

Project Title: Control of potato aphid (*Macrosiphum euphorbiae*), in spring, on strawberry

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Project Leaders: Dr Michelle Fountain
East Malling Research
New Road, East Malling, Kent
ME19 6BJ
Tel: 01732 843833 Fax: 01732 849067

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Key Personnel: Dr Michelle Fountain, Adrian Harris

Industry representative: Andrew Reeve, Langdon Manor Farm, Goodnestone, Faversham, Kent, ME13 9DA

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GROWER SUMMARY

Headline

- Potato aphid populations begin to recover within two weeks of some insecticide applications to strawberry.

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 and potato 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 honeydew 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 (HortLINK) - demonstrated that autumn sprays of thiacloprid reduced spring infestations of aphids on strawberry. However, autumn applications need to be well timed and their efficacy 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 the use of 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 is 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 10.4°C). Numbers of aphids on the untreated control plots continued to increase over the trial period. All the tested insecticides (both those approved and non-approved on strawberry) 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, Aphox or Pyrethrum.

Because all of the tested products 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) at 1.50 l/ha, lambda-cyhalothrin (Hallmark with zeon technology) at 0.150 l/ha, pirimicarb (Aphox) at 0.560 kg/ha, pymetrozine (Chess) at 0.400 kg/ha, pyrethrins (Pyrethrum) at 2.4 l/ha and thiacloprid (Calypso) at 0.250 l/ha. An air assisted knapsack sprayer was used to apply the sprays at 1,000 l/ha. Water sensitive papers were stapled on the outer, middle and inner leaves before spraying for evidence of spray coverage. A pre-assessment of the numbers of aphids on leaves was made. Counts of aphids were made one and two 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 (two weeks later) on plants treated with chlorpyrifos and pymetrozine in both spray trials. Only lambda-cyhalothrin gave consistent, long-term, (over two 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 no evidence for resistance has been found to date.

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. Water sensitive papers attached during spraying will give a reasonable indication if 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 than ingested by aphids.
- Growers should monitor the effects of insecticide sprays to ensure control is being achieved.

SCIENCE SECTION

Control of potato aphid (*Macrosiphum euphorbiae*), in spring, on strawberry

Introduction

Background

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. 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* (Fig. 1). This is more likely to 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 brought forward by protected cropping with crops under fleece and tunnels, this is becoming a more regular and widespread problem. *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).



Figure 1. Potato aphid adult and nymphs on strawberry leaf

Lifecycle

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). For more information see:

<http://www.cabi.org/isc/?compid=5&dsid=32154&loadmodule=datasheet&page=481&site=144>

Biological control

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.

Conventional crop protection products

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 moderately long (6-8 weeks) harmful effects on the predatory mite *N. cucumeris* which is frequently used for biocontrol of tarsonemid mite and thrips in strawberry crops.
- 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*.
- 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/AHDB Horticulture SF 94).

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).

Objective

To improve the control of potato aphid (*Macrosiphum euphorbiae*) in the spring on strawberry.

Initially the objective for Year 2 was to compare the most efficacious insecticides at different temperatures to determine the effects that climate has on product performance. However, because all of the products tested in 2013 were effective at reducing numbers of *M. euphorbiae* it was decided to test the products on two farms in two commercial strawberry crops where there were reported difficulties in controlling the pest.

Materials and methods

Site

The two commercial plantations were:

- I. 'Mount Pleasant' at David Figgis, Wey Street Farm Cottages, Wey St, Hernhill, Faversham, Kent. cv. Elegance, in Tunnels 1 and 2.
- II. 'Diary Field' at Hugh Lowe Farms, Hadlow Place Farm, Hartlake Road, Golden Green, Kent. cv. Camarillo, in Tunnels 16 and 17.

Experimental design and layout

The trials were randomised block experiment with four replicates of each treatment including an untreated control. Each plot was 6.6 m in length (only the middle 10 or 25 (Sites I and II respectively) plants were assessed).

Treatments

Products were tested on strawberry (*Fragaria x ananassa*) in 'real' field conditions using an air assisted knapsack sprayer are detailed in Table 1.

Acetamaprid was not applied as this has a harvest interval of 365 days. Pymetrozine has an interval of three days, but the aphid, in preliminary resistance testing, was shown to be able to survive a period of starvation and to recover. All of the products were approved for use on strawberry. Water sensitive papers were stapled on the under surfaces of the outer, middle and inner leaves before spraying one of the plots and photographs taken of the papers for evidence of spray coverage (Fig. 2).



Figure 2. Water sensitive paper stapled to outer leaf of strawberry plant

Table 1. Insecticide products tested for control of *Macrosiphum euphorbiae*, in 2014.
*maximum product use rate for organic media grown plants (l/ha)

	Product	Product dose (/ha)	Harvest Interval	Approval
1.	Chlorpyrifos (Equity) 480g/l EC (13008)	1.50 l	7 d	20082711
2.	Lambda-cyhalothrin (Hallmark with Zeon Technology 100g/l CS)	0.150 l	3 d	1705/11
3.	Pirimicarb (Aphox 50% w/w WG) (13011)	0.560 kg	3 d	20070152
4.	Pymetrozine (Chess 50% w/w WG)	0.400 kg	3 d	0504/07
5.	Pyrethrins (Pyrethrum 5 EC 50 g/l) (22-8/13, 92317)	2.4 l	Not Stated	20100231
6.	Thiacloprid (Calypso SC 450 g/l)	0.250 l	3 d	0334/06
7.	Untreated	-	-	-

NB: Treatment 1 was not applied at Site II

Treatment application

One treatment was applied at a volume rate of 1000 l/ha using an air assisted Birchmier knapsack sprayer (by PA1, PA6, PA9 and BASIS qualified EMR staff). A pink Micron restrictor nozzle was used and the application rate was based on a planting of 40,000 plants/ha. Each plant received 25 ml of sprayate. 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 minus the final volume of sprayate 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 95 and 110% of the target applications (Table 2.).

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

Site and date	Treatment No:	Accuracy (%)
I. 10 Apr 2014 (pre bloom)	1	98
	2	104
	3	110
	4	101
	5	108
	6	98
II. 23 May 2014 (flower)	2	102
	3	97
	4	95
	5	100
	6	100

Assessments

A pre-assessment (Site I; 10 April, Site II; 23 May) of the total numbers of adult and nymph aphids on 10 plants and 25 plants, respectively, was done. The post spray assessments were done on Site I on 16, 22 April and Site II, 30 May, 05 June in the centre of each plot. Plots were randomly allocated to treatments ensuring that all treatments had a range of densities of aphids. One central (mid-age) leaf from the centre of each of the plants was selected and numbers of live aphids counted (Fig. 1). 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).

Plot maintenance

Sprays for diseases were applied by the host grower as and when necessary. The grower was requested not to spray aphicides during the three weeks of the trial.

Meteorological records

Dry and wet bulb temperature, wind speed and direction were recorded before and after each spray occasion (Table 3). RH% was estimated from the dry and wet bulb temperature readings. A Stevenson's screen with two data loggers to record temperature and humidity every 30 minutes was deployed in the tunnel from the date of first spraying.

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 (Kmh)	direction
10 Apr	10:00	14-19	11-16	70-73	0	N/A
23 May	09:50	16-21	12-19	62-83	2.1	s

Resistance testing

A sample of *M. euphorbiae* was randomly selected from the strawberry plants at Site II and sent to Stephen Foster at Rothamsted Research for resistance testing. Colonies were screened for resistance to pirimicarb and pymetrozine; bioassay at 100 ppm.

Statistical analysis

Repeated measures ANOVA, covariance adjusted for pre-treatment counts were done and analyses conducted on $\text{Log}_{10}(\text{mean}+1)$ transformed data.

Compliance

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 insecticide applications were applied in typical conditions for the time of year. Site I had not yet been covered with polythene. Site II was under polythene at the time of the trial. Note that Site I was sprayed in typical spring conditions where the temperatures at night were often below 5°C (Fig. 3.). This indicates that temperature was not a major factor in the efficacy of the treatments. At Site II the night time temperatures were always above 5°C.

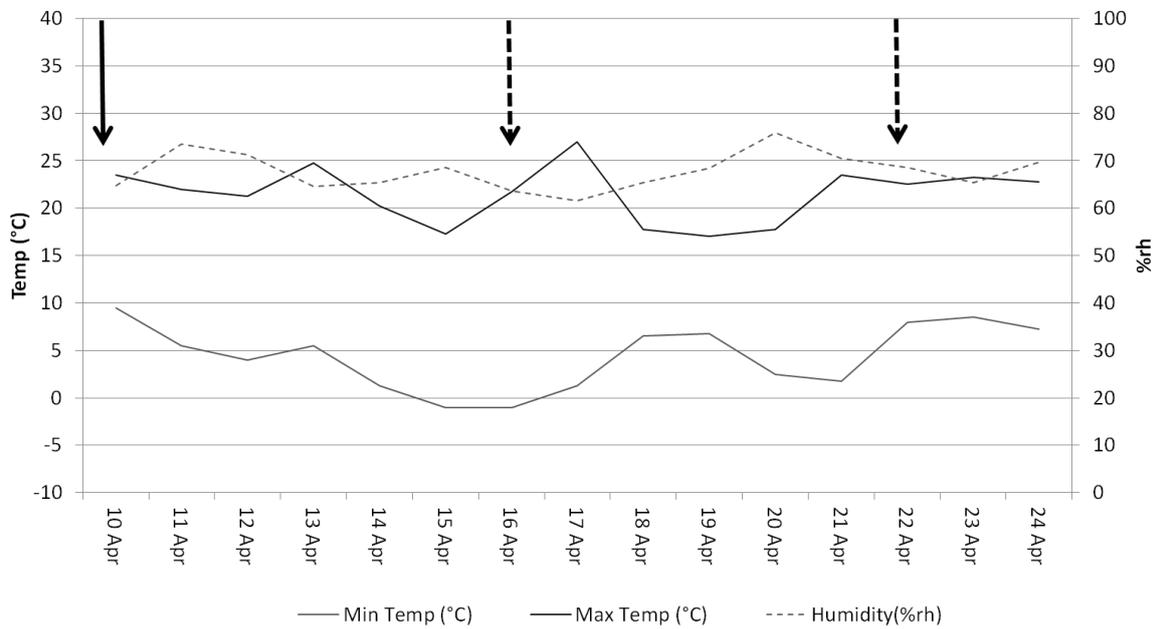
Spray coverage

Spray coverage (droplets) was generally very good at both sites. Site I plants were low growing with dead material surrounding the plants (early season clean up not done at time of spraying) and Site II plants had a very upwards growing habit. There was a good leaf spray coverage in both of the trials in the outer (O), middle (M) and inner (I) leaves of the plants.

The majority of the outer leaves and middle leaves were saturated (completely blue papers) although some of the inner leaves showed only droplets. A couple of these had small areas that had received a lower dose of pesticide (smaller more sparse droplets).

There was a significant reduction in the numbers of *M. euphorbiae* on strawberry leaves a week after the insecticides were applied (Tables 4 and 5). At both sites the numbers of aphids in the untreated control plots were significantly lower in the Week 2 assessment compared to the Week 1 assessment (Figs 4 and 5). This could be due to a number of factors including disease, predation or population fluctuations.

The numbers of aphids continued to increase significantly in the plots treated with thiacloprid, chlorpyrifos, pymetrozine and pyrethrins (Site I) and pirimicarb and pymetrozine (Site II, NB: chlorpyrifos not tested) two weeks after the single application. Only lambda cyhalothrin (both sites) and thiacloprid (Site II) kept numbers of aphids low two weeks following application. At Site II there was no overall significant difference between the numbers of aphids on the control plants and the plants treated with a single application of pymetrozine. There were no significant phytotoxic effects of the insecticide applications on the plants.



A
B

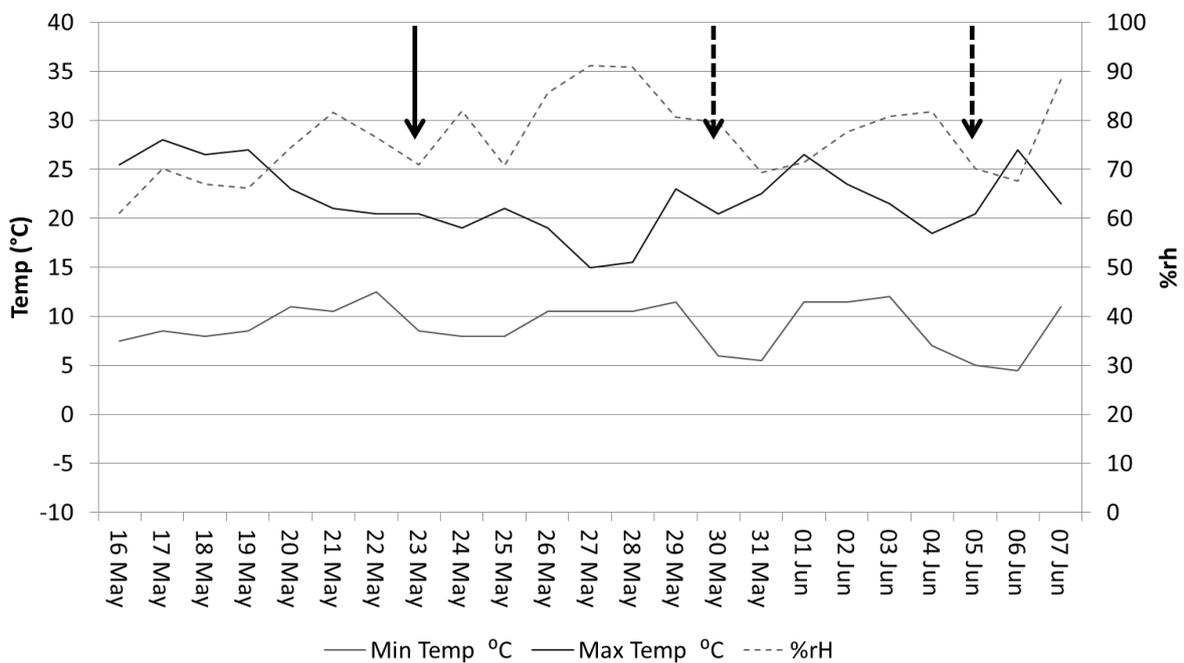


Figure 3. Weather data for the duration of the trial at Site I (A) and Site II (B), solid arrows = spray application date, hatched arrows = assessment dates

Resistance testing

There was no evidence of pirimicarb resistance in *M. euphorbiae* from Site II. There was some reduced sensitivity to pymetrozine but all the mobile aphids were dead at 120 h after being transferred to fresh, untreated leaves (Rothamsted Ref: Me 5606).

Table 4. Mean and Log₁₀(+1) mean numbers of *Macrosiphum euphorbiae* per leaf at Site I

Treatment/Date	Actual mean			Log ₁₀ (+1) mean		
	16 Apr	22 Apr	total	16 Apr	22 Apr	total
Pirimicarb	0.323	0.473	0.398	0.0761	0.0932	0.0847
Thiacloprid	0.057	0.382	0.22	0.0105	0.0895	0.05
Chlorpyrifos	0.146	0.946	0.546	0.0344	0.1522	0.0933
Pymetrozine	0.554	0.929	0.741	0.093	0.1575	0.1253
Lambda-cyhalothrin	0	0	0	0	0	0
Pyrethrins	0.054	0.479	0.267	0.0164	0.1034	0.0599
Untreated	3.293	1.718	2.505	0.4188	0.2751	0.3469
Time	0.629	0.7		0.0922	0.1238	
				Treat		
				F pr.	<.001	
				s.e.d.	0.04165	
				l.s.d.	0.08788	
				Time		
				F pr.	0.098	
				s.e.d.	0.01905	
				l.s.d.	0.03751	

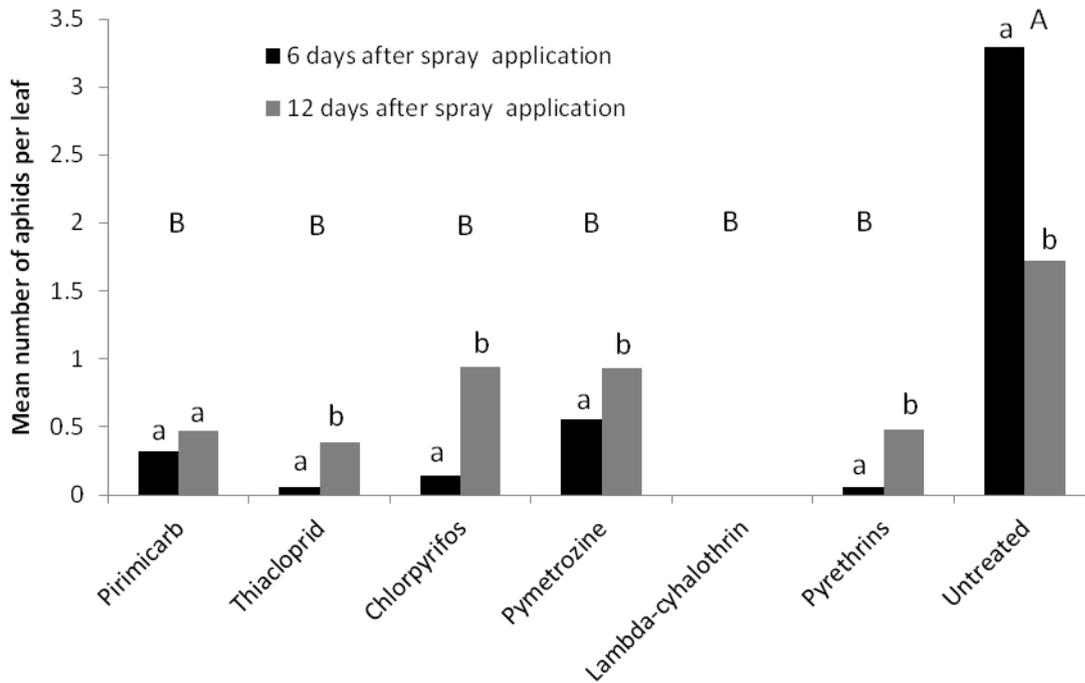


Figure 4. Mean numbers of potato aphid (*Macrosiphum euphorbiae*) per leaf on strawberry plants treated with insecticides at Site I. NB: Lower case letters show sig diff between assessments 6 and 12 days after spray application. The upper case letters show an overall significant difference from the untreated control.

Table 5. Mean and $\text{Log}_{10}(+1)$ mean numbers of *Macrosiphum euphorbiae* per leaf at Site II

Treatment/Date	Actual mean			$\text{Log}_{10}(+1)$ mean		
	30 May	05 Jun	total	30 May	05 Jun	total
Pirimicarb	0.102	0.942	0.522	0.0284	0.1534	0.0909
Thiacloprid	0.197	0.187	0.192	0.0418	0.0347	0.0383
Pymetrozine	0.569	0.929	0.749	0.1314	0.1658	0.1486
Lambda-cyhalothrin	0	0	0	0	0.0012	0
Pyrethrins	0.12	0.26	0.19	0.0318	0.0626	0.0472
Untreated	1.491	0.681	1.086	0.2544	0.1401	0.1972
Time	0.397	0.488				
				Treat		
				F pr.	0.016	
				s.e.d.	0.05193	
				l.s.d.	0.11137	
				Time		
				F pr.	0.231	
				s.e.d.	0.01045	
				l.s.d.	0.02052	

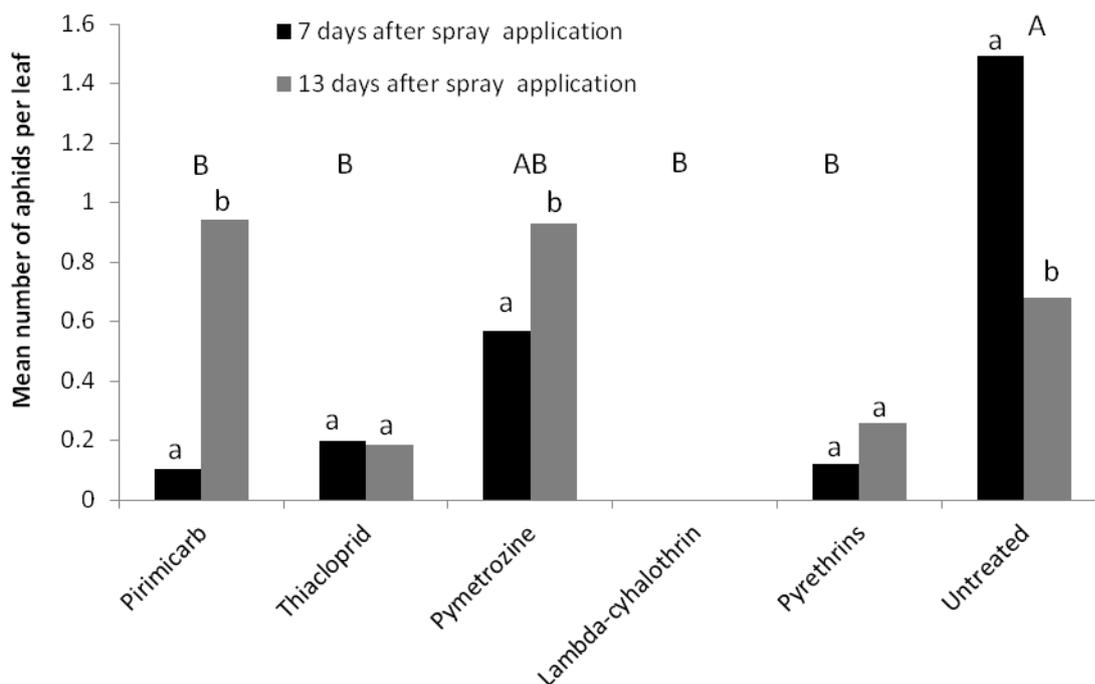


Figure 5. Mean numbers of potato aphid (*Macrosiphum euphorbiae*) per leaf on strawberry plants treated with insecticides at Site II. NB: Lower case letters show sig diff between assessments 6 and 12 days after spray application. The upper case letters show an overall significant difference from the untreated control.

Conclusions

- Spray coverage of the insecticide treated strawberry plants was acceptable;
- Numbers of *M. euphorbiae* on the untreated control plots declined at both sites over the trial period;
- All of the applied insecticides reduced the numbers of *M. euphorbiae* on strawberry leaves a week after the insecticides were applied;
- *M. euphorbiae* numbers increased by the second assessment (two weeks later) on plants treated with thiocloprid, chlorpyrifos, pymetrozine and pyrethrin;
- Only lambda cyhalothrin gave consistent long-term (over two 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 after two weeks;
- It is possible that some individual *M. euphorbiae* were able to tolerate sprays of pymetrozine, received a lower dose or were not directly intercepted by the spray;
- No evidence for resistance has been found to date.

Future work

The objective for Year 3 as set out in the original proposal is:

- Objective 3. Determine if control can be improved with the addition of adjuvants and/or two way mixes of insecticides.

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