Project title:	Control of potato aphid (*Macrosiphum euphorbiae*), in spring, on strawberry
Project number:	SF 140
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Report:	Year 3 final report, 2015
Previous report:	Year 1 and 2 reports, 2013, 2014
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Date project commenced:	1 April 2013
Date project completed (or expected completion date):	31 March 2016

DISCLAIMER

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.

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GROWER SUMMARY

Headline

- The reduction in dose of effective aphid control products by 50% in admixture with Silwett achieved the same control of potato aphid on strawberry as the full rate applied alone.

Background and expected deliverables

A range of aphids are pests of strawberry, including the strawberry aphid (*Chaetosiphon fragaefolii*), the shallot aphid (*Myzus ascalonicus*), the melon and cotton aphid (*Aphis gossypii*), the glasshouse aphid (*Aulacorthum solani*) and the potato aphid (*Macrosiphum euphorbiae*). They cause direct damage to the plant; including distortion, and strawberry aphid and some other species may transmit viruses. The potato aphid has become a more common pest of strawberry in recent years. It produces copious amounts of honey dew which contaminates the fruit. Many of the insecticides applied to strawberry through the season are targeted to control potato aphid.

AHDB Horticulture project SF 094 (*Minimising pesticide residues in strawberry through integrated pest, disease and environmental crop management*, Defra HortLINK HL0191) - demonstrated that autumn sprays of thiacloprid reduced spring infestations of aphids on strawberry. However, autumn applications need to be well timed and are subject to the weather and ground conditions in October. Hence, some plantations may not receive sprays, leading to problems with aphids early the following spring. There is a need to identify which products would be more effective in spring. There are reports by agronomists that some populations of *Macrosiphum euphorbiae* may be less susceptible than others to certain insecticides, but this currently appears to have no impact on the levels of control that can be achieved with approved insecticides in brassicas and potato (IRAG 2008; 2012).

Another possible cause for failure in control may be that temperatures are not high enough in the spring for uptake of plant protection products into the plant.

Summary of the project and main conclusions

The aim of the project was to improve the control of potato aphid (*M. euphorbiae*) in the spring on strawberry. In the first year (2013) we screened nine insecticides; acetamiprid (Gazelle), a coded product, chlorpyrifos (Equity), flonicamid (Teppeki), lambda-cyhalothrin (Hallmark), pirimicarb (Aphox), pymetrozine (Chess), pyrethrins (pyrethrum) and thiacloprid (Calypso) in a randomised block experiment on potted strawberry plants. These were compared to an untreated control. The trial was done in typical spring temperatures (average 10.4ºC). Numbers of aphids on the untreated control plots continued to increase over the trial period. All the tested strawberry approved and non-approved insecticides reduced numbers of aphids on the strawberry plants by at least 80%. By the end of the trial (10 May) no aphids were found on plants that had been treated with Gazelle, the coded product, Hallmark, Pirimicarb or Pyrethrins.

Because all the products tested in the 2013 trial were successful at controlling *M. euphorbiae*, the aim of the study in 2014 was to test the survival of *M. euphorbiae* in commercial strawberry plantations.

Two *M. euphorbiae* infested commercial strawberry plantations in Kent were used for the replicated trials and included an untreated control. The treatments were; chlorpyrifos (Equity), lambda-cyhalothrin (Hallmark with Zeon technology), pirimicarb (Aphox), pymetrozine (Chess), pyrethrins (Pyrethrum 5EC) and thiacloprid (Calypso), all at the recommended field rate. An air assisted knapsack sprayer was used to apply the sprays in 1,000 l/ha. Water sensitive papers were stapled on the underside of the; outer, middle and inner leaves before spraying, for evidence of spray coverage. A pre-assessment of the numbers of aphids on leaves was done. Counts of aphids were done 1 and 2 weeks after the insecticide applications. Samples of aphids from one site were sent for resistance testing to Rothamsted Research.

Adequate spray coverage of the insecticide treated strawberry plants was achieved. Numbers of *M. euphorbiae* on the untreated control plots declined at both sites over the trial period. All of the tested insecticides reduced the numbers of *M. euphorbiae* for at least one week. *M. euphorbiae* numbers increased by the second assessment (2 weeks later) on plants treated with chlorpyrifos and pymetrozine in both spray trials. Only lambda-cyhalothrin gave consistent, long-term, (over 2 weeks) control of *M. euphorbiae*. At one site there was no overall significant difference between the numbers of *M. euphorbiae* on the untreated plants and the plants treated with pymetrozine after a single application. It is possible that some individual *M. euphorbiae* were able to tolerate sprays of pymetrozine but so far no evidence for resistance has been found.

Because in 2014 all of the applied insecticides reduced the numbers of *M. euphorbiae* on strawberry leaves a week after the insecticides were applied, the aim of the study in 2015 was to test if control could be improved with the addition of adjuvants.

A purpose planted strawberry plantation at East Malling Research was used for the replicated trial and included an untreated control. The treatments were lambda-cyhalothrin (Hallmark with Zeon technology), pirimicarb (Aphox), pymetrozine (Chess), pyrethrins

(Pyrethrum 5EC) and Silwet L-77. All products were used at the recommended field rates and were also tested with Silwet L-77 at a 50% reduced rate. All treatments were applied twice at a 12-day interval with an air assisted knapsack sprayer (in 1,000 l/ha). A pre-assessment of the numbers of aphids on leaves was done. Counts of aphids were done 5 days and 11 days after the first application and 1 and 7 days after the second application.

Numbers of *M. euphorbiae* on the untreated control plots declined over the trial period. Single applications of lambda-cyhalothrin, pirimicarb or pyrethrum, or the same products at half the dose in admixture with Silwet L-77 significantly reduced the numbers of *M. euphorbiae* on the strawberry plants for at least one week. *M. euphorbiae* numbers on the treated plots had increased by the second assessment (11 days post application) but had decreased on the untreated control plots to the point where the differences between them were no longer statistically significant.

In all three years of the project the numbers of aphids on the untreated control plots declined naturally after 2 weeks from the pre-assessment. This could be because of natural levels of predation, disease or parasitism.

Financial benefits

Potentially, if not controlled, aphid infestations can lead to complete crop loss. No quantitative data on industry average losses resulting from aphid infestation is available but conservatively assuming that 1% of the crop is lost, this is equivalent to 507 tonnes of strawberries, worth £2.1 million p.a. Improved control as a result of this work would reduce the scale of these losses considerably. The results of this study may also be transferable to other affected crops such as raspberry, loganberry and hops.

Action points for growers

- Growers should ensure good spray coverage of the underside of strawberry leaves and into the crown of the plant. Water sensitive papers attached to the leaves during spraying will help to give a reasonable indication of whether this is being achieved.
- Insecticide resistance management must be incorporated into spray programmes by following the recommendations on the product label and rotating modes of actions of pesticides.
- Many aphicides are more effective at warmer temperatures, when they have a better fumigant action (chlorpyrifos, pirimicarb) and/or are more rapidly taken up into the plant for ingestion by aphids.

- Growers should monitor the effects of insecticide sprays to ensure control is being achieved.
- Consider autumn applications (post-harvest) for aphid control, as these have been shown to greatly reduce spring populations of aphids the following year.
- Growers should also monitor natural predator and parasitoid levels to determine whether intervention with a plant protection product is necessary.

SCIENCE SECTION

Introduction

Aphids are common and important pests of strawberry. They damage plants directly by sucking sap, causing plant distortion and contaminating foliage, flowers and fruits with honeydew and cast skins. In addition, the most common species, the strawberry aphid (*Chaetosiphon fragaefolii*), transmits a number of virus diseases which often occur in complexes. Another important pest species, the melon and cotton aphid (*Aphis gossypii*), infests foliage and flowers forming dense colonies in patches which produce copious secretions of honeydew which rapidly become blackened by sooty mould. This aphid can also transmit mottle virus. Insecticide resistant strains of this aphid species are widespread and growers have difficulty achieving control with organophosphate (OP), carbamate or pyrethroid insecticides.

In recent years growers have reported problems in controlling aphids in early spring, in particular the potato aphid, *Macrosiphum euphorbiae* (Figure 1). This could be a consequence of lower temperatures reducing the efficacy of products than aphicide resistance alone (IRAG 2008, 2012). As the strawberry growing season is being bought forward by protected cropping with crops under fleece and tunnels, this is becoming a more regular and widespread problem.

Figure 1. Potato aphid adult and nymphs on strawberry leaf

M. euphorbiae produces honeydew and cast skins resulting in sooty moulds, making the fruit unmarketable (Trumble et al. 1983). It can also distort the leaves and berries (Irving et al. 2012). *M. euphorbiae* is a host alternating species and is asexual when breeding on strawberry during the growing season with winged forms produced from April where they migrate to other hosts including potato, tomato and lettuce. In Europe, and most other areas where *M. euphorbiae* is an exotic species, the life cycle is mainly anholocyclic (without males). Populations survive parthenogenetically, overwintering on potato eyes or in heated or unheated glasshouses. Under suitable conditions it can breed on strawberry all year round (Alford 1984). It develops rapidly in the spring on the young foliage of strawberry and is polyphagous. The aphid also feeds on raspberry, loganberry and hops (Alford 1984). See http://www.cabi.org/isc/datasheet/32154 for more information.

There are several factors that naturally control *M. euphorbiae* populations. Heavy rainfall washes aphids off plants (Hughes 1963; Maelzer 1977), however, this mortality factor is small because most aphids are usually present on the protective under surface of leaves (Walker et al. 1984) and most strawberry production is now under protection.

Many aphids are controlled by predators, parasites and pathogens (Hagen & van den Bosch 1968). In HortLINK Project HL0191, SF94, small plot experiments examined the effects of sowing flowering plants alongside strawberry plantings on numbers of aphid predators and parasitoids in the crop. The plants used were *Medicago sativa, Silene dioecia, Echium vulgare* and a mixture of annual species, cornflower (*Centaurea cyanus*), corn marigold (*Anthemis arvensis*) and corn chamomile (*Chrysanthemum segetum*). There was no apparent effect of these flowering plants on the numbers of beneficials found in adjacent strawberry plants when compared with a bare soil control. *Aphidius eglanteriae* proved difficult to mass produce so an alternative species, *Ephedrus cerasicola,* was assessed for its effectiveness in reducing *Chaetosiphon fragaefolii* populations in a potted plant experiment. A mix of six parasitoids was used and compared with *E. cerasicola* alone and an untreated control; this mix has been designed to contain species that attack all the main aphid pests of strawberry. Results showed that releasing parasitoids onto aphid-infested plants significantly reduced the populations of both *C. fragaefolii* and *M. euphorbiae*. Distributors of the six species mix of aphid parasitoids of aphids recommend that parasitoids are introduced to crops before aphids are seen in order to increase the potential to control populations effectively.

Aphids on strawberry are mainly controlled by sprays of insecticides, often applied as a routine against a range of pests in spring before flowering, with supplementary sprays of aphicides when damaging infestations develop. Several insecticides approved on strawberry crops in the UK are effective against aphids and several have a specific label recommendation for control of these pests. Some have harmful effects on biocontrol agents commonly used in strawberry crops, including predatory mites, *Phytoseiulus persimilis* and

Neoseiulus cucumeris, and other predators and parasites that can be used for biocontrol of aphids.

1) Chlorpyrifos is a moderately persistent OP insecticide which is fairly effective against aphids but will not control resistant strains of the melon and cotton aphid (*Aphis gossypii*). It has a moderately long duration (six-eight weeks) of harmful effects on the predatory mite *N. cucumeris* which is frequently used for biocontrol of tarsonemid mite and thrips in strawberry crops and long harvest intervals.

2) The contact and translaminar carbamate, pirimicarb, is comparatively safe to beneficials and biocontrol agents but not effective against resistant strains of the *A. gossypii* and less likely to be efficacious at temperatures below 15°C.

3) The contact and translaminar chloronicotinyl insecticide, thiacloprid, has an EAMU for use on strawberries and will control resistant strains of the *A. gossypii*. It is moderately harmful to predatory mites used as biocontrol agents and very harmful to *Orius* predatory bugs.

4) Pymetrozine is a systemic insecticide and has an EAMU for use in strawberry. It acts mainly as an aphid anti-feedant. Its main advantage is that it is comparatively safe to natural enemies and biocontrol agents, including the predatory midge *Aphidoletes aphidimyza* (Singh 2015).

5) Acetamiprid is only approved for non-harvested strawberry, e.g., nursery plants and the harvest interval is 365 days.

In field experiments where acetamiprid and abamectin were tested against *C. fragaefolii*, acetamiprid was very effective at reducing numbers of the aphid. Naturally occurring beneficial anthocorid species were reduced in number but not eliminated in the acetamiprid treatment (Fitzgerald 2004).

In a field scale trial using four different timings of thiacloprid between the end of September and beginning of November, all applications reduced the numbers of *M. euphorbiae* on the crop the following spring compared to the untreated control (less than 50 aphids/100 leaves compared to more than 400 aphids/100 leaves) (HortLINK HL0191/HDC SF94).

There is a need to identify which of these products would be more effective under cooler spring temperatures. A large proportion of UK strawberry production is under polythene tunnels and so products need to be trialled in both protected and outdoor crops.

There are reports by agronomists that some populations of *M. euphorbiae* may be less susceptible than others to certain insecticides, but this has no impact currently on the levels of control that can be achieved with approved insecticides in brassicas and potato (IRAG 2008; 2012).

This project aimed to improve the control of potato aphid (*Macrosiphum euphorbiae)* on farm grown strawberry

In 2013 all of the approved products for aphid control on strawberry successfully reduced populations of potato aphid without any negative impact due to low temperatures. In 2014 all of the applied insecticides reduced the numbers of *M. euphorbiae* on strawberry leaves a week after the insecticides were applied. Hence in 2015 we tested whether the addition of a wetting agent could improve spray cover and therefore control.

Materials and methods

The site of the trial was a dedicated strawberry *(Fragaria* x *ananassa)* planting of the variety Elsanta at East Malling Reaserch Plot SP243. It was a randomised block experiment with 4 replicates of each treatment including an untreated control. Each plot was 4.4 m in length (only the middle 5 plants were assessed).

All of the products were approved for use on strawberry (Table 1).

Table 1. Insecticide products tested for control of *Macrosiphum euphorbiae,* in 2015.

Product	Product dose (/ha)	Harvest Interval	Approval
1 Hallmark with Zeon technology 100g/l CS	0.150 l	3 d	1705/11
2 Hallmark with Zeon technology 100g/l CS + Silwet L-77	0.075 l 50 ml	3 d	1705/11
3 Pirimicarb (Aphox 50% w/w WG)	0.560 kg	3 d	20070152
4 Pirimicarb (Aphox 50% w/w WG) + Silwet L-77	0.280 kg 50 ml	3 d	20070152
5 Pymetrozine (Chess 50% w/w WG)	0.400 kg	3 d	0504/07
6 Pymetrozine (Chess 50% w/w WG) + Silwet L-77	0.200 kg 50 ml	3 d	0504/07
7 Pyrethrins (Pyrethrum 5 EC 50 g/l)	2.4 l	Not Stated	20100231
8 Pyrethrins (Pyrethrum 5 EC 50 g/l) + Silwet L-77	1.4 l 50 ml	Not Stated	20100231
9 Silwet L-77	50 ml	-	-
10 Untreated	-	-	-

Treatments were applied at a volume rate of 1000 l/ha using an air assisted Birchmeier B245 motorised knapsack mist blower (by PA1, PA9 and BASIS qualified EMR staff). A pink micron restrictor nozzle was used to maintain a constant flow rate and the application rate was based on a planting of 40,000 plants/ha. Each plant received 25 ml of diluent. The accuracy of application of each treatment was estimated by measurement of the amount of spray that had actually been applied (calculated from the initial volume minus the final volume of diluent left in the tank, divided by amount that should have been left had the spray been applied at exactly the correct volume rate). Applications were between 99 and 128% of the target applications (Table 2).

Table 2. Accuracy of spray application estimated from the amount of diluent remaining in the spray tank after application.

Date	Treatment No:	Accuracy (%)
28 May 15 (pre bloom)	1	122
	2	117
	3	125
	4	117
	5	110
	6	119
	7	127
	8	105
	9	115
10 June 14 (flower)	1	128
	2	104
	3	99
	4	101
	5	99
	6	108
	7	99
	8	102
	9	99

Plants were pre-assessed on 27 May for the total numbers of adult and nymph aphids on one central (mid-age) leaf from the centre of each of 5 plants per plot. Plots were randomly allocated to treatments ensuring that all treatments had a range of densities of aphids. The post-spray application assessments were done on 3, 9 and 17 June (6 days and 12 days post first application and 7 days post second application) using the same methodology as the pre-assessment. Aphid species were checked according to EPPO PP1/252. The crop was examined for the presence of phytotoxic effects (or visible remains of the product).

Sprays for diseases were applied by the farm as and when necessary.

Dry and wet bulb temperature, wind speed and direction were recorded before and after each spray occasion (Table 3). Relative humidity (RH%) was estimated from the dry and wet bulb temperature readings. Full weather data was available from the EMR met station for the duration of the trial.

Table 3. Weather conditions at the time of spray application. N/A = Not applicable.

Date	Time	Air temperature			Wind	
		°C dry	°C wet	RH%	speed (km/h)	Direction
28 May	08:00	15-20	13-18	80	10-12	W
10 Jun	08:00	11-16	10-12	90-62	4-7	N

Repeated measures analysis of variance (adjusted for covariate) were done in GenStat on square root transformed data to stabilise for variances.

The study was conducted according to the EMQA ORETO quality management system. EPPO guideline EPPO PP1/252 was followed as closely as possible for the treatment and assessment of the trial.

Results

The site was covered for the duration of the trial and all the insecticide applications were applied in typical conditions for the time of year (Figure 2.). This indicates that temperature was not a major factor in the efficacy of the treatments in this experiment as the minimum temperature never dropped below 5°C, even at night.

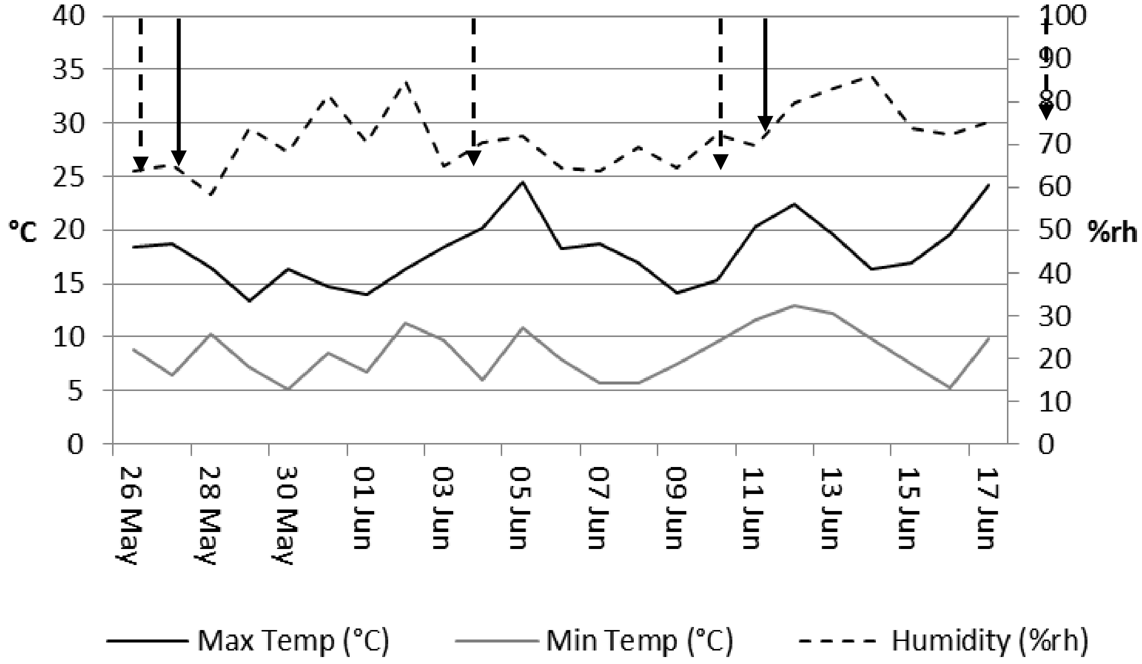

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Figure 2. Weather data for the duration of the trial. Solid arrows = spray application date, hatched arrows = assessment dates.

There was no significant difference between aphid numbers on plots at the pre-assessment and so this was omitted from further analyses. There was a significant reduction in the number of *M. euphorbiae* on strawberry leaves across all treatments over the duration of the trial (Figure 3). The numbers of *M. euphorbiae* in the untreated control, Silwet L-77 and pymetrozine plots were significantly lower by the second and third assessments (Table 4). The decrease in numbers of *M. euphorbiae* in theses plots could be due to a number of factors including disease, predation, parasitism or other natural population fluctuations.

There were no significant differences between the untreated control, Silwet L-77, or either of the pymetrozine treatments, however both lambda-cyhalothrin and pirimicarb at full rate or half rate in admixture with Silwett reduced numbers of *M. euphorbiae* by the first assessment (03 June). By the second assessment (09 June) the numbers of *M. euphorbiae* on the control plots had decreased such that there was no significant difference between the treatments (Figure 3). This was still the case by the third assessment on 17 June.

There were no significant phytotoxic effects of the insecticide applications on the plants or any visual signs of residues of the products applied.

Table 4. Mean and SQRT mean numbers of *Macrosiphum euphorbiae* per leaf. Covariate (pre assessment) adjustment was not significant and was removed from the final analyses. The same lower case letter denotes not significantly different from each other between treatments. The * denotes significantly different from each other within a treatment but between dates.

	Actual mean				SQRT mean			
Treatment/Date	27-May	03-Jun	09-Jun	17-Jun	03-Jun	09-Jun	17-Jun	
1 Hallmark with Zeon technology 100g/l CS	16.9	0.25	0.00	0.00	0.069b	0.050a	0.000a	
2 Hallmark with Zeon technology 100g/l CS+ Silwet L-77	14.35	0.10	0.12	0.00	0.056b	0.000a	0.000a	
3 Pirimicarb (Aphox 50% w/w WG)	11.95	1.15	3.93	1.20	0.735b	1.100a	0.245a	
4 Pirimicarb (Aphox 50% w/w WG)+ Silwet L-77	8.60	4.00	4.09	0.35	1.467b	0.825a	0.257a	
5 Pymetrozine (Chess 50% w/w WG)	8.15	5.80	5.93	0.05	2.404a	0.967a	0.050a	*
6 Pymetrozine (Chess 50% w/w WG)+ Silwet L-77	11.30	4.65	5.78	0.20	1.673a	1.066a	0.171a	*
7 Pyrethrins (Pyrethrum 5 EC 50 g/l)	16.50	0.35	0.54	0.00	0.058b	0.420a	0.000a	
8 Pyrethrins (Pyrethrum 5 EC 50 g/l)+ Silwet L-77	16.55	0.40	0.32	0.05	0.248b	0.444a	0.050a	
9 Silwet L-77	20.65	13.00	3.03	1.40	2.778a	1.104a	0.549a	*
10. Untreated	22.30	7.00	0.00	2.40	1.956a	0.723a	0.839a	*
				Treat/time				
				F pr.	<0.001			
				s.e.d.	0.447			
				l.s.d.	0.923			
				d.f.	69.76			

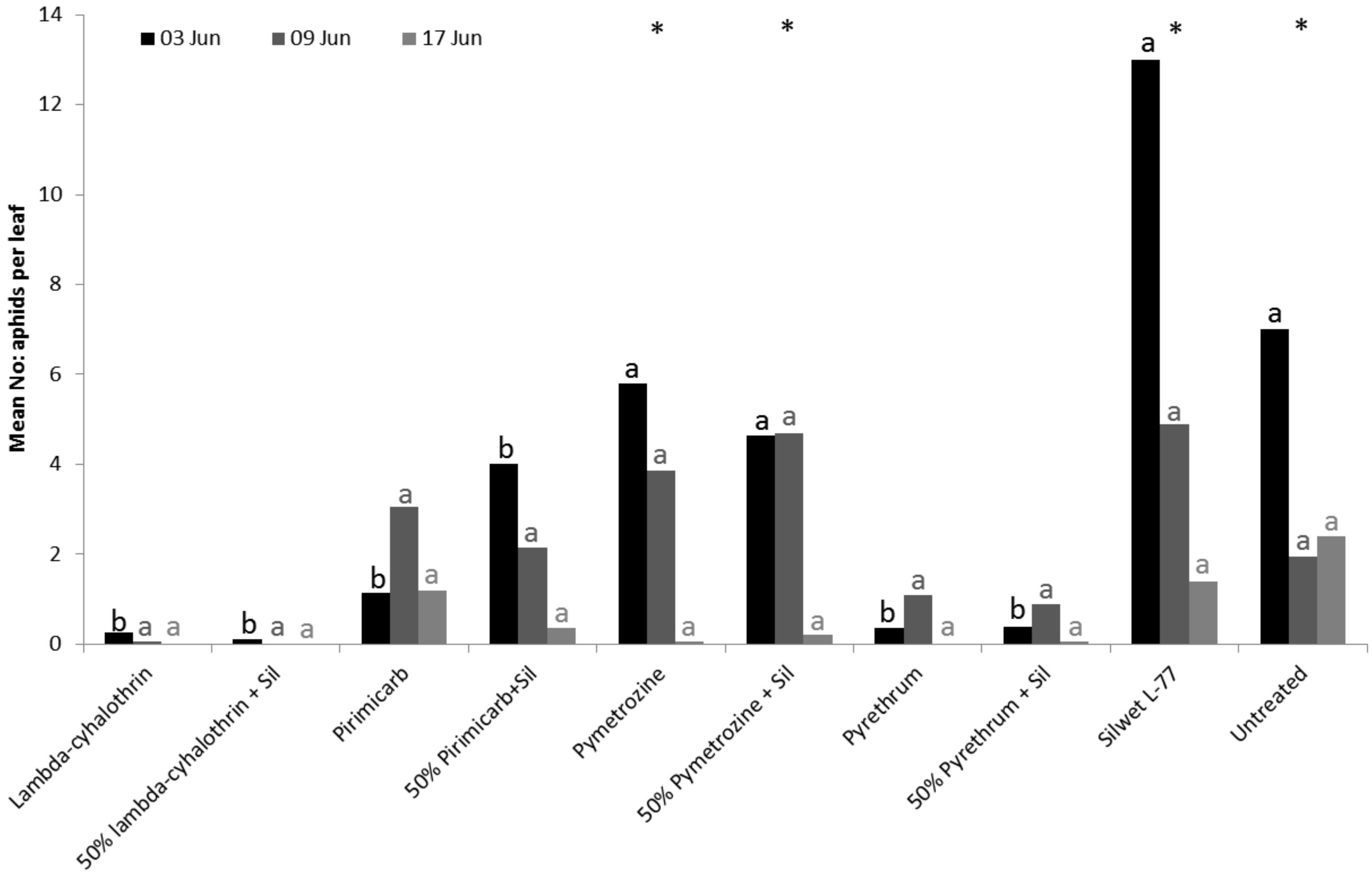

Figure 3. Mean numbers of potato aphid (*Macrosiphum euphorbiae)* per leaf on strawberry plants treated with insecticides. The same lower case letter denotes not significantly different from each other between treatments. * denotes significantly different from each other within a treatment between dates.

Discussion and Conclusions

- Numbers of *M. euphorbiae* on the untreated control plots declined over the trial period.
- Lambda cyhalothrin, pirimicarb and pyrethrum (alone or at half rate in admixture with Silwett) reduced numbers of *M. euphorbiae* on strawberry leaves with in six days of the products being applied.
- Reduction of the rate of the plant protection product by 50% and the addition of Silwet L-77 gave no additional control compared to the product at the full rate applied alone.
- *M. euphorbiae* numbers decreased naturally on the untreated control and Silwet L-77 only plots by the second assessment.
- None of the products gave consistent, measurable, long-term control (over 2 weeks) of *M. euphorbiae*.
- Natural levels of predation, parasitism or disease may control aphids if natural enemies are in sufficient numbers.
- The threshold for spraying aphids needs to be revised to take account of the numbers of predators and parasitoids in the crop.

Future work

An investigation of the efficacy of insecticides used to control *M. euphorbiae* when diluted by use of higher water volumes, persistence of these applications and efficacy at lower temperatures may help to explain some of the findings of this trial. As would an investigation of the clonal variation of *M. euphoribiae* to survive periods of starvation and susceptibility to the insecticide pymetrozine. Monitoring of natural levels of predation may give insight into more environmentally friendly methods of aphid control. Aphid behaviour – also plays an important part in how plants are recolonised after spray applications and these behavioural response need to be studied. One or more of these will be tested in the AHDB Strawberry Pests project SF156.

Knowledge and Technology Transfer

25 November 2015 Adrian Harris - Control of *Macrosiphum euphorbiae* in strawberry, Technical Up-Date on Soft Fruit Research. EMRA/AHDB Soft Fruit Day:

26 November 2014 Michelle Fountain - Control of potato aphid in strawberry, Technical Up-Date on Soft Fruit Research. EMRA/HDC Soft Fruit Day:

Acknowledgements

We would like to thank the funders of the research AHDB for their support. We would also like to thank Maddie Cannon, Bethan Shaw, Emilio Fernandez Rico, Dieter Baets, Alvaro Delgado, George Laws, Janie Morton, Rebeca Conde-Ruiz and Gloria Endredi for their help with treatment application and assessments. Thanks are owed to Phil Brain for his advice on the statistics used. We are grateful to Graham Caspell for facilitating with the use of the crop.

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