AHDB HORTICULTURE

Grower Summary

SF156

Improving integrated pest management in strawberry

Year 3 Annual report, March 2018

Project title:	Improving integrated pest management in strawberry
Project number:	SF 156
Project leader:	Michelle Fountain, NIAB-EMR, New Road, East Malling, Kent ME19 6BJ
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Key staff:	Jerry Cross, Jean Fitzgerald, Chantelle Jay, Phil Brain, Adrian Harris, Luca Csokay, Francesco Maria Rogai, Glen Powell (NIAB-EMR); Steve Edgington, (CABI); William Kirk, (Keele University); Clare Sampson (Russell IPM); David Hall, Dudley Farman (NRI); Tom Pope, Juliane Graham, Rosie Homer, Rob Graham, Charlotte Rowley (Harper Adams University); Robert Irving (ADAS), Neil Audsley (Fera)
Location of project:	NIAB EMR
Industry Representative:	Louise Sutherland, Freiston Associates Ltd.
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GROWER SUMMARY

This project addresses the main pest problems reported by the UK strawberry industry, except for spotted wing drosophila (SWD), which is covered in other projects. Within this project, it is planned to work on five objectives over the five year duration:

1. Develop effective biological methods for managing western flower thrips, *Frankliniella occidentalis* (WFT), compatible with pesticide use against SWD, improve the reliability of biocontrol of WFT with predatory mites, and develop effective approaches to the use of entomopathogenic fungi (EPF) for control of WFT.
2. Refine pest control programmes on strawberry, integrating pesticides with phytoseiid mites.
3. Develop IPM compatible controls for European tarnished plant bug (*Lygus rugulipennis*), common green capsid (*Lygocoris pabulinus*), and strawberry blossom weevil (*Anthonomus rubi*).
4. Improve insecticide control of the potato aphid, *Macrosiphum euphorbiae,* so as to be more compatible with IPM programmes.
5. Improve the control of aphids through the growing season.

For ease of reading, this Grower Summary report is split into sections for each of the objectives being worked upon. In Year 3 of the project, Objectives 1, 2, 3, 4 and 5 were worked on and are reported here.

Western flower thrips

Objective 1 - Develop effective biological methods for managing western flower thrips, *Frankliniella occidentalis* (WFT), compatible with pesticide use against SWD, improve the reliability of biocontrol of WFT with predatory mites, and develop effective approaches to the use of entomopathogenic fungi (EPF) for control of WFT.

In Year 3 of the project, the work on WFT was broken into Tasks 1.1 and 1.2

Task 1.1. Develop and determine the efficacy and ease of use of the prototype extraction device for WFT and the predatory mite Neoseiulus cucumeris in commercial strawberry crops, by agronomist and growers

Task 1.2. Determine the distribution of Neoseiulus cucumeris on commercial strawberry plants after their introduction for WFT management

Headlines

- An extraction device has been developed to improve the level of detection of both WFT and predator numbers in strawberry plants.
- The presence of WFT as prey in strawberry plants increases the number *of N. cucumeris* on flowers and button fruits.

Background and expected deliverables

Task 1.1.

In 2015, methyl isobutyl ketone (MIK) was shown to be effective as a fumigant to extract arthropods from button fruit, with higher numbers recorded by extraction compared to ‘by eye’ assessments of flowers or fruits (see 2016 Annual Report). Three prototype monitoring devices, making use of this fumigant extraction method, were constructed. Based on grower/advisor feedback on the different designs and prototypes, a ‘Tupperware’ type device was chosen for further development based on its robustness, ease of use, and transparency. A few modifications were required, and to increase the ease of counting, a segmented counting surface was included.

Following initial laboratory studies to assess the efficacy of the device in extracting thrips and mites from flowers and fruit, further laboratory experiments were carried out in the summer and autumn of 2017 to achieve a more thorough calibration of the device with *N. cucumeris*. Field studies were also carried out during the summer by agronomists and growers to explore the efficacy and ease of use of the extraction device in commercial strawberry crops.

Task 1.2.

In 2016, when multiple releases of high numbers of *N. cucumeris* were made in small field plots, very few predators were recovered from flowers or button fruit after release. Some commercial growers have also reported finding very few or no predators in flowers or on fruit after multiple releases. In order to make rational decisions on release and sampling strategies for *N. cucumeris*, it is important to determine whether the mites are present on other parts of the plant, or if they are not surviving in the crop. In the first year of the project, the scientists recorded numbers of thrips and *N. cucumeris* on different aged flowers and fruits but did not record numbers on other plant parts. It is important to understand mite distribution on the plants as results will guide more effective sampling strategies, including the effective use of the prototype extraction device. Two experiments were set up to address the questions: Where do the mites disperse to when released onto the plant? What is the best plant part to sample to assess populations? Does the presence of WFT on the plants affect distribution of *N. cucumeris*? Is there a diurnal pattern of movement of *N. cucumeris* on strawberry button fruits and flowers?

Summary of the project and main conclusions

Task 1.1.

In laboratory experiments, single or groups of 10 button fruits were inoculated with known numbers of *N. cucumeris*. Mites were then extracted using the device containing MIK for 20 minutes and then fruits were washed further with ethanol to remove any remaining mites.

In addition, field assays tested the efficacy of the MIK and extraction device. Fruits were initially inspected using a hand lens, then arthropods extracted with the MIK in the extraction device before washing the fruit back in the laboratory with ethanol to remove further arthropods.

In the laboratory, from individual fruits placed in the extraction there was a close correlation between the numbers of *N. cucumeris* released and the numbers recovered (R^2=0.987) which indicated that around 57% of the mites that are actually present on the fruit were recovered.

When groups of 10 fruit were inoculated, the same calibration revealed that the device extracted about 60% of mites present on the fruit (R^2=0.993).

In the field test, no *N. cucumeris* could be seen on the fruit using a hand lens. However, the device recovered 27% of mites from button fruit and 5% from flowers. It was also possible to assess the presence of other arthropods on button fruit and flowers using the device. 68% and 81% of WFT were extracted using the device from button fruit and flowers, respectively.

The extraction device also increased detection of *Orius* on both button fruit (direct observation 26%; extraction device 85%) and flowers (direct observation 55%; extraction device 94%).

Hence the device can be used to make estimates of *N. cucumeris* in the field giving approximately 30% and 5% of the actual numbers present on fruit and flowers, respectively.

Task 1.2.

In a glasshouse experiment, to assess the distribution of *N. cucumeris* on strawberry plants after release, eighteen plants were placed in each of two glasshouse compartments at NIAB EMR. WFT from laboratory cultures were released onto plants in one compartment at approximately 20 mixed stages per plant; the second compartment had no WFT released. Five days after WFT release *N. cucumeris,* from a commercial supplier, was released onto each plant in both compartments at a rate of ~200 mites per plant. One, four and seven days after release, six plants were randomly selected from each treatment. Numbers of each plant part at the time of sampling were recorded and the plants were destructively sampled in the glasshouse; all plant parts were separated into closed containers. Plant parts assessed were: old leaves, recently expanded leaves, folded leaves, flowers, button fruit, remaining fruit, developing fruit clusters and the crown. In addition, a sample of the *N. cucumeris* carrier material from the leaf surfaces of each plant was taken. Numbers of *N. cucumeris* and WFT were counted from the different plant parts to assess distribution over the plant after release and the data analysed to determine if there were differences in *N. cucumeris* distribution when prey was present.

Results showed that, as in earlier studies, most WFT were found on the strawberry flowers and fruits. Most *N. cucumeris* had dispersed from the carrier material within one day of release, but around 50% of the total numbers of mites released were not recorded on the plants. *N. cucumeris* were recorded on all assessed plant parts but there were low numbers on the leaf samples. In the overall analyses of the results the presence of prey affected the distribution of *N. cucumeris* on the plants; there were significantly higher numbers of *N. cucumeris* on both flowers and fruits in the treatment where WFT had been released. These results confirmed earlier work that button fruit were the most effective plant parts to assess populations of *N. cucumeris* in the crop and highlights that the presence of prey (WFT) has a significant effect on the distribution of the predator.

In a following field experiment on a commercial crop to determine if there is a diurnal pattern of movement of *N. cucumeris* over the plant, several introductions of *N. cucumeris* were made. Data loggers were used to record temperature and humidity throughout the experimental period, and the photosynthetically active light levels (400-700 nm) were also monitored. Button fruit and flower samples were taken five times during the day; 09.00; 12.00; 15.00; 18.00 and 21.00. Sampling was repeated on three days, with a one day gap between the first two samples and a four day gap between the second and third sample to allow the plants to recover and produce more open flowers and button fruits. Each assessment unit consisted of 10 flowers or 10 button fruit. These bulk samples were collected into ethanol and arthropods were extracted using our standard laboratory washing technique. Numbers of *N. cucumeris,* thrips adults and larvae and *Orius* adults and nymphs were counted. Arthropods recorded on the sample units in relation to sampling time and date, position within the tunnel, and environmental conditions (mean temperature and mean light intensity for the 60 mins before each sample) were analysed.

There was a diurnal pattern of movement of arthropods on strawberry. In the overall statistical analyses of the data, the mean temperature in the hour prior to sampling significantly affected the number of arthropods recorded in samples of flowers and button fruits. No other variable tested had any effect on arthropod distribution. Numbers of *N. cucumeris* declined by around 3% for every 1°C increase in mean temperature calculated per hour, over the range recorded in the experiment (18-33°C). Predatory *Orius* adults and WFT adults were recorded in higher numbers as the mean temperature increased whereas WFT larvae decreased in abundance. Numbers of *N. cucumeris* are likely to be lower in flowers and button fruit at higher temperatures. Therefore if very low numbers are recorded in samples it would be worth revisiting the plantation when temperatures have decreased to confirm establishment of the predator.

Financial benefits

Western flower thrips (*Frankliniella occidentalis*) causes bronzing of fruit. It has become difficult to control because of resistance to crop protection products and a lack of effective alternative biological controls. Financial losses can be high, exceeding £15m to the UK industry alone in 2013. This project is testing new approaches to monitoring and control of WFT whilst maintaining control of other pests, particularly by conserving and improving efficacy of introduced arthropod biocontrol agents and entomopathogenic fungi in the crop.

Action points for growers

- Sample button fruit to determine establishment of *N. cucumeris* in the crop.

- If temperatures are high, it is likely that fewer *N. cucumeris* will be found in the fruitlets and flowers and re-sampling to ascertain establishment may be needed.
- Avoid sampling for *N. cucumeris* in the mid-day heat.
- Sample mid-aged flowers to determine thrips numbers in the crop.
- Consider reducing the number of repeated applications of tank mixes of plant protection products as these may be harmful to introduced *N. cucumeris*.
- Careful thought needs to be given to the tank mixes used, ensuring that thrips and tarsonemid control is achieved early before SWD enters the crop and requires treatment.
- Reduce use of crop protection products where possible to ensure that *N. cucumeris* gains control of WFT before SWD control is needed.

Integrating pesticides with phytoseiid mites

Objective 2 - Refine pest control programmes on strawberry, integrating pesticides with phytoseiid mites.

In Year 3 of the project, the work on potato aphid concentrated on Task 2.2.

Task 2.2. In field, effect of insecticides commonly used to target spring aphids on the establishment of N. cucumeris, aphids and parasitoids

Headline

- Repeated applications of some fungicides can cause reductions of *N. cucumeris* numbers in the crop. This can be alleviated by further applications of *N. cucumeris.*

Background and expected deliverables

Predatory mites such as *Neoseiulus cucumeris* can form a very successful part of Integrated Pest Management (IPM). However, they can be vulnerable to plant protection products, including, potentially, fungicides. In addition, increased use of plant protection products against other pests, such as SWD, can potentially interfere with IPM. Although some plant protection products have been shown to be safe or only slightly harmful to *N. cucumeris* in single applications, in the field, products are applied multiple times, and in tank mixes. In Year 1 of the project, the scientists demonstrated that tank mixes of Nimrod/Teldor and Signum/Systhane and Aphox/Rovral had a detrimental effect on *N. cucumeris* numbers in strawberry. However, adverse effects were only statistically significant after the third spray application, suggesting that previous studies in the literature might have underestimated the toxicity of these products to *N. cucumeris* under normal commercial usage.

In Year 2, the science team tested Calypso (thiacloprid) and potassium bicarbonate+Activator90, products that the industry had suggested could be harmful to *N. cucumeris* over multiple applications or in tank mixes. These were compared to Nimrod+Teldor applications, a treatment tested in the previous year. We also tested whether a secondary addition of *N. cucumeris* could mitigate any effects of these spray treatments.

N. cucumeris were released onto strawberry plants before the trial began and three applications of plant protection products were applied, with assessment of adult and immature *N. cucumeris* numbers on button fruit made after each application. No evidence was found that Calypso, potassium bicarbonate+Activator90 or Nimrod+Teldor had a detrimental effect on *N. cucumeris* populations. An additional release of *N. cucumeris* after the second spray treatment led to an increase in adult *N. cucumeris* in the crop.

Neither Calypso nor the secondary addition of *N. cucumeris* had a significant effect on thrips numbers. However, there were significantly lower numbers of thrips in the potassium bicarbonate+Activator90 treated plots compared to the water controls. The reason for this was not clear.

Data on the introduction of *N. cucumeris* following a pesticide application is generally based on laboratory side-effects tests and does not consider timing, temperature or leaf expansion. A study began in March 2018 to test, in-field, effects of insecticides commonly used to target spring aphids on the establishment of *N. cucumeris* and other potential predators in the crop.

Summary of the project and main conclusions

Results will be reported at the field meeting in 2018 and reported in full in the 2019 annual report.

Financial benefits

From a pest like western flower thrips (WFT), strawberry growers can typically lose 20% or more of their fruit. For a crop yielding 30 tonnes/ha, this equates to 6 tonnes/ha and at a value of £2,400 per tonne, losses of £14,400 per hectare.

Frequent introductions of high numbers of predatory mites such as *Neoseiulus cucumeris* are not only expensive to purchase, but costly to introduce by hand. Potential damage or disruption to the mites caused by the use of harmful fungicide mixes or other crop protection products will lead to reduced efficacy of control and hasten the onset of WFT induced damage, resulting in further financial losses.

It is therefore vital that growers are better informed of those fungicide mixes or other products which may have an adverse effect on the expensive predatory mites which have been introduced.

Action points for growers

- Consider reducing the number of repeated applications of tank mixes of plant protection products as these may be harmful to introduced *N. cucumeris*.
- Careful thought needs to be given to the tank mixes used, ensuring that thrips and tarsonemid mite control is achieved early before SWD enters the crop and requires treatment.

IPM controls for capsids and blossom weevil

Objective 3. Develop IPM compatible controls for European tarnished plant bug (*Lygus rugulipennis*), common green capsid (*Lygocoris pabulinus*) and strawberry blossom weevil (*Anthonomus rubi*)

In Year 3 of the project, the work on capsids was broken into Tasks 3.1 and 3.2

Task 3.1. To investigate the potential of a multi-pheromone blue sticky trapping system for Lygus rugulipennis, Lygocoris pabulinus and Frankliniella occidentalis

Task 3.2. To investigate the potential of a push-pull system for control of capsids in strawberry

Headline

- Some early success has been gained in reducing capsid numbers in strawberry crops using a novel 'push-pull system' of control.

Background and expected deliverables

Task 3.1.

In strawberry, western flower thrips, *Frankliniella occidentalis* (WFT), causes bronzing of the fruit. It has become difficult to control because of resistance to crop protection products and lack of effective alternative biological controls. Financial losses can be high, exceeding £15m to the UK industry alone in 2013. From June onwards European tarnished plant bug, *Lygus rugulipennis*, becomes a damaging pest of strawberry requiring routine control. Feeding in flowers and on green fruits can cause up to 80% crop loss, rendering production uneconomical. Traditional crop protection products used for control can disrupt biological control agents and increase residues in fruits. *Lygocoris pabulinus* (common green capsid) is also a damaging pest, which tends to be sporadic in appearance and locally distributed within the crop.

Blue sticky traps are currently employed for WFT control. These can be enhanced with a WFT aggregation pheromone, which can typically double the catch. If these could also be used in conjunction with capsid pheromones this would potentially provide in-crop control of potentially three pest species. *L. rugulipennis* is currently trapped using a *Lygus* sex pheromone lure within a green bucket trap and cover; catches, including of females, can be increased with the addition of the plant volatile phenylacetaldehyde (PAA). The trapping system for *L. pabulinus* uses the same pheromone lure, but attached to a blue sticky trap placed vertically in the crop.

Task 3.2.

Push-pull strategies have both an element which repels insect pests (the push), and an attractant source to draw the pest away from the crop (the pull). In addition the pull can be combined with a killing agent to prevent the pest re-entering the crop and to reduce population growth. Using synthetic semiochemicals, a push-pull system could be deployed to enable medium-term control of capsids. This study investigated whether; 1) the capsids, *L. rugulipennis* and *L. pabulinus*, could be repelled from a strawberry crop using hexyl butyrate (push system), 2) perimeter pheromone trapping system (pull system) could be used in conjunction with the repellent system for improved efficacy and 3) whether *Lygus* damage (i.e. cat-facing of the fruit), was reduced where treatments were applied.

Summary of the project and main conclusions

Task 3.1.

We investigated whether *L. rugulipennis* and *L. pabulinus* can be attracted to blue sticky traps with the addition of a *Lygus* sex pheromone lure + PAA only or whether the *Lygus* pheromone + PAA can be used in conjunction with the WFT pheromone, and, finally, if beneficial arthropods are also attracted to the trapping system.

Experiments were set up in multiple strawberry crops in mid to late June and covered a two-month period within 2017. Treatments included: 1) Blue dry sticky trap board - 25 cm x 10 cm, 2) blue dry sticky trap board + WFT pheromone lure, 3) blue dry sticky trap board + *Lygus* sex pheromone lure + PAA or 4) blue dry sticky trap board + WFT pheromone lure + *Lygus* sex pheromone lure + PAA. Traps were placed 10 m apart in a randomised block design.

As expected, *L. rugulipennis* and *L. pabulinus* were attracted to a blue sticky trap with *Lygus* sex pheromone + PAA. However, 20% of capsids could detach themselves from the blue sticky traps. The *Lygus* sex pheromone lure + PAA was compatible with the WFT pheromone and thrips catches were always higher when a WFT lure was present.

The PAA lure also appeared to attract lacewings and syrphids. PAA is essential to increase catches of the female *L. rugulipennis* however; the floral component may be detrimental to some beneficial species.

Task 3.2.

A field experiment was set up as a randomised block design, with four tunnelled strawberry crops as replicates. Each treated area was a 25 m x 25 m plot. Treatments included:1) Push - Hexyl butyrate (HB) sachets every 2 m, 2) Pull - Lygus sex pheromone + PAA in green “bucket traps” every 8 m around the perimeter of the plot, 3) Push–Pull – treatment 1 and 2 combined or 4) control plot with no traps or repellents. The experiment ran for two months from 4 July and the effect on capsid numbers throughout the season and resultant fruit damage was monitored.

There were significantly fewer adult and nymph *L. rugulipennis* where the ‘push’ was applied compared to where the ‘push’ was not applied. Differences were not statistically significant for *L. pabulinus* adults and nymphs, although overall numbers were lower where a treatment was applied. There was no significant effect of ‘pull’ only treatment when used alone.

There was also significantly less fruit damage where there was a ‘push’ treatment and a ‘pull’ treatment were combined compared to no treatment. To our knowledge this is the first study to show that a push-pull strategy could give significant control of capsids.

Financial benefits

Lygus rugulipennis (European tarnished plant bug) and *Lygocoris pabulinus* (common green capsid) are serious pests on everbearer strawberries causing crop losses by feeding on developing fruits which become deformed and unmarketable. Over 50% of fruit may be downgraded as a result of capsid feeding in unsprayed crops. The development of improved trap and monitoring systems for capsids will help growers to identify the exact time of their appearance in the crop, allowing control measures to be implemented at the optimum time. Should traditional spray control products be employed, the numbers required can be reduced by applying at the optimum time, saving money on unnecessary sprays. Novel control methods such as the ‘push-pull system’ will help to reduce reliance on traditional control products, which will further reduce crop protection costs for growers. Such a system will also enhance biological control methods employed for other pests, increasing their efficacy and reducing the need to introduce additional numbers of predatory mites, further reducing costs.

Action points for growers

- It is too early to identify any positive action points from the work on this objective so far.

Potato aphid

Objective 4. Improve insecticide control of the potato aphid, *Macrosiphum euphorbiae,* so as to be more compatible with IPM programmes.

In Year 3 of the project, the work on potato aphid concentrated on Task 4.2.

Task 4.2. Determine the effect of low and fluctuating temperatures on the ability of aphid parasitoids to parasitise the potato aphid, Macrosiphum euphorbiae.

Headline

- The parasitoids *Aphidius ervi* and *Praon volucre* require minimum temperatures of 8°C and 12°C respectively to effectively parasitise the potato aphid.

Background and expected deliverables

Several species of aphid are regularly found infesting strawberry crops. Five of the most frequently found and most damaging are the strawberry aphid (*Chaetosiphon fragaefolii*), the melon and cotton aphid (*Aphis gossypii*), the shallot aphid (*Myzus ascalonicus*), the glasshouse-potato aphid (*Aulacorthum solani*) and the potato aphid (*Macrosiphum euphorbiae*).

In recent years the control of early season aphids such as the potato aphid has become more problematic due to the withdrawal of commonly used insecticides. The remaining chemical options often have limited efficacy (AHDB Projects SF 140 and 156) and there is little evidence that biological controls are effective at the low temperatures experienced in early spring. The potato aphid causes damage to the crop through the production of honeydew and cast skins which result in sooty moulds and make the fruit unmarketable. Feeding action of these aphids can also result in distortion of the leaves and fruit. The species may breed all year round on strawberry crops if conditions allow and populations can build up rapidly in the spring.

Two aphid parasitoid species (*Aphidius ervi* and *Praon volucre*) commonly found in strawberry crops are known to readily parasitise potato aphid and may contribute to control. Both species occur naturally in the environment but can be introduced as biological control products as either a single species in the case of *A. ervi* or as part of a mix of six parasitoid species (*Aphidius colemani, A. ervi, A. matricariae, Praon volucre, Ephedrus cerasicola* and *Aphelinus abdominalis*).

Temperature is a key factor in determining the developmental time of insect species. Current knowledge suggests that the lower developmental threshold of *P. volucre* from the egg to mummy stage is 3.8°C and for mummy to adult development is 5.5°C. In comparison, the lower developmental thresholds for egg to mummy development and mummy to adult development of *A. ervi* in *Sitobion avenae* are 2.2°C and 6.6°C respectively. Although parasitoid development at low temperatures is extremely slow, *A. ervi* has been found to have a negative effect on pea aphid reproductive capacity following oviposition. This suggests that even if the parasitoid larvae do not kill the adult aphids as quickly early in the season, they may still be effective at reducing aphid populations.

Temperature can also affect the ability of the parasitoid to successfully locate and parasitise the aphid. Previous work has shown that oviposition by *A. ervi* and *P. volucre* on the grain aphid remained low below 10°C in both species. Flight and walking activity both increased with temperature, with *A. ervi* being consistently more active than *P. volcure*. The lower flight threshold was 10°C for both species and walking activity continued down to 8°C. This suggests that these parasitoid species would still be capable of locating aphids at low temperatures early in the season.

The aim of this work was to determine the effect of low and fluctuating temperatures on the ability of *A. ervi* and *P. volucre* to parasitise the potato aphid.

Summary of the project and main conclusions

Air temperatures recorded in a polytunnel and an unheated glasshouse located in West Sussex confirmed that from early in the year, temperatures were above minimum thresholds for parasitoid activity. In the studied polytunnel, air temperatures rose above 12°C for at least 18% of the time in the month of February 2014, increasing to 33% in March and 52% in April. In the studied unheated glasshouse, air temperatures rose above 12°C for at least 11% of the time in the month of February 2015, increasing to 33% in March and 82% in April.

A series of experiments were completed under controlled temperature conditions. Each experiment used an unfurled strawberry leaf placed in a glass Petri dish with the stem immersed in 2.5 ml of water. The leaf was infested with 10 potato aphid nymphs and conditioned at the treatment temperature for 24 hours prior to the start of the experiment. Mated female parasitoids were separated out into a different glass Petri dish with access to a 20% sugar solution and conditioned similarly. Two female parasitoids were introduced to each dish of aphids and left for 24 hours at the treatment temperature. The parasitoids were then removed and the aphids were maintained on the strawberry leaf at 20°C for a further seven days before they were dissected to determine if parasitism had occurred. To confirm parasitoid larval development at low temperatures, additional replicates of parasitised aphid treatments and 20 mummies of each species were maintained at the lowest constant temperature at which parasitism was previously observed.

The minimum temperature at which parasitism of potato aphid by *A. ervi* occurred under constant conditions was 8°C. The minimum temperature at which parasitism of the same aphid species by *P. volucre* occurred under constant conditions was 12°C. There were a greater number of dishes with parasitism occurring in *A. ervi* compared to *P. volucre* as a result of the lower temperature threshold. Development of parasitoid larvae inside the aphid host was confirmed for both species of parasitoid in aphids maintained at constant low temperatures for two weeks. Similarly, adult emergence from aphid mummies was also confirmed at these constant low temperatures for both species.

Where temperatures fluctuated between 2°C and then eight hours at 8, 13 or 18°C, the minimum temperature at which parasitism by *A. ervi* occurred was 8°C. The minimum temperature at which parasitism by *P. volucre* occurred under fluctuating conditions was 13°C.

Both parasitoid species responded to higher temperature fluctuations (8°C for *A. ervi* and 13°C for *P. volucre*) and parasitised aphids in less than two hours when switched from 2°C.

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.

Action points for growers

- Consider autumn applications (post-harvest) of insecticides for aphid control as these have been shown to reduce populations of aphids found in crops the following year.
- Carefully monitor both aphid numbers and their associated natural enemies within crops in order to determine the need for insecticide sprays. Do not treat all fields the

same. Consider the species of aphid prevalent and the damage it may cause, including plant virus spread.

- Where spring applications of insecticides are considered necessary, growers should ensure that there is good spray coverage, in particular the undersides of leaves and the crown of the plant. Consider the use of water sensitive papers to visualise how effectively spray applications achieve this.
- Some populations of aphid pests e.g. the melon and cotton aphid (*Aphis gossypii*) have developed insecticide resistance. Growers should ensure that they follow insecticide resistance management guidelines on the product label and rotate between insecticides with different modes of action.
- It is important to carefully consider the compatibility of the available insecticide options with aphid natural enemies as well as the biological control programmes used to control other pests of strawberry crops.
- Consider early season releases of *Aphidius ervi* to control potato aphid when daytime temperature exceed 8°C regularly for at least part of the day. *Praon volucre* is currently only available as part of a mix of parasitoid species (including also *A. ervi*) and may also be considered for releases when daytime temperatures exceed 12°C regularly for at least part of the day.
- Although aphid parasitism may occur at low temperatures, the development of the aphid parasitoid will be very slow at these temperatures and may take several weeks to complete. The absence of mummified aphids does not, therefore, reliably indicate lack of parasitoid activity. Carefully monitor aphid populations within crops for presence of adult parasitoids. If possible, move some aphid infested plants to a warmer environment for 7-10 days, checking regularly for presence of mummified aphids.

Aphid control

Objective 5. Improve control of aphids through the growing season.

In Year 3 of the project, the work on potato aphid concentrated on Task 5.1.

Task 5.1. Thresholds for aphids and natural enemies; assessments to demonstrate confidence in control strategies.

Headline

- Before June, there are very few natural enemies in strawberry crops and therefore other control measures should be employed to supress aphid populations until natural numbers build.

Background and expected deliverables

Strawberry crops are affected by a range of aphid pests. The most difficult to control is the potato aphid, as populations often resurge after spray application, probably due to incomplete control as shown in AHDB Project SF 140. In this project, it was also found that aphid numbers in the untreated plots had a tendency to decline rapidly by the end of the experiments because of the increases in natural enemies.

Crop protection sprays can be harmful to natural enemies which might otherwise be controlling pests in the crop. Often there is a lag between the build-up of the pest and the immigration and build-up of the predators and parasitoids. This lag period is often a critical time for the build-up of the natural enemies, but a time when sprays for aphids are more likely to be applied.

The aim of this study was to monitor and demonstrate the importance of naturally occurring aphid enemies in everbearer and June bearer strawberry crops. We compared three crops in both Junebearer and everbearer fields for aphid build-up in the crop, in relation to natural enemy appearance. We also aimed to demonstrate the effects of pest spray programmes on potato aphid and natural enemies and show the relationship between population 'peaks and toughs' of pest and natural enemies. Studies were made on two farms with historically different degrees of aphid and natural enemy numbers. On each farm, three Junebearer and three everbearer fields were selected. To obtain an overall picture of the changes in natural enemy populations throughout the year, fields were chosen within the same or as similar a landscape as possible on the farms. Hence they had the same potential pool of pests and natural enemies.

Summary of the project and main conclusions

Both farms were visited each week from 5 April until 30 August. At each visit, 25 plants were thoroughly searched in a different central row of the cropping area and the numbers and species of aphids and natural enemies were counted and plotted.

There was a high variability in aphid species and numbers between farms and between crops in the same landscape. The main pest was potato aphid although other pests (*Aphis gossypii*, thrips, two-spotted spider mites and glasshouse whitefly) were present. Winged aphids peaked on 9 June. The main aphid predators recorded were the green lacewing and hoverfly larvae. Hoverfly larvae were present in low numbers across the two farms through the season and green lacewing larvae became more prevalent from 4 July. It is known that a single larva of the marmalade hoverfly (*Episyrphus balteatus*) can consume 660-1,140 aphids during development and a single green lacewing larva 566-789 aphids before pupating. Other predators, such as spiders, ladybirds and *Orius* were also observed in low numbers.

The parasitoids *Praon* sp. and *Aphidius* sp. were the main species parasitising aphids. *Aphelinus* sp. parasitism was also present but at a lower incidence.

The pest and natural enemy fauna was more diverse in the ever-bearers than in the June bearers. In both crop types, there were delays in the natural enemy's population growth compared to the pest population growth. However, with the increase of natural enemies, the number of aphids declined. It is evident from this study, so far, that before June there are very few natural enemies in strawberry crops and therefore other control measures should be employed to supress aphid populations until natural numbers build. Controls introduced by growers should be sensitive to the natural enemies likely to enter the crop later in the season.

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.

Action points for growers

- Consider carefully early season applications of pesticides and wherever possible select products that are likely to be less harmful to aphid parasitoids and *N. cucumeris* that may or may not be obvious within the crop. Use either https://www.koppert.com/side-effects/ or http://www.biobestgroup.com/en/side-effect-manual to help inform product selection.