Project title:	Managing ornamental plants sustainably (MOPS)
Project number:	CP 124
Work package title:	Efficacy of plant protection products against sucking insects – melon and cotton aphid / protected hardy nursery stock
Work package leader:	Dr Tom Pope, Harper Adams University
Report:	Final report, January 2016
Previous report:	Annual report, December 2014
Key staff:	Dr Tom Pope, Harper Adams University Grace Smith, Harper Adams University Prof Simon Edwards (Statistical advice), Harper Adams University
Location of work:	Harper Adams University
Date work commenced:	1st December 2013
Date work completed (or expected completion date):	31st January 2016

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

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

Dr. Tom W. Pope
Lecturer in Entomology
Harper Adams University

Signature .... Date 29-01-2015............

Report authorised by:

Prof. Peter Kettlewell
Research Co-ordinator
Harper Adams University

Signature .... Date 29-01-2015

CONTENTS

GROWERS SUMMARY

Headline

- The conventional insecticides Mainman (flonicamid) and product 59 gave good control (greater than 99% reduction) of melon and cotton aphid on Hebe plants.
- All biopesticides tested reduced numbers of melon and cotton aphid and have the potential to be incorporated into IPM programmes used against this pest.

Background and expected deliverables

The melon and cotton aphid (*Aphis gossypii*) is one of the most serious pests of ornamentals due to the wide range of plants it attacks and because it has developed resistance to several groups of pesticides. *Aphis gossypii* is very polyphagous and common on protected ornamental and hardy nursery stock (HNS) hosts including begonia, chrysanthemum, *Coronilla*, cyclamen and *Hebe*. This aphid species tends to form large colonies on stems, young leaves and growing points. Plants attacked by this pest may yellow, wilt and, if damage is severe, die.

The purpose of Objective 2 within the MOPS project was to test the efficacy of plant protection products against sap sucking insects. Specifically, Objective 2.3 was to test the efficacy of products against the melon and cotton aphid on a selected susceptible protected HNS species.

Summary of the work and main conclusions

Seven plant protection products (Table 1) were tested against melon and cotton aphid (*Aphis gossypii*) on *Hebe* (cv. Purple Pixie) plants grown under polytunnel conditions between July and August 2015 at Harper Adams University. Environmental conditions within the polytunnel were measured through the use of dataloggers and via a nearby meteorological recording station. The polytunnel was ventilated by rolling up the sides of the polytunnel to allow airflow through mesh walls.

Table 1. Products tested

MOPS code number	Authorisation status	Biopesticide or conventional pesticide
Water control	-	-
Movento (spirotetramat)	EAMU 20111987	Conventional
130	Unauthorised	Biopesticide
62	Unauthorised	Biopesticide
200	Unauthorised	Conventional
59	Unauthorised	Conventional
179	Unauthorised	Biopesticide
Mainman (flonicamid)	EAMU 20130045	Conventional

Plants were provided by Bransford Webbs as plugs in late March and these plants were potted into John Innes No. 2 Compost in 9 cm diameter pots on 1 and 2 April 2015. Plants were grown on in a screened glasshouse compartment until 2 July when the plants were transferred to the polytunnel. Nine plants were arranged in three rows of three in each of 48 plots. Each plot was 0.5 m x 0.75 m in size and screened on three sides with horticultural fleece in order to physically separate each plot. Plants were watered from beneath via capillary matting.

The population of aphids used in this experiment was established from field-collected aphids (aphids supplied by Dove Associates) from a commercial ornamentals nursery. Aphids were maintained in the insectary at Harper Adams University on *Hebe* plants under controlled environmental conditions (20°C and 60% relative humidity) for two months prior to use. All nine plants in each plot were artificially infested with fragments (leaves and stems) of aphid-infested *Hebe* plants taken from the aphid culture on 6 July.

All plant protection products were applied using an Oxford Precision Sprayer fitted with an HC/1.74/3 nozzle, in 600 litres of water per hectare using 3 bar pressure. A water control was applied using the same water volume and pressure. No adjuvants were used for any products tested. Each plant protection product and the water control was applied at weekly intervals for four weeks. Aphid numbers were recorded one day before the first spray application was applied on 17 July and then three and six days after this application. Aphid numbers were then recorded six days after the second (24 July) and third (31 July) spray applications and nine days after the fourth (7 August). In addition, assessments of phytotoxicity were completed after each spray application.

Aphid numbers recorded one day before the first spray application were relatively high and continued to increase over the next few weeks in the water control (Table 2).

Table 2. Application timing, aphid counts and aphid numbers in water control

Date	**Aphid numbers recorded/spray application**	**Aphid numbers per plant in water control**
16 July 2015	Aphid numbers recorded	9
17 July 2015	Spray application	-
20 July 2015	Aphid numbers recorded	6
23 July 2015	Aphid numbers recorded	7
24 July 2015	Spray application	-
30 July 2015	Aphid numbers recorded	12
31 July 2015	Spray application	-
6 August 2015	Aphid numbers recorded	25
7 August 2015	Spray application	-
16 August 2015	Aphid numbers recorded	24

The conventional insecticide spirotetramat (Movento) noticeably reduced melon and cotton aphid numbers during the first and second weeks after the first spray application but control (greater than 80% reduction) was not apparent until three weeks after the first spray application. Product 59 (a conventional pesticide), gave very good control (greater than 80% reduction) one week after the first spray application, which was faster than Movento and all the other tested products (see Figure 1). Flonicamid (Mainman) noticeably reduced melon and cotton aphid numbers one week after the first spray application and gave good control (greater than 80% reduction) two weeks after the first spray application. In plots treated with product 59, melon and cotton aphid numbers had been reduced to a mean of less than one aphid per plant after two spray applications, while in plots treated with Mainman this level of control was achieved after three spray applications. In plots treated with Movento, melon and cotton aphid numbers had been reduced to a mean of less than eight aphids per plant after three spray applications. It is normally recommended that Movento is applied before aphid numbers have increased to the levels seen at the start of this experiment. It is notable that Movento, Mainman and product 59 were the most effective products tested and all have systemic activity in the plant.

Products 130, 62 and 179 (all biopesticides) significantly reduced numbers of aphids in plots compared with the water control by the end of the experiment. In all cases, the relative reductions in aphid numbers in plots treated with these products were not apparent until four weeks after the first spray application. It should, however, be noted that these products did not noticeably reduce aphid numbers compared with the start of the experiment. Products 130 and 179 were more effective in some plots than in others meaning that results were more variable than for product 62 or the conventional insecticides Movento, Mainman or product 59.

All three biopesticide products tested work through direct contact with the pest and so variability in control is likely to be associated with spray coverage rather than the product itself. Initial work using water sensitive paper indicated that while spray coverage of upper leaf surfaces was generally good, coverage of lower leaf surfaces was relatively poor. This suggests that the efficacy of these biopesticide products could be further improved through achieving better spray coverage. It is interesting, however, that product 62, despite also working through direct contact with the pest, was more consistent in how effectively it controlled aphids in each plot.

Product 200 (a conventional pesticide) was the only product tested to not provide any control of melon and cotton aphids. Numbers of aphids in plots treated with this product increased throughout the four weeks over which this experiment was completed.

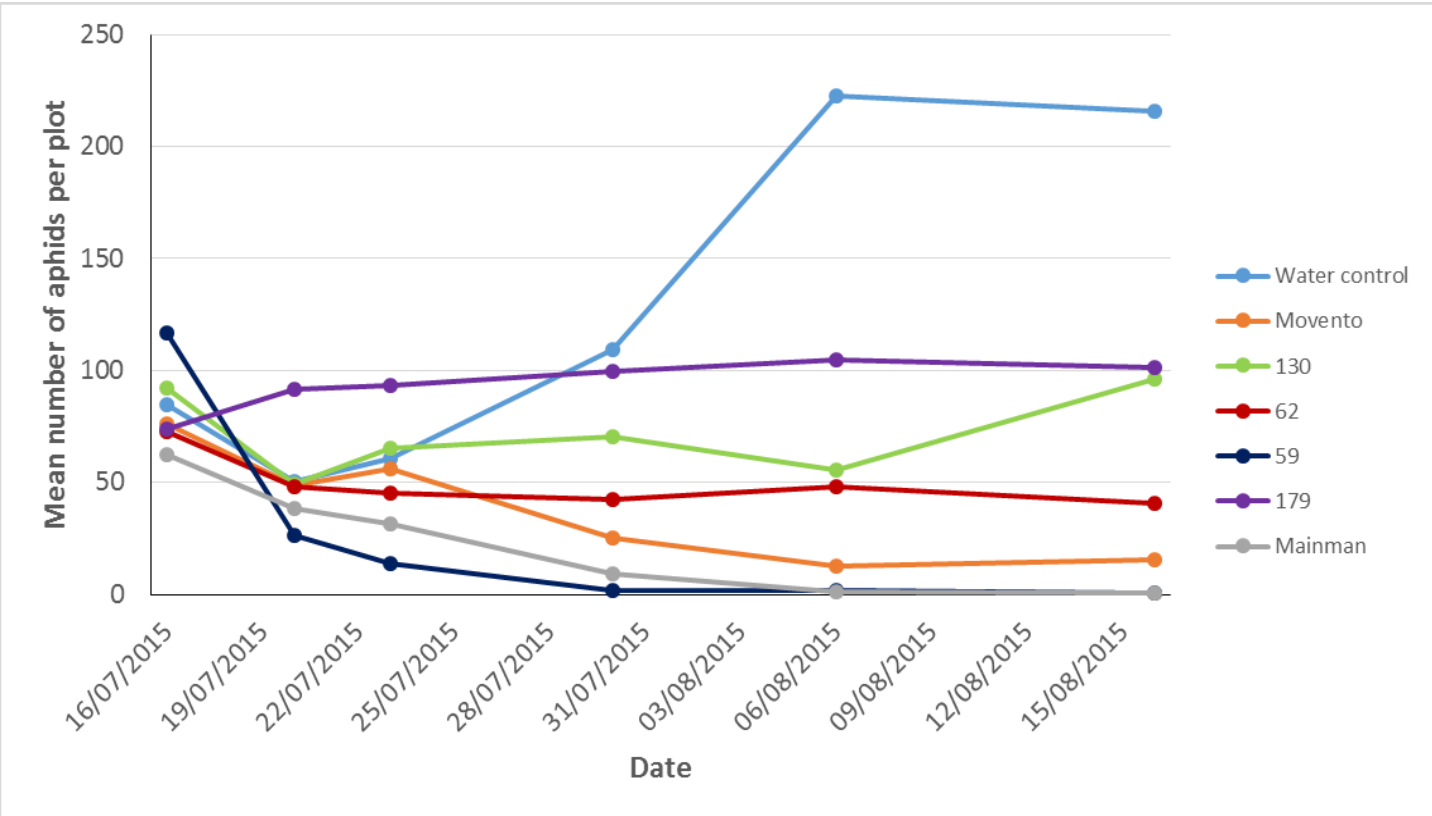


Figure 1. Mean numbers of aphids per plot on each assessment date (9 plants sampled in each plot). Mean numbers of aphids per plot for product 200 excluded as numbers were much higher than the water control.

There was no evidence of any phytotoxicity caused by the plant protection products tested. Plants became naturally infested with low numbers (mean of <1 per plant) of peach-potato aphids (*Myzus persicae*) regardless of treatment. A few plants (13 out of 432 plants) became infested with two-spotted spider mite (*Tetranychus* urticae) early in the experiment but this was effectively controlled using a release of *Phytoseiulus persimilis*. Very low numbers of thrips were also recorded on plants. Natural enemies included aphid parasitoids (*Aphidius* spp.), seen as mummified aphids, hoverfly adults, eggs and larvae (mainly *Episyrphus balteatus*). These natural enemies were present in low numbers (aphid mummies were the most numerous but a mean <1 aphid mummy per plant recorded on any one assessment). Despite the low numbers of natural enemies recorded, each of the natural enemies mentioned here was seen in plots to which each of the products was applied.

Action points for growers

- Consider flonicamid (Mainman) as a very effective option for control of melon and cotton aphid, reducing aphid numbers more quickly and to a greater extent than Movento.
- Consider spirotetramat, applied as Movento for the control of melon and cotton aphid when aphids are first seen.
- When product 59, a conventional insecticide, gains approval in the future, consider its use against melon and cotton aphid as it showed similar levels of efficacy to Mainman. Product 59 works both via contact and through ingestion and displays translaminar movement (moves to the opposite leaf surface) when applied to foliage and is xylem-mobile (upwardly mobile within the plant).
- Products 130, 62 and 179 (all biopesticides) reduced aphid numbers compared with the water control and when these products gain approval in the future they may provide a useful option, as part of IPM programmes, to control melon and cotton aphid.
- Results presented here are broadly similar to those reported in year one of this project in which the same products were tested against peach-potato aphid (*Myzus persicae*) on pansy; therefore these treatments should give control of a range of aphid species.
- Select products that are compatible with biological control agents if using an IPM programme for aphid control.

SCIENCE SECTION

Introduction

Various aphid species can damage ornamental plants but one of the most serious pest species is the melon and cotton aphid (*Aphis gossypii*) due to the wide range of plants this species of aphid attacks and because it has developed resistance to several groups of pesticides.

Aphis gossypii is very polyphagous and common on protected ornamental hosts including begonia, chrysanthemum, *Coronilla*, cyclamen and *Hebe*. This aphid species tends to form large colonies on stems, young leaves and growing points. Plants attacked by this pest may yellow, wilt and, if damage is severe, die.

Effective chemical control of this aphid is difficult due to its resistance to many currently available chemical pesticides. UK populations of *A. gossypii* are resistant to carbamates such as pirimicarb e.g. Aphox (Furk & Hines, 1993). This type of resistance is known as Modified AcetylCholineEsterase or MACE resistance). There is also widespread resistance to pyrethroids such as deltamethrin (e.g. Decis). This type of resistance is known as knockdown resistance or kdr resistance (Marshall *et al.,* 2012).

Due to problems with pesticide resistance, leading growers of protected ornamentals use biological control methods within IPM programmes. Several aphid parasitoid species are now available either as single or mixed species. The most common species used for control of *A. gossypii* is *Aphidius colemani*, sometimes supplemented with the predatory midge *Aphidoletes aphidimyza* whose larvae are voracious predators of many aphid species. Growers using IPM sometimes need to use an IPM-compatible aphicide e.g. immediately before dispatch or to supplement control during the summer when aphid numbers can increase rapidly.

Pesticides commonly used by growers of protected ornamentals and HNS for control of *Aphis gossypii* within IPM programmes include pymetrozine (Chess) and flonicamid (Mainman). Biopesticides used include the natural plant extracts product Majestik and the plant stimulant SB Plant Invigorator. The entomopathogenic fungus, *Beauveria bassiana* (Naturalis-L) has been tried for aphid control on some nurseries but with limited success, possibly due to humidity requirements following application. Other pesticides used include spirotetramat (Movento) and the neonicotinoids thiacloprid (Calypso) and acetamiprid (Gazelle SG). However, these products are less compatible with IPM and although these particular neonicotinoids are not affected by current restrictions on use of neonicotinoids, many retailers are asking growers not to use any neonicotinoids at all on their produce. This further restricts the pesticide options for aphid control.

Materials and methods

Site and crop details

Table 3. Test site and plot design information

Test location:	Harper Adams University
County	Shropshire
Postcode	TF10 8NB
Soil type/growing medium	John Innes No. 2
Nutrition	n/a
Crop	*Hebe*
Cultivar	Purple Pixie
Glasshouse* or Field	Polytunnel
Date of planting/potting	Plug plants potted up on 2 April 2015
Pot size	9 cm diameter pots
Number of plants per plot	9
Trial design (layout in Appendix C)	Randomised block
Number of replicates	6
Plot size w (m), l (m), total area (m^2)	0.5 m x 0.75 m
Method of statistical analysis	ANOVA

*Temperature and relative humidity conditions are given in Appendix B

Treatment details

Table 4. Detail of products tested

MOPS code number	Active ingredient(s)	Manufacturer	Batch number	a.i. conc.	Formulation type
1. Water control	-	-	-	-	-
2. Movento	spirotetramat	Bayer CropScience	ECE4101299	150 g/l	OD
3. 130	N/D	N/D	N/D	N/D	N/D
4. 62	N/D	N/D	N/D	N/D	N/D
5. 200	N/D	N/D	N/D	N/D	N/D
6. 59	N/D	N/D	N/D	N/D	N/D
7. 179	N/D	N/D	N/D	N/D	N/D
8. Mainman	flonicamid	Belchim Crop Protection	3111-02	500 g/kg	WG

Table 5. Treatments

Product name or MOPS code number	Application timing	Rate of use (product)	Spray volume (L/ha)
1. Water control	Weekly x 4	-	600
2. Movento	Weekly x 4	0.5 l/ha	600
3. 130	Weekly x 4	0.3% (1.8 l/ha)	600
4. 62	Weekly x 4	0.65 l in 100 l water (3.9 l/ha)	600
5. 200	Weekly x 4	0.313 kg/ha	600
6. 59	Weekly x 4	0.2 l/ha (24 g active substance/ha)	600
7. 179	Weekly x 4	0.4% (2.4 l/ha)	600
8. Mainman	Weekly x 4	0.14 kg/ha	600

Application timing	
A1	17 July 2015
A2	24 July 2015
A3	31 July 2015
A4	7 August 2015

Table 6. Application details

Application No.	**A1**	**A2**	**A3**	**A4**
Application date	17/7/2015	24/7/2015	31/7/2015	7/8/2015
Time of day	18:00	18:00	18:00	18:00
Application method	Oxford Precision Sprayer fitted with a HC/1.74/3 nozzle, in 600 litres of water per ha using 3 bar pressure	Oxford Precision Sprayer fitted with a HC/1.74/3 nozzle, in 600 litres of water per ha using 3 bar pressure	Oxford Precision Sprayer fitted with a HC/1.74/3 nozzle, in 600 litres of water per ha using 3 bar pressure	Oxford Precision Sprayer fitted with a HC/1.74/3 nozzle, in 600 litres of water per ha using 3 bar pressure
Temperature of air – max/min (°C)	23.5	17.0	24.5	25.0
Relative humidity (%)	81.6	87.0	54.0	73.0
Cloud cover (%)	n/a	n/a	n/a	n/a
Crop growth stage	Flowering	Flowering	Flowering	Flowering
Crop comments	-	-	-	-
Other*:	-	-	-	-

*Includes soil temperature and moisture details where relevant

The application method used was agreed upon following consultation with industry representatives, a spray application expert (David Talbot, ADAS) and product manufacturers. Efficacy of the application method was assessed before the first treatment application by attaching water-sensitive papers to spare *Hebe* plants arranged in the same way as in the experimental plots. This allowed spray coverage on the upper and lower leaf surfaces to be determined for leaves in the upper, middle and lower crop canopy.

Target pest(s)

Table 7. Target pest(s)

Common name	Scientific Name	Infection level pre-application
Melon and cotton aphid	*Aphis gossypii*	Fairly high, mean numbers of 62-116 aphids/plot (7-13 aphids/plant in each plot)

Each *Hebe* plant was infested with pieces of aphid infested *Hebe* plant on 6 July. This was carried out by cutting leaves or sections of stem from an aphid-infested plant and carefully laying these pieces of plant material on previously uninfested plants in each plot. Aphids used to infest *Hebe* plants had been collected from a commercial nursery and were maintained on *Hebe* plants through several generations before the start of the experiment.

Assessments

For each assessment of aphid numbers the central stem of each plant was selected and the number of aphids recorded on the leaves and flowers coming off this stem recorded as well as any aphids on the stem itself. Aphid counts were done in-situ but to aid counting of aphids each plant was carefully lifted so that the undersides of the leaves could easily be seen.

Table 8. Assessments

Assessment No.	**Date**	**Growth stage (BBCH scale)**	**Timing of assessment relative to last application**	**Assessment type(s) (e.g. aphid numbers and crop safety)**
1	16/7/2015	Flowering (65)	1 day before first application	Number of aphids/plant
2	20/7/2015	Flowering (65)	3 day after application	Number of aphids/plant
3	23/7/2015	Flowering (65)	6 days after application	Number of aphids/plant & crop safety
4	30/7/2015	Flowering (65)	6 days after application	Number of aphids/plant & crop safety
5	6/8/2015	Flowering (65)	6 days after application	Number of aphids/plant & crop safety
6	16/8/2015	Flowering (65)	9 days after application	Number of aphids/plant & crop safety

Statistical analysis

Data were analysed weekly (not across weeks) using analysis of variance (ANOVA) with Ln (c=1) transformation of raw data to calculate means, variance, LSDs ($p<0.05$). Genstat 17th Edition was used as advised by Prof. Simon Edwards (Harper Adams University). Graphs show a simpler representation of the data without any transformation, so that trends and dynamics over the experiment can be visualised.

Results

Spray coverage

The application method used achieved good spray coverage on the upper leaf surfaces in the upper, middle and lower crop canopies. However, spray coverage on the lower leaf surface was poor at all positions within the crop canopy (Figure 2).

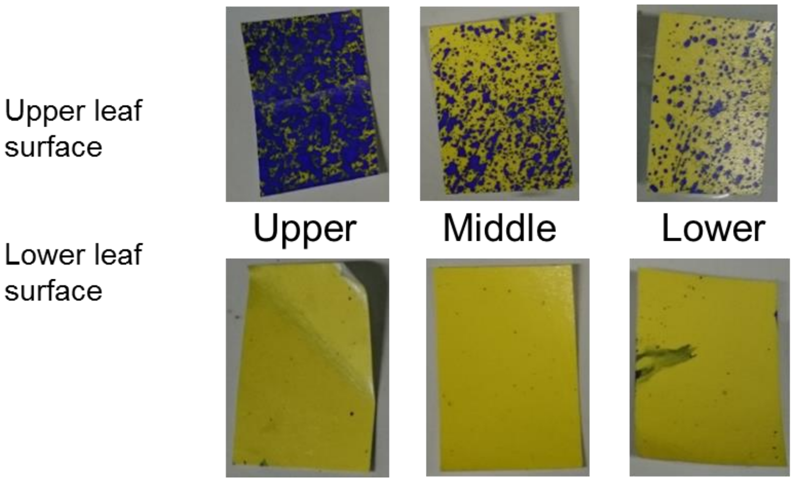


Figure 2. Spray coverage on water sensitive paper positioned on the upper and lower leaf surfaces in the upper, middle and lower crop canopy.

Efficacy against Aphis gossypii

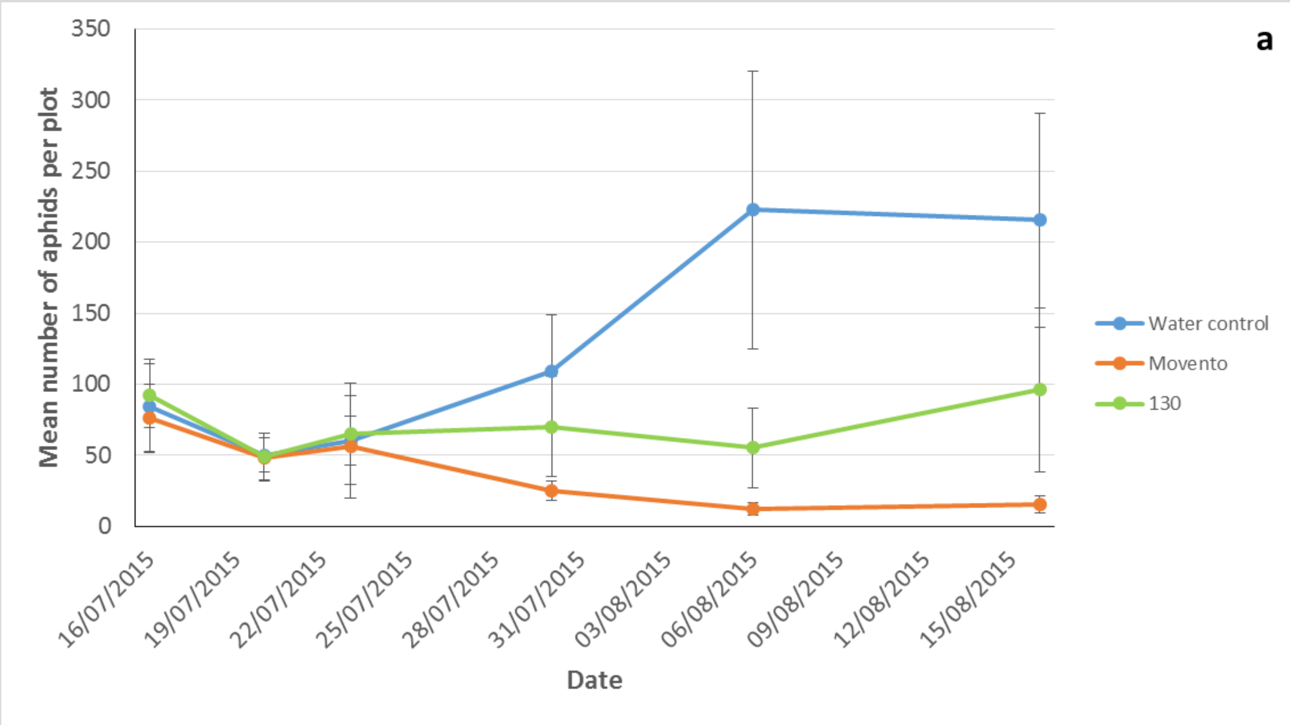
Results are summarised in the Figure 3 (graphical plot) and Table 7 (with ANOVA statistics) below. The graphs show that two products tested, Mainman and product 59, had reduced aphid numbers to close to zero in each plot by the end of the experimental period. Movento also reduced aphid numbers from a mean of 76 aphids per plot at the start of the experiment to 15 aphids per plot at the end of the experiment. Mean aphid numbers per plot were similar to, or slightly lower than, numbers at the start of the experiment in plot treated with products 130, 62 or 179. In plots treated with product 200, aphid numbers increased throughout the experimental period.

Statistical analysis of the Ln (c=1) transformed aphid count data shows that there was no difference in aphid numbers between treatments before the first spray application but that there were statistically significant treatment effects for all assessments completed from six days after the first spray application. No block effects were recorded on any of the assessment dates. Individual comparisons between treatment means (LSD at 5%) shows that three days after the first treatment application, there was no treatment effect. Six days after the first spray application, product 59 had significantly reduced aphid numbers compared with the water control (-ve control). Six days after the second spray application, Mainman and product 59 had significantly reduced aphid numbers compared with the water control. Aphid numbers were again significantly lower in plots treated with

Mainman or product 59 compared with plots treated with the water control six days after the third spray application. Movento (+ve control) had also significantly reduced aphid numbers compared with the water control six days after the third spray application. Aphid numbers in plots treated with Movento were not statistically different to numbers of aphids in plots treated with product 59 but were significantly higher than in plots treated with Mainman. Nine days after the fourth spray application, all products, except product 200, had significantly reduced aphid numbers compared with the water control. Aphid numbers in plots treated with Mainman or product 59 were, however, significantly lower than in plots treated with Movento or products 130, 62 and 179. Aphid numbers in plots treated with Movento or products 130, 62 and 179 were not statistically different.

Table 9. Effect of treatments on *Aphis gossypii*. Raw data transformed using Ln (c=1) and presented as mean number of aphids/plot. Numbers in a column followed by the same letter are not significantly different at P <0.05 based on individual contrasts (LSD).

Product name or MOPS code	16/7/2015	20/7/2015	23/7/2015	30/7/2015	6/8/2015	16/8/2015
1. Water control	4.07^{a}	3.83^{a}	$3.83^{b,c}$	$4.26^{c,d}$	$4.66^{d,e}$	4.89^{c}
2. Movento	4.16^{a}	3.63^{a}	$3.41^{a,b}$	$2.97^{b,c}$	$2.11^{b,c}$	2.40^{b}
3. 130	4.39^{a}	3.57^{a}	$3.50^{a,b}$	$3.34^{b,c}$	$3.14^{c,d}$	3.46^{b}
4. 62	4.20^{a}	3.12^{a}	$3.23^{a,b}$	$3.39^{b,c}$	$3.29^{c,d}$	3.23^{b}
5. 200	4.21^{a}	4.40^{a}	4.89^{c}	5.38^{d}	5.94^{e}	6.72^{d}
6. 59	4.48^{a}	2.98^{a}	2.27^{a}	0.68^{a}	$0.75^{a,b}$	0.46^{a}
7. 179	4.12^{a}	3.42^{a}	$3.49^{a,b}$	$3.44^{b,c}$	$3.33^{c,d}$	3.35^{b}
8. Mainman	4.08^{a}	3.52^{a}	$3.24^{a,b}$	2.23^{b}	0.53^{a}	0.35^{a}
F value (7 d.f.) Treatment	0.27 (P = n.s.)	0.95 (P = n.s.)	2.46 (P <0.036)	8.64 (P <0.001)	11.34 (P <0.001)	22.04 (P <0.001)
F value (5 d.f.) Block	0.43 (P = n.s.)	0.55 (P = n.s.)	0.79 (P = n.s.)	0.59 (P = n.s.)	0.47 (P = n.s.)	2.03 (P = n.s.)
LSD (treatment)	0.82	1.28	1.33	1.35	1.57	1.30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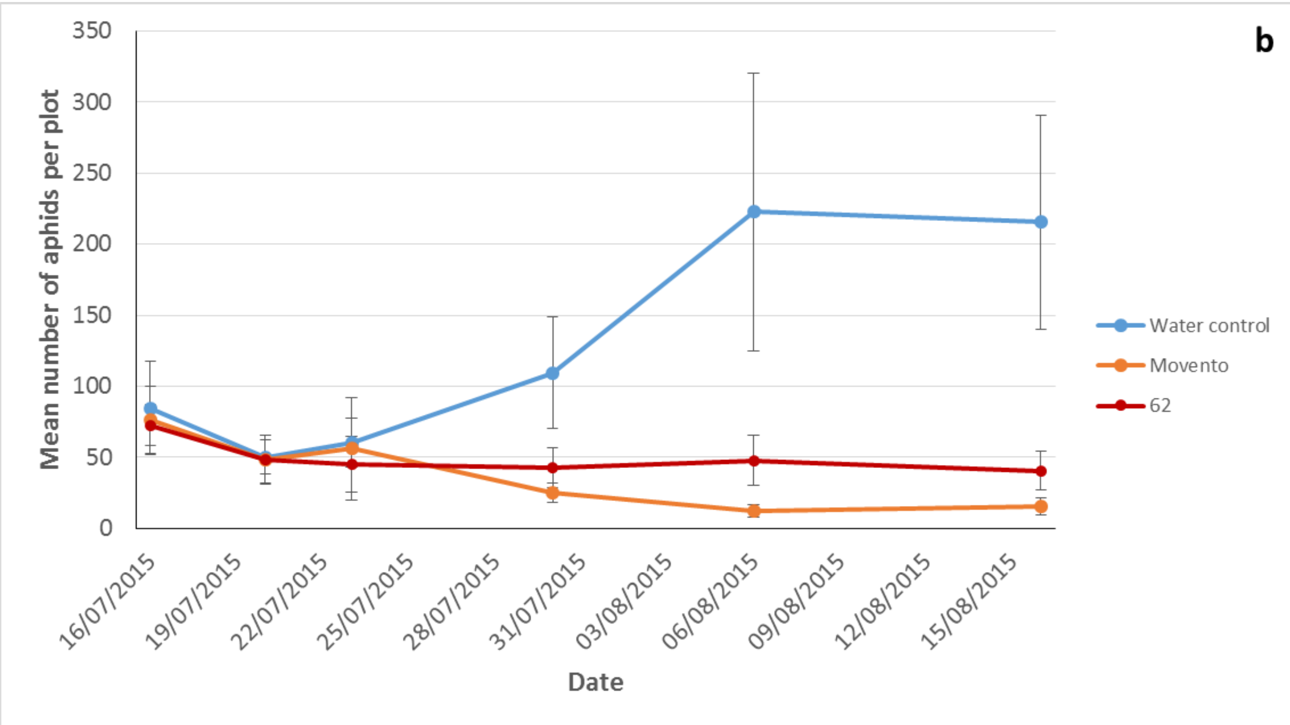
Date
Water control
Movento
130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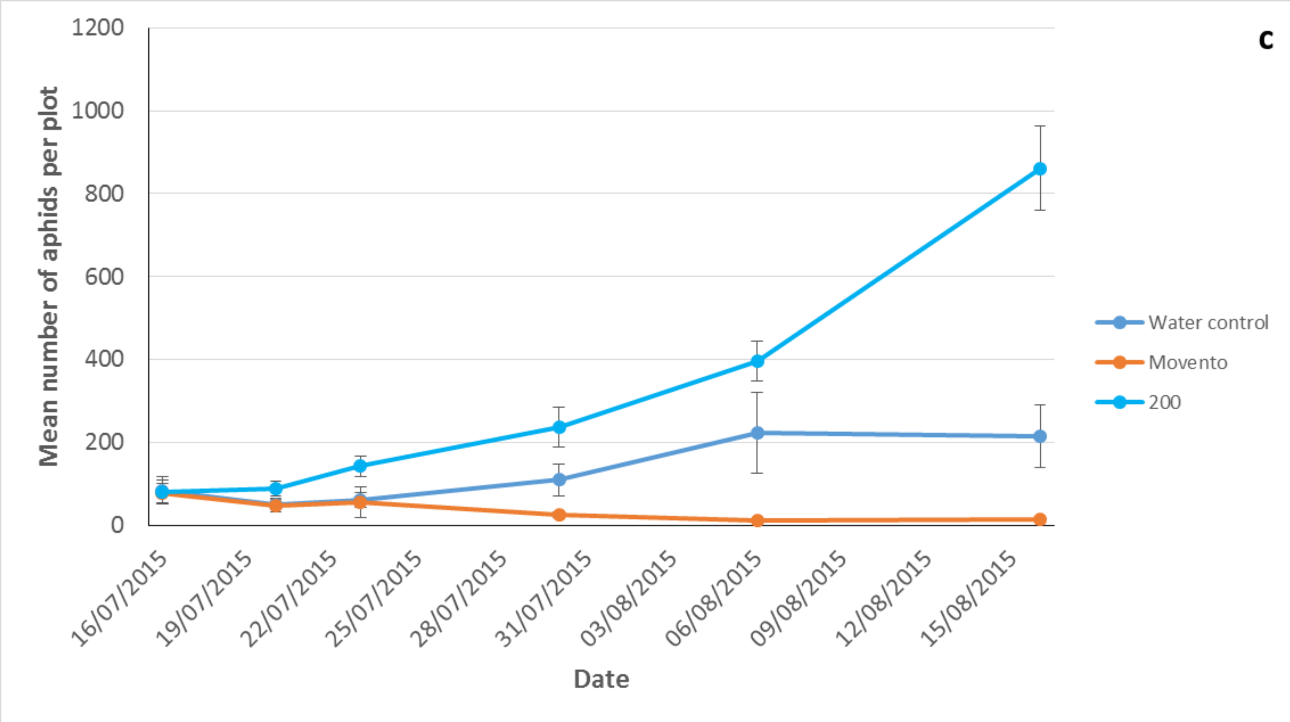
Water control
Movento
62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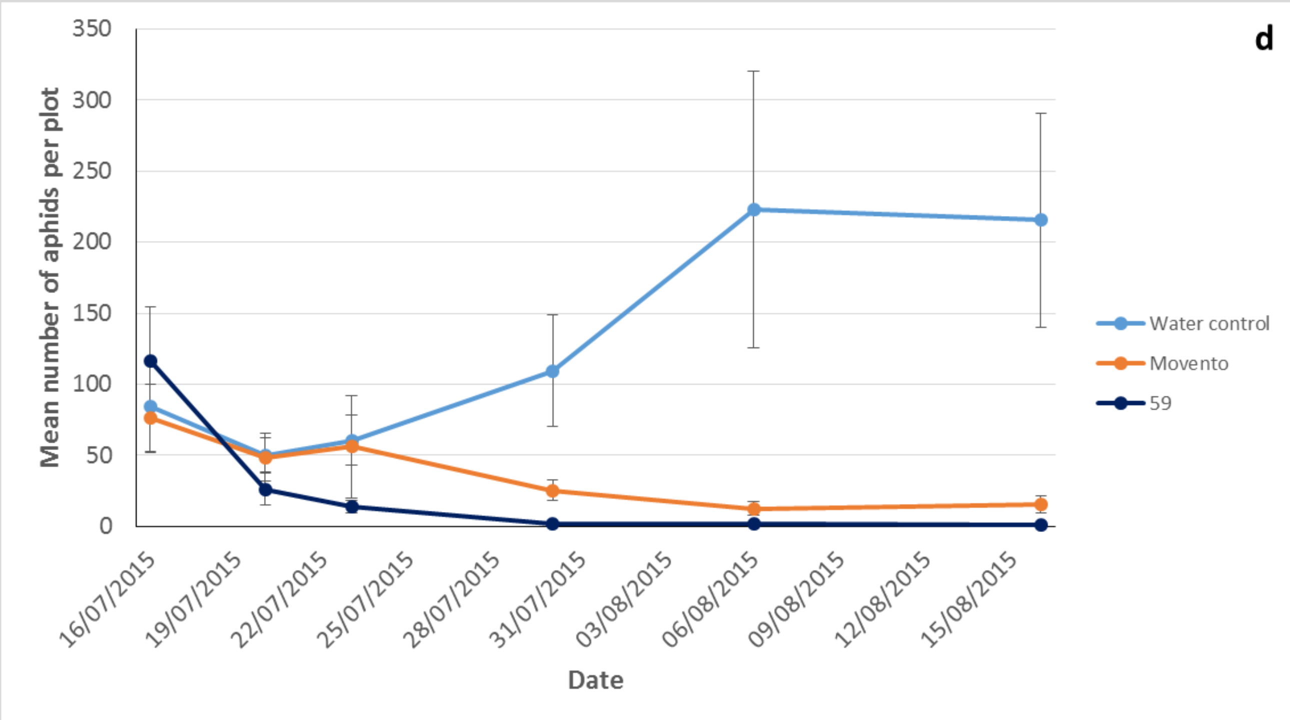
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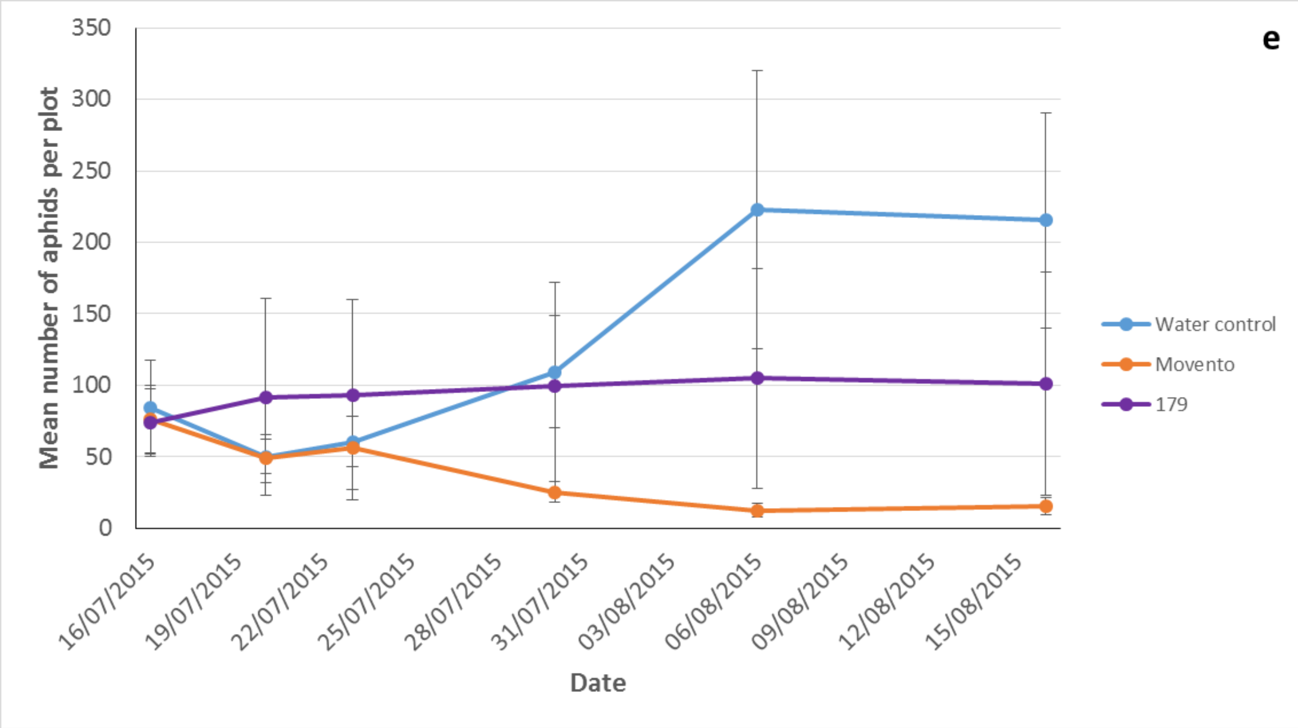
Water control
Movento
59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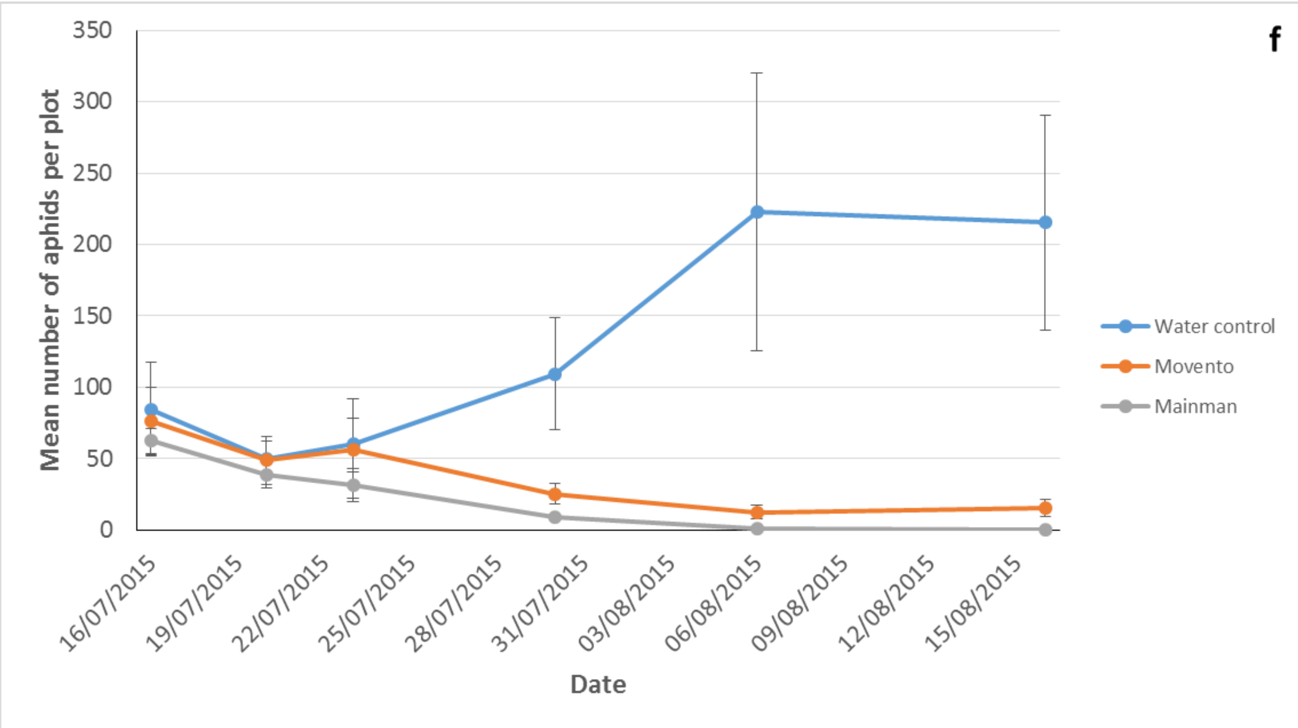
Date
Water control
Movento
179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Date
Water control
Movento
Mainman

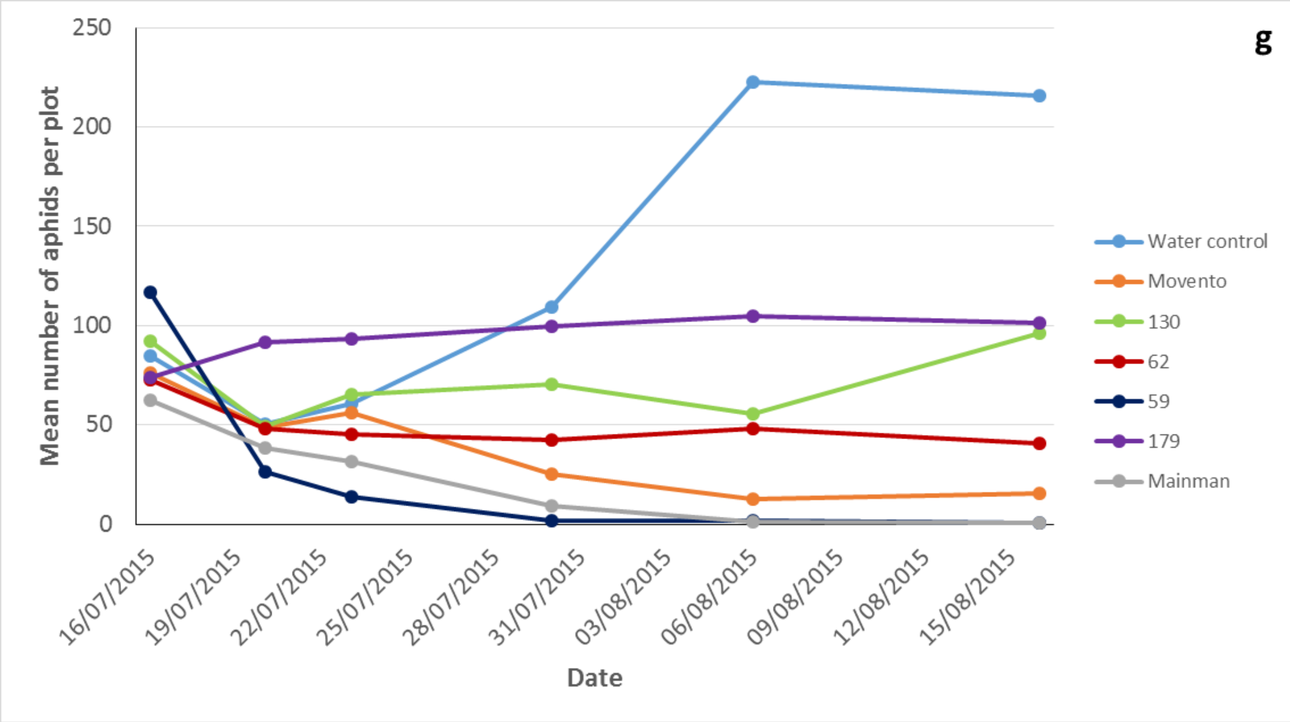


Figure 3. Mean numbers of aphids per plot on each assessment date (9 plants sampled in each plot), with standard errors. Graphs **a** to **f** present results for each product separately against water (-ve control) and Movento (+ve control). Graph **g** presents results for all products (except product 200) against water (-ve control) and Movento (+ve control). These graphs are complementary to Table 7 and use averages calculated from raw data, rather than the transformed data used in the statistical analysis. The graphs therefore show actual aphid counts per plot (without transformation) and trends over time in a simpler way so the dynamics of treatment effects can be visualised clearly.

Crop damage

Table 10. Crop damage recorded in terms of both numbers of damaged leaves and flowers in all plots and severity of damage observed (none, slight, medium, strong).

Product name or MOPS code	23/7/2015	30/7/2015	6/8/2015	16/8/2015
1. Water (-ve control)	0 leaves 0 flowers	0 leaves 0 flowers	0 leaves 0 flowers	0 leaves 0 flowers
2. Movento (+ve control)	0 leaves 0 flowers	0 leaves 0 flower	0 leaves 0 flowers	0 leaves 0 flower
3. 130	0 leaves 0 flowers	0 leaves 0 flower	0 leaves 0 flowers	0 leaves 0 flowers
4. 62	0 leaves 0 flowers	0 leaves 0 flowers	0 leaves 0 flowers	0 leaf 0 flowers

5. 200	0 leaves 0 flowers	0 leaves 0 flowers	0 leaves 0 flowers	0 leaves 0 flowers
6. 59	0 leaves 0 flower	0 leaves 0 flowers	0 leaves 0 flowers	0 leaves 0 flowers
7. 179	0 leaf 0 flower	0 leaf 0 flowers	0 leaves 0 flowers	0 leaves 0 flowers
8. Mainman	0 leaves 0 flowers	0 leaves 0 flowers	0 leaves 0 flowers	0 leaves 0 flowers

There was no evidence of phytotoxicity in any of the treatments applied.

Formulations

No problems were encountered during mixing or application of any of the product formulations under test.

Effect on non-target

No effects on other pests were noted during the completion of this trial. A few plants (13 out of 432 plants) became infested with two-spotted spider mite (*Tetranychus urticae*) early in the experiment but this was effectively controlled using a release of *Phytoseiulus persimilis*. Plants also became naturally infested with low numbers (mean of <1 per plant) of peach-potato aphids (*Myzus persicae*) regardless of treatment. Very low numbers of thrips were also recorded on plants. Plots became infested regardless of treatment but plots treated with product 59 or Mainman were free of *M. persicae* by the end of the experiment while small numbers of this aphid species were present in at least some plots treated with each of the other products tested. Natural enemies included aphid parasitoids (*Aphidius* spp.), seen as mummified aphids, hoverfly adults (mainly *Episyrphus balteatus*), eggs and larvae. These natural enemies were present in low numbers (aphid mummies were the most numerous but a mean <1 aphid mummy per plant recorded on any one assessment). Despite the low numbers of natural enemies recorded, aphid parasitoids and hoverflies were seen in plots regardless of treatment applied. This demonstrated that some natural enemies survived treatment, however further information would be needed to inform compatibility with biological control agents used in an IPM programme.

Discussion

Each *Hebe* plant was carefully infested with *A. gossypii* on 2 July by placing pieces of aphid infested *Hebe* plant on previously uninfested plants in each plot. By 16 July, one day before the first spray application, the mean numbers of aphids on plants in each treatment was recorded as 7-13 aphids per plant. This suggests that the aphids were fairly quick to establish on *Hebe* and probably reflects the fact the aphid had been cultured on the same plant species for several generations before the start of this experiment. Throughout the experiment aphid numbers continued to increase in the water control (-ve control) plots and had reached a mean of 24 aphids per plant by the end of the experiment (16 August).

No phytotoxicity symptoms on the *Hebe* plants were observed for any treated in this experiment. This included any changes to leaf and flower colour, which were observed, most notably, for products 179 and 62 (both biopesticides) on pansy in the 2014 experiment.

There were significant treatment effects at all assessment dates from six days after the first spray application. The results obtained for Movento (+ve control) and water (-ve control) were as expected giving confidence when interpreting results for the products. Movento gave control of the *A. gossypii* but this was not apparent until three weeks after the first spray application. This reflects the fact that spirotetramat, the active ingredient of Movento, works by inhibiting insect lipid (fatty acid) biosynthesis and as such is slower acting than insecticides that target the insect nervous system. This result is similar to that recorded for Movento controlling *Myzus persicae* on pansy. Product 59 (a conventional pesticide), gave good control six days after the first spray application, which was faster than Movento. Product 59 is a neurotoxin, which helps to explain the faster speed of kill. Flonicamid (Mainman) was also faster acting than Movento, giving good control two weeks after the first spray application. Flonicamid is a selective homopteran feeding blocker. The results reported here for Mainman and product 59 are similar to those reported for these products when used against *M. persicae* on pansy in 2014.

In plots treated with Mainman and product 59, *A. gossypii* numbers had been reduced to a mean of less than one aphid per plant after two spray applications. Interestingly both of these products have systemic activity, which may have been important in targeting all aphids on each plant and overcoming any limitations in spray coverage. Spray coverage indicated through the use of water sensitive paper was good on upper leaf surfaces but poor on lower leaf surfaces. Products 130, 62 and 179 (all biopesticides) work through direct contact with the insect. Results for two of these products, 130 and 179, were more variable than for product 62 or for the conventional insecticides spirotetramat, flonicamid or product 59. This was apparent with aphid numbers being reduced to a greater extent in some plots than in others. This appears to support the idea that poor spray coverage may have been at least partly responsible for the efficacy of these products and suggests that the efficacy of these products could be further improved by achieving better spray coverage.

Results for product 179 were for example comparable with those of Movento if aphid counts from one of the six plots is excluded from the analysis.

Despite the limitations of currently available spray application techniques, products 130, 62 and 179 had all significantly reduced *A. gossypii* numbers by the end of the experiment compared with the water control. As such, these products may be usefully incorporated into IPM programmes used to control *A. gossypii* and help to reduce to reduce the risk of resistance developing to conventional insecticides.

Product 200 (a conventional pesticide) was not effective and aphid numbers increased rapidly in plots treated with this insecticide. Surprisingly, aphid numbers were significantly higher in plots treated with this product than in plots treated with the water control. Product 200 works when it is ingested by an insect rather than through contact with spray residues. Although not systemic, this product does have translaminar activity, which should allow effective control of insects feeding on the leaves and flowers of plants and should mean that good coverage of the upper leaf surface is sufficient for this product to be effective against aphids feeding on lower leaf surfaces.

Conclusions

- *Hebe* plants were successfully infested with *Aphis gossypii* and populations increased in the plots treated with the water (-ve control) during the experiment.
- The standard insecticide, Movento (+ve control), was reasonably effective at controlling aphid populations three weeks after the first spray application.
- With the exception of product 200 (a conventional pesticide), all of the products gave some control of *A. gossypii* on protected *Hebe*.
- Mainman and product 59 (both conventional pesticides) were faster acting and more effective than Movento.
- Products 130, 62 and 179 (all biopesticides) reduced aphid numbers compared with the water control and can provide a useful option, as part of an IPM programme, to control melon and cotton aphid.
- No phytotoxicity symptoms were seen in this experiment.
- Results presented here are broadly similar to those reported in year one of this project in which the same products were tested against peach-potato aphid (*Myzus persicae*) on pansy.

References

Foster, S. & Blackshaw, R. (2012). Sustaining the effectiveness of new insecticides against aphid pests in the UK. *Final report to Defra Project RD-2008-3471 (HDC project FV 344)*.

Furk, C. & Hines, C.M. (1993). Aspects of pirimicarb resistance in the cotton and melon aphid, *Aphis gossypii* Glover (Homoptera: Aphidiidae). *Annals of Applied Biology*. 123, 9-17.

Marshall, K.L., Moran, C., Chen, Y.Z. & Hwerron, G.A. (2012) Detection of kdr pyrethroid resistance in the cotton aphid, *Aphis gossypii* (Hemiptera: Aphididae), using a PCR-RFLP assay. *Journal of Pesticide Science*. 37, 169-172.

Appendix A – study conduct

Harper Adams University are officially recognised by United Kingdom Chemical Regulations Directorate as competent to carry out efficacy testing in the categories of agriculture, horticulture, stored crops, biologicals & semiochemicals. National regulatory guidelines were followed for the study.

GLP compliance will not be claimed in respect of this study.

Relevant EPPO/CEB guideline(s)		Variation from EPPO
PP 1/152(4)	Design and analysis of efficacy evaluation trials	none
PP 1/135(4)	Phytotoxicity assessment	none
PP 1/181(4)	Conduct and reporting of efficacy evaluation trials including GEP	none
PP 1/23(2)	Aphids on ornamental plants	Size of the plot dividers limited the number of plants to 9 rather than a minimum of 10. Six replicates of each treatment rather than a minimum of four. Hebe is not listed as a test crop to be used in glasshouse trials. Separate polytunnels were not used for different treatments and instead plot dividers were used to effectively prevent insecticide drift.

There were no significant deviations from the EPPO and national guidelines other than those indicated above.

Appendix B – *meteorological data*

Location of the weather station	52.783, -2.433
Distance to the trial site	400 m
Origin of the weather data	Harper Adams University met station

Long-term averages from *location*

Month/period	**Min temp (ºC)**	**Max temp (ºC)**	**Rainfall (mm)**
September (1981-2010)	9.1	17.9	57.2
October (1981-2010)	6.3	13.9	67.8

Average conditions during the trial: (datalogger within polytunnel)

Month/period	**Av temp (ºC)**	**Min temp (ºC)**	**Max temp (ºC)**	**Av RH (%)***	**Rainfall (mm)**
16/07/2015 to 16/8/2015	18.8	4.0	41.0	-	-

***protected crops only**

Weather at treatment application: (datalogger within polytunnel)

Month/period	**Min temp (ºC)**	**Max temp (ºC)**	**Rainfall (mm)**
17/7/2015	23.5	23.5	-
24/7/2015	17.0	17.0	-
31/7/2015	24.5	24.5	-
7/8/2015	25.0	25.0	-

Appendix C – *agronomic details*

Growing system

Crop	**Cultivar**	**Planting/sowing date**	**Row width (m) or pot spacing**
Hebe	Purple Pixie	Plug plants potted up on 1 and 2 April 2015	Pots arranged in three rows of three – spacing between pots 5 cm

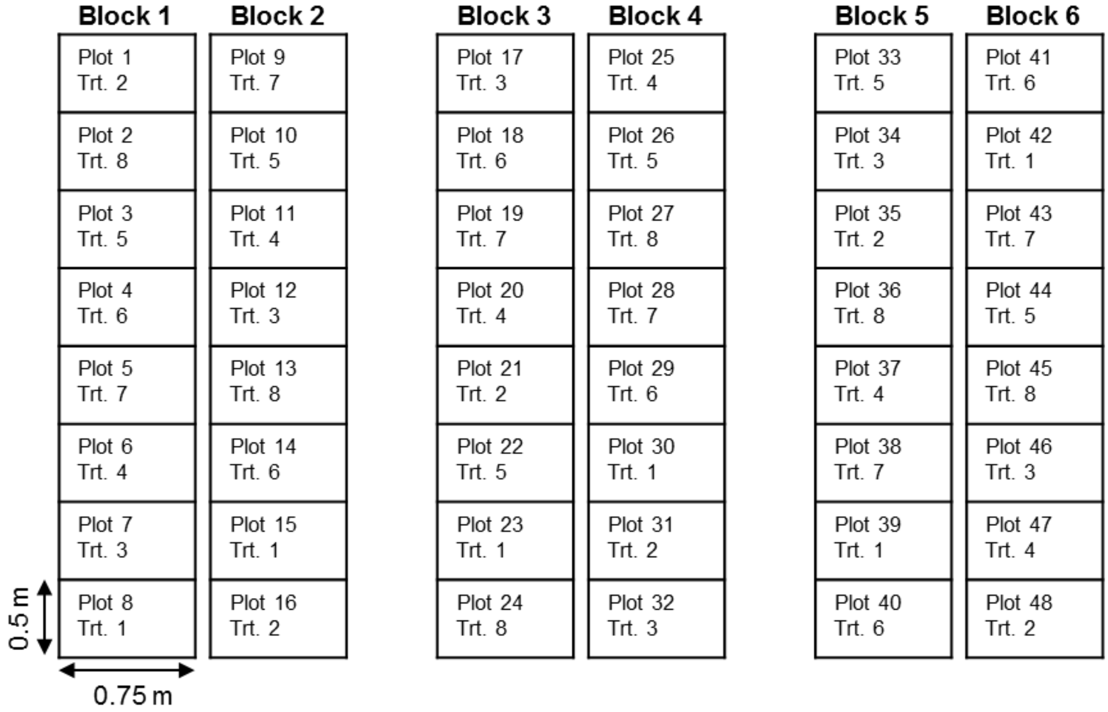
Other pesticides - active ingredient(s) / fertiliser(s) applied to the trial area

Date	**Product**	**Rate**	**Unit**
06/05/2015	Signum	0.9	kg/ha
13/05/2015	Fenomenal	1.7	kg/ha
20/05/2015	Fubol Gold	1.425	kg/ha
04/06/2015	Signum	0.9	kg/ha
19/06/2015	Fubol Gold	1.425	kg/ha
10-7-2015	4000 *Phytoseiulus persimilis* applied	5/plant	Predatory mite

Details of irrigation regime (pot-grown crops)

Type of irrigation system employed (e.g. overhead sprinkler, hand watering, drip, ebb and flow, capillary sandbed or capillary matting)
Capillary matting

Appendix D – *trial layout*



Appendix E – *copy of the certificate of official recognition of efficacy testing facility or organisation*

Certificate of

Official Recognition of Efficacy Testing Facilities or Organisations in the United Kingdom

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This certifies that

CERC - Harper Adams University College

complies with the minimum standards laid down in Regulation (EC) 1107/2009 for efficacy testing.

The above Facility/Organisation has been officially recognised as being competent to carry out efficacy trials/tests in the United Kingdom in the following categories:

Biological and Semiochemicals
Stored Crops
Agriculture/Horticulture

Date of issue:	26 July 2013
Effective date:	9 April 2013
Expiry date:	8 April 2018

Signature

Authorised signatory

Certification Number
ORETO 343

HSE
Chemicals Regulation Directorate

Department of
Agriculture and Rural Development

Appendix F – *photographs*

Figure 4. Plot dividers within polytunnel

Figure 5. Arrangement of 9 *Hebe* plants potted into 9 cm pots within a plot

Figure 6. Melon and cotton aphids on a *Hebe* bud in a water control plot

Figure 7. Melon and cotton aphids on stems of a Hebe plant in a water control plot

