AHDB

HORTICULTURE

Grower Summary

CP 077

Sustainable Crop and Environment Protection – Target Research for Edibles (SCEPTRE)

All Years (2010-2015)

Disclaimer

The results and conclusions in this report may be based on an investigation conducted over one year. Therefore, care must be taken with the interpretation of the results.

Use of pesticides

Only officially approved pesticides may be used in the UK. Approvals are normally granted only in relation to individual products and for specified uses. It is an offence to use non-approved products or to use approved products in a manner that does not comply with the statutory conditions of use, except where the crop or situation is the subject of an off-label extension of use.

Before using all pesticides check the approval status and conditions of use.

Read the label before use: use pesticides safely.

Further information

If you would like a copy of the full report, please email the AHDB Horticulture office (hort.info.@ahdb.org.uk), quoting your AHDB Horticulture number, alternatively contact AHDB Horticulture at the address below.

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The results and conclusions in this report are based on investigations conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work, it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of results, especially if they are used as the basis for commercial product recommendations.

Project Number:	CP 077
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Project Leader:	Dr Tim O'Neill
Contractor:	ADAS UK Ltd
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Headline

- Potential new plant protection products have been identified to fill many of the crop protection gaps on edible crops arising from changing legislation.

Background and expected deliverables

Numerous widely used conventional chemical plant protection products 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 plant protection products 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 list contains 77 candidates), as required under Regulation (EC) No. 1107/2009.

The effect of these measures on future availability of plant protection products, 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.

At around €300 million per compound, the cost of finding and developing new plant protection products is prohibitive for many crops. Horticultural crops are ‘minor crops’ in a global crop protection market and rarely the primary focus of new product development. Registration of products is complex, usually expensive and requires 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 plant protection product treatments that support sustainable production of edible crops. Opportunities available include:

- new chemical actives;
- a rapidly increasing number of biopesticides in the registration pipeline;
- 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 plant protection products 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 (pests, diseases and weeds) working across the major organizations currently delivering applied crop protection research.

Summary of the project and main conclusions

A total of 137 field, greenhouse and cold-store experiments to determine plant protection treatment efficacy and/or crop safety were conducted on 38 priority crop protection problems between October 2010 and March 2015 (Table 1). Additional trials in 2011 examined herbicide residues in field vegetable crops. The proportion of experiments by sector was: field vegetables 53%, soft fruit 23%, protected edibles 17% and top fruit 7%; the proportion of experiments by target was: diseases 36%, pests 39%, weeds 25%. The specific disease, pest and weed problems examined are detailed in Table 1.

Consultation was undertaken annually with around 25 companies marketing conventional chemical plant protection products and/or biopesticides to identify plant protection products of potential benefit to UK horticulture that might be included in project experiments. Only products where the active substance(s) were listed on Annex 1, had been submitted for listing, or there was a clear intention to seek listing, were considered for inclusion in SCEPTRE experiments. Decisions on which products to include in experiments were made by the project disease, pest and weed Research Management Groups, taking advice from HDC crop protection managers and a biopesticide consultant to the project on likelihood of products coming to the UK market.

Over the project life, a total of 92 conventional synthetic plant protection products and 67 biopesticides were evaluated (Table 2). The numbers of products available for evaluation was 90, 44 and 25 for fungicides, insecticides and herbicides respectively. Very few bioherbicides were available for testing, and only 20 conventional herbicides. The biopesticides examined comprised microorganisms (38), botanicals (17) and other substances (e.g. salts) (12). The greatest number of products was evaluated on field vegetables (98), with similar numbers on soft fruit (74) and protected edibles (64), and the least on top fruit (31); the latter reflects the fact that no pest or weed control work was done on top fruit.

Potential new plant protection products were identified for all the priority disease, pest and weed problems examined, with the exception of new herbicides suitable for rocket, swede and mizuna (benfluralin screened in 2010 was safe, though it did not control groundsel). Leading novel products for the disease, pest and weed problems examined are detailed in Tables 3-7. Products that were as effective, or more effective, than the standard reference product used in an experiment are identified (in bold type); products that reduced the pest compared with the untreated but were less effective than the reference product are shown in normal type.

For control of the target diseases examined (Table 3), the proportion of leading products performing as well as the grower standard reference product was greater for conventional synthetic fungicides (76.5%) than for biofungicides (44.2%). Biofungicides with treatment efficacy equal to the reference synthetic conventional fungicide were identified for brassica downy mildew, brassica powdery mildew, strawberry powdery mildew, cucumber powdery mildew, apple powdery mildew, leek rust and strawberry crown rot. It is notable that apart from strawberry crown rot (*Phytophthora cactorum*), these diseases are all caused by biotrophic fungi; and most are powdery mildew diseases. The primarily external fungal growth of powdery mildews may explain the greater susceptibility of this group of pathogens to the contact-acting biofungicides.

During the project a total of 90 products were evaluated for disease control, comprising 50 conventional fungicides and 40 biofungicides. Cassiopeia was registered during the project's life. There are a further 6 unique product x crop uses of fungicides in the pipeline and 21 planned.

During the project a total of 44 products were tested for insect control and this included 15 products based on microorganisms, 7 based on botanicals and 22 conventional insecticides. There are now 6 unique product x crop uses of conventional insecticides in the registration pipeline and 11 planned. Steward was approved for use on outdoor strawberry and shown to control European tarnished plant bug. Dipel was registered during the project's life and 9 further uses of biopesticides are planned.

During the project a total of 20 conventional herbicides and 5 other products were tested for weed control. Wing-P was registered for use on outdoor lettuce and Sencorex Flow on outdoor celeriac. Shark gained authorisation and tests confirmed its safety over blackcurrant and efficacy against common nettle. Registration of a further 17 unique product x crop uses of conventional herbicides is planned.

Key results are highlighted below, arranged by crop within the four sectors (field vegetables, soft fruit, protected edibles and top fruit).

Please note: The mention of a named plant protection product on a particular crop in this report does not necessarily indicate that use of that product is permitted on the particular crop; it is always the responsibility of the user to check product registration details, especially target crop and application method, on the CRD database, before use. The active ingredients of named plant protection products are listed in Appendix 1.

1. Field vegetables

Brassica

Diseases

- Novel active substances were identified for control of powdery mildew, downy mildew, ring spot and Alternaria leaf spot.
- Cassiopeia was shown to have good broad-spectrum activity against brassica foliar diseases.
- Effective, sustainable fungicide programmes were developed for powdery mildew and ring spot using information on individual product efficacies.

Pests

- Identification of a number of conventional insecticides (50, 55, 198, 199, 200) that look promising for cabbage root fly control on transplanted crops.
- Insecticides 50, 59 and 60 provided good control of cabbage aphid. Bioinsecticides Naturalis L, 62 and 130 provided some control
- Insecticides 48 and 67 provided effective control of caterpillars on brassica crops. Bioinsecticides 64, 130 and Lepinox Plus also provided good control.
- For control of silver Y moth, the insecticides Tracer, 50 and 48 were 100% effective and four bioinsecticides (51, Lepinox Plus, Nemasys C and 130) showed statistically-significant activity to varying degrees.

Carrot

- Novel insecticides 50, 60, 75 and 100 have the potential to control willow-carrot aphid.

Leek

Diseases

- Vertisan provides a new mode of action group for rust control, increasing options for resistance management.
- Biofungicide 105 applied eight times at 10 day intervals greatly reduced rust.

Pests

- In 2011 and 2013, the insecticide product 50 provided a significant level of control of thrips on leek, as did the commercial standard, Tracer, and product 48 in 2011.
- The commercial standard, Tracer, significantly reduced the numbers of leek moth caterpillars as did insecticide products 48, 50, 67, 75, 149, 198, 200 and bioinsecticides 61, 62, 130, 201.

Lettuce

- For control of currant-lettuce aphid, two of the insecticides (50, 60) provided effective control as foliar sprays in 4 of the six trials in which they were tested. Product 50 was also applied as a drench/spray treatment to the peat blocks in 2014 and provided control for some of the growth period. The insecticide 59 was evaluated in 5 trials and was effective in 4 of them. The bioinsecticides were less effective overall, but product 130 provided some control in 2014.

Field vegetables – weed control

Weeds

- SCEPTRE funded data generation supported new EAMU approvals for use of Wing-P (3044/12) on outdoor crops of lettuce and for use of Sencorex Flow (0916/15) on outdoor crops of carrot, celeriac, mallow and parsnip.
- Two new residual herbicides (191 and 196) were identified for use in bulb onions. In particular, 191 gave good post-emergence weed control with no crop safety issues.
- Bandspraying maximum permitted dose rates of residual herbicides between crop rows, whilst using a safer residual herbicide choice/dose over the crop row, can significantly reduce both overall weed levels in the field and crop phytotoxicity.
- Although not directly funded by SCEPTRE, the first Agricultural Electric Weeder to be built in the UK since the early 1980's was extensively trialled by the project on a range of vegetable crops. The machine showed potential and was comparable in cost-efficacy with standard commercial inter-row mechanical weed control in brassica crops.
- Benfluralin was evaluated for courgettes and umbelliferous crops. Residues data were generated for brassicas as part of SCEPTRE in 2011. Benfluralin is now registered for some vegetables in EU countries (Belgium and the Netherlands) and Dow AgroSciences are working to expedite successful approval in the UK for several crops through Mutual Recognition.
- A linuron alternative was found to be useful for carrot, parsnip, coriander, celery, leek and onion, dwarf and broad beans, vining peas and possibly spinach pre-weed-emergence, and in a few of these crops post-weed-emergence. In 2014 it was further tested, as product 191, in tank-mixes and programmes in 6 umbelliferous crops. The company is generating residues data for many of these crops.
- Herbicide 05 was safe in a number of vegetables and weed control was excellent. The active substances are going through Annex 1 renewal – If successful it may be possible for authorisations in UK, with some uses in vegetables after 2017.
- Herbicide 165, a chloroacetamide with the same mode of action as propachlor, pre-weed-emergence controls groundsel and was safe to onion, leek, lettuce, courgette, vining peas and dwarf green beans. The company is obtaining residues data for vegetables, starting with peas.

- Herbicide 166, in the same class of chemistry as diflufenican, is at an early stage of development. It appears safe in umbellifers and some other crops, but it does not control groundsel or annual meadow-grass.
- Herbicide 190, a sulfonylurea, was most effective applied pre-weed-emergence. The best timing for courgette was soon after transplanting but before weed emergence, dwarf French bean pre-emergence. However, herbicide 190 may not be progressed.
- Groundsel: this has become the worst weed with often more than one flush, reducing quality in some crops because it is toxic. Fortunately new herbicides in the screen (165, 190 and dimethenamid-p, a component of Wing-P) are effective. Herbicide 191 gives some control.
- Mayweeds: a problem in carrots, is controlled by herbicide 191.

Spring onion

- Control of downy mildew was achieved with Cassiopeia and product 197.
- There was a demonstrable benefit of multiple (3 or 4) different actives in each spray application for control of spring onion downy mildew, rather than using a single active.

2. Soft fruit

Blackcurrant

- Shark gained authorisation in 2014 and tests confirmed its crop safety over blackcurrant buds and its efficacy for common nettle control.
- Conventional herbicide 135 gave some control of creeping thistle and good control of common nettle in blackcurrants and raspberries and was safe when applied over blackcurrant buds or to raspberry canes.
- The potential for electric weed control was demonstrated with a test rig used for selective control of perennial weeds in a mature blackcurrant plantation.

Raspberry

- Two biopesticides (62,130; glasshouse and polytunnel trials over 4 years) were selected as providing useful levels of aphid control against two pest species (large raspberry aphid, potato aphid) under protected cultivation. They were compatible with biocontrol using commercially reared and released parasitoid wasps and with predation by endemic hoverflies and other natural enemies.
- At least one novel conventional insecticide (59) provided very good aphid control comparable with the industry standard, Calypso. Another conventional product (50) was

also promising against early attack (potato aphid) but is not sufficiently persistent to be effective over a 6 week period if it can only be applied twice (fortnightly). Further work on forecasting, modelling and spray timings is needed to optimize the use of these products against two aphid pests with different population dynamics.

- These new IPM tools are compatible with the raspberry IPM toolbox already developed under previous RESAs and HortLink funding, using pest-resistance varieties and semiochemical-enhanced raspberry beetle traps.

Strawberry

Diseases

- This project resulted in the first identification of products (Signum, Switch, Thianosan, 25a, 37, 77) with activity against strawberry fruit soft rots (*Mucor* and *Rhizopus* spp.).
- Identification of two new conventional synthetic fungicides (Cassiopeia and Percos) and two biofungicides (Prestop and 40) with activity against strawberry crown rot.
- Identification of four new conventional synthetic fungicides for control of strawberry powdery mildew (Talius, Galileo, 77, 159).
- Identification of two biofungicides (6, 105) that reduced strawberry powdery mildew and could be used in a programme with conventional fungicides.

Pests

- Chess WG, the industry standard selective insecticide when work commenced, was found to be only partially effective against European tarnished plant bug.
- Steward was identified as a new effective selective insecticide for control of European tarnished plant bug (EAMU approval on outdoor strawberry obtained as a result of this project). Use of the adjuvant Silwet L-77) with Steward increased efficacy (Steward used at ½ dose due to addition of Silwet L-77).
- Coded product 59 is a promising new selective insecticide for control of European tarnished plant bug.
- Treatments with selective insecticides for control of European tarnished plant bug are likely to be best if applied on a large scale, due to pest migration.

Weeds

- Three residual herbicides were identified as safe to use over strawberry foliage. Of these, conventional herbicide 74 has the best potential for an EAMU in the short term.
- One conventional (124) and one bioherbicide (109) have potential for use as strawberry runner control treatments in case the standard treatment glufosinate-ammonium continues to be in short supply. Bioherbicide 109 was also effective as a control for docks.

- One bioherbicide (116) also has potential for runner control although uncertainty over future availability in the UK meant it was not possible to test it in 2014, it should be available on the market in 2016.

3. Protected edibles

Cucumber

- Several novel conventional fungicides (Talius, 08, 25a, 77) and biofungicides (Serenade, 80, 90) were effective in controlling cucumber powdery mildew.
- For Pythium root rot, several conventional fungicides (Amistar, Signum, 183) were identified with potentially higher efficacy than Previcur Energy.
- Identification of conventional synthetic fungicides (Amistar, Signum, 175) with potential to control Phomopsis root rot, a disease where no product with known activity against the pathogen is currently available.

Sweet pepper

- Biopesticide 62 reduced aphids on peppers.
- Several biopesticides were initially promising against WFT in early trials (52, 82, 92), as were the insecticides 48, 50 and 54.
- Insecticide 200 showed promise against WFT in later trials, being the only product to do so at this time.

Tomato

<u>Diseases</u>

- Several conventional fungicides (Vertisan, Galileo, 77) were identified for control of grey mould (Botrytis).

<u>Pests</u>

- Early trials supported potential of biopesticides 01, 51, 52, 53, 81, 91, 92 and 130 and insecticides 54 and 60 to target glasshouse whitefly.
- Biopesticide 62 reduced glasshouse whitefly on tomato in later trials.
- Biopesticide 92 showed promise against red spider mite on tomato in later trials, with earlier trials supporting similar promise for biopesticides 01, 51, 62, 91 and insecticide 131.
- Work revealed significant potential of biopesticide 130 to control multiple pest species (e.g. glasshouse whitefly and aphid species).

- Failure of industry standards in multiple trials supports the need to identify alternative pest control measures.
- Potential compatability of selected biopesticides with biological control was reported in trials with peach potato aphid (and *Aphidius colemani*), glasshouse whitefly (and *Encarsia formosa*) and red spider mite (and *Phytoseiulus persimilis*), though further experimentation is needed to confirm these preliminary results.

4. Top fruit

Apple

- Identification of several new conventional fungicides to control apple powdery mildew (17, 25a, 32, Galileo, Talius, 128 and 159).
- The possibility of reducing the number of conventional synthetic fungicides used in a season-long programme for control of apple powdery mildew by adopting a Managed Disease Control approach was demonstrated. The MDC programme used conventional synthetic fungicides each time mildew levels had increased from the previous week, and biofungicides when it had remained constant or declined.
- All of the biofungicides evaluated to control apple powdery mildew (secondary infection) failed to reduce the disease when treatment commenced at a high level of mildew or from a moderate mildew level but when disease pressure in the orchard was high.
- Novel conventional fungicide 77 gave excellent control of powdery mildew on apple (as well as on cucumber and strawberry).

Pear

- Four biofungicides (Nexy, Serenade ASO, 98 and 99) were identified that reduced botrytis storage rot in cold-stored pears compared with untreated fruit.

Table 1. Summary of field, greenhouse and cold-store experiments conducted on priority pest problems in the SCEPTRE project: October 2010 – March 2015

Sector and crop	Target pest	Number of experiments				Total
		2011	2012	2013	2014	
<u>Field vegetables</u>						
Bulb onion	Weeds	-	2	-	1	3
Brassica	Dark leaf spot	2	1	-	-	3
	Downy mildew	2	-	-	-	2
	Powdery mildew	-	2	1	1	4
	Ring spot	-	2	1	1	4
	Aphids	1	-	-	1	2
	Caterpillars	1	-	-	-	1
	Cabbage root fly	1	1	-	1	3
	IPM (pests)	-	2	2	-	4
	Weeds	-	-	3	-	3
Carrot	Aphid	1	-	-	-	1
Courgette	Weeds	-	-	-	1	1
Leek	Rust	-	1	1	1	3
	Onion thrips	1	2	2	1	6
	Weeds	-	-	3	-	3
Lettuce	Aphid + caterpillar	1	8	6	2	17
Multiple crops	Herbicide screen	1	1	1	1	4
Spring onion	Downy mildew	-	-	1	1	2
Umbelliferous	Weeds	-	-	-	6	6
<u>Bush and soft fruit</u>						
Blackcurrants	Weeds	2	2	1	1	6
Raspberry	Spur blight	-	-	-	1	1
	Aphids	1	1	1	1	4
	Weeds	-	-	1	-	1
Strawberry	Crown rot	-	1	1	1	3
	Powdery mildew	-	-	-	2	2
	Soft rots	1	1	1	-	3
	Lygus	1	1	1	1	4
	Herbicides	1	2	1	3	7

Table 1 cont'd

Sector and crop	Target pest	Number of experiments				Total
		2011	2012	2013	2014	
Protected edibles						
Cucumber	Black root rot	-	-	2	1	3
	Powdery mildew	2	1	-	-	3
	Pythium root rot	-	-	1	1	2
Pepper	Aphids	-	-	1	1	2
	WFT	1	1	-	1	3
Tomato	Grey mould	2	1	2	-	5
	Glasshouse whitefly	1	1	-	-	2
	Spider mite	1	2	1	-	4
Top fruit						
Apple	Powdery mildew	1	2	2	2	7
Pear	Botrytis rot in stored fruit	1	1	1	-	3
Totals		26	39	38	34	137

Table 2. Summary of types of plant protection product (PPP) evaluated in SCEPTRE field and glasshouse experiments

Total number of unique products	Type of PPP		Types of biopesticide		
	Conventional pesticides	Biopesticides	Micro-organism	Botanical	Other
By sector					
Field vegetables	58	40	23	10	7
Protected edibles	39	35	25	8	2
Soft fruit	38	26	11	12	3
Top fruit	14	17	10	2	5
By category					
Fungicides	50	40	23	7	10
Insecticides	22	22	15	7	0
Herbicides	20	5	0	3	2
Total unique products	92	67	38	17	12

Table 3. 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	**Inf**	**Cas**	**-**	-	-	-
	Onion	2014	1.4	Mixtures	**Cas**	181	**197**	*	*	*
Powdery mildew	Brassica	2012	1.1	Rudis	**Cas**	**28**	**89**	**90**	11	**40+90**
	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	**Sig**	**10**	**27**	*	*	*
	Leek	2013	1.1	Amistar Top	**Ami**	**Ver**	**Gal**	Ser	105	-
	Leek	2014	1.3	AmiT/Rud/Nat	**Cas**	**Ver**	**Gal**	**105**	*	*
Soft fruit										
Crown rot	Strawberry	2012	2.3	Paraat	**Cas**	-	-	**40**	**Pre**	-
Powdery mildew	Strawberry	2014	2.3/4	Systhane	**Tal**	**77**	**Gal**	**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	Ver	77	Pre	09	Ser
	Tomato	2012	3.2	Signum	08	25a	Gal	-	-	-
	Tomato	2013	3.1	Rov/Swi/Sig	**Ver**	**77**	**Gal**	-	-	-
Phomopsis	Cucumber	2013	3.1a	-	**-**	**-**	**-**	-	-	-
	Cucumber	2014	3.1b	-	Ami	Sig	175	-	-	-
Powdery mildew	Cucumber	2011	3.1	Systhane	**Tal**	**08**	**77**	**Ser**	**80**	**90**
	Cucumber	2012	3.1	Sys/Nim	**08**	**25a**	**77**	90	105	**154**
Pythium	Cucumber	2013	3.2	Previcur Energy	Ami	Sig	183	-	-	-
	Cucumber	2014	3.2	Previcur Energy	**Ami**	**Sig**	**183**	-	-	-
Top fruit										
Botrytis	Pear	2012	4.2	Rovral WG	*	*	*	Ser	98	99
	Pear	2013	4.2	Rovral WG	*	*	*	Ser	-	-
	Pear	2014	4.3	Rovral WG	*	*	*	Nxy	99	Ser
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**	**Gal**	-	**90**	**105**	**157**

* – no products in this category evaluated. adj – adjuvant; Ami – Amistar; AmiT – Amistar Top; Cas – Cassiopeia; Cos – Cosine; Gal – Galileo; Inf – Infinito; 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; Nxy – Nexy; V- Vertisan; W - wetter

- 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 4. 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	**Mov**	**50**	**54**	-	-	-
	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**	**67**	-	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**	**Ste**	**54**	**53**	-	-
	Strawberry	2012	2.5	Calypso	**Ste**	**60**	-	*	*	*
	Strawberry	2013	2.4	Chess	**Ste**	59	-	*	*	*
	Strawberry	2014	2.6	Chess	**Ste**	**59**	-	*	*	*
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; Mov – Movento; Nat – Naturalis-L; Ste- Steward

† - Bioinsecticides evaluated in combination with release of natural enemies. See also Table 4 footnotes.
Please see individual experiment reports, within the annual reports, for full details.

Table 5. Novel herbicide products identified as crop-safe to a range of field vegetable crops

Crop	Safe when applied pre weed emergence	Safe when applied post weed emergence
Drilled		
Broad bean	05, 165, 166	(123)
Bulb onion	164, 165, 166, 191	05, (123), 166
Carrot	Ben, 05, 164, 166, 191	76, 05, 166, 191
Coriander	Ben, 05, 166, 191	76, 05, 191
Dwarf French bean	Ben, 05, 164, 166, 190, 191	190
Flat leaf parsley	191	(191)
Leek	164, 165, 166, 191	76, 05, 166
Parsnip	Ben, 05, 166, 191	76, 05, 166, 191
Pea	Ben, 05, 165, 166, 191	(123)
Transplanted		
Cauliflower	Ben, 05, 165, 166, 191	165
Celery	Ben, 05, 166, (191)	76, 05, 166, (191)
Celeriac	Ben, 191	191
Courgette	Ben, 165, 190	190
Lettuce	Ben, (05), 166	(05), (123)

( ) – slight damage; Ben- benfluralin.

In a 2010 HDC herbicide screen, benfluralin (coded as H3) was safe to most crops including mizuna, rocket and swede but it killed baby-leaf spinach. HDC H1 (a different formulation of 191) was safe to baby-leaf spinach but killed mizuna, rocket and swede. No other safe solutions were identified for baby-leaf spinach, mizuna, rocket and swede in SCEPTRE.

The fruit herbicide work focused on conventional herbicides as relatively few bioherbicides were made available and they were all non-selective contact acting. Three conventional herbicides were suitable for use as residual herbicides in strawberry (Table 6). One conventional and one bioherbicides was suitable for runner control in strawberry (Table 6). Four conventional herbicides and two bioherbicides were suitable for use as directed treatments for the control of perennial weeds (Table 7). Electric weed control was shown to have some potential as a selective control measure in blackcurrant plantations.

Table 6. Novel herbicide products identified as crop-safe to strawberries

Safe when applied over foliage	Safe when applied as runner control between rows
(05), 74, 76, 165	109, 124

( ) = slight damage

Table 7. Leading novel products (product name or code number in numerical order) identified for control of perennial weeds as directed treatments in bush and cane fruit: 2011-2013

Crop	Weed	Year	Exp. Ref.	Reference product	Leading 3 products					
					Herbicides			Bioherbicides		
Fallow	Dock	2011	2.4	-	R+S	72	102	-	-	-
Raspberry	Dock	2012	1.12	Rosate 36	124	-	-	116	-	-
Fallow	Dock	2013	2.8	Rosate 36	124	-	-	109	116	-
Fallow	Nettle	2011	2.4	-	R+S	72	102	-	-	-
Raspberry	Nettle	2012	1.12	Rosate 36	124	-	-	-	-	-
Blackcurrant	Nettle	2012	2.7	Roundup	72	-	-	*	*	*
Fallow	Nettle	2013	2.8	Rosate 36	124	-	-	109	116	-
Fallow	Thistle	2011	2.4	-	R+S	72	102	-	-	-
Raspberry	Thistle	2012	1.12	Rosate 36	124	-	-	116	-	-
Blackcurrant	Thistle	2012	2.7	Roundup	72	135	-	109	-	-

Please see individual reports, within the Annual SCEPTRE reports, for details. R+S – Roundup + Shark.