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

Headline

Spring applications of insecticides were effective against potato aphid, *Macrosiphum euphorbiae,* in 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 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 sometimes possibly some other species transmit viruses. The potato aphid has become a more common pest of strawberry in recent years. It produces copious amounts of honey dew which can contaminate the fruit. Many of the insecticides applied through the season are targeted to control potato aphid.

HDC project SF 094 - *Minimising pesticide residues in strawberry through integrated pest, disease and environmental crop management* (HortLINK HL0191) - demonstrated that autumn sprays of thiacloprid helped control 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. 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 has no impact on the levels of control that can be achieved with approved insecticides in brassicas and potato (IRAG 2008; 2012).

Another cause of incomplete control may be due to insufficient temperatures in the spring preventing uptake of plant protection products into the plant.

This project will determine which crop protection products are best for control of aphids (potato aphid in particular) on strawberry in the spring and whether their efficacy can be improved in admixture with other aphicidal products or adjuvants.

Summary of the project and main conclusions

The main aim of the project was to improve the control of potato aphid (*M. euphorbiae*) in the spring on strawberry. In the first year nine insecticides were screened: acetamiprid (Gazelle), a coded product, chlorpyrifos (Equity) flonicamid (Teppeki), lambda-cyhalothrin (Hallmark), pirimicarb (Aphox), pymetrozine (Chess), pyrethrins (Pyrethrum) and thiacloprid (Calypso). These were compared to an untreated control.

A randomised block design polytunnel trial was set up using plants in their third year of growth and inoculated with *M. euphorbiae.* Two insecticide applications, 2 weeks apart (19 Apr and 03 May), were applied at 1000 l/ha using a hand pump knapsack sprayer. The average daily air temperatures on the days the plants were sprayed were 5.0°C and 13.0°C, respectively. A pre-assessment of the numbers of adult and nymph aphids on three young leaves in the centre of each plant was made on 17 April. Post treatment application assessments were made on 22 April, 29 April and 10 May. On all occasions, five centre (mid age) leaves per plant were selected from four plants per plot to assess numbers of live adults and nymphs. In addition, samples of *M. euphorbiae* were collected from three farms experiencing difficulties in controlling the aphid and sent to Rothamsted Research for resistance testing.

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 approved and non-approved insecticides tested including acetamiprid (Gazelle), the coded product, chlorpyrifos (Equity), flonicamid (Teppeki), lambda-cyhalothrin (Hallmark), pirimicarb (Aphox), pymetrozine (Chess), pyrethrins (Pyrethrum) and thiacloprid (Calypso), 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. Chess was less effective. There were no significant phytotoxic effects. Resistance testing indicated that some populations of *M. euphorbiae* may be able to survive a period of starvation caused by pymetrozine (Chess), but more sampling is needed to confirm this and how widespread it may be.

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 per annum. 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 a good spray coverage of the underside of strawberry leaves. Water sensitive papers attached during spraying will give a good 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 then ingested by aphids

SCIENCE SECTION

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

Introduction

Background

General

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.

The problem

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 bought forward by protected cropping with crops under fleece and tunnels, this is becoming a more regular and widespread problem.

Figure 1. Potato aphid adults and nymphs on strawberry leaf

Damage

Damage varies between the species of aphid, but on strawberry, *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).

Lifecycle

M. euphorbiae is a host alternating species and is asexual when breeding on strawberry during the growing season, with sexually reproductive forms produced from April where they migrate to other hosts including potato, tomato and lettuce, and again in the autumn to *Rosa sp*. However, most 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 are aphids usually present on the protected 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/HDC SF 94, 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 beneficial insects 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 the 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 (six-eight 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 the efficacious at temperatures below 15^{o}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 has a harvest interval of 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 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

- Year 1: Screen up to nine insecticides to determine the most efficacious products for controlling potato aphid on strawberry

Materials and methods

Site

All facilities and testing were at East Malling Research, New Road, East Malling, Kent ME19 6BJ by kind permission of Gary Saunders. *M. euphorbiae* were cultured in glasshouse N. The trial was done in the NSA polytunnel (Fig. 2).

Culture and plot infestation

Aphids were collected from various strawberry crops around EMR, both field and glasshouse, where they had been difficult to control the previous year. On 13 February 2013, 260 strawberry (*Fragaria x ananassa*) plants (cv. Evie II, in pots, in their third year) were moved into the glasshouse and inoculated with *M. euphorbiae* by spreading infested leaves over the tops of the plants. The plants inoculated with *M. euphorbiae* were moved on 2 April into the tunnel, which was covered in polythene to maintain higher than average spring temperatures to encourage aphids to reproduce, until the treatments were applied.

On 4 April six large *M. euphorbiae* females were added to each plot to encourage population growth.

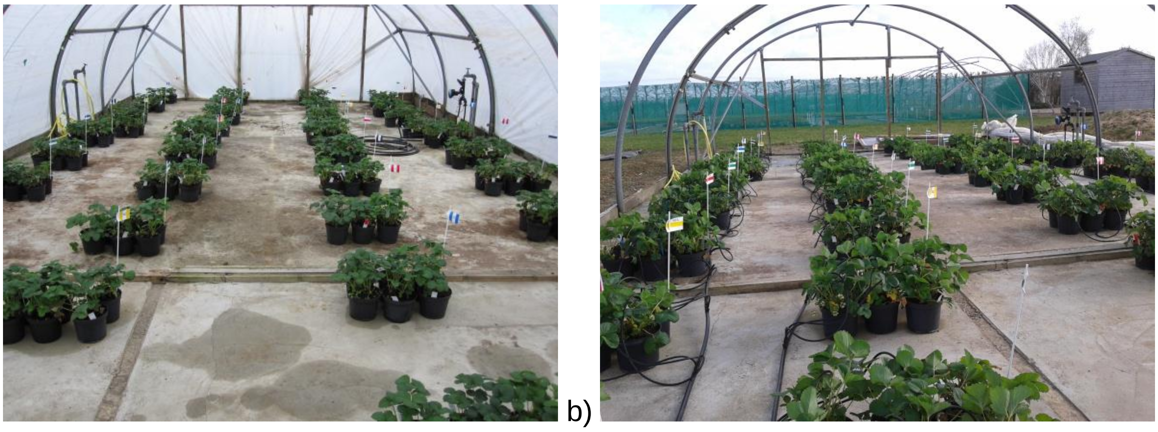
a) b)


Figure 2. (a) Trial set up to encourage aphid population growth and (b) during trial

Experimental design and layout

The trial was a randomised block experiment with four replicates of 10 treatments including an untreated control. Each plot consisted of six drip irrigated, potted plants (=240 plants). The plots in each block were arranged end to end in a row, with 1 m spacing between (Fig. 3). Plants were in their third year of growth giving a dense canopy.

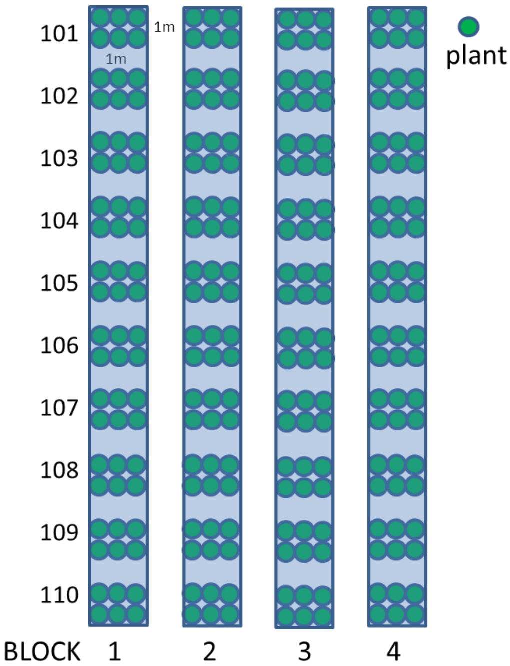


Figure 3. Set up of plants (green circles) in plots (groups of six) in polytunnel

Treatments

Products tested are detailed in Table 1 and included flonicamid (Teppeki) and a coded product, not approved for use on strawberry.

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

Product	Product dose (/ha)	Harvest Interval	Approval
1. Chlorpyrifos (Equity) 480g/l EC	1.50 l	7 d	20082711
2. Acetamiprid (Gazelle 20% w/w SG)	0.500 kg	365 d	2857/08
3. Lambda-cyhalothrin (Hallmark with Zeon technology 100g/l CS)	0.150 l	3 d	1705/11
4. Pirimicarb (Aphox 50% w/w WG)	0.560 kg	3 d	20070152
5. Pymetrozine (Chess 50% w/w WG)	0.400 kg	84 d	0504/07
6. Pyrethrin (Pyrethrum 5 EC 50 g/l)	2.4 l*	Not Stated	20100231
7. Thiacloprid (Calypso SC 450 g/l)	0.250 l	3 d	0334/06
8. Flonicamid (Teppeki 50% w/w WG)	140 g	-	No approval
9. Coded HDCI 057	1.0 l	-	No approval
10. Untreated	-	-	-

Treatment application

Two treatments, two weeks apart, were applied at a volume rate of 1,000 l/ha using a hand pump knapsack sprayer with a hand lance (by PA1 and PA6 qualified EMR staff). This minimised inter-plot contamination by spray drift. An Albuz 208 purple hollow cone 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 generally accurate (Table 2.), although four applications were only within 8% of target.

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

Spray round and date		Treatment No:	Accuracy (%)
1.	19 April	1	100%
		2	100%
		3	100%
		4	100%
		5	92%
		6	100%
		7	100%
		8	100%
		9	100%
2.	03 May	1	100%
		2	92%
		3	100%
		4	108%
		5	100%
		6	100%
		7	92%
		8	100%
		9	100%

Assessments

A pre-assessment of the numbers of adult and nymph aphids on three young leaves in the centre of each plant was done on 17 April (Fig. 1). Post treatment application assessments were done on 22 April (three days after the first application), 29 April (10 days after the first application) and 10 May (seven days after the second spray application). On all occasions five centre (mid age) leaves per plant were selected from four plants per plot for numbers of live adults and nymphs. Aphid species were checked according to EPPO PP1/252. In addition, a phytotoxicity assessment was done on 26 April.

Plot maintenance

All plants were supplied with drip irrigation. The plantation was inspected weekly to check for pests, disease and any other problems. Plants were de-blossomed and de-fruited before the trial was started, and on each inspection, to discourage visits by pollinating insects and to encourage vegetative growth.

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. Hourly temperature, humidity and rainfall records were collected from the EMR weather station.

Table 3. Weather conditions at the time of spray application

Date	Time	Air temperature			Wind	
		°C dry	°C wet	% rh	speed (Kmh)	direction
19 Apr	08:00	8	7.5	93	6	NW
03 May	09:30	15	10	53	0	N/A

N/A = not applicable

Resistance testing

Samples of *M. euphorbiae* were randomly selected across strawberry crops from three Kent farms experiencing difficulties in controlling the aphid and sent to Stephen Foster at Rothamsted Research for resistance testing. Colonies screened for resistance to imidacloprid, pirimicarb, lambda-cyhalothrin and pymetrozine; bioaasssay at 100 ppm.

Statistical analysis

Repeated measures ANOVA, covariance adjusted for pre-treatment was done where applicable and analyses was conducted on Log_{10}(mean+1) transformed data.

Results

The insecticide applications were applied in typical spring temperatures and there was very little rainfall throughout the trial period (Fig. 4). Average daily temperatures ranged from 4.6 – 14.3°C (overall average 10.4°C).

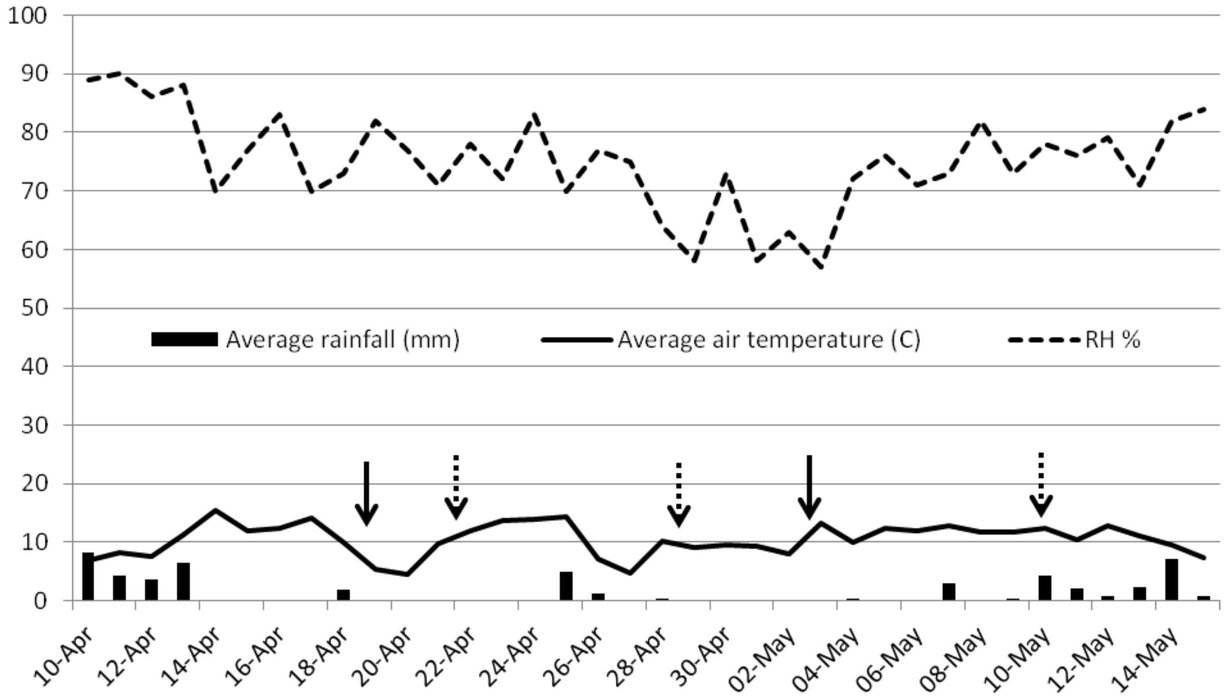


Figure 4. Weather data for the duration of the trial, solid arrow = spray application, hatched arrow = assessment date

There was a significant reduction in the numbers of *M. euphorbiae* on strawberry leaves over the duration of the trial on all of the plots, with the exception of the untreated plants, where numbers of aphids increased between 22 Apr and 10 May (Table 4). All of the insecticide treated plants had significantly lower numbers of aphids on the leaves by the end of the experiment compared to the untreated control (Table 4, Fig 5). By the final assessment, no aphids were found on plants that had been treated with Gazelle, the coded product HDCI 057, Hallmark, Pirimicarb or Pyrethrins. Chess was less effective than all the other treatments at reducing aphid numbers (Table 4, Fig 5). There were no significant phytotoxic effects of the insecticide applications on the plants.

Resistance testing

There was no evidence of resistance to imidacloprid, pirimicarb or lambda-cyhalothrin in two of the samples of *M. euphorbiae* tested. In sample 1, 77% of the population was affected or dead (not resistant) when treated with pymetrozine. In sample 3, all aphids died in culture, but the sample from the second farm gave only 18% affected or dead after exposure to pymetrozine (Table 5). Unaffected nymphs from this culture were moved to fresh, untreated leaves to see if they could grow to adults and reproduce. The test was repeated on the surviving aphid population and only 26% of the population was affected. However, all of the aphids died two days later. It was concluded that the population was not resistant and that the *M. euphorbiae* population had a high genetic variation which enabled it to survive a period of starvation.

Table 4. Mean and $Log_{10}(+1)$ mean numbers of *Macrosiphum euphorbiae* per five leaves. Covariate (pre assessment) adjustment was not significant and was removed from final analysis. There was no time * treat interaction

Treatment/Date	**Actual mean**	**$Log_{10}(+1)$ mean**			
		22-Apr	**29-Apr**	**10-May**	**overall**
Acetamiprid (Gazelle 20% w/w SG)	2.1	0.685	0.151	0	0.279a
Coded product HDCI 057	2.1	0.450	0.195	0	0.215a
Chlorpyrifos (Equity) 480g/l EC	3.2	0.349	0.595	0.354	0.433a
Flonicamid (Teppeki 50% w/w WG)	3.1	0.556	0.270	0.195	0.340a
Lambda-cyhalothrin (Hallmark 100g/l CS)	2.5	0.540	0.336	0	0.292a
Pirimicarb (Aphox 50% w/w WG)	2.0	0.749	0.075	0	0.275a
Pymetrozine (Chess 50% w/w WG)	8.7	1.060	0.945	0.376	0.794c
Pyrethrins (Pyrethrum 5 EC 50 g/l)	2.9	0.687	0.520	0	0.402a
Thiacloprid (Calypso SC 450 g/l)	5.1	0.584	0.525	0.369	0.493a
Untreated	55.7	1.125	1.715	1.804	1.548b
Time					
22 April	7.28				0.679
29 April	9.95				0.533
10 May	8.95				0.310
				Treat	
				F pr.	<.001
				s.e.d.	0.127
				d.f.	27
				l.s.d.	0.261
				Time	
				F pr.	<.001
				s.e.d.	0.088
				d.f.	50
				l.s.d.	0.182

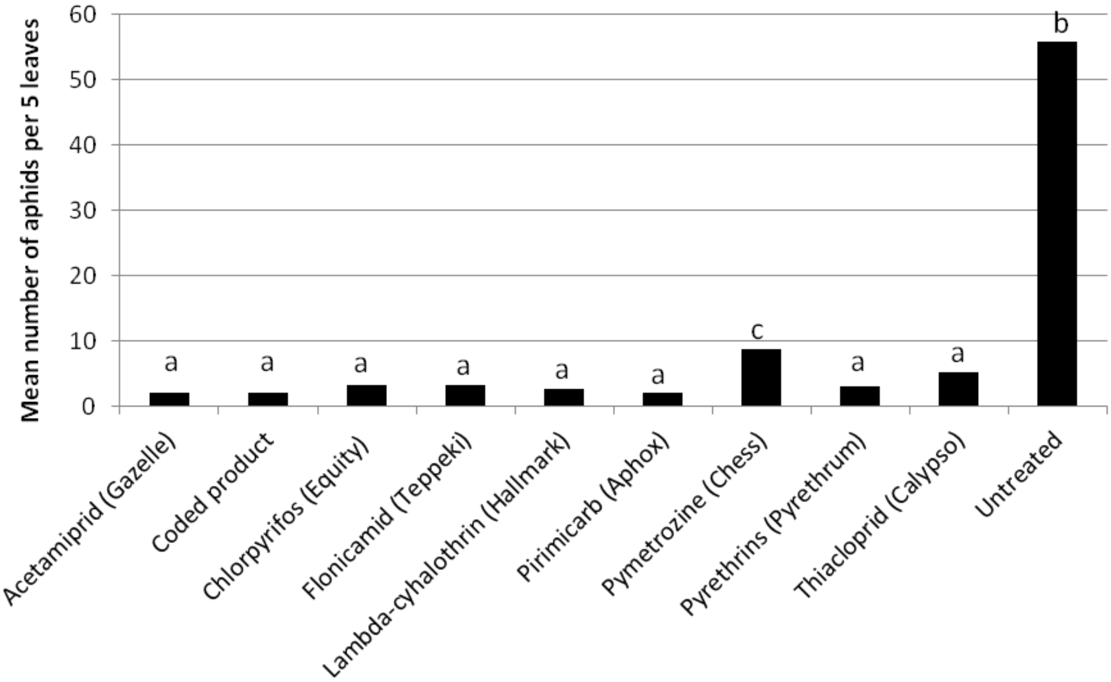


Figure 5. Overall mean numbers of potato aphid (*Macrosiphum euphorbiae)* per five leaves on strawberry plants treated with insecticides

Table 5. Pymetrozine resistance testing and spray programmes pre sampling of aphid colonies from three farms in Kent

Farm	**1**	**2**	**3**
Date collected	**10 June 13**	**11 June 13 MF**	**19 Jun 13**
Spray programme	13 April – Masai 23 April - Aphox/Calypso 02 May - Calypso 21 May - Hallmark	07 Jan - Chlorpyrifos 11 Feb - Chlorpyrifos 23 Apr - Aphox/Calypso 30 Apr - Calypso/Chess 27 May - Pyrethrum 01 Jun - Pyrethrum	Not supplied
% affected or dead	77 % test 1	18 % test 1 26% test 2 Died 2 days later	All died in culture

Conclusions

- The trial was done in typical spring temperatures (average 10.4^{o}C)
- Numbers of aphids on the untreated control plots continued to increase over the trial period
- All tested strawberry approved and non-approved insecticides [acetamiprid (Gazelle), the coded product HDCI 057, chlorpyrifos (Equity) flonicamid (Teppeki), lambda-cyhalothrin (Hallmark), pirimicarb (Aphox), pymetrozine (Chess), pyrethrins

(Pyrethrum), thiacloprid (Calypso)] reduced the 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
- Chess was less effective than all the other treatments at reducing aphid numbers
- There were no significant phytotoxic effects of the insecticide applications on the plants
- Resistance testing indicated that some populations of *M. euphorbiae* may be able to survive starvation caused by pymetrozine (Chess), but more sampling is needed to confirm this and how widespread it may be

Future work

The objectives for years 2 and 3 as set out in the original proposal are:

- Objective 2. Compare the most efficacious insecticide at different temperatures to determine the effects that climate has on the product's performance (Yr 2)
- Objective 3. Determine if control can be improved with the addition of adjuvants and/or two way mixes of insecticides.

Acknowledgements

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