Project Title	Tunnel-grown everbearer strawberry: biology and integrated control of western flower thrips
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Project leaders:	Jude Bennison, ADAS Dr Jean Fitzgerald, EMR
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Key staff:	Jude Bennison, ADAS Study Director Dr Jean Fitzgerald, EMR Study Director Mike Lole, Heather Maher, Kerry Maulden, ADAS Site Managers Dr Chantelle Jay, EMR entomologist Dr William Kirk, Keele University, consultant to project
Location of project:	ADAS Boxworth, East Malling Research and commercial strawberry farms
Project coordinator:	Stephen McGuffie, R. D. McGuffie & Sons, New Farm, Elmhurst, Lichfield, Staffs. WS 13 8EX.
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The results and conclusions in this report are based on a series of experiments 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.

Jude Bennison
Senior Research Entomologist
ADAS

Signature .... Date ....

Dr Jean Fitzgerald
Senior Research Entomologist
EMR

Signature .... Date ....

Report authorised by:

Dr Tim O'Neill
Horticulture Research Manager
ADAS

Signature .... Date ....

Dr Chris Atkinson
Head of Science
EMR

Signature .... Date ....

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Headline

Amblyseius cucumeris offers good potential for biocontrol of western flower thrips, but ideally needs to be in place in the crop by mid-March in slow-release sachet formulation.

Background and expected deliverables

Over recent years significant economic losses have occurred in some everbearer strawberry crops due to thrips damage. Several thrips species can infest strawberry crops, but western flower thrips (WFT) is becoming more prevalent and is thought to be responsible for the main thrips damage symptoms (fruit russeting). Identification of thrips is a specialist skill and many strawberry growers are unaware of which thrips species are present on their farms.

Until recent years, growers used the pyrethroid Talstar/Starion (bifenthrin) for control of thrips and some other strawberry pests. However, WFT is widely resistant to this and many other insecticides. Some growers of glasshouse strawberry are successfully using Integrated Pest Management (IPM) programmes, which include very limited pesticide input, achieving biological control of thrips primarily with the predatory mite *Amblyseius cucumeris*. However, biological control of thrips in outdoor and tunnel-grown everbearers has proved unreliable and many growers of these crops still rely on pesticides.

In June 2005, a specific off-label approval (SOLA) was secured for the use of Tracer (spinosad) on protected strawberry and in 2008, the product gained on-label approval for use on protected strawberry. Tracer is currently the most effective pesticide against WFT and unlike Talstar/Starion, it is compatible with most biological control agents. However, widespread resistance to Tracer has been confirmed in WFT populations in other countries and in 2008 a resistant population of WFT in a UK everbearer crop was confirmed. Thus Tracer should be used within an integrated strategy rather than as the only means of control.

The biology of WFT in strawberry crops is not fully understood. This project aimed to provide key information on WFT biology and behaviour in everbearer crops, including where it pupates in the crop during the breeding season and whether it overwinters, and if so, where. This project also aimed to identify how widespread WFT is on everbearer crops in England and Scotland, and to design improved integrated control strategies. Results of the project will enable growers to target the pest more effectively with biological control agents, within improved, sustainable integrated control strategies.

Summary of the project and main conclusions

Objective 1: Identify the extent of WFT occurrence in everbearer strawberry on a wide geographical spread of strawberry farms in England and Scotland and identify factors affecting thrips incidence and success of integrated control strategies (ADAS)

- In 2006, WFT was confirmed as being widespread throughout England, on 8 of the 18 farms sampled. One of the WFT-infested crops was under glass and the others were field-grown everbearers, most of which were tunnelled at the time flowers were sampled.
- WFT was not found in samples from Scotland in 2006 but they were found in consultancy samples sent to ADAS from Scotland in 2005.
- WFT was more of a problem in fields with a history of WFT and where plants or beds were kept from one year to the next.
- Case studies confirmed that *A. cucumeris* had provided good control of WFT in glasshouse crops, but had given unreliable control in everbearer crops grown in the field or in Spanish tunnels. On most everbearer crops, the predators are likely to have been released too late and at inadequate rates and frequency for effective thrips control.
- Pesticides used for thrips control (before Tracer was available) and for control of other pests and diseases on everbearers would have had adverse effects on *A. cucumeris*.

Objective 2: Determine the pupation sites of WFT during the summer period in everbearer strawberry fields and the implications for control strategies (EMR)

In experiments in the field and in the glasshouse, the majority of WFT pupated in the soil directly under the strawberry plants and in the soil close to the plants within the raised beds or grow bags. Only low numbers of WFT pupated on the plants or in the straw or soil under the straw in the alleys. This pupation behaviour may give opportunities for the use of biological control strategies against WFT pupae in the soil.

Objective 3: Determine whether WFT overwinters in everbearer strawberry crops and if so, identify when and from where they emerge (EMR and ADAS)

- In the EMR experiment in year 1, WFT released to everbearer plants in the field at EMR in September 2006 successfully overwintered in the crop. WFT adults were found on sticky traps between 16 March and 4 May 2007. This confirmed that WFT had survived the mild winter of 2006/07 but the overwintering location in the crop was unknown.
- In the ADAS experiment in year 2, naturally occurring WFT survived the mild winter of 2007/08 in a commercial field of everbearers in Herefordshire, where WFT had been a problem during 2007. The first WFT adults were detected on 14 March 2008, in

dandelion and groundsel flowers and on overwintered strawberry plants.

- Field emergence traps at the Herefordshire site set up on 19 March 2008 demonstrated that WFT adults emerged from overwintered strawberry plants, soil in the planting hole, plant debris on the polythene covering the beds, straw in the alleys and soil under the straw, between 19 March and 1 May.
- Thus, keeping everbearer strawberry plants and/or beds from one year to the next allows WFT to overwinter in the crop and to infest the plants the following spring.
- IPM programmes for WFT control in overwintered everbearers ideally need to be in place by mid-March, before the crop is in flower, much earlier than is currently done in practice.

Objective 4: Using knowledge gained from objectives 1-3, design and test integrated control strategies for WFT (ADAS and EMR)

Year 2 (2007)

- The effectiveness of predatory mites against WFT was tested in field experiments at two sites; on a commercial farm in Herefordshire, where WFT had been a problem on everbearers in recent years (ADAS), and at EMR in Kent (EMR), where WFT was released as it did not occur naturally. Both experiments included releases of *A. cucumeris*, a predator of young thrips larvae. The EMR experiment also included releases of *Hypoaspis miles*, a predator of ground dwelling invertebrates including WFT pupae and WFT larvae that drop to the ground to pupate.
- At the ADAS site, 3 releases of *A. cucumeris* sprinkled onto the plants at either 100 or 150 per m^2 on 3 and 17 May and 7 June did not lead to successful establishment of the predators and thus gave no control of WFT. Poor predator establishment was probably due in part to adverse weather conditions, ranging from hot and dry, cold and windy, to severe floods (the crop was not tunnelled until just before the final assessment on 5 July).
- At EMR, 3 releases of *A. cucumeris* sprinkled onto the plants at 200 per m^2 on 24 August and 5 and 21 September did not lead to predator establishment until the final assessment on 4 October and no control of WFT was achieved. An application of Lorsban (chlorpyrifos) to the experimental plots to reduce numbers of other thrips species on 7 August may have prevented earlier establishment of the predator. *Hypoaspis miles* released at 200 per m^2 on the same three release dates were not found in soil samples at the final assessment, probably due to the soil around the plants being dry (*H. miles* prefers to live in damp soil). No effect of releases of *H. miles* on WFT numbers was detected.

Year 3 (2008)

As *A. cucumeris* did not establish in the 2007 experiments, two experiments in 2008 tested higher numbers and earlier releases of the predator. *A. cucumeris* 'slow release' sachets that are used successfully in glasshouse strawberries and in other protected crops were tested. One sachet per 2 m length of bed was put onto the plants on two occasions. The sachets were tested alone or in combination with the 'loose' predators sprinkled onto the plants at 200 per m^2 on two release dates. Use of *A. cucumeris* against WFT larvae on the plants was tested alone or in combination with ground-dwelling biological control agents against WFT pupae in the ground. The ADAS experiment included the predatory staphylinid beetle *Atheta coriaria* which was shown in HDC project PC 261 to reduce numbers of WFT in potted ornamentals when introduced as a grower 'DIY' rearing-release system. The EMR experiment included soil applications of the insect-pathogenic nematode *Steinernema feltiae*. *S. feltiae* is used successfully for WFT control on chrysanthemums but effective methods for using it for WFT control in strawberries have not yet been developed.

ADAS experiment

- In the ADAS experiment on the same commercial farm in Herefordshire that hosted the 2007 experiment, most of the thrips found in the flowers were WFT.
- WFT adults and larvae were present in low numbers when the fleece was removed from the crop in mid-May. The grower was advised to apply Tracer to reduce WFT numbers two days before the experiment was set up on 15 May.
- *A. cucumeris* successfully established in the flowers of plants treated with slow release sachets on 15 and 29 May. Using the 'loose' product in addition to the sachets on the same dates did not lead to higher numbers of predators in the flowers.
- *Amblyseius californicus* also established naturally in the flowers on both untreated plants and on those treated with *A. cucumeris* and were likely to be feeding on pollen.
- Mean numbers of WFT per flower remained low in all treatments until the final flower assessment on 7 July, when mean numbers of adults and larvae reached 3 per flower on untreated plants and were significantly lower on plants treated with biological control agents. Using the 'loose' *A. cucumeris* or *A. coriaria* in addition to the sachets gave no additional benefits in reducing WFT numbers.
- Significantly more undamaged fruit (i.e. no WFT bronzing) was recorded on plants treated with biological control agents (76-92% undamaged) than on untreated plants (56% undamaged) when assessed on 17 July. Numbers of undamaged fruit were not increased by the use of 'loose' *A. cucumeris* or *A. coriaria* in addition to the sachets.
- *A. coriaria* survival is likely to have been adversely affected by the substrate in the rearing-

release boxes becoming dry after the boxes were left on the soil in the beds. The wicking system used for keeping the substrate in the boxes damp is effective in glasshouse ornamentals and herbs but would need to be adapted for any further testing in strawberries.

- Although *A. cucumeris* had led to lower numbers of WFT and damage than on untreated plants, WFT pressure was still high and the grower applied Tracer at the end of the experiment on 18 July. Further research is needed on developing a robust integrated strategy for sustained management of WFT throughout the everbearer season.

EMR experiment

- Despite there being a large population of WFT in the EMR plantation in autumn 2007, WFT were not present in the crop in 2008 so were released to the experimental plots on 25 July.
- *A. cucumeris* successfully established in the flowers of plants treated with the sachets on 18 May and 7 June. As at the ADAS site, using the ‘loose’ product in addition to the sachets did not lead to higher numbers of predators in the flowers.
- As in the ADAS experiment, naturally occurring *A. californicus* also established in the flowers of both untreated plants and those treated with *A. cucumeris*.
- Mean numbers of thrips (WFT and other species) were significantly lower in August in plots with established populations of *A. cucumeris* than in plots treated with Talstar.
- Soil applications of *S. feltiae* on 8 and 15 August did not affect numbers of WFT.
- *Orius* sp. predatory bugs naturally colonised the plants in August and are likely to have contributed to control of WFT, in combination with *A. cucumeris*.

Financial benefits

The results of the project have increased grower awareness of WFT as a pest of everbearers and provided key information on the risk of WFT overwintering in everbearer fields and providing an early source of the pest in the following crop.

The average everbearer crop yields 20,000 kg of class 1 fruit per ha over one season with a current value of £3 per kg (£60,000 per ha). At a conservative estimate, if WFT infests the crop, 20% of the fruit can be downgraded to class 2 for half of the picking season. The value of class 2 fruit is less than £1.50 per kg. Thus WFT currently cause estimated financial losses of approximately £3,000 per ha per season. However, losses due to WFT have been higher on some farms and now that WFT resistance to Tracer has been confirmed in UK everbearers, losses would be much higher if resistance becomes widespread.

The cost of two releases of *A. cucumeris* using the sachets tested in the 2008 experiments would be approximately £325 per ha, although this cost would be lower if buying large quantities. If this strategy for *A. cucumeris* prevented fruit downgrading due to WFT damage for the whole everbearer season, it would give a potential 923% return on investment.

The results of the 2008 experiments were encouraging as they showed that using *A. cucumeris* in sachets led to successful establishment of the predators, lower WFT numbers and lower numbers of damaged fruit than on untreated plants. However, funding did not allow the experiments to continue for the whole everbearer season. Further research is needed to develop a robust IPM programme throughout the everbearer season, for long-term WFT control and reduced losses. On farms with high WFT pressure, it is likely that other components in the IPM strategy will be needed in addition to *A. cucumeris*.

Action points for growers

- ‘Map’ WFT incidence on the farm by getting thrips identified in each field every season.
- When considering whether to retain everbearer plants or beds from one season to the next, remember that this can increase the risk of WFT surviving over the winter and infesting the crop early the following year. Dispose of any plant material, debris, straw and polythene promptly and carefully to reduce sources of thrips.
- Keep tunnels and surrounding areas weed-free to reduce other sources of WFT.
- If WFT is present on the farm, and if using *A. cucumeris* for control, do not delay release until thrips are seen and do not rely on the rates recommended for tarsonemid control. Early use in slow-release sachets could lead to better *A. cucumeris* establishment than sprinkling the ‘loose’ product onto the plants. Plan your IPM programme with your biological control supplier and consultant well in advance.
- Do not assume that all predatory mites in flowers are *A. cucumeris*. Naturally-occurring *A. californicus* are common in strawberry flowers where they feed on pollen and some other pests if present, particularly spider mites. They do not provide control of WFT.
- Monitor regularly for pests and diseases. Manage IPM programmes carefully. If a pesticide is needed, selecting one safest to any biological control agents being used.
- Do not rely solely on Tracer for thrips control as this can lead to WFT resistance. Use Tracer within an IPM programme and follow Resistance Management Guidelines, taking care not to exceed the maximum four applications per crop per year. Time use of Tracer carefully and if appropriate, reserve an application for the end of the season to reduce overwintering WFT. If Tracer gives poor control of thrips, contact your consultant or the supplier so that your thrips population can be tested for possible resistance.

Science Section

Introduction

Everbearer strawberries provide 50% of the total strawberry yield on a typical farm producing for supermarkets. Over the last three years there have been significant crop losses due to thrips damage (such as fruit russeting) on some farms. Main-season varieties grown under glass are also at risk.

From six sites sampled by East Malling Research (EMR) in 2003 (SF 60), the widespread flower thrips species *Thrips major* (rose or rubus thrips), and *T. tabaci* (onion thrips) were most abundant, with western flower thrips (WFT), *Frankliniella occidentalis,* found only at one site (Fitzgerald, 2004). In July 2005, ADAS confirmed WFT to be present at each of four sites in England and Scotland (Bennison, unpublished data). At one site, WFT was the only species found and at the remaining sites it was present with a mixture of other species, including *T. major*, *T. fuscipennis* (also known as rose thrips), *T. tabaci* and *T. vulgatissimus* (no common name). WFT appears to be becoming more prevalent on everbearer strawberries grown under plastic polytunnel protection; one reason for this could be the higher temperatures found under protection compared with the field situation.

Some UK growers of protected strawberry are using Integrated Pest Management (IPM) programmes including very limited pesticide use, basing biological control of thrips mainly on the predatory mite *Neoseiulus (Amblyseius) cucumeris*, sometimes supplemented with spot releases of the predatory mite *Hypoaspis* sp. and/or the predatory bug *Orius* sp. This strategy is successful under glass but is less reliable in tunnel-grown strawberries, although naturally-occurring *Orius* spp. can give useful control if allowed to establish. Some pesticides used against other pests, e.g. capsids, and against diseases can interrupt biological control of thrips in tunnel-grown crops.

Many other growers are reliant on pesticides alone for thrips control. Until recently growers have used the pyrethroid bifenthrin (Talstar/Starion) against thrips and some other strawberry pests. This pesticide kills all thrips species except WFT (which is resistant to pyrethroids and many other pesticides); this could contribute to the predominance of WFT at some sites. Talstar is also lethal to all released and naturally-occurring beneficial invertebrates such as predatory mites (*Amblyseius* spp.) and predatory bugs (*Orius* spp.). Thrips surviving Talstar will therefore not be kept in check by natural enemies.

In June 2005, Tracer (spinosad) was given specific off-label approval (SOLA) for use on protected strawberry and during 2008, the product gained on-label approval for use on protected strawberry. Tracer was shown to be effective against WFT in bioassays and in a field experiment undertaken by EMR in SF 60 (Fitzgerald, 2004). Although Tracer is currently the most effective pesticide against WFT, resistance has already been documented in other countries (Herron & James, 2005; Loughner *et al.*, 2005). Resistance to Tracer was confirmed in one WFT population on a UK everbearer strawberry crop in 2008. As part of a resistance management strategy in the UK, Tracer is currently limited to four applications per structure per year. Therefore it is essential that it is used within an integrated strategy rather than as the only means of control.

The biology of WFT in strawberry crops is not fully understood. This includes uncertainty about the main source of the pest, which could include brought-in infested strawberry plants, wild or other cultivated host plants from which adults migrate into the strawberry crop, or overwintering sites in the field. There is evidence that WFT may survive mild winters by sheltering in soil or plant debris (McDonald *et al*., 1997). Some strawberry growers have observed higher WFT numbers in the second year pick of everbearers, indicating that WFT might overwinter on site and present a potential threat in the following season.

Another key aspect of WFT biology is the pupation site during the breeding season in the host crop. In research in a Defra-funded project (HH3102TPC), Bennison (2006) confirmed that on chrysanthemum and cucumber, most WFT pupate in the soil or substrate beneath the plants (Bennison *et al*., 2004). Confirmation of the pupation site of WFT within strawberry plantings (e.g. on the plant, in the soil around the plant or in the soil, straw or leaf litter in the alleys) could improve control methods by guiding application of certain biocontrol agents to specific areas.

Some biocontrol agents, such as the predatory mites, *Hypoaspis* spp. and the entomopathogenic nematode, *Steinernema feltiae* (e.g. 'Nemasys'), will reach WFT larvae and pupae in the soil, whereas pesticides will not. In a review of potential biocontrol strategies in strawberry and raspberry by EMR (SF 66), the possibility of using a soil-dwelling predatory mite, *Hypoaspis miles*, together with the already widely used plant-inhabiting mite *Neoseiulus (Amblyseius) cucumeris* to enhance biocontrol of thrips in strawberry was highlighted (Fitzgerald *et al*., 2005). Both *H. miles* and *H. aculeifer* were shown in Defra-funded research project (HH3102TPC) to feed on late second stage WFT larvae which drop to the ground to pupate, and also on the pupal stages (Bennison *et al*., 2002), whereas *A. cucumeris* feed only on the first stage larvae on the plants. 'Nemasys' is currently successfully being used by some chrysanthemum growers to control WFT. The nematodes are compatible with most pesticides and biological control agents. Research in Defra project HH3102TPC confirmed that foliar sprays of ‘Nemasys F’ can reduce WFT populations on chrysanthemums, and indicated that the main life stages killed may be those in the soil as, even when applied as foliar sprays, nematodes do reach and persist in the growing medium (Bennison, 2006). EMR results from SF 60 (Fitzgerald, 2004) and trials done by Becker Underwood Ltd (the supplier of ‘Nemasys’) have shown that foliar sprays of the nematodes can give some control of WFT on strawberry. Growers need to know how the nematodes might be used successfully and economically for WFT control on strawberry.

Overall aim of project

The overall aim was to improve integrated control of WFT on tunnel-grown everbearer strawberry. This was achieved by determining key aspects of WFT biology and behaviour on strawberry to enable integrated control strategies to be more effectively and economically targeted against the pest, and by testing different combinations of biological control agents within an integrated control strategy.

Detailed project objectives

1. Identify the extent of WFT occurrence in everbearer strawberry on a wide geographical spread of strawberry farms in England and Scotland and identify factors affecting thrips incidence and success of integrated control strategies (ADAS).
2. Determine the pupation sites of WFT during the summer period in everbearer strawberry fields and the implications for control strategies (EMR).
3. Determine whether WFT overwinters in everbearer strawberry crops and if so, identify when and from where they emerge (EMR and ADAS).
4. Using knowledge gained from objectives 1-3, design and test integrated control strategies for WFT (ADAS and EMR).

Objective 1

Identify the extent of WFT occurrence in everbearer strawberry on a wide geographical spread of strawberry farms in England and Scotland and identify factors affecting thrips incidence and success of integrated control strategies (ADAS)

Work in this objective was completed in year 1 and is described fully in the first annual report (Bennison & Fitzgerald, 2007). The main conclusions were:

- In 2006, WFT was confirmed as being widespread throughout England, on 8 of the 18 farms sampled. One of the WFT-infested crops was under glass and the others were field-grown everbearers, most of which were tunnelled at the time flowers were sampled.
- WFT was not found in samples from Scotland in 2006 but they were found in consultancy samples sent to ADAS from Scotland in 2005.
- WFT was more of a problem in fields with a history of WFT and where plants or beds were kept from one year to the next.
- Case studies confirmed that *A. cucumeris* had provided good control of WFT in glasshouse crops, but had given unreliable control in everbearer crops grown in the field or in Spanish tunnels. On most everbearer crops, the predators are likely to have been released too late and at inadequate rates and frequency for effective thrips control.
- Pesticides used for thrips control (before Tracer was available) and for control of other pests and diseases on everbearers would have had adverse effects on *A. cucumeris*.

Objective 2

Determine the pupation sites of WFT during the summer period in everbearer strawberry fields and the implications for control strategies (EMR).

Work in this objective was completed in year 1 and is described fully in the first annual report (Bennison & Fitzgerald, 2007). The main conclusions were:

- In experiments in the field and in the glasshouse, the majority of WFT pupated in the soil directly under the strawberry plants and in the soil close to the plants within the raised beds or grow bags. Only low numbers of WFT pupated on the plants or in the straw or soil under the straw in the alleys. This pupation behaviour may give opportunities for the use of biological control strategies against WFT pupae in the soil.

Objective 3

Determine whether WFT overwinters in everbearer strawberry crops and if so, identify when and from where they emerge (EMR and ADAS)

Work in this objective was completed in years 1 and 2 and was described fully in the first and second annual reports (Bennison & Fitzgerald, 2007 and 2008). The main conclusions were:

- In the EMR experiment in year 1, WFT released to everbearer plants in the field at EMR in September 2006 successfully overwintered in the crop. WFT adults were found on sticky traps between 16 March and 4 May 2007. This confirmed that WFT had survived the mild winter of 2006/07 but the overwintering location in the crop was unknown.

- In the ADAS experiment in year 2, naturally occurring WFT survived the mild winter of 2007/08 in a commercial field of everbearer strawberries in Herefordshire, where WFT had been a problem during 2007. The first WFT adults were detected on 14 March 2008, in the flowers of dandelion and groundsel growing in the crop, and in the crowns and old foliage of overwintered strawberry plants.
- Field emergence traps at the Herefordshire site set up on 19 March 2008 demonstrated that WFT adults emerged from overwintered strawberry plants, soil in the planting hole, plant debris on the polythene covering the beds, straw in the alleys and soil under the straw, between 19 March and 1 May.
- Thus, keeping everbearer strawberry plants and/or beds from one year to the next allows WFT to overwinter in the crop and to infest the plants the following spring.
- IPM programmes for WFT control in overwintered everbearer crops in England ideally need to be in place by mid-March and before the crop is in flower. This is much earlier than done in commercial practice.

Objective 4

Using knowledge gained from objectives 1-3, design and test integrated control strategies for WFT (ADAS and EMR)

Work in this objective was completed in years 2 and 3. The year 2 work was described fully in the second annual report (Bennison & Fitzgerald, 2008). The main conclusions in year 2 were:

- The effectiveness of predatory mites against WFT was tested in field experiments at two sites; on a commercial farm in Herefordshire, where WFT had been a problem on everbearers in recent years (ADAS), and at EMR in Kent (EMR), where WFT was released as it did not occur naturally. Both experiments included releases of *Amblyseius cucumeris*, a predator of young thrips larvae. The EMR experiment also included releases of *Hypoaspis miles*, a predator of ground-dwelling invertebrates including WFT pupae and WFT larvae that drop to the ground to pupate.
- At the ADAS site, 3 releases of *A. cucumeris* sprinkled onto the plants at either 100 or 150 per m^2 on 3 and 17 May and 7 June did not lead to successful establishment of the predators and thus gave no control of WFT. Poor predator establishment was probably due in part to adverse weather conditions, ranging from hot and dry, cold and windy, to severe floods (the crop was not tunnelled until just before the final assessment on 5 July).
- At EMR, 3 releases of *A. cucumeris* sprinkled onto the plants at 200 per m^2 on 24 August

and 5 and 21 September did not lead to predator establishment until the final assessment on 4 October and no control of WFT was given. An application of Lorsban (chlorpyrifos) to the experimental plots to reduce numbers of other thrips species on 7 August may have prevented earlier establishment of the predator (chlorpyrifos is classed as 'harmful' to *A. cucumeris* for 6-8 weeks). *H. miles* released at 200 per m^2 on the same 3 release dates were not found in soil samples, probably due to the soil around the plants being dry (*H. miles* prefers to live in damp soil). Thus the effect of *H. miles* on WFT numbers could not be determined.

Full report of year 3 work in Objective 4 (ADAS and EMR)

As *A. cucumeris* did not establish in the 2007 experiments, two experiments in 2008 tested higher numbers and earlier releases of the predator. *A. cucumeris* 'slow release' sachets that are used successfully in glasshouse strawberries and in other protected crops were tested at one sachet per 2 m length of bed on two occasions. The sachet formulation is a breeding-release pack in which food (prey mites) and shelter are provided; the predatory mites leave the sachet over a 6-week period. As food is provided in the sachets, they can be placed in the crop before thrips and/or pollen are available for the *A. cucumeris* to feed on.

The *A. cucumeris* sachets were tested alone or in combination with the 'loose' predatory mites sprinkled onto the plants at 200 per m^2 on two release dates. Use of *A. cucumeris* against WFT larvae on the plants was tested alone or in combination with ground-dwelling biological control agents against WFT pupae in the ground (since it had been shown in year 1 that most WFT pupate in the ground in everbearer crops). The ADAS experiment on a commercial farm in Herefordshire included the predatory staphylinid beetle *Atheta coriaria*, which was shown in HDC project PC 261 to reduce numbers of WFT in potted ornamentals when introduced as a grower 'DIY' rearing-release system. The experiment at EMR in Kent included soil applications of the entomopathogenic nematode *Steinernema feltiae*. *S. feltiae* are used successfully for WFT control on commercial chrysanthemum crops but effective methods for using them for WFT control in strawberries have not yet been developed.

ADAS experiment: Materials and Methods

Objective: To determine whether *A. cucumeris* can establish on everbearer strawberry and reduce numbers of WFT, and to determine whether control of WFT can be improved by using a ground-dwelling predatory beetle (*Atheta coriaria*) against WFT pupae in the ground.

Site: A commercial farm in Herefordshire (the same site, but not the same field, as that used for the ADAS experiment in 2007 and for the overwintering studies in 2007/08).

Variety: Jubilee

Planting date: Planted in March 2008, using beds that had been used for growing everbearers in 2007.

Treatment of crop with spinosad before experiment set-up

The experiment was set up on 15 May 2008, as soon as possible after the grower had removed the fleece covering the crop and when the risk of frost was over (sub-zero temperatures had occurred in early May 2008). The crop was assessed for WFT the week before the experiment was set up, when the plants were still small and not yet touching, and when some but not all the plants had an open flower. As WFT were confirmed in some of the flowers, the grower was advised to apply spinosad (Tracer) before the experiment was set up, as experience has shown that *Amblyseius cucumeris* gives more effective control of WFT if applied preventively rather than curatively. Tracer was applied on 13 May and the experiment was set up two days later, to allow the spinosad time to kill WFT.

Experiment treatments

1. Untreated control

2. *Amblyseius cucumeris* in sachets, one sachet per 2m length of bed, repeated after 2 weeks (15 and 29 May).

3. *Amblyseius cucumeris* in sachets as in 2, plus 'loose' product at 200 per m^2 on 15 and 29 May.

4. *Amblyseius cucumeris* as in 3, plus *Atheta coriaria* at one rearing-release box per 8m length of bed.

Experiment layout

Six adjacent Spanish tunnels were used for the experiment. The tunnels were already covered with polythene at the time of set-up. A separate tunnel was used for each of treatments 1-4. Two additional tunnels were used as 'buffer' tunnels each side of the tunnel used for treatment 4, as a precaution against *A. coriaria* adults flying between tunnels.

Plants in these buffer tunnels were not assessed during the experiment but were treated with 'loose' *A. cucumeris* as included in treatment 3, to protect the crop from WFT.

There were five replicate plots in each treatment tunnel, running down the length of the tunnel. Each plot was eight metres long and 7.5 metres wide (i.e the whole width of the tunnel). Each tunnel (and plot) had five parallel beds of plants but only the middle bed and one or two (as required) of the adjacent beds were used for sampling flowers and fruit. Four metres at each end of the run of five plots in each tunnel were used as 'guard plots' i.e. they were treated with the appropriate treatment for that tunnel, but were not used for sampling. The guard plots were to avoid any potential plot edge effects. There were 5.5 plants per metre length of bed (in two rows per bed), thus each sampling bed contained 44 plants and each plot contained 220 plants.

Treatment methods

A. cucumeris in sachets and in the 'loose' formulation were supplied by BCP. The *A. cucumeris* in sachets were placed vertically in the plant canopy, with the exit hole at the top. The base of each sachet was placed so that it just touched the soil in the planting hole, in order to keep the humidity in the sachets high and thus favour the survival of both the prey mites and the predatory mites in the sachets. On the first treatment date on 15 May, each sachet was stapled to a white plastic plant label pushed into the soil, making sure that the exit hole was not covered. On the second treatment date on 29 May, the plants were bigger than on the first treatment date, therefore each sachet was secured to the plants using the integral sachet hook.

The 'loose' *A. cucumeris* was supplied in tubs of bran carrier, with 50,000 predators per tub. Predator viability in each tub was checked in the laboratory on the day of receipt, by emptying sub-samples of the carrier into a petri dish and examining it under a low-power microscope. To facilitate even spread of predators over plants in the experimental plots, the predators with carrier were divided (by weight) into smaller plastic screw-top tubes, each tube containing the correct release rate for each of the plots to be treated.

Atheta coriaria were reared at ADAS Boxworth in 25 plastic rearing-release boxes, using the method developed by ADAS in HDC-funded project PC 239 (Bennison, 2007). Each box contained 1.5 litres of damp substrate (coir compost and vermiculite), to which 60 adult *A. coriaria* were added. The beetles were fed with a commercial turkey feed and the boxes were maintained at 25°C in a controlled temperature room for four weeks before the field experiment was set up. Numbers of beetle adults and larvae per box were estimated in three representative boxes, in 12 x 30ml sub-samples of the substrate taken the day before the experiment was set up. Five boxes per plot (one in the middle of each bed) were placed in the tunnel used for treatment 4. The box lids were covered in aluminium foil to reflect the sun, and the insect-proof mesh was removed from the ventilation holes in the lids to allow the beetles to come out of their own accord when positioned in the plots. Each box was placed onto the bed, after cutting a flap in the black plastic covering the bed, so that the box sat on the soil, thus allowing uptake of moisture through the holes (plugged with cotton wool) in the base of the boxes. Each box was secured with a piece of wire, pushed into the bed at each side of the box. Care was taken not to pierce the irrigation pipe running down the middle of each bed under the polythene.

On each of the three assessment dates after experiment set-up, the beetles in each box were fed with turkey feed by opening the lid and sprinkling the feed over the surface of the substrate. The substrate was dampened with water if necessary, using a plant mister. After adding the food (and water if necessary) it was incorporated into the substrate by mixing gently. Each box was then secured back into position on the bed, using the wire stake.

Control of other pests and diseases

Phytoseiulus persimilis were released to all plants in the experimental tunnels on 21 May, the week after spider mite damage was first detected by ADAS on goat willows in the tunnels. *P. persimilis* releases were repeated a week later on 29 May. BCP 'sure shot' system was used, at 10 predators per m length of bed (one shot per metre). The grower was asked to liase with ADAS before use of any pesticide needed for other pests such as aphids, strawberry blossom weevil or capsids. If a pesticide or fungicide was needed, one least harmful to *A. cucumeris*, *P. persimilis* and *A. coriaria* was used. Records of pesticides used on the experimental plants were checked with the grower at the end of the experiment.

Assessments

WFT and predators in flowers: On the day the experiment was set up on 15 May and on each of the subsequent three assessment dates (29 May, 12 June and 7 July), samples of10 flowers were taken from each experimental plot just before any predator releases. Fully open flowers were selected and placed into screw-top tubes containing 70% alcohol. Care was taken to include the calyx of each flower and to place each flower quickly into the tube to avoid any thrips escaping. At ADAS Boxworth, each flower was dissected in 70% alcohol under a binocular microscope and the following records were made:

- Numbers of thrips adults and larvae per flower.
- 20 randomly selected thrips adults from across the experiment area were identified by mounting them in Heinz medium on glass slides and examining them under a high power microscope. Numbers of WFT were recorded and any other thrips species were recorded but not identified to species.
- Numbers of predatory mites per flower.
- Any predatory mites were identified to species by mounting them in Heinz medium on glass slides and examining them under a high power microscope.

WFT damage to fruit: On the final assessment date on 17 July, 20 ripe fruits per plot were assessed for WFT damage. The following records were made:

- Numbers of 'clean' fruit i.e. free from thrips damage.
- Numbers of fruit with 'slight' bronzing (one patch of bronzing around 1-3 seeds).
- Numbers of fruit with 'moderate' bronzing (up to 50% of fruit damaged).
- Numbers of fruit with 'severe' bronzing (more than 50% fruit damaged).
- Numbers of fruit with slight, moderate or severe brown 'tracking' (scarring) under the calyx.

Atheta coriaria bait pots: Dispersal of *A. coriaria* from the rearing-release boxes was monitored in the tunnel where they were used and in the untreated tunnel, using 'bait pots', a method developed in PC 239. Two bait pots were used in the middle bed of each plot in the two tunnels, each one being two metres away from the release box. The bait pots were 8 cm diameter plastic plant pots, filled with damp compost with a 'pinch' of turkey feed incorporated. Each pot was sunk into the soil in the bed, positioned after a flap was cut in the black polythene and folded back, so that the rims of the pots were level with the soil, thus allowing beetle access.

On each of two consecutive assessment dates following experiment set-up (29 May and 12 June), the compost in each bait pot was emptied into a plastic sandwich box and any *A. coriaria* adults and larvae were recorded. The dampness of the compost (damp or dry) was recorded. A 'pinch' of turkey feed was added to the compost in the sandwich box, then the compost (and any beetles) were returned to each bait pot. The bait pot was watered if necessary so that the compost remained damp.

Temperature records: Soil and crop canopy temperatures were recorded using two 'Tinytalk' dataloggers in the soil in the tunnel used for treatment 4, and using one datalogger in the crop canopy in each of the tunnels used for treatments 2 and 3. The dataloggers were positioned in a middle plot in each of these tunnels. The dataloggers buried in the soil were placed so that the sensor was 3mm below soil surface.

Data analysis

Mean numbers of WFT (adults and larvae) and *Amblyseius cucumeris* per flower on each assessment date, and percentage fruit with the selected categories of thrips damage on the final assessment date, were subjected to analysis of variance (ANOVA).

ADAS experiment: Results and Discussion

Thrips species

The thrips species recorded in the flowers were mainly *Frankliniella occidentalis* (WFT) throughout the experimental period (Table 1).

Table 1. Proportion of WFT in thrips flower samples on the four assessment dates

Date	**% WFT**
15 May	93%
29 May	86%
12 June	73%
7 July	80%

Numbers of WFT per flower

Mean numbers of WFT adults plus larvae per flower are given in Table 2. It was anticipated that WFT would overwinter in the experimental tunnels, as the beds had been retained from the previous year's (2007) crop. Thus it was intended to set up the experiment and to release the first *A. cucumeris* in sachets as soon as possible after planting the crop in 2008, when the risk of frost was over, to allow the predators to establish before WFT were present. However, *A. cucumeris* could not be released until mid-May as night frosts were still occurring until then and the crop was covered in fleece to protect the plants. WFT were confirmed in the first few flowers a few days after the fleece was removed from the crop. This indicated that as in the 2007 experiment on the same farm, WFT had overwintered in the beds and emerged in the spring to infest the new plants. Thus the grower was advised to reduce the numbers of WFT by using spinosad (Tracer) on 13 May, before the experiment was set up. Tracer was partially effective but low numbers of WFT were still present in the flowers two days later on 15 May, when the experiment was set up and the first *A. cucumeris* were released (Table 2 and Figure 1). The 'loose' product for *A. cucumeris* was released to the plants on the same two dates as the sachets of predators, as some of the plants were already in flower and WFT were already present, thus both pollen and thrips were available as food for the 'loose' predators.

Although mean numbers of WFT adults and larvae were significantly higher in the untreated tunnel (0.2 per flower) than in the other treatment tunnels (up to 0.06 per flower) on the set-up date on 15 May (Table 2), WFT numbers were very low. Numbers remained low and were statistically similar in untreated and all other treatment tunnels on the second and third assessments on 29 May and 12 June (Table 2).

On the fourth and final WFT assessment on 7 July, mean numbers of WFT adults and larvae had increased to three per flower in the untreated tunnel (Table 2 and Figure 1). Significantly fewer WFT adults and larvae per flower were found in the tunnels treated with each of the biological control treatments (Table 2 and Figure1). There were no significant differences between mean numbers of WFT adults and larvae per flower in plots treated with *A. cucumeris* sachets, *A. cucumeris* sachets plus 'loose' product, or *A. cucumeris* sachets plus 'loose' product plus *Atheta coriaria* (means of 1.7, 0.9 and 0.9 per flower respectively, Table 2 and Figure 1). This result indicated that there was no benefit in sprinkling the 'loose' *A. cucumeris* onto the plants in addition to using the sachets, nor in using the rearing-release boxes of *A. coriaria*.

The increases in numbers of WFT per flower in all tunnels in early July could partly have been due to the breeding of the WFT in the experimental tunnels. However, the heavy WFT pressure from immediately adjacent strawberry crops, where biological control measures were not being used against thrips, could also have contributed to the WFT population in the experimental tunnels. *A. cucumeris* feed only on young thrips larvae; they do not eat thrips adults, including any flying in from neighbouring crops. Thus, although *A. cucumeris* led to significantly lower numbers of WFT in the three treated tunnels than in the untreated tunnel, thrips numbers in the treated tunnels might have been lower if the surrounding crops had been treated with a biological control programme for thrips. The grower was advised to apply Tracer to the experimental tunnels after the final WFT counts had been done on 7 July. Tracer was applied on 11 July and repeated one week later, according to label recommendations.

Table 2. Mean numbers of WFT adults and larvae per flower on 15 May (pre-release of

A. cucumeris), 29 May, 12 June and 7 July. * significantly less than in untreated controls, *P*<0.05.

Date	Untreated control	*A. cucumeris* sachets on 15 & 29 May	*A. cucumeris* sachets plus 'loose' product on 15 & 29 May	*A. cucumeris* sachets plus 'loose' product on 15 & 29 May plus *A. coriaria*
15 May	0.2	0.02*	0.06*	0.06*
29 May	0.22	0.1	0.08	0.1
12 June	0.3	0.4	0.1	0.22
7 July	2.98	1.70*	0.86*	0.94*

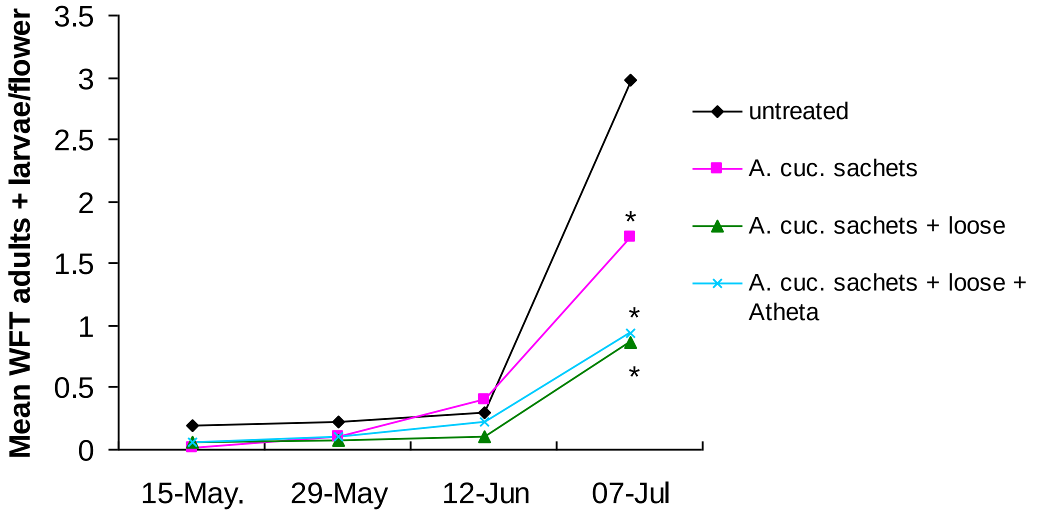

Figure 1. Mean numbers of WFT adults plus larvae per flower sampled on 15 May (pre-release of *A. cucumeris*), 29 May, 12 June and 7 July. * significantly more than in untreated control, *P*<0.05. *A. cucumeris* had been released on 15 and 29 May.

WFT damage to fruit

On the fruit assessment date on 17 July, significantly less WFT bronzing occurred in the three treated tunnels (76-92% undamaged fruit) than in the untreated control tunnel (56% undamaged fruit, Figure 2). There were no significant differences in percentage undamaged fruit between the three biological control treatments. These results reflect the numbers of WFT per flower in untreated and treated tunnels, i.e. *A. cucumeris* released in sachets led to a reduction in numbers of WFT and to an increase in percentage undamaged fruit, and these effects were not enhanced by additional releases of 'loose' *A. cucumeris* or by using the rearing-release system for *A. coriaria*.

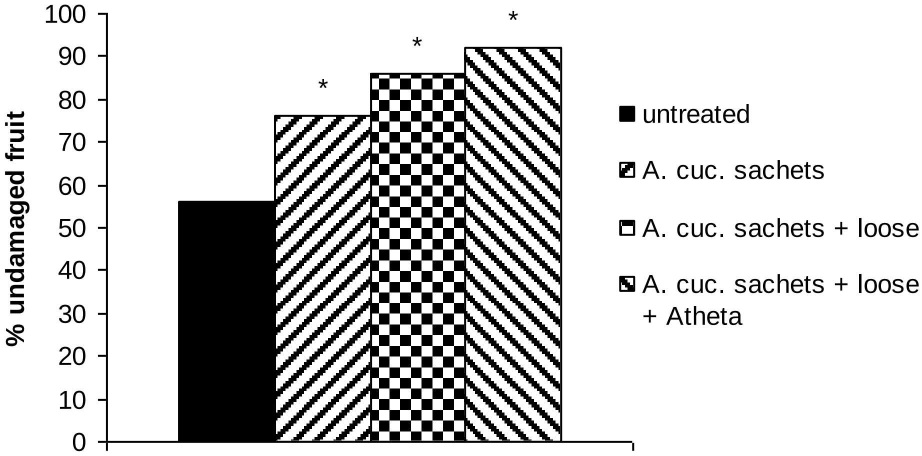

Figure 2. Mean % undamaged fruit sampled on 17 July. * significantly more than in untreated control, $P<0.05$. *A. cucumeris* had been released on 15 and 29 May.

Most of the fruit damage was slight (one patch of bronzing around 1-3 seeds). In the untreated control tunnel, 12% of the fruit was severely damaged (over 50% of the fruit surface bronzed) and in treated tunnels, less than 5% of the fruit had severe damage (Figure 3). However, these differences were not statistically significant. On the same date as the fruit damage assessment, the grower graded out approximately 5% of fruit picked from the experimental tunnels. This confirmed that the experimental assessments were consistent with those used in commercial practice. During July 2008, the retail demand for strawberries was high as there was a market shortage. In a season when plenty of strawberries are available, quality standards are higher, leading to fruit with any visible WFT damage being downgraded.

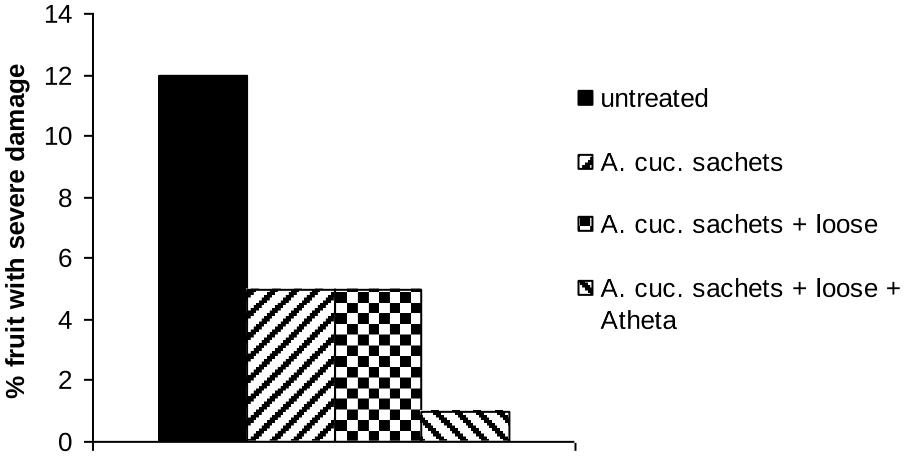

Figure 3. Mean % fruit with severe WFT damage, sampled on 17 July. No significant differences between treatments. *A. cucumeris* had been released on 15 and 29 May.
Numbers and species of predatory mites per flower

All predatory mites found in the flower samples were mounted on microscope slides and examined under a high power microscope for identification to species. On the experiment set-up date on 15 May, immediately before release of *A. cucumeris*, no predatory mites were detected in the flowers. On the three subsequent assessment dates, both *A. cucumeris* and *A. californicus* were confirmed in the flowers (Tables 3 and 4 and Figures 4 and 5). Some predatory mites could not be identified to species (Table 5), due to diagnostic features being obscured in the specimens mounted on slides. Thus, numbers of confirmed *A. cucumeris* and *A. californicus* are likely to be underestimates.

Numbers of A. cucumeris: Mean numbers of confirmed *A. cucumeris* per flower are shown in Table 3 and Figure 4. Only one individual was recorded in flowers in the untreated tunnel, on 29 May. The results indicated that there was very little migration of the *A. cucumeris* released in the other tunnels to the untreated tunnel.

A. cucumeris had begun to establish in the flowers in treated tunnels by the second release date on 29 May and establishment had improved by 12 June, with a mean of 0.2 per flower in the three treated tunnels (Table 3). On the final flower assessment date on 7 July, there was a mean of 0.3 *A. cucumeris* per flower in the three treated tunnels, which was significantly higher than in the untreated control tunnel (where no *A. cucumeris* were found on either 12 June or 7 July). There were no significant differences in numbers of *A. cucumeris* per flower in the three treatment tunnels, which indicated that sprinkling the 'loose' product on the plants in addition to using the slow-release sachets on the plants did not lead to higher numbers of predators in flowers. This result reflects the similar WFT control given by the different *A. cucumeris* treatments, i.e. there was no benefit in sprinkling the 'loose' *A. cucumeris* onto the plants in addition to using the sachets.

Table 3. Mean numbers of *A. cucumeris* per flower sampled on 15 May (pre-release of *A. cucumeris*), 29 May, 12 June and 7 July. *A. cucumeris* had been released on 15 and 29 May. * significantly more than in untreated control.

Date	**Untreated control**	***A. cucumeris* sachets on 15 & 29 May**	***A. cucumeris* sachets plus 'loose' product on 15 & 29 May**	***A. cucumeris* sachets plus 'loose' product on 15 & 29 May plus *A. coriaria***
15 May	0	0	0	0
29 May	0.02	0	0.02	0.02
12 June	0	0.24	0.28	0.18
7 July	0	0.26*	0.3*	0.36*

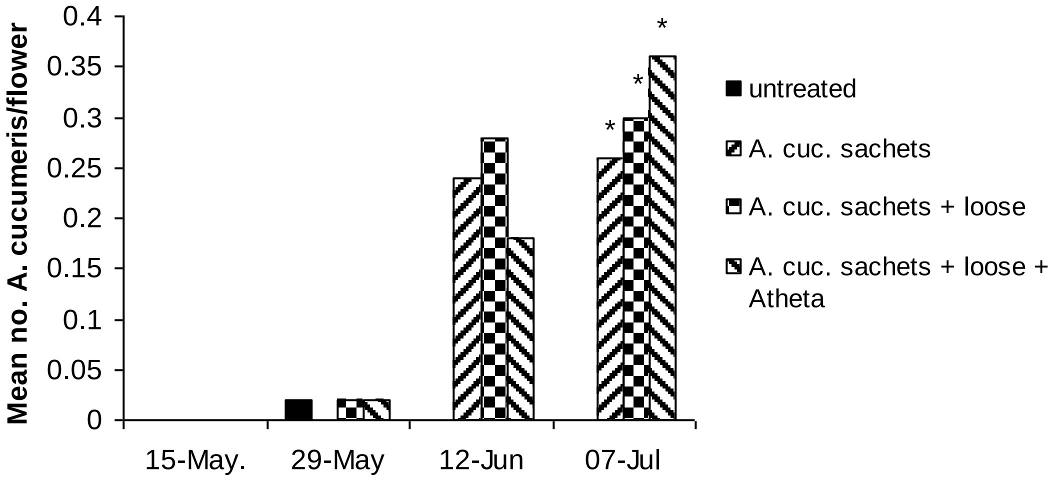

Figure 4. Mean numbers of *A. cucumeris* per flower sampled on 15 May (pre-release of *A. cucumeris*), 29 May, 12 June and 7 July. *A. cucumeris* had been released on 15 and 29 May. * significantly more than in untreated control.

Numbers of A. californicus: Mean numbers of confirmed *A. californicus* per flower are shown in Table 4 and Figure 5. *A. californicus* were detected in flowers from 29 May and had established in all the experimental tunnels by 7 July, including the tunnel untreated with *A. cucumeris*. Mean numbers of *A. californicus* per flower reached up to 1.6 per flower on 7 July (Table 4 and Figure 5), and there were no significant differences in numbers between any of the treatments. As in the year 2 experiment done on the same farm (but not the same field), *A. californicus* were naturally occurring as they had not been released in the experimental plots or in the surrounding field. *A. californicus* are commercially available as spider mite predators, but the UK licence currently limits their release only to fully protected structures (i.e. not Spanish tunnels). In addition to feeding on spider mites, they also feed on pollen and on other invertebrates including thrips larvae, although they are not regarded as good thrips predators (Croft *et al*, 1998). As numbers of *A. californicus* were statistically similar in all treatment tunnels in this experiment, there is no evidence that they contributed to WFT control. Two-spotted spider mites had infested plants in the experimental tunnels in mid-May, but were well-controlled by *Phytoseiulus persimilis* released at the first sign of damage and repeated one weeks later. It is possible that *A. californicus* also contributed to the control of spider mites, but as in the year 2 experiment, the *A. californicus* could also have fed and established on pollen in the flowers.

Table 4. Mean numbers of *A. californicus* per flower sampled on 15 May (pre-release of *A. cucumeris*), 29 May, 12 June and 7 July. *A. cucumeris* had been released on 15 and 29 May. No significant differences between treatments.

Date	**Untreated control**	***A. cucumeris* sachets on 15 & 29 May**	***A. cucumeris* sachets plus 'loose' product on 15 & 29 May**	***A. cucumeris* sachets plus 'loose' product on 15 & 29 May plus *A. coriaria***
15 May	0	0	0	0
29 May	0.04	0	0	0.04
12 June	0.28	0.02	0.3	0.08
7 July	0.4	0.2	0.8	1.58

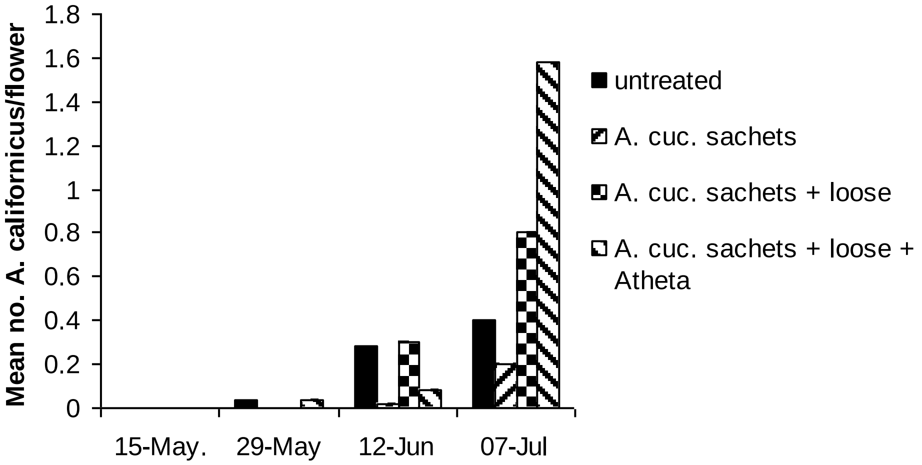

Figure 5. Mean numbers of *A. californicus* per flower sampled on 15 May (pre-release of *A. cucumeris*), 29 May, 12 June and 7 July. *A. cucumeris* had been released on 15 and 29 May. No significant differences between treatments.

Numbers of unidentifiable predatory mites: Mean numbers of unconfirmed species of predatory mites are shown in Table 5.

Table 5. Mean numbers of unidentifiable predatory mites per flower sampled on 15 May (pre-release of *A. cucumeris*), 29 May, 12 June and 7 July. *A. cucumeris* had been released on 15 and 29 May

Date	**Untreated control**	***A. cucumeris* sachets on 15 & 29 May**	***A. cucumeris* sachets plus 'loose' product on 15 & 29 May**	***A. cucumeris* sachets plus 'loose' product on 15 & 29 May plus *A. coriaria***
15 May	0	0	0	0
29 May	0.08	0.04	0.06	0.06
12 June	0	0	0.02	0.08
7 July	0	0.06	0.16	0.22

Atheta coriaria rearing-release boxes and bait pots

There was a mean of 1911 *A. coriaria* adults and larvae per rearing-release box when estimated on 14 May, the day before placing them in the tunnel used for treatment 4. At the end of the experiment after collection from the tunnel on 17 July, there was a mean of only 51 adults and larvae per box. On the 29 May assessment, the substrate in most of the rearing-release boxes was observed to be very dry despite using the wicking system designed to keep the substrate damp. After this date, the grower was asked to hand-water the boxes from above and this had improved the maintenance of the substrate dampness when assessed on 12 June. Experience in HDC project PC 239 has shown that keeping the rearing substrate damp is critical to allow successful breeding and survival of *A. coriaria* (Bennison, 2007). The dry substrate in the boxes for the early part of this experiment will have led to reduced beetle breeding and survival, and thus to low numbers of adults leaving the boxes and dispersing in the strawberry crop. Although the wicking system for the rearing-release boxes has been shown to be effective in glasshouse production of pot and bedding plants and pot herbs (Bennison, 2008), an improved method of keeping the substrate damp when used in strawberry beds would need to be tested in any further work on evaluating their potential in strawberries.

Mean numbers of *A. coriaria* adults and larvae in the bait pots on 29 May and 12 June are shown in Table 6. Only one staphylinid beetle resembling *A. coriaria* was found in the untreated tunnel, on 29 May (a mean of 0.1 per bait pot). This individual could have migrated from the tunnel where rearing-release boxes had been used, or it could have occurred naturally, as *A. coriaria* is native to the UK. *A. coriaria* adults and larvae were found in the bait pots in the tunnel where rearing-release boxes of the predators had been used, but in very low numbers (Table 6). The compost in the bait pots was very dry when the assessments were made, despite them having been sunk in the soil of the beds so that the rims of the pots were level with the soil. The beds were irrigated with drip irrigation lines sunk in the soil but these did not dampen the soil sufficiently to keep the compost in the bait pots damp. As in the rearing-release boxes, the dry substrate in the bait pots would not have been favourable for *A. coriaria* colonisation, breeding and survival.

Table 6. Mean numbers of *A. coriaria* adults and larvae per bait pot in the tunnel treated with *A. coriaria* rearing-release boxes and in the untreated tunnel on 29 May and 12 June (rearing-release boxes were set up on 15 May).

Date	Treatment	Mean no. *A. coriaria* adults per bait pot	Mean no. *A. coriaria* larvae per bait pot
29 May	*A. cucumeris* sachets plus 'loose' product plus *A. coriaria* boxes	0.3	0.4
	Untreated	0.1	0
12 June	*A. cucumeris* sachets plus 'loose' product plus *A. coriaria* boxes	0.1	1.2
	Untreated	0	0

Temperature records

The two replicate dataloggers recording temperatures 3mm below the soil surface in the tunnel used for treatment 4 (which included using the rearing-release boxes for *A. coriaria*) gave slightly different readings and this commonly occurs, hence the use of the replicate dataloggers. Minimum temperatures were similar but the two dataloggers recorded maximum temperatures of 29.1°C and 34.3°C respectively. Similarly, the two replicate dataloggers recording temperatures in the crop canopy in the tunnel used for treatments 2 and 3 (*A. cucumeris* in sachets alone or in combination with the 'loose' product) gave slightly different readings. As with the soil dataloggers, minimum temperatures were similar but the two dataloggers recorded maximum temperatures of 36.8°C and 33.2°C respectively. The temperatures recorded by the soil and crop canopy dataloggers reading the highest maximum temperatures are shown in Figures 6 and 7, to show the most extreme conditions that could have been experienced by thrips and biological control agents in the soil or crop canopy environments.

Mean temperatures during the experiment 3mm below the surface of the soil are shown in Figure 6. Mean daily minimum, maximum and mean soil temperatures ranged from 12.4-20°C, 15.1-34.3°C and 14-23.2°C respectively. WFT are known to pupate successfully at temperatures as low as 12°C (Lacasa, 1990) and at fluctuating temperatures between 18.5°C and 36°C (Robb, 1989). *A. coriaria* are known to breed successfully at temperatures between 15°C and 32.2°C (Miller & Williams, 1983) and to survive but not breed at 10°C (Bennison, 2009). No information is yet available on the effect of temperatures reaching 34.3°C on *A. coriaria* breeding and survival, but the beetles survived compost temperatures of up to 33°C in rearing-release boxes used in commercial potted herbs (Bennison, 2007). The datalogger recorded this maximum soil temperature of 34.3°C on only one date in June.

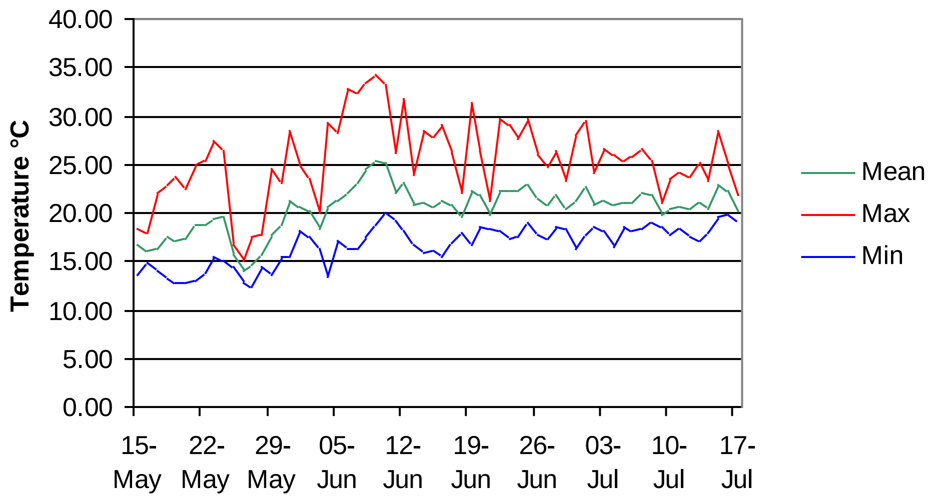

Figure 6. Minimum, mean and maximum soil temperatures recorded between 15 May and 17 July.

Mean daily temperatures during the experiment in the crop canopy are shown in Figure 7. Mean daily minimum, maximum and mean temperatures ranged from 8.1-18°C, 14.7-36.8°C and 12.7-23.5 °C respectively. *A. cucumeris* can develop at temperatures as low as 8°C, but at 35°C, less than 50% of the eggs hatch and 90% of the larvae die (Malais & Ravensberg, 2003). Temperatures reached 36.8°C on only two dates in May and for the remainder of the experimental period, temperatures were within the known range for *A. cucumeris* breeding and survival.

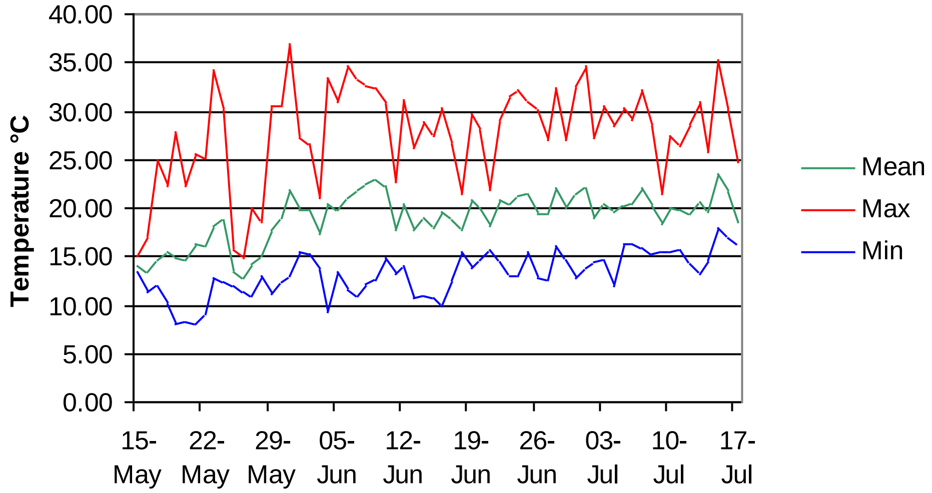

Figure 7. Minimum, mean and maximum crop canopy temperatures recorded between 15 May and 17 July.

Integration of pesticides with Amblyseius cucumeris

Pesticides and fungicides used on the crop during the experimental period are shown in Table 7. The successful establishment of *A. cucumeris* suggests that the use of these pesticides did not have any significant adverse effects on this predator. Quinoxyfen (Fortress) was applied on 21 May, the same date as the first application of *P. persimilis* was applied for spider mite control, and one week before the second application of *P. persimilis*. As there is no information available from biological control companies on the compatibility of Fortress with beneficials, the good control of spider mites by *P. persimilis* in this experiment provides useful evidence that Fortress seems to be compatible with this predator.

Table 7. Pesticides and fungicides applied by the grower to experimental plots and side effects on *A. cucumeris*, *P. persimilis* and *A. coriaria* * no specific information available for *A. coriaria* but known effects on 'beetles' (in general) given.

Date	**Trade name**	**Active ingredient**	**Effect on *A. cucumeris* (applied 15 and 29 May)**	**Effect on *P. persimilis* (applied 21 and 29 May)**	**Effect on *A. coriaria** (applied 15 May)**
13 May 11 and 18 July	Tracer	spinosad	Safe	Safe	Safe
21 May	Fortress	quinoxyfen	No information available	No information available	No information available
21 June	Systhane	myclobutanil	No information available but safe to other predatory mites e.g. *A. californicus*, *Hypoaspis*	Safe	Safe
11 July	Serenade	*Bacillus subtilis*	Safe	Safe	Safe

ADAS experiment: Conclusions

- The majority of thrips found in the flowers of the commercial crop in Herefordshire where the experiment was sited were WFT.

- WFT adults and larvae were present in low numbers when the fleece protecting the crop was removed in May. This indicated that as in the previous year on this farm, WFT had survived in the overwintered beds used for cropping everbearers during the previous season.

- Spinosad (Tracer) was applied to the crop on 13 May to reduce WFT numbers and the experiment was set up two days later. Live WFT adults and larvae were present in low numbers (up to 0.2 per flower) on 15 May when the experiment was set up.

- *A. cucumeris* successfully established in the flowers of plants treated with the slow-release sachets on 15 and 29 May and with the sachets in combination with the 'loose' *A. cucumeris* sprinkled onto the plants at 200 per m^2 on 15 and 29 May. Using the 'loose' product in addition to the sachets did not lead to significantly higher numbers of predators establishing in the flowers.

- Naturally-occurring *A. californicus* also established in the flowers in statistically similar numbers on both untreated plants and on those treated with the three biological control combinations and were likely to be feeding on pollen or spider mites rather than on WFT.

- Mean numbers of WFT remained low on all experimental plants until the final flower assessment on 7 July. On this date, mean numbers of WFT adults and larvae had increased to 3 per flower on untreated plants and were significantly lower on plants treated with biological control agents. There were no significant differences between mean numbers of WFT adults and larvae on plants treated with *A. cucumeris* sachets alone (1.7 per flower), *A. cucumeris* sachets plus 'loose' product (0.9 per flower) or *A. cucumeris* sachets plus 'loose' product plus *A. coriaria* rearing-release boxes (0.9 per flower). This result reflected the statistically similar numbers of *A. cucumeris* being found in flowers of plants treated with the three biological control combinations, i.e. *A. cucumeris* in sachets significantly reduced numbers of WFT compared with numbers on untreated plants, and there was no benefit in using the additional 'loose' *A. cucumeris* or *A. coriaria*.

- Significantly more undamaged fruit (i.e. less WFT bronzing damage) was recorded on fruit treated with biological control agents (76-92% undamaged fruit) than on untreated plants (56% undamaged fruit). This result reflects the mean numbers of WFT and *A. cucumeris* per flower in the different treatments i.e. *A. cucumeris* in sachets led to significantly higher numbers of the predators in the flowers, lower numbers of WFT and a higher percentage of undamaged fruit. These significant effects were not enhanced by the additional use of 'loose' *A. cucumeris* or by using the rearing-release system for *A. coriaria*.

- *A. coriaria* breeding, survival and dispersal is likely to have been adversely affected by the dryness of the substrate in the rearing-release boxes. Although the wicking system used in the boxes has been successful when used in protected herbs and ornamentals (Bennison, 2007), an improved wicking system to keep the substrate damp would need to be developed before any further evaluation of the system in strawberries.

- Although *A. cucumeris* had led to lower numbers of WFT and damage than in untreated plots, WFT pressure was still high and the grower applied Tracer to the experimental tunnels at the end of the experiment on 18 July. Further research is needed on developing a robust integrated strategy for sustained management of WFT throughout the everbearer season.

EMR experiments: Materials and Methods

Objective: To determine whether *A. cucumeris* can establish on everbearer strawberry and reduce numbers of WFT, and to determine whether control of WFT can be improved by using the entomopathogenic nematode *Steinernema feltiae*.

Site: An area of one year old everbearer strawberries at EMR was used for these experiments.

Variety: Flamenco.

Planting date: 3 May 2007.

Treatments

1. *Amblyseius cucumeris* sachets at one per 2 m length of row placed out on 18 May. On 7 June additional sachets were placed between the previous ones. The first sachets were attached to plastic stakes which held the sachets in the canopy of the small plants and the second set was attached directly to the larger plants.
2. As in 1 plus loose *A. cucumeris* at 200 m^{-2} applied on 28 June and on 16 August, when flowers were present.
3. As in 2 plus *Steinernema feltiae* applied to the planting holes at 65,000 nematodes per plant on 8 and 15 August.
4. Control with no predator releases.
5. An additional control set up on 18 July; this had had no predator releases and a pyrethroid application (bifenthrin; Talstar) was made to remove naturally occurring predators and any thrips species apart from WFT (which are resistant to pyrethroids) that were present.

Predatory mites were obtained from BCP Certis, Wye, UK. Prior to release of loose *A. cucumeris* the numbers of predators in three samples of a set volume of carrier from each supplied tube were counted under a binocular microscope. From this the volume of carrier needed to dispense the mites at the required release rate per plant was calculated. This volume of carrier was dispensed onto each plant using a small graduated container. Entomopathogenic nematodes were supplied by Becker Underwood.

Experimental layout

Each plot consisted of 40 plants in a double row raised bed covered with polyethylene mulch and was separated from other plots within the bed by a gap of c 3 m. The plants were spaced 0.4 m apart between the rows and 0.45 m apart in the rows. Each bed was 6 m apart and was located in the centre of a Spanish tunnel. Plants were crown thinned on 1 April to reduce vegetative growth and deblossomed on 7 May in line with commercial practice for everbearers for production of flowers and fruits later in the season. The polythene was erected on the tunnels at the start of the experiment on 15 May. The experiment was a randomised block design with five blocks and initially four treatments per block.

This planting had been used for the biocontrol experiments in this project in 2007. Large numbers of WFT had been present in the planting at the end of 2007 as a result of releases from glasshouse cultures with a mean of 6 WFT adults plus larvae per flower on 4 October 2007. Treatments were randomly re-allocated to plots within the blocks for the experiment in 2008. Plots within each tunnel comprised one block of the experimental design. From 18 July a fifth treatment was added to the design. One extra plot in each tunnel that had previously been unused and had received no predator releases was paired with the existing control plot within that block. A Talstar application was randomly assigned to one of each pair of control plots in each block.

Due to the low numbers of thrips recorded in the experiment up until 5 July (see below) WFT were released onto the strawberry plants on 25 July from infested bean plants reared in a glasshouse; approximately 20 WFT (all stages) were added to each strawberry plant. At this time there was a mean of 10 open flowers per plant plus green and ripe fruit.

Assessments

An initial flower sample of 20 flowers from across the planting was taken on 6 May. Subsequent flower samples (10 per plot) were taken before deployment of each set of sachets on 18 May and 7 June. Very few flowers were present when the sample was taken on 7 June. The plants were de-fruited and derunnered on 11 June to encourage a new flush of flowers. By 26 June flowers were present and a flower sample (10 per plot) was taken. A release of loose *A. cucumeris* was made on 28 June when reasonable numbers of flowers were present (these loose predators would need pollen as a food source if thrips or other prey numbers were low at the time they were released), and another flower sample was taken on 5 July. After release of WFT onto the plants on 25 July, further samples were taken on 7 and 20 August and on 2 September. A second release of loose *A. cucumeris* was made on 16 August.

Flower samples were processed by washing insects and mites off the flowers by agitating them in 70% alcohol. Numbers of thrips adults and larvae and of predatory mites and any insects were then recorded under a stereomicroscope. Several species of thrips and predatory mites occur on strawberry and it is not possible to identify the species unless individuals are mounted on a slide, using a mounting medium which clears the body contents, thus allowing diagnostic features to be seen when inspected under a compound microscope. A sample of thrips and predatory mites collected from flower samples were mounted on microscope slides and identified in this way.

Data analysis

Numbers of thrips and predatory mites in the different treatments on the eight sample dates were square root transformed and compared using repeated measures ANOVA.

EMR experiment: Results and Discussion

Numbers and species of predatory mites per flower

In the initial flower sample taken on 6 May, two thrips larvae and one immature predatory phytoseiid mite were found in 20 flowers. In the sample taken on 16 May prior to the first predator release, a mean of 0.1 mites per flower were found over all plots. Nineteen adult phytoseiids were mounted on microscope slides, cleared and identified. Sixteen (84%) were *A. cucumeris*. The remaining three specimens were not identifiable as they had either not cleared sufficiently or had eggs obscuring diagnostic characteristics. These mites had presumably overwintered from releases made in 2007.

Since the experiment was designed to test the effects of releases of predators before WFT had become numerous on the planting, no acaricide application was made to reduce the overwintered *A. cucumeris* population as possible residual effects of acaricides on released predators would have delayed the start of the experiment. It was considered that the low predator background population would be increased significantly in the release plots compared with the no release control plots so enabling any effects of predator release on WFT numbers to be identified.

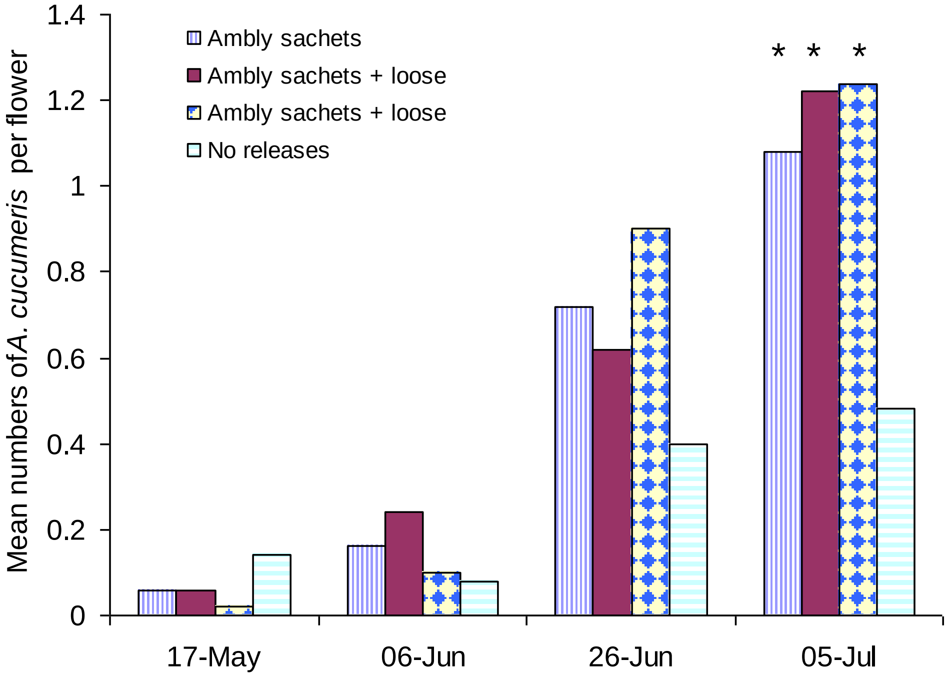

Figure 8. Mean numbers of immature plus adult *A. cucumeris* per flower May – July 2008. * significantly greater than the no release control. Treatments 1, 2 and 3 had releases of *A. cucumeris* sachets on 18 May and 7 June; treatments 2 and 3 also received loose *A. cucumeris* on 28 June; treatment 4 received no releases of predators. Treatments 2 and 3 were identical on these sample dates since soil applications of *S. feltiae* were not made until 8 and 15 August.

Analysis showed that there was a significant overall increase in *A. cucumeris* numbers from May to the beginning of July (P<0.001) (Figure 8), with higher numbers recorded on 26 June and 5 July compared with 17 May (pre first release) and 6 June (2 weeks after the first release). There was a significant effect of treatment on numbers of *A. cucumeris* recorded (P<0.05), with overall significantly lower numbers in the plots where no mites had been released, indicating that different population levels had successfully been set up in the experimental plots (Figure 8 and Table 8). There was no difference in numbers of *A. cucumeris* recorded among the three mite release plots. This would be expected for samples taken on the first three dates as these plots had all received the same treatment (sachets only) until that time.

However, following the release of loose *A. cucumeris* on 28 June, there was no difference in numbers of *A. cucumeris* in the different release treatments at the next sample date (Figure 8 and Table 8). On 5 July there were significantly lower numbers of *A. cucumeris* in the control plots compared with the release plots, and although not significant, there had been a similar pattern on 26 June. On 26 June, 74 adult phytoseiids were mounted on slides, cleared and identified. A total of 93 adult phytoseiids were recorded from samples taken on this date. Thus 80% of adult mites recorded were identified. Of those 68 (92%) were *A. cucumeris*. As in the previous sample identifications the remaining specimens were not identifiable. No other species of predatory mite was identified from these samples.

Table 8. Means of square root transformed numbers of *A. cucumeris* (immatures plus adults) per 10 flowers May – July 2008. Comparison between means is based on the pooled error from the repeated measures ANOVA adjusted for correlations among observations. LSD P=0.05 for comparing treatments on the same day (43 df) is 1.02 and for overall treatment comparisons (12 df) is 0.36

Date	Treatment			
	1	2	3	4
17 May	0.483	0.483	0.946	1.000
6 June	1.112	1.083	0.600	0.683
26 June	2.656	2.449	2.884	1.966
5 July	3.149	3.438	3.450	1.931
Grand mean	1.850	1.863	1.970	1.395

Treatments 1, 2 and 3 had releases of *A. cucumeris* sachets on 18 May and 7 June; treatments 2 and 3 also received loose *A. cucumeris* on 28 June; treatment 4 received no releases of predators. Treatments 2 and 3 were identical on these sample dates since soil applications of *S. feltiae* were not made until 8 and 15 August.

Numbers of predatory mites were lower in August than in early July (Figures 8 & 9; Tables 8 & 9). However, there was a significant increase in numbers per flower through August (P<0.001). From samples taken on 20 August and 2 September, 45 adult predatory mites were identified from a total of 200 individuals recorded (23% of total). Of these 26, (73%) were *A. californicus*. Only 7 individuals (16%) were *A. cucumeris* and the remaining 5 individuals (11%) were three additional mite species.

It is not clear why *A. cucumeris* became substantially displaced by *A. californicus* between the samples taken on 26 June, when all mites identified were *A. cucumeris* (see above), and 20 August. No *A. californicus* were released onto the plants, and so must have naturally colonised from other vegetation. Earlier Defra-funded work (Fitzgerald *et al*., 2008) showed that *A. cucumeris* and *A. californicus* were found in different niches within everbearer strawberry plants; *A. cucumeris* was found mostly on folded leaves and flower/fruit clusters whereas *A. californicus* was found mostly on old leaves. It is possible that both species were present on the plants throughout the experiment but that they were spatially separated early in the season, so that *A. californicus* were not found in flower samples. A reduction in prey numbers on the leaves may have caused the *A. californicus* to move to less favoured parts of the plant, including the flowers, in search of prey. It is not clear if *A. californicus* will feed on WFT in strawberry crops. In the ADAS experiment, *A. californicus* was also found in low numbers on all experimental plots, but earlier in the season, mostly in June.

Since more than one predatory mite species was present in the sampled flowers in the EMR experiments, and not all the mites from each sample were identified, the term ‘predatory mites’ is used in the remainder of this report. There was no significant overall effect of treatment on numbers of predatory mites in flower samples in August; there were similar numbers in the no release plots that had not been treated with Talstar as in the plots where the predator had been released (Figure 9 and Table 9). There was an indication of a treatment by time effect ($P<0.05$). On 7 August numbers of predatory mites in the plots that had been treated with Talstar were lower than numbers in the other treatments, indicating that the pyrethroid application had reduced but not eliminated the predators from these plots. However, by 20 August and 2 September numbers of predatory mites were higher in the Talstar treated plots; this may in part be due to the higher populations of WFT recorded in the Talstar treated plots in late August and early September (see below).

Table 9. Means of square root transformed numbers of predatory mites (immatures plus adults) per 10 flowers August – September 2008. Comparison between means is based on the pooled error from the repeated measures ANOVA adjusted for correlations among observations. LSD P=0.05 for comparing treatments on the same day (45 df) is 0.86 and for overall treatment comparisons (16 df) is 0.62

Date	Treatment				
	1	2	3	4	5
7 August	1.293	2.086	1.476	1.478	0.766
20 August	1.483	1.977	1.358	1.759	2.239
2 September	2.525	2.209	2.523	1.973	2.722
Grand mean	1.767	2.091	1.786	1.737	1.909

Treatments 1, 2 and 3 had releases of *A. cucumeris* sachets on 18 May and 7 June; treatments 2 and 3 also received loose *A. cucumeris* on 28 June and 16 August; treatment 3 also received soil applications of *S. feltiae* on 8 and 15 August; treatment 4 had no predator releases; treatment 5 was a no release control and also received an application of Talstar on 18 July

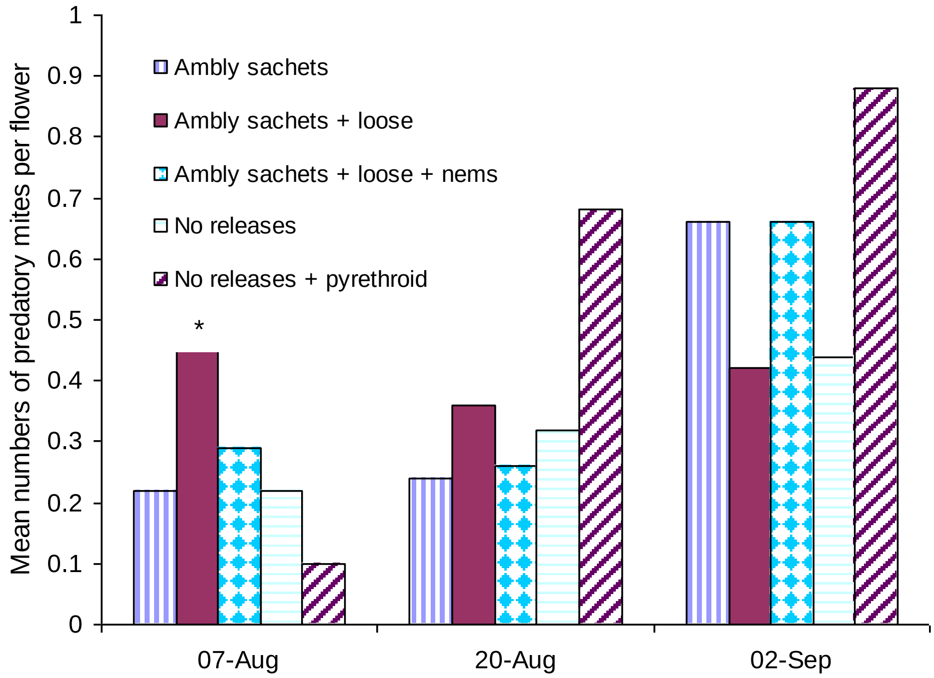

Figure 9. Mean numbers of immature plus adult predatory mites per flower August – September 2008. * significantly higher than the no release plus Talstar treatment

Numbers and species of thrips per flower

The establishment of different population levels of *A. cucumeris* did not affect numbers of thrips in the flowers and there were no differences in thrips numbers between treatments from May to early July (Figure 10 and Table 10). Thrips numbers were significantly higher in June compared with May ($P<0.01$). On 6 June a total of 47 adult thrips were recorded. 10 individuals were mounted on slides and inspected under a compound microscope. Based on numbers of antennal segments (8 segments for *Frankliniella*) 9 were found not to be WFT. The remaining individual was a *Frankliniella* species.

On 26 June 130 adult thrips were recorded in total and slides were made of 57 individuals (44% of total). None of these were found to be WFT. On 26 June a total of 60 adult thrips were recorded and slides were made of 37 individuals (62% of total). Only one was identified as a *Frankliniella* species. It is not clear why populations of WFT were not higher in this plantation since there had been around 6 per flower in samples taken in October 2007 and experiments at EMR and on a commercial farm in Herefordshire showed that WFT could successfully overwinter in strawberry plantations. However, the plantation had not been sprayed with insecticides so it is possible that naturally occurring predators had reduced WFT numbers early in the season.

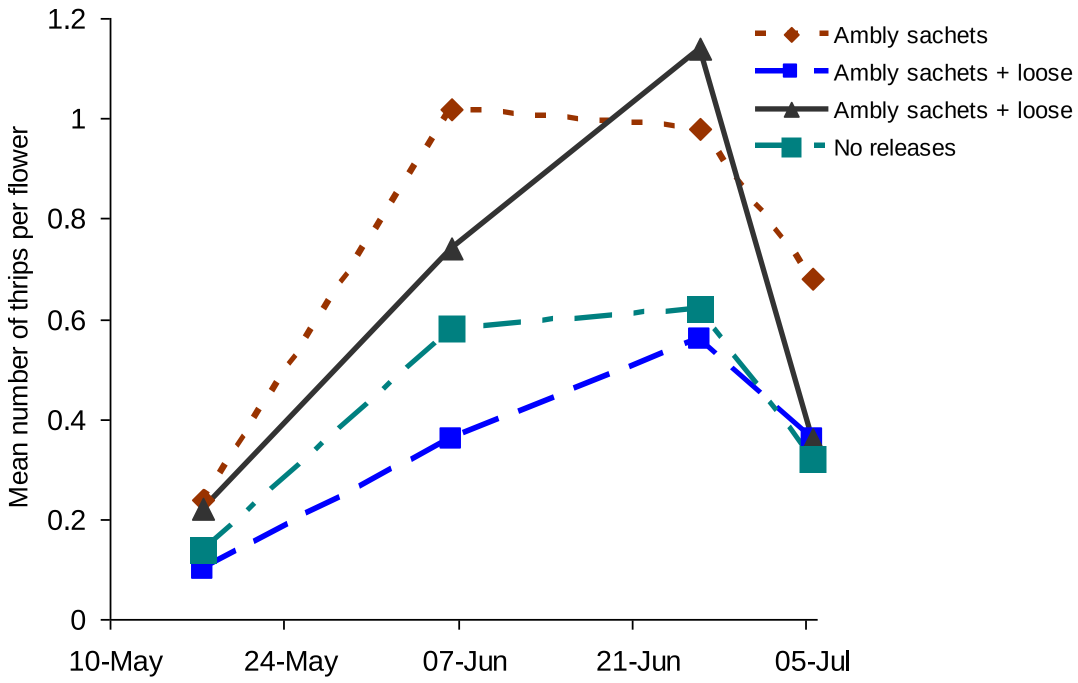

Figure 10. Mean numbers of thrips adults plus larvae per flower May – July 2008. Treatments 2 and 3 were identical on these sample dates since soil applications of *S. feltiae* were not made until 8 and 15 August.

Table 10. Means of square root transformed numbers of thrips (larvae plus adults) per 10 flowers May – July 2008. Comparison between means is based on the pooled error from the repeated measures ANOVA adjusted for correlations among observations. LSD P=0.05 for comparing treatments on the same day (51 df) is 1.34 and for overall treatment comparisons (12 df) is 0.56

Date	Treatment			
	1	2	3	4
17 May	1.45	0.77	1.45	1.03
6 June	2.68	1.78	2.52	2.24
26 June	2.86	1.96	3.26	2.22
5 July	2.42	1.82	1.65	1.51
Grand mean	2.35	1.58	2.22	1.75

Treatments 1, 2 and 3 had releases of *A. cucumeris* sachets on 18 May and 7 June; treatments 2 and 3 also received loose *A. cucumeris* on 28 June; treatment 4 received no releases of predators. Treatments 2 and 3 were identical on these sample dates since soil applications of *S. feltiae* were not made until 8 and 15 August.

Since most of the thrips present were not WFT, the pest was released from glasshouse cultures onto the experimental plots on 25 July; approximately 20 WFT (adults and larvae) were added to each strawberry plant. At this time there was a mean of 10 open flowers per plant plus green and ripe fruit. In addition a fifth treatment was added to the experiment;

plots that had not received any releases of predators were sprayed with Talstar on 18 July to remove any naturally occurring predators and any thrips other than WFT.

During August there was a significant decrease in thrips numbers over time in all plots (P<0.001) (Figure 11 and Table 11). There was also a significant effect of treatment with numbers of thrips being significantly higher in the Talstar treated plots (P<0.001); predatory mite numbers had been significantly lower in these plots in the assessment done on 7 August. There were no significant differences in thrips numbers among the other treatments (Table 11), in all of which plots numbers of predatory mites were similar (Table 9). This result indicates that the presence of predatory mites had a significant effect on the pest populations. There was a significant interaction of treatment with time (P<0.05); although numbers of thrips were higher in the Talstar treated plots on all three sample dates this difference did not become significant until 20 August. There was no effect of the two applications of *S. feltiae* on thrips populations in this experiment.

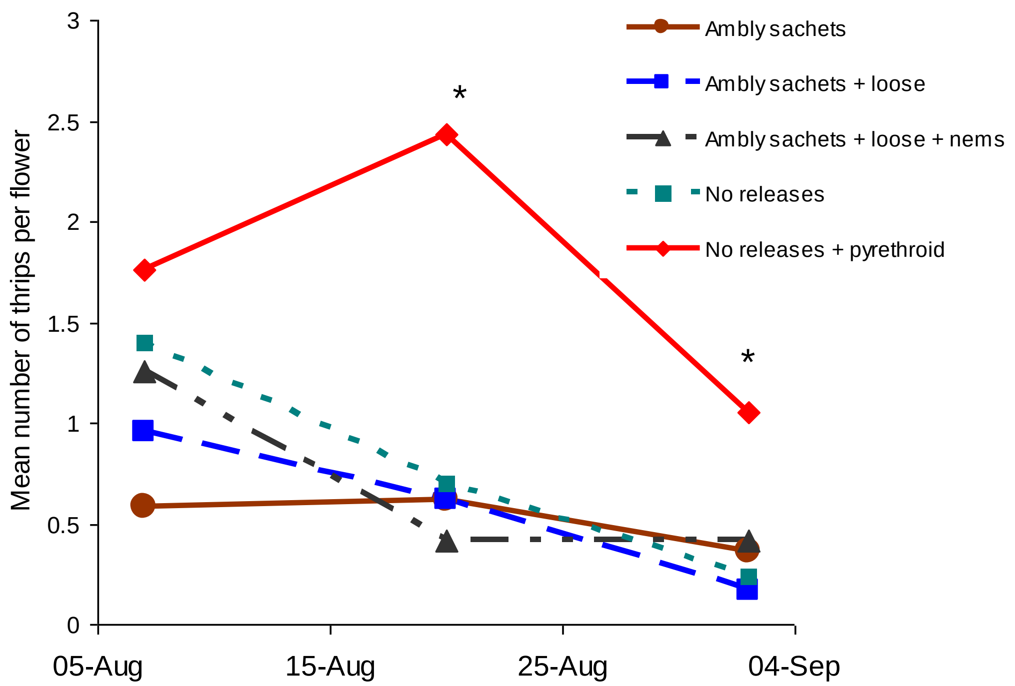

Figure 11. Mean number of thrips adults plus larvae per flower August – September 2008. * significantly higher than the other treatments

Between 7 August and 2 September a total of 404 adult thrips were recorded from the flower samples. 25% of these were mounted on slides, cleared and identified. Approximately 50% of the thrips identified were WFT. In September, 12 out of 45 thrips (27%) recorded from plots that had received the Talstar application were identified. All of these were WFT. Assuming that these results were a true reflection of the species present in the plantation, and assuming that the relative proportions of thrips larvae were the same as for thrips adults, all the thrips in the Talstar treatment and only 50% of thrips in the other treatments were WFT.

Table 11. Means of square root transformed numbers of thrips (larvae plus adults) per 10 flowers August – September 2008. Comparison between means is based on the pooled error from the repeated measures ANOVA adjusted for correlations among observations. LSD P=0.05 for comparing treatments on the same day (43 df) is 0.93 and for overall treatment comparisons (16 df) is 0.66

Date	Treatment				
	1	2	3	4	5
7 August	3.691	3.036	3.528	3.727	4.108
20 August	2.420	2.287	2.027	2.423	4.735
2 September	1.836	1.326	1.949	1.487	3.089
Grand mean	2.649	2.216	2.501	2.546	3.978

Treatments 1, 2 and 3 had releases of *A. cucumeris* sachets on 18 May and 7 June; treatments 2 and 3 also received loose *A. cucumeris* on 28 June and 16 August; treatment 3 also received soil applications of *S. feltiae* on 8 and 15 August; treatment 4 had no predator releases; treatment 5 was a no release control and also received an application of Talstar on 18 July

Thus the difference in numbers of WFT in the no predator release plus Talstar treated plots compared with the other plots was even greater than indicated in Figure 11. It is not clear if thrips species other than WFT cause the same sort of feeding damage seen when large populations of WFT are present, but they may do. Species other than WFT are not currently considered a problem in soft fruit production, partly because they are easy to control with insecticides. However, predatory mites and insects are likely to attack all thrips species present.

Other predators

Orius species adults and nymphs were present in low numbers during August and September (Figure 12; Tables 12 and 13); these are generalist predatory insects also known as 'flower bugs' as they commonly feed on pollen in addition to invertebrate prey, including thrips adults and larvae. *Orius* sp. adults fly into flowering crops particularly when high numbers of prey are present. Analysis showed that over all treatments, numbers of *Orius* sp. nymphs were higher on 20 August and 2 September than on 7 August (P<0.05) (Table 12). This corresponds with the timing of reduction in thrips populations (see above, Table 11). Numbers of *Orius* sp. nymphs were significantly lower in the Talstar treated plots than in the other treatments overall (P<0.01) and were lowest in this treatment on all sample occasions (Figure 12). This result demonstrates the known persistence of the adverse effects of pyrethroid insecticides such as Talstar on predatory insects. The fact that lower numbers of *Orius* sp. nymphs were found on the Talstar treated plots may have played a part in the development of higher populations of thrips on these plots.

Table 12. Means of square root transformed numbers of *Orius* nymphs per 10 flowers August – September 2008. Comparison between means is based on the pooled error from the repeated measures ANOVA adjusted for correlations among observations. LSD P=0.05 for comparing treatments on the same day (51 df) is 0.79 and for overall treatment comparisons (16 df) is 0.51

Date	Treatment				
	1	2	3	4	5
7 August	0.693	1.229	0.683	0.766	0.000
20 August	1.566	1.076	1.093	1.820	0.251
2 September	1.133	1.216	0.811	1.244	0.428
Grand mean	1.130	1.174	0.862	1.277	0.226

Treatments 1, 2 and 3 had releases of *A. cucumeris* sachets on 18 May and 7 June; treatments 2 and 3 also received loose *A. cucumeris* on 28 June and 16 August; treatment 3 also received soil applications of *S. feltiae* on 8 and 15 August; treatment 4 had no predator releases; treatment 5 was a no release control and also received an application of Talstar on 18 July

Table 13. Means of square root transformed numbers of *Orius* adults per 10 flowers August – September 2008. Comparison between means is based on the pooled error from the repeated measures ANOVA adjusted for correlations among observations. LSD P=0.05 for comparing treatments on the same day (38 df) is 0.82 and for overall treatment comparisons (16 df) is 0.60

Date	Treatment				
	1	2	3	4	5
7 August	0.912	0.683	1.029	0.400	0.566
20 August	0.200	0.600	0.000	0.600	0.210
2 September	0.341	0.341	0.483	0.200	0.742
Grand mean	0.485	0.541	0.504	0.400	0.506

Treatments 1, 2 and 3 had releases of *A. cucumeris* sachets on 18 May and 7 June; treatments 2 and 3 also received loose *A. cucumeris* on 28 June and 16 August; treatment 3 also received soil applications of *S. feltiae* on 8 and 15 August; treatment 4 had no predator releases; treatment 5 was a no release control and also received an application of Talstar on 18 July

Numbers of *Orius* sp. adults were highest on 7 August (P<0.05), but there was no effect of treatment on adult numbers (Table 13). Since adult *Orius* sp. are active fliers they would have been moving from plot to plot. It is likely that eggs would have been laid in all plots but that Talstar residues prevented their development in the treated plots resulting in the significantly lower numbers of *Orius* sp. nymphs recorded in those plots.

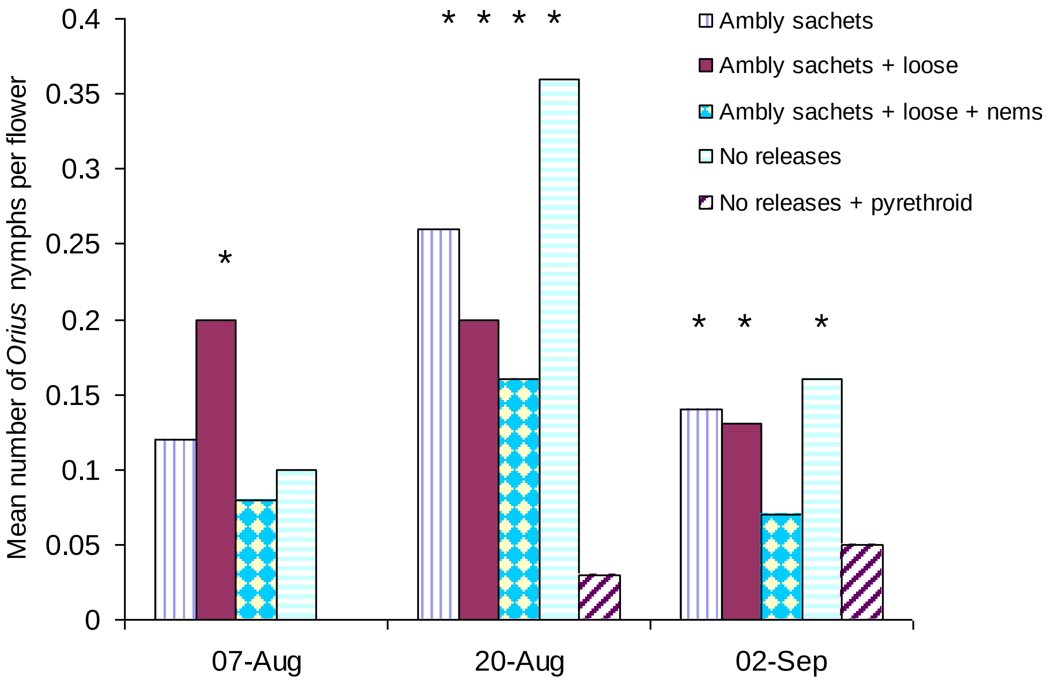

Figure 12. Mean number of *Orius* nymphs per flower August – September 2008. * significantly higher than the Talstar treated control

EMR Experiment: Conclusions

- *Amblyseius cucumeris* overwintered successfully in the experimental plots from releases made in 2007.
- Despite high numbers of WFT being present at the end of experiments in 2007 very few were identified from samples taken during May and June 2008. Therefore releases of WFT were made to the experimental plots on 25 July.
- *A. cucumeris* successfully established from early season sachet releases, and differential population levels were set up in treatment plots.
- Since most of the thrips present during May and June were not WFT it was not possible to assess effects of *A. cucumeris* on WFT at this time.
- Thrips (WFT and other species) numbers were significantly lower in August in plots with established populations of *A. cucumeris* than in plots treated with Talstar.
- Releases of loose *A. cucumeris* did not significantly increase numbers of predatory mites in flowers compared with plots where sachets alone had been used earlier in the season.
- There was no effect of soil applications of *S. feltiae* on thrips numbers in this experiment.

- The predatory mite *A. californicus* was found in flower samples in late August although it was not present in flower samples taken up until the end of June and had not been released in the planting.
- *Orius* spp. were found naturally colonising the plantation in August.
- In plots where *Orius* spp. numbers were reduced by a Talstar application numbers of thrips were higher.
- It is probable that a combination of releases of *A. cucumeris* plus natural colonisation by *Orius* spp. caused the reduction of thrips seen in this experiment.
- The higher WFT numbers in the Talstar-treated control are evidence that biological control (natural and/or augmented) was significantly reducing WFT populations in the field.

Overall conclusions from ADAS and EMR experiments

- In both experiments, *A. cucumeris* successfully established in the flowers of plants treated with slow release sachets. Using the 'loose' product in addition to the sachets on the same dates did not lead to higher numbers of predators in the flowers.
- Mean numbers of WFT (and other thrips species in the EMR experiment) were significantly lower on plants where *A. cucumeris* had established than on untreated plants (or on Talstar-treated plants in the EMR experiment). Using the 'loose' *A. cucumeris* addition to the sachets gave no additional benefits in reducing thrips numbers.
- Use of *A. coriaria* (ADAS experiment) or *S. feltiae* (EMR experiment) in addition to *A. cucumeris* gave no additional reductions in thrips numbers.
- In the ADAS experiment, significantly more undamaged fruit (i.e. no WFT bronzing) was recorded on plants treated with biological control agents (76-92% undamaged) than on untreated plants (56% undamaged). Numbers of undamaged fruit were not significantly increased by the use of 'loose' *A. cucumeris* or *A. coriaria* in addition to the sachets.
- In the ADAS experiment, although *A. cucumeris* had led to lower numbers of WFT and damage than on untreated plants, WFT pressure was still high and the grower applied Tracer at the end of the experiment on 18 July. Further research is needed on developing a robust integrated strategy for sustained management of WFT throughout the everbearer season.
- *Orius* spp. predatory bugs naturally colonised the plants in the EMR experiment and are likely to have contributed to thrips control, in combination with the *A. cucumeris*.

Technology transfer

- HDC News article May 2008.
- Jean Fitzgerald presented the results of the project at an HDC/EMRA soft fruit day on 11 November 2008.
- Jude Bennison presented results of the project to ADAS fruit consultants at EMR in January 2009.
- Jude Bennison presented the results of the project to Landseer (who market Tracer) in November 2008.
- Jude Bennison presented results of the project to the ADAS soft fruit growers group in Oxfordshire in March 2009.

Acknowledgements

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