.2 | 8.2 | 19.5 | 84.0 |
| 6. PEP-208 (B) | 14.3 | 20.7 | 34.5 | 197.2 |
| F probability | 0.539 | <0.001 | 0.957 | <0.001 |

Data shown are combined totals of adults + nymphs.

The numbers of *A. solani* were initially low (this species has a low treatment threshold due to its potential capacity as a vector of viruses) and populations crashed mid-way through the study due to natural parasitism.

- There were significant efficacy effects, *vs* the control, for the standard and several of the experimental treatments. *Aulacorthum solani* numbers were reduced in plots treated with Chess on the first three of the four post-treatment sampling occasions (P<0.05). Reduced numbers were also seen in plots treated with bioinsecticides 62 (6DAAs 1 and 2) and 130 (6DAA2). Failure to detect differences between treatments later into the trial period probably reflected low counts overall (as a consequence of parasitism), more than treatment efficacy *per se*.

- A natural infestation of *Myzus persicae* established on plants before the first sprays. Levels of this species were reduced by Chess and bioinsecticides 62 and 130.

*Discussion*

*Aulacorthum solani* established well on the crop, with statistically uniform pest distributions throughout the glasshouse prior to treatment and numbers in the control treatment that increased between the pre-treatment and 6DAA1 count. Numbers of *A. solani* in all treatments (including the control) began to decline from 6DAA2 due to parasitism. Results obtained after this time should be interpreted with a degree of caution because of this. Despite the limitations of the study, results suggest that bioinsecticide 130, and especially 62, warrant further consideration for control of this species on glasshouse peppers. The industry standard, Chess, was effective in this trial, thus supporting its current use. The same three products also reduced a natural infection of the aphid *Myzus persicae*.

## 3.4 Assessment of the efficacy of several insecticides and bioinsecticides against western flower thrips in peppers

One replicated trial was conducted in June-July 2014 to evaluate the efficacy of conventional insecticides and bioinsecticides for the control of western flower thrips (*Frankliniella occidentalis*) (WFT) in peppers. The results obtained were compared with untreated controls and the trial protocol was validated by inclusion of a standard treatment Calypso (thiacloprid) applied at recommended rates.

Four applications of each treatment were made, except Calypso which was applied twice. Treatments applied are listed below:

**Table 3.4.1.** Detail of conventional insecticides (C) and bioinsecticides (B) evaluated for control of western flower thrips in pepper - 2014

| Treatment | Rate of product used | Application timing |
|---|---|---|
| 1. Untreated | - | - |
| 2. Calypso (C) | 0.48 L/Ha | 5/6, 12/6 |
| 3. PEP-200 (C) | | 5/6, 12/6, 19/6, 26/6 |
| 4. PEP-62 (B) | | 5/6, 12/6, 19/6, 26/6 |
| 5. PEP-130 (B) | | 5/6, 12/6, 19/6, 26/6 |
| 6. PEP-209 (B) | | 5/6, 12/6, 19/6, 26/6 |

*Results*

**Table 3.4.2.** Effect of conventional insecticides (C) and bioinsecticides (B) on control of western flower thrips and aphids in pepper – 26 June 2014 (6 days after final spray)

| Treatment | | Mean number WFT per plot | | Mean number aphids (*Myzus persicae*) per plot |
|---|---|---|---|---|
| | | Adults | Nymphs | |
| 1. | Untreated | 90.4 | 30.6 | 88.9 |
| 2. | Calypso (C) | 116.5 | 44.8 | **1.0** |
| 3. | PEP-200 (C) | 87.4 | **9.4** | **19.2** |
| 4. | PEP-62 (B) | 57.2 | 35.5 | **31.3** |
| 5. | PEP-130 (B) | 111.8 | 23.7 | **11.7** |
| 6. | PEP-209 (B) | 74.5 | 27.5 | 47.0 |
| F probability | | 0.005 | <0.001 | <0.05 |

- The size of the WFT infestation was moderate/high.
- Conventional insecticide 200 significantly reduced the number of WFT nymphs on three of the four post-treatment sampling occasions (P<0.05). Bioinsecticide 062 reduced the number of adult thrips compared with Calypso, but not in comparison with the untreated control.
- A natural infestation of aphids (*Myzus persicae*) was reduced by Calypso, conventional insecticide 200 and bioinsecticides 62 and 130.

*Discussion*

Western flower thrips established well on the crop and was distributed evenly throughout the glasshouse prior to treatment. Results suggest that insecticide 200 can be recommended for future trials based on its efficacy against western flower thrips nymphs. No treatment exerted a statistically significant effect on adult thrips (*vs* the control). The industry standard, Calypso, was ineffective in this trial. Further work should ascertain if this result is repeatable and hence, whether continued use of Calypso against western flower thrips can be recommended.

## 4. Top fruit

### 4.1 Evaluation of full season fungicide programmes for control of powdery mildew in apple 2014

One replicated large orchard plot trial was conducted in 2014 to evaluate the efficacy of full season fungicide programmes based on experimental fungicides identified from trials in 2011-2013 for the control of powdery mildew (*Podosphaera leucotricha)* in apple on cvs.

Cox and Gala. The results obtained were compared to a standard fungicide programme based on products currently registered for use on apple. No untreated control was included. Fifteen applications were made in each programme; the first three sprays and the final spray (not listed) were common to all programmes.

**Table 4.1.1.** Detail of fungicide product used in programmes, for control of apple powdery mildew – 2014

| Treatment | UK rate of product (per ha) | Dosage rate a.s. | Other diseases controlled |
|---|---|---|---|
| 1. Untreated | - | - | - |
| 2. Systhane 20EW | 330 ml | 66 g/ha myclobutanil | Scab |
| 3. Topas | 0.5 L | 0.05 L/ha penconazole | Scab |
| 4. Kindred | 0.6 L | 0.2 L/ha meptyldinocap | None |
| 5. Stroby | 0.2 kg | 0.1 kg/ha kresoxim-methyl | Scab |
| 6. APL-32 | - | - | - |
| 7. APL-128 | - | - | - |
| 8. APL-17 | - | - | - |
| 9. APL-25a | - | - | - |
| 10. APL-25 | - | - | - |
| 11. Cosine | 0.5 L | 0.025 L/ha cyflufenamid | None |
| 12. Kumulus DF | 5 kg | 4 kg/ha sulphur | Scab |
| 13. Talius | 0.25 L | 0.05 L/ha proquinazid | None |
| 14. PP Captan 80 | 2 kg | 1.6 kg/ha captan | Scab |

**4.1.2.** Detail of fungicide programmes for apple powdery mildew – 2014

| Timing | Standard programme | Experimental programme 1 | Experimental programme 2 |
|---|---|---|---|
| 30 April (blossom) | Systhane + Captan | 128 | 17 |
| 14 May | Systhane + Captan | 32 | 17 |
| 28 May | Systhane + Captan | 128 | 128 |
| 3 June | Cosine | Cosine | Cosine |
| 10 June | Topas + Captan | Talius + Captan | Talius + Captan |
| 17 June | Systhane + Stroby + Captan | 25a + Captan | 25a + Captan |
| 23 June | Cosine + Captan | Cosine + Captan | Cosine + Captan |
| 30 June | Topas + Captan | 25a + Captan | 25a + Captan |
| 9 July | Kumulus + Captan | Talius + Captan | Talius + Captan |
| 14 July | Topas + Captan | 128 | 128 |
| 22 July | Topas + Captan | 32 | 17 |
| 7 Aug | Topas + Captan | Topas + Captan | Topas + Captan |

*Results*

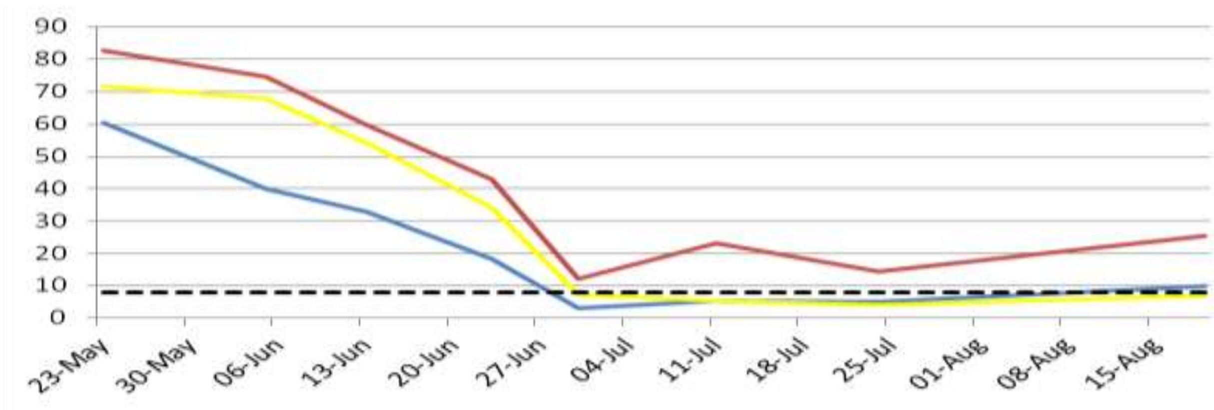


**Figure 4.1.1.** Mean % mildewed leaves on apple shoots cv. Cox assessed on 8 occasions following treatment with various fungicide programmes in 2014. Red = standard programme, Blue = Experimental programme 1, Yellow = Experimental programme 2

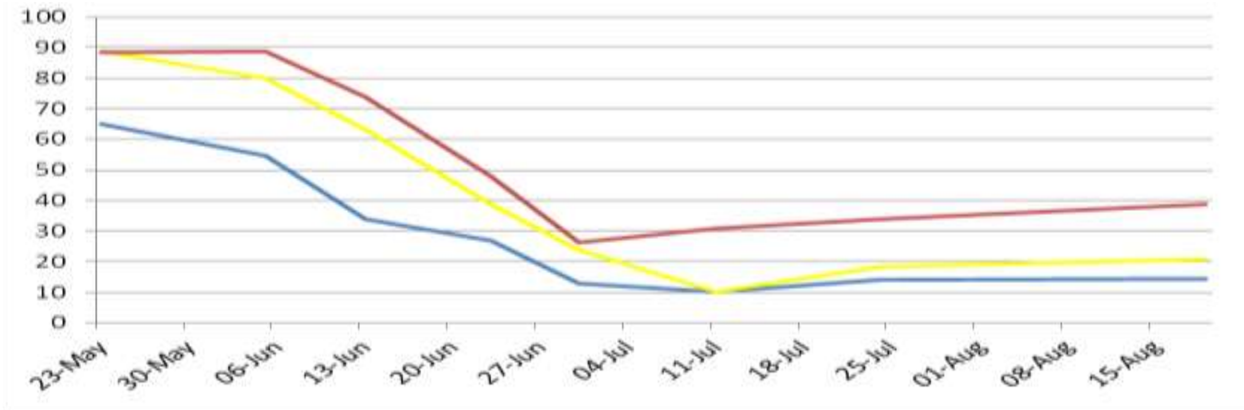


**Figure 4.1.2.** Mean % mildewed leaves on apple shoots cv. Gala assessed on 8 occasions following treatment with various fungicide programmes in 2014. Red = standard programme, Blue = Experimental programme 1, Yellow = Experimental programme 2

- A standard programme for scab control consisting of three sprays (12 March, 24 March, and 10 April) was applied up to blossom. Test programmes were applied from blossom (30 April) until extension growth ceased at the end of the growing season (07 August).
- The programmes selected for evaluation were based on the best fungicides selected from products evaluated in 2011-2013.
- Fungicide choice in the experimental programmes was based on chemical group and other diseases controlled. Thus products with a broad spectrum of activity were targeted early and late in the programme whereas mildew-specific products were used in mid-summer. Using products from similar chemical groups in succession was avoided where possible.
- The incidence of secondary mildew on extension growth at the start of the trial was high at around 80 % mildewed leaves on both Cox and Gala. This was due to a high incidence of primary mildew on flowers and shoots.
- Mean % mildewed leaves for eight assessments for Cox and Gala are shown in the two figures above. All programmes applied reduced mildew incidence overall to around 10% mildewed leaves. The best control was achieved by the Experimental programme 1 and the least effective control was achieved by the standard programme.
- The orchard used was variable in terms of tree vigour with both vigorous tree growth areas and stunted growth areas so it is difficult to draw any conclusions of effect of treatments on fruit size. For russet on cv Cox the lowest score was recorded on fruit from Experimental programme 1 which also resulted in the best mildew control. Differences in russet score on cv Gala were less obvious.

*Discussion*

The orchard had a high incidence of both primary blossom and vegetative mildew. Consequently, at the start of the trial the incidence of mildew in the orchard was high. In the standard fungicide programme, it was not possible to avoid using products from the same chemical groups in succession due to lack of registered products. Hence, the repeated use of the DMI fungicides penconazole and myclobutanil. In all three programmes the fungicides applied in spring steadily reduced the incidence of secondary mildew down to 10-20% mildewed leaves with Experimental programme 1 resulting in the best mildew control at the end of the trial. However, even in the best Experimental programme the incidence of secondary mildew was still above the threshold of 8% for Cox (a threshold above which significant effects on yield and fruit quality occur) for most of the season. Using the experimental programmes over a number of seasons would eventually result in secondary mildew incidence below 8% for most of the season as reducing the incidence of primary mildew is the key to mildew control during the growing season.

## 4.2 Assessment of the efficacy of conventional fungicide and biofungicide programmes for control of apple mildew

One replicated trial was conducted in 2014 to evaluate the efficacy of ten different programmes combining fungicides and biofungicides for the control of powdery mildew (*Podosphaera leucotricha*) in apple. The results obtained were compared with an untreated control and the standard treatment Systhane 20EW (myclobutanil) applied at recommended rates.

Eight of the programmes (T3-T10) consisted of ten applications; three applications of one fungicide and seven application of one biofungicide (Table 4.2.1). Two of the programmes (T11-T12) were managed such that choice of fungicide or biofungicide was based on mildew risk. The standard product, Systhane 20EW, was applied as a full programme.

**Table 4.2.1.** Detail of conventional fungicides (C) and biofungicides (B) used in spray programmes for apple powdery mildew - 2014

| Products | UK rate of product /ha | Dosage rate a.s. |
|---|---|---|
| Systhane 20EW (C) | 330 ml | 66 g/ha myclobutanil |
| SF2014-APL-17 (C) | - | - |
| SF2014-APL-32 (C) | - | - |
| SF2014-APL-146 (C) | - | - |
| SF2014-APL-06 (B) | - | - |
| SF2014-APL-90 (B) | - | - |
| SF2014-APL-105 (B) | - | - |
| SF2014-APL-157 (B) | - | - |
| Talius (C) | 0.25 L | 0.05 L proquinazid |
| Cosine (C) | 0.5 L | 0.025 L cyflufenamid |

**Table 4.2.2.** Fungicide programmes evaluated for control of powdery mildew on apple – 2014

| Treatment | Timing (22 May – 28 May) of sprays | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1. Untreated | - | - | - | - | - | - | - | - | - | - |
| 2. Systhane 20EW (C) | Sys | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 3. APL-32 (C) / APL-105 (B) | 32 | ✓ | 105 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 32 |
| 4. APL-32 (C) / APL-157 (B) | 32 | ✓ | 157 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 32 |
| 5. APL-32 (C) / APL-90 (B) | 32 | ✓ | 90 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 32 |
| 6. APL-32 (C) / APL-06 (B) | 32 | ✓ | 06 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 32 |
| 7. APL-17 (C) / APL-105 (B) | 17 | ✓ | 105 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 17 |
| 8. APL-17 (C) / APL-157 (B) | 17 | ✓ | 157 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 17 |
| 9. APL-17 (C) / APL-90 (B) | 17 | ✓ | 90 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 17 |
| 10. APL-17 (C) / APL-06 (B) | 17 | ✓ | 06 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | 17 |
| 11. Managed A | 17 | ✓ | 88 | ✓ | 06 | Cos | 157 | 06 | 146 | 17 |
| 12. Managed B | 32 | ✓ | 88 | 06 | 157 | Cos | 06 | 157 | 146 | 32 |

Sys – Systhane 20EW; Cos – Cosine

A ✓ indicates the same product was applied as the previous spray.

- A standard programme for scab and mildew control was applied up to the end of blossom. Test programmes were applied from the start of extension shoot growth (22 May).

- The programmes selected for evaluation were based on the best biofungicides and fungicides selected from products evaluated in 2012 and 2013.
- The programmes were based on using fungicides at the start to rapidly reduce the incidence of secondary mildew and at the end of the programme to ensure mildew incidence was low and reduce the risk of mildew infection of terminal buds. Biofungicides were used in the middle of the programme.
- In treatments 11 and 12 the programmes were managed, basing product choice on the incidence of mildew such that when the mildew incidence increased a fungicide was selected.
- Despite the standard programme the incidence of secondary mildew on extension growth at the start of the trial was high at around 80 % mildewed leaves.

*Results*

**Table 4.2.3.** Effect of fungicides and biofungicides applied in programmes of 10 sprays on control of powdery mildew in apple and russet on apple fruit – 2014

| Treatment | Mean % mildewed leaves (mean of 9 assessments) | Mean total russet score (0-400) |
|---|---|---|
| 1. Untreated | 99.2 | 137.5 |
| 2. Systhane 20EW (C) | **50.3** | **77.5** |
| 3. APL-32 (C) / APL-105 (B) | **57.4** | 129.5 |
| 4. APL-32 (C) / APL-157 (B) | **65.2** | 121.5 |
| 5. APL-32 (C) / APL-90 (B) | **56.1** | **96.5** |
| 6. APL-32 (C) / APL-06 (B) | **56.3** | **77.3** |
| 7. APL-17 (C) / APL-105 (B) | **62.8** | 108.5 |
| 8. APL-17 (C) / APL-157 (B) | **65.8** | 103.5 |
| 9. APL-17 (C) / APL-90 (B) | **60.4** | 105.8 |
| 10. APL-17 (C) / APL-06 (B) | **71.2** | 113.0 |
| 11. Managed A | **35.0** | **94.3** |
| 12. Managed B | **36.5** | **83.5** |
| F probability | <0.001 | 0.009 |
| LSD (p = 0.05) | 8.92 | 32.93 |

% mildew data are angular transformed values, mean of 9 assessments over the season.

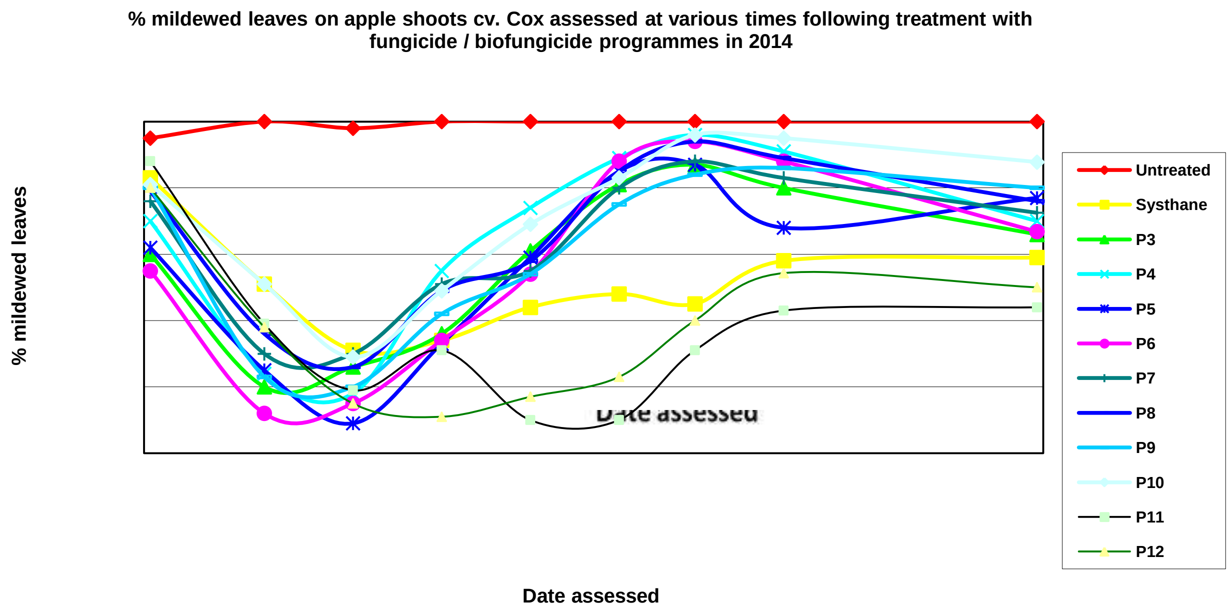


**Fig 4.2.1.** Mean % mildewed leaves on apple shoots cv. Cox assessed on 9 occasions following treatment with various fungicide / biofungicide programmes in 2014

- Mean % mildewed leaves for 9 assessments are shown in the Table 4.2.3. Almost 100% leaves were mildewed in untreated plots.
- All programmes applied significantly reduced mildew incidence overall. The best control was achieved by the standard Systhane 20EW programme and the two managed programmes (T11 and T12). The two managed programmes were better than Systhane 20EW.
- In programmes 3-9 the two fungicide applications at the start of the trial reduced the incidence of mildew down to 20-40 % mildewed leaves. Once the programmes changed to the biofungicides at spray timing 3, in all cases the incidence of powdery mildew increased rapidly back to the starting incidence. Mildew incidence fell again when the programmes switched back to fungicides.
- There were no clear treatment effects on fruit size.
- The highest russet score was recorded in fruit from untreated plots and was most likely due to powdery mildew. In general, significantly less russet was recorded on fruit from plots where the mildew control was better (Treatments 2, 5, 6 11, 12).

*Discussion*

A standard programme for scab and mildew control was applied up to the end of blossom. Test programmes were applied from the start of extension shoot growth. The programmes were based on using fungicides at the start to rapidly reduce the incidence of secondary mildew and at the end of the programme to ensure mildew incidence was low and reduce the risk of mildew infection of terminal buds. Biofungicides were used in the middle of the programme. In other crops biofungicides would tend to be placed in the pre-harvest period to minimise residues. However, it is essential that mildew control at the end of extension growth (usually near harvest) in apples is good to minimise the risk of mildew overwintering in the buds and the choice of biofungicides, which from the previous trials in 2012 and 2013 have demonstrated poorer control of mildew, would not be as effective as fungicides at this time. Despite the standard three spray pre-blossom programme the incidence of secondary mildew on extension growth at the start of the trial was high at around 80 % mildewed leaves. This is obviously a high incidence of powdery mildew and hence a stern test for the programmes. Almost 100% of leaves were mildewed in untreated plots. All programmes applied significantly reduced mildew incidence overall. The best control was achieved by the standard Systhane 20EW programme and the two managed programmes (11 and 12). Overall, the two managed programmes performed significantly better than the standard Systhane programme. However, this was most likely due to better control of mildew by the fungicides (17, 32 and 88) used at the start of the programme. By the end of the programme, after the use of the biofungicides, mildew control in P11 and P12 was similar to that achieved by Systhane 20EW. However, these programmes only achieved a 50-70% reduction in secondary mildew. The cultivar Cox is very susceptible to mildew (an incidence of 8% mildewed leaves is sufficient to reduce yield and quality) and, in orchards where mildew incidence is high, it is difficult to see how biofungicides could be used with fungicides for mildew control. However, where the mildew incidence is low and where cultivars are less susceptible to mildew then they could be used as part of a managed programme.

## 4.3 Assessment of the efficacy of biofungicide dips against Botrytis fruit rot in cold stored pears

Two replicated trials were conducted in 2013 to evaluate the efficacy of several biofungicides applied as post-harvest dips for the control of Botrytis rot (*Botrytis cinerea*) in cold stored pears. The results obtained were compared with untreated controls and the trial protocol was validated by inclusion of the standard treatment Rovral (iprodione) applied at the rate recommended on the EAMU. One trial was stored in air at -1$^{o}$C. The second trial was stored in controlled atmosphere (CA) (2% O2; 0% CO2) at -1$^{o}$C. The storage period was approximately 6 months. Each treatment was applied once as a post-harvest dip on 19 September 2013.

**4.3.1.** Detail of post-harvest dip treatments evaluated for control of Botrytis rot in stored pears – 2013/14

| Treatment | Fruit temperature | UK rate of product/L | Dose rate a.s. per L |
|---|---|---|---|
| Air store trial | | | |
| 1. Untreated, inoculated | Ambient | - | - |
| 2. Untreated, uninoculated | Ambient | - | - |
| 3. Rovral WG | Ambient | 1.3 g | 0.975 g iprodione |
| 4. PER-178 | Ambient | - | - |
| 5. PER-178 | Cold | - | - |
| 6. PER-99 | Ambient | Low rate | - |
| 7. PER-99 | Ambient | High rate | - |
| 8. Nexy | Ambient | - | 0.19 g *Candida oleophila* |
| 9. Nexy | Cold | - | 0.19 g *Candida oleophila* |
| 10. PER-188 | Ambient | - | - |
| 11. PER-40 | Ambient | - | - |
| 12. PER-168 | Ambient | - | - |
| CA store trial | | | |
| 1. Untreated, uninoculated | Ambient | - | - |
| 2. Rovral WG | Ambient | 1.3 g | 0.975 g iprodione |
| 3. PER-178 | Ambient | - | - |
| 4. PER-99 | Ambient | - | - |
| 5. Nexy | Ambient | - | 0.19 g *Candida oleophila* |

*Results*

**Table 4.3.2.** Effect of post-harvest dip treatments on Botrytis fruit rot in pears – 1 April 2014. % values are angular transformed; figures in brackets are back transformed

| Treatment | Fruit temperature at treatment | UK rate of product/L | % Botrytis fruit rot |
|---|---|---|---|
| Cold air storage (-1ºC) | | | |
| 1. Untreated, inoculated | Ambient | - | 42.3 (45.2) |
| 2. Untreated, uninoculated | Ambient | - | **2.3** (0.2) |
| 3. Rovral WG | Ambient | 1.3 g | **20.1** (11.9) |
| 4. PER-178 | Ambient | - | **31.6** (27.5) |
| 5. PER-178 | Cold | - | 37.2 (36.5) |
| 6. PER-99 | Ambient | Low rate | **24.4** (17.1) |
| 7. PER-99 | Ambient | High rate | 35.4 (33.6) |
| 8. Nexy | Ambient | - | **26.3** (19.6) |
| 9. Nexy | Cold | - | **29.4** (24.1) |
| 10. PER-188 | Ambient | - | 43.4 (47.1) |
| 11. PER-40 | Ambient | - | 33.3 (30.2) |
| 12. PER-168 | Ambient | - | 30.1 (25.2) |
| F probability | | | <0.001 |
| LSD | | | 10.29 |
| CA storage (-1ºC) | | | |
| 1. Untreated, uninoculated | Ambient | - | 40.4 (41.9) |
| 2. Rovral WG | Ambient | 1.3 g | **13.3** (5.3) |
| 3. PER-178 | Ambient | - | **35.4** (33.5) |
| 4. PER-99 | Ambient | - | 41.5 (43.9) |
| 5. Nexy | Ambient | - | 41.9 (44.5) |
| F probability | | | <0.001 |
| LSD | | | 4.21 |

Experiment 1 – Air storage

- Pears inoculated with Botrytis were introduced into crates of healthy pears to ensure disease development. Botrytis spread in untreated fruit was moderate with 45% fruit with Botrytis.

- Biofungicide 178 and Nexy were applied to fruit at both cold and ambient temperatures to see if fruit temperature affected biofungicide performance, based on observation from 2012 trial.
- The spread of Botrytis fruit rot was reduced significantly by Rovral, 178, -99, Nexy, Nexy – cold and 168. There was least Botrytis fruit rot (20.1%) in fruit treated with the standard fungicide Rovral WG.
- The spread of Botrytis was greater in both 178 and Nexy applied to cold fruit compared to fruit treated at ambient temperature, but the differences were not significant, suggesting that fruit temperature could be a factor in biofungicide performance.

Experiment 2 – CA storage

- Pears inoculated with Botrytis were introduced into crates of healthy pears to ensure disease development. Botrytis spread in untreated fruit was moderate with 42% fruit with Botrytis.
- The spread of Botrytis fruit rot was reduced significantly only by 178. The biofungicides 99 and Nexy appeared to be ineffective in CA, whereas they were effective in the air store trial.

*Discussion*

The use of inoculated fruit in the trial ensured that Botrytis rot developed in the fruit but was also a severe test for the performance of the biofungicides. In the air-stored trial the biofungicides 178, 99, Nexy, Nexy - cold and 168 were effective in reducing the spread of Botrytis although not as effective as the fungicide standard Rovral. It appears that applying biofungicides to cold fruit can reduce their efficacy although the differences between treatments 4 and 5 (178) and 8 and 9 (Nexy) were not significant. Once pears are harvested they need to be placed in store and cooled as rapidly as possible to ensure quality fruit at the end of the storage period. So after drenching and allowing fruit to drain they are placed immediately in cold store, probably within 30 mins of treatment. Thus there was only a short time for the biofungicide to develop on the fruit surface. If the fruit is cold i.e. has already been in the cold store prior to treatment, then the opportunity for the biofungicide to perform is possibly further reduced. Experiment 2, where the fruit was stored in CA conditions, showed that whereas incidence of Botrytis rot in the untreated was similar to that in air storage, only 178 performed similarly to that in air storage. Possibly some types of biofungicides do not perform as well under CA conditions as in air due to the nature of the active substances. This is an important factor since in the UK most pears for long term storage are now stored in CA. However, only one trial has been conducted in CA and further trials should be conducted to establish whether these results are correct.

## **Technology transfer** (1 October 2013 – 28 February 2015)

Factsheet

O'Neill TM & Gwynn R (2014). Getting the best from biopesticides. HDC Factsheet 10/14.

Articles

Atwood J (2015). Soft fruit update. *HDC News* (in press)

Atwood J (2014). SCEPTRE: latest results in soft fruit. *HDC News* **201**, pp 28-30

Berrie A (2014). SCEPTRE: latest results in apples. *HDC News* **204**, 12-13

Brough W (2014). From Sceptre to MOPS – crop protection research for ornamentals. *HDC Ornamentals Review*.

Collier R, Huckle A, Jukes A & Mayne S (2014). SCEPTRE: latest results on field vegetables. *HDC News* **202**, 28-30.

Collier R, Huckle A, Jukes A & Mayne S (2014). SCEPTRE: latest results in brassicas. *HDC News* **203**, 28-29.

Croft P, McPherson M & Wright K (2014). SCEPTRE: latest results in protected edibles. *HDC News* **205**, 28-30.

George D R, Banfield-Zanin J A, Collier R, Cross J, Birch A N E, O'Neill T (2015) (Feb 28$^{th}$ submission). The role of the SCEPTRE project in increasing commercial availability of effective glasshouse pest control products in the UK. *Insects* (in preparation)

Knott C (2014). Total workout for herbicide trio. *HDC News* **199**, 24-25

Knott C (2014). Double hit for courgette weed control. *HDC News* **208**, 25-27

Knott C (2015). Herbicides for carrots and their allies. *HDC News* **209**, 20-23

O'Neill TM (2014). Sceptre progress report. *HDC Crop Protection Review*

Raffle S (2013). Sceptre opens up future options. *HDC Soft fruit review 2013*, p 8

Richardson A (2013). Weed control in brassicas. Brassica Grower Association Newsletter (December)

Presentations

Atwood J (2014). Blackcurrant weed projects in SCEPTRE. Blackcurrant Growers Association R&D meeting, 3 December 2014.

Berrie A (2014). Soft fruit disease management. EMRA/HDC Soft Fruit Day, East Malling Research, 26 November 2014.

Collier R (2014). Field vegetable pest control update, 7 February 2014, Pershore College, Worcs.

George D, Banfield-Zanin J, Burns C, Wright K, McPherson M (2015). Biopesticide work on protected edibles in SCEPTRE. HDC Biopesticides Workshop – Protected Edibles, 27 January 2015, Stoneleigh Park UK

George D, Banfield-Zanin J (2015). Pests on glasshouse edibles: Tomato and pepper. SCEPTRE Conference, 24 February 2015, Peterborough, UK

George D (2015). Compatibility of reduced risk insecticides with biocontrol. SCEPTRE Conference, 24th February 2015, Peterborough, UK

George D, Banfield-Zanin J, Burns C, Wright K, McPherson M (2015). Biopesticide work on protected edibles in SCEPTRE. BioGreenhouse EU COST meeting, 10 March 2015, STC, UK

Knott C (2013). Potential herbicide solutions for vegetables. Vegetable Consultants Association, Stilton, 26 November 2013

O'Neill TM (2014). New crop protection methods for edible crops. IBMA (UK) Annual Meeting, Cambridge, 15 May 2014.

O'Neill T M (2015). The SCEPTRE project: Aims, overview and outcomes. SCEPTRE Conference, 24 February 2015, Peterborough

O'Neill TM (2014). Securing plant protection products for sustainable tomato production. Annual Tomato Conference, Warwick, 26 September 2014.

O'Neill TM (2013). New crop protection methods for field vegetables, 4 February 2014, Bayer Vegetable Conference, Peterborough.

O'Neill TM (2013). Protected edible work in Sceptre, 4 December 2013, TGA Technical Committee, Stoneleigh.

Raffle S (2014). Sceptre Update – Soft fruit and top fruit. HDC Fruit Agronomists Day, 25 February 2014.

Richardson A (2013). Sceptre work on onions, 20 November 2013, UK Onion and Carrot Conference, Peterborough.

Wedgwood E (2014). Sceptre work on onion downy mildew, 29 January 2014, Onion Growers Association Technical Meeting, Lincs.

Wright K (2013). Sceptre work on cucumbers, 18 October 2013, Cucumber Growers Day, Waltham Abbey.

Events

Sustainable Crop Protection. Project Conference, Peterborough, 24 February 2015 (Tim O'Neill, Roma Gwynn, Erika Wedgwood, Rosemary Collier, Nick Birch, Jerry Cross, Angela Berrie, Robert Saville, Martin McPherson, David George, John Atwood, Andy Richardson, Cathy Knott)

HDC Biopesticides Workshop – Protected Edibles. Stoneleigh, Warwickshire, 27 January 2015 (Roma Gwynn, David George).

Fruit for the future. James Hutton Institute Open Day, 17 July 2014 (Nick Birch, William Deasy).

Vegetable Weed Control Open Day, Elsom Seeds Trial Ground, Spalding, 25 and 26 June 2014 (Cathy Knott, Andy Richardson).

Field vegetable disease and weed control. ADAS Boxworth Open Day, 3 June 2014 (Lynn Tatnell, Maria Tzortzi, Angela Huckle, Sarah Mayne, Tim O'Neill).

Elsom Seeds Open Day, Spalding, 10-11 October 2013 (Angela Huckle, Peter Gladders, Sarah Mayne, Tim Boor)

## Appendix 1 Priority crop protection targets examined in this project

### Diseases

| 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 | - | - |

**Pests**

| 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.

**Weeds**

| 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 | Many crops | Strawberry |
| | 3 | Perennial weeds | - | - |
| | 4 | Alleyways/runners | - | Strawberry |
| | 5 | Band spraying | Vegetables | - |
| | 6 | Non-herbicide methods | Several | Electric weed control |