Horticultural Fellowship Awards

Interim Report Form

Project title:	Maintaining the expertise for developing and communicating practical Integrated Pest Management (IPM) solutions for Horticulture
Project number:	CP 089
Project leader:	Jude Bennison, ADAS
Report:	Annual, 31 March 2015
Previous reports:	Annual reports 2012, 2013 and 2014
Fellowship staff:	Jude Bennison, Senior Entomologist, ADAS Boxworth (lead Fellowship mentor) Mike Lole, Senior Entomologist, ADAS (mentor) Steve Ellis, Senior Entomologist, ADAS High Mowthorpe (mentor) Chris Dyer, Statistician, ADAS (mentor) Heather Maher, Senior Research Manager, ADAS Boxworth (mentor until August 2012, ad hoc training after this date) Kerry Maulden, Senior Research Manager, ADAS Boxworth (mentor)
(“Trainees”)	Gemma Hough, Entomologist, ADAS Boxworth (Fellowship trainee Entomologist and Project Manager from Dec 2012) Sacha White, Entomologist, ADAS

	Boxworth (Fellowship trainee Entomologist from May 2013)
	Chloe Whiteside, Research Technician, ADAS Boxworth (Fellowship trainee scientific support staff until October 2013, now a Trainee Horticultural Consultant)
	Robert Drummond, Technician, ADAS Boxworth (Fellowship trainee scientific support staff until October 2014)
	Abby Wood, Technician, ADAS Boxworth (Fellowship trainee scientific support staff until January 2014)
	Steven Richardson, Technician, ADAS Boxworth (Fellowship trainee scientific support staff)
Location of project:	ADAS Boxworth and commercial farms and nurseries
Industry Representative:	None
Date project commenced:	01 April 2011
Date project completed (or expected completion date):	31 March 2016

DISCLAIMER

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 ....08 April 2015...........................

Report authorised by:

ADAS

Barry Mulholland

Signature ....Date ....31 March 2015...............................

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Progress Against Objectives

Objectives

Objective	Original Completion Date	Actual Completion Date	Revised Completion Date
1. Provide mentoring of two next generation ADAS research entomologists to equip them with the knowledge, skills, competencies and flexibility required to develop IPM strategies on horticultural crops.	31/03/2016	ongoing	-
2. Deliver practical solutions to selected current and emerging pest management problems through specific applied research projects.	31/03/2016	ongoing	-
3. Transfer knowledge and new IPM developments to the industry through a range of communication media.	31/03/2016	ongoing	-

Summary of Progress

Objective 1: Mentor two ‘next generation’ IPM research Entomologists

Tom Pope was already in post at ADAS Boxworth at the start of the Fellowship. He joined ADAS in 2009 and worked with Jude Bennison and colleagues on a range of projects investigating the biology and control of various horticultural pests including aphids, cabbage root fly and vine weevil. As part of the Fellowship Tom led work on predatory mites in soft fruit, biological control of vine weevil, incidence of aphid hyperparasitoids and biological control of aphids on outdoor lettuce. In August 2012, Tom left ADAS to join Harper Adams University as a lecturer in entomology and applied pest management research, where he is now training future entomologists. Tom is now a valued research collaborator with ADAS, already working with Jude Bennison and her team in two Defra-funded IPM projects and the HDC Vine weevil review.

Gemma Hough joined ADAS Boxworth and replaced Tom Pope as a research entomologist in December 2012 after completing a HDC-funded PhD studentship on the biology and control of currant lettuce aphid at Warwick University. As part of the Fellowship Gemma took over work on biological control of vine weevil, biological control of aphids on lettuce and monitoring hyperparasitism in HNS. Gemma has been involved in a range of HDC projects which include a review of vine weevil control and Managing Ornamental Plants Sustainably (MOPS) (where Gemma led the vine weevil work). Gemma is also project leader for

Scaptomyza flava on baby-leaf salads (FV 408a) and the recently completed Evaluating aphid control strategies (FV 435).

Gemma Gillies joined ADAS Boxworth in October 2011 and assisted on Fellowship projects taking over work on biological control of vine weevil in August 2012. Gemma left ADAS to return to teaching in December 2012 and ADAS recruited Sacha White to replace her in its pest management team.

Sacha White joined ADAS in May 2013. Sacha completed his PhD at the University of Warwick, looking at the implications of new sustainable greenhouse systems for pests, diseases and biological control. He also completed the Integrated Pest Management Msc at Imperial College London and has previous experience in various aspects of entomological research. As part of the Fellowship Sacha has worked on the biological control of aphids in field-grown lettuce and on the identification of thrips species on strawberry during 2014 and controlling vine weevil larvae with the predatory beetle *Atheta coriaria* during 2015. Sacha is also involved in the delivery of projects investigating improved control of the invasive oak processionary moth (Defra funded), slug control in wheat (commercial), insecticide resistance in the UK (part HDC funded) contributions toward the AHDB "Encyclopedia of pests and natural enemies in field crops" (AHDB funded), wireworm control in potatoes (commercial) and peach-potato aphid and cabbage stem flea beetle in oilseed rape.

Mentoring activities during the second year of the Fellowship included:

Visits to commercial nurseries and farms

During 2014-2015 visits were made by Gemma Hough and Sacha White. Nurseries and farms visited included:

Hardy nursery stock: Gemma Hough visited Swallowfield nursery.

Soft fruit: Gemma Hough and Sacha White visited various strawberry farms while setting up trials, monitoring the occurrence of thrips species and carrying out late night searches for vine weevil adults to supply the ADAS culture for research purposes (Copas farms, H&H Duncalfe, New Farm Produce and Starkey's Fruit).

Field vegetables: Gemma Hough visited rocket growers in East Anglia while collecting *Scaptomyza flava* for FV 408a project. Gemma attended the Leek Growers' Association Agronomy day.

Protected edibles: Gemma Hough visited sweet pepper growers to collect aphid samples for a collaborative project with Rothamsted Research on aphid resistance. Gemma Hough visited protected lettuce (Madestein), herb (Madestein) and strawberry growers (Hall Hunter). Gemma Hough visited Vitacress Herb unit, Hill Brothers' and Roundstone nursery as part of the HDC/IPPS Study Day 2014 'Innovation in Plant Production'.

General horticulture: Gemma Hough undertook external training towards her BASIS certificate in commercial horticulture.

Pest and biocontrol agent identification

Laboratory training on identification of key horticultural pests was completed by Gemma Hough and Sacha White as well as key members of the scientific support team at ADAS Boxworth during 2015. Training courses included:

- Predatory mite identification (training given by Mike Lole)
- Thrips identification refresher course (given by Jude Bennison and Mike Lole)
- Identifying the cause of pest damage on horticultural and arable crops (training given by Gemma Hough and Sacha White to ADAS scientific support staff).
- Extracting entomopathogenic nematodes from soil samples using a modified Baermann funnel (training given by Roma Gwynn and Jude Bennison)

Technical updates on biocontrol agents, biopesticides, pesticides and horticultural research

Technical meetings with ADAS horticultural colleagues, suppliers of pesticides, biopesticides and biocontrol agents were attended throughout the year. These meetings provided updates on new products under development or those recently available for use by UK growers e.g. Leek Growers' Association Agronomy day, HDC/IPPS Study Day 2014 'Innovation in Plant Production' and HDC research update meetings were also attended e.g. HDC Herbaceous perennial technical discussion group.

Scientific conference attended by Gemma Hough and Sacha White included:

● IOBC-WPRS Working Group "Integrated Control in Protected Crops, Temperate Climate. Belgium Ghent (Gemma)

● IOBC VIII Workshop on Integrated Soft Fruit Production. Vigalzano, Pergine Valsugana (Trentino, Italy) (Gemma)

● AAB Advances in IPM 2014, Olde Barn Hotel, Marston, Lincolnshire, 19-20 November 2014.

<u>Objective 2: Deliver practical solutions to selected current and emerging pest management problems through specific applied research projects</u>

<u>2012 projects</u>

- Contribution of overwintered predatory mites to pest mite control on strawberry
- Aphid hyperparasitoids on protected edibles, soft fruit and ornamentals
- Biological control of aphids on lettuce
- Efficacy of entomopathogenic nematodes against vine weevil

<u>2013 projects</u>

- Efficacy of entomopathogenic nematodes against vine weevil
- Aphid hyperparasitoids on protected ornamentals
- Biological control of aphids on lettuce
- Review of the control of leaf and bud nematodes

<u>2014 projects</u>

- Monitoring the rose thrips, *Thrips fuscipennis* at commercial strawberry sites
- Comparing damage by *Thrips fuscipennis* with *Frankliniella occidentalis* (western flower thrips) - Gemma
- A literature review on current knowledge of *T. fuscipennis* biology, overwintering sites and natural enemies - Gemma
- Potential of the predatory beetle *Atheta coriaria* for biological control of vine weevil - Sacha

<u>Objective 3: Transfer knowledge of new IPM developments to the industry</u>

Knowledge transfer activities delivered by Gemma Hough and Sacha White in year four of this project related both to this project, and also to other horticultural projects, included:

Publications (with input from experienced ADAS colleagues):

- HDC News articles on the ADAS entomology fellowship (CP 89), the leaf miner *Scaptomyza flava* (FV 408) March 2015 edition, Evaluating aphid control strategies (FV435) March 2015 edition and Managing Ornamental Plants Sustainably (CP 124) April 2015 edition.
- Update of HDC Factsheet 10/12 Whitefly (in progress).

● Pope, T., Gundalai, E., Hough, G., Roberts, H., Wood, A., Bennison, J., Prince, G., Chandler, D. (2015). Improved understanding of vine weevil movement. Integrated protection of fruit crops Subgroup “Soft Fruits” IOBC-WPRS Bulletin Vol. 109, pp 99-102.

● Hough, G., Bennison. J., Wood, A. & Maulden, K. (2015) Biological control of vine weevil larvae on protected strawberry. Integrated protection of fruit crops Subgroup “Soft Fruits” IOBC-WPRS Bulletin Vol. 109, pp 103-106.

● Ellis, S., White, S., Holland, J., Smith, B., Collier, R., & Jukes, A. (2014) Encyclopedia of pests and natural enemies in field crops. AHDB- funded.

Presentations to industry:

● HDC Leafy Salads Road Show- Gemma presented Evaluating aphid control strategies FV 435 at Huntapac and Stoneleigh.

● Managing Ornamental Plants Sustainably (MOPS). Gemma presented the results at GroSouth and the Herbaceous perennial technical discussion group.

● HGCA monitoring panel – Sacha presented Combating insecticide resistance in major UK pests.

AAB – Sacha co-presented a paper with Jude Bennison on the potential of the predatory beetle *Atheta coriaria* for biological control of vine weevil. AAB conference - Advances in IPM 2014, Olde Barn Hotel, Marston, Lincolnshire, 19-20 November 2014.

● Poster presentation, Sacha White. Combating insecticide resistance in major UK pests. BBRO Winter Conference, Peterborough Arena, 10 February 2015

● HDC soft fruit agronomists day, EMR, 12 February 2015. Gemma participated in the delivery of a thrips identification workshop with Jude Bennison

Presentations at scientific conferences:

● IOBC – Gemma presented on Biological control of vine weevil larvae on protected strawberry. Integrated protection of fruit crops Subgroup “Soft Fruits” 25-30 May 2014

● AAB – Sacha co-presented with Jude Bennison on the Potential of the predatory beetle *Atheta coriaria* for biological control of vine weevil. Advances in IPM 2014, Olde Barn Hotel, Marston, Lincolnshire, 19-20 November 2014.

● Sacha co-presented with Jude Bennison on Improving control of oak processionary moth. Invasive insects and trees: detection, management and policy, University of Hull, 19-20 February 2015.

Milestones not being reached

None

Do remaining milestones look realistic?

Yes

Other achievements in the last year not originally in the objectives

Trainees have worked with experienced ADAS entomologists and collaborating scientists on a wide range of horticultural projects over the last year. These included:

- CRD-funded project PS2134 - Use of refuge traps to disseminate entomopathogenic fungi for the control of adult vine weevil. Site managed by Gemma Hough.
- HortLINK project HL001107 - Biological, semiochemical and selective chemical management methods for insecticide resistant western flower thrips on protected strawberry. Site managed by Gemma Hough.
- HDC project- A review of vine weevil knowledge in order to design best-practice IPM protocols suitable for implementation in UK horticulture (CP 111). Gemma Hough was one of the co-authors.
- HDC project Managing Ornamental Plants Sustainable (MOPS). Gemma led the vine weevil work during 2014.
- HDC project FV408a Baby-leaf Cruciferae: Improved control of *Scaptomyza flava* – Led by Gemma Hough
- HDC project FV 435 Evaluating aphid control strategies- led by Gemma Hough
- AHDB-HGCA funded project – Pests and Beneficials Encyclopaedia for Arable and Field Crops. Co-authored by Sacha White.
- DEFRA-funded (CRD) – PS2722 Combating insecticide resistance in major UK pests. delivered by Sacha White.
- Defra-funded – TH0102 Improved Control Methods for Oak Processionary Moth. Report co-authored by Sacha White
- HGCA-funded Project RD-2140025 Cabbage stem flea beetle larval survey – led by Sacha White

Changes to Project

Are the current objectives still appropriate for the Fellowship?

Indicate any changes to the ordinal objectives that you would like to make and provide any information that you can to support this decision.

None

GROWER SUMMARY

Headline

- Rose thrips, *Thrips fuscipennis* has damaged strawberry fruit in different UK geographic locations, on crops where western flower thrips has been well controlled by the predatory mite *Neoseiulus cucumeris*. At present this species is susceptible to spinosad (Tracer) but due to the risk of the development of resistance to this pesticide, reliable IPM methods are needed.

Background

Rose thrips, Thrips fuscipennis

Knowledge gained by ADAS during 2013/14 in the IPM Fellowship confirmed that native thrips species were causing strawberry fruit damage in various commercial crops and geographic locations. The rose thrips, *Thrips fuscipennis,* was been identified in both 2013 and 2014 as commonly occurring in large numbers associated with rapidly-occurring fruit bronzing and malformed fruit, in crops where western flower thrips, *Frankliniella occidentalis,* had been well controlled by *Neoseiulus cucumeris* (Figure 1).

Figure 1 Damage on strawberry associated with *T. fuscipennis*

T. fuscipennis adults are darker in colour than those of WFT but are very similar to other *Thrips* species that can be found in strawberry flowers (Figure 2a and 2b).

Figure 2a Rose thrips, *Thrips fuscipennes* (left) **2b** western flower thrips, *Frankliniella occidentalis* (right)

Growers have often applied spinosad (Tracer) which has given effective control. However, growers are concerned about the risk of insecticide resistance and would like a biological control option. In addition, growers are likely to wish to reserve Tracer for use against SWD if needed, as the number of applications per crops are currently limited to four per year on protected strawberry. Some growers consider that as these species seem to migrate into the crop as adults in large numbers they are not controlled by *N. cucumeris* which only feeds on first instar WFT larvae. It is unknown whether *N. cucumeris* can successfully predate *T. fuscipennis* larvae.

In this year's Fellowship the following work has been carried out by Gemma Hough on *Thrips fuscipennis*:

- Monitoring *Thrips fuscipennis* at a commercial strawberry site
- A literature review on current knowledge of *T. fuscipennis* biology, overwintering sites and natural enemies
- Comparing damage by *Thrips fuscipennis* (rose thrips) with *Frankliniella occidentalis* (western flowers thrips, WFT)

Potential of the predatory beetle Atheta coriaria for biological control of vine weevil

Vine weevil (*Otiorhynchus sulcatus*) is one of the most serious pest problems in both soft fruit and hardy nursery stock crops. Adult weevil damage to leaves and the presence of larvae around roots can make containerised ornamental plants unmarketable. Root damage caused by larvae in both ornamental and soft fruit crops leads to reduced plant vigour and yields and if damage is severe, to plant death.

Growers of susceptible soft fruit crops such as strawberry and raspberry commonly use entomopathogenic nematodes for vine weevil control, usually applied through drip-irrigation systems. This method is usually effective in substrate-grown crops but not in field-grown crops. Growers of containerised hardy ornamentals have until recently largely relied on the use of persistent insecticides in the growing media for vine weevil control. However, the choice of insecticides is now very limited due to recent EC restrictions on the use of neonicotinoid insecticides and in addition, growers are under pressure to reduce reliance on pesticides in favour of IPM. Entomopathogenic nematodes are used in containerised ornamentals for vine weevil control but drip irrigation is little used in these crops, therefore nematodes have to be applied using a drench. This method is labour-intensive and drenching can be less effective on large, closely spaced plants, when much of the drench can end up on the floor rather than on the target substrate in the pots. The entomopathogenic fungus *Metarhizium anisopliae* (Met52) is available for incorporation in growing media for vine weevil control, but its temperature requirements limits its use in ornamentals and the current formulation is impractical for use in soft fruit.

There is a need to improve biological control of vine weevil and a potential candidate for supplementing other biological control methods is the predatory beetle *Atheta coriaria*. This predator is commercially available for biological control of sciarid and shore flies in protected crops, where it feeds on both eggs and larval stages. In CRD-funded project PS 2130, ADAS demonstrated that in the laboratory, both *A. coriaria* adults and larvae predated young vine weevil larvae, although they did not feed on the eggs. The predator was investigated further in a semi-field experiment.

Summary

Monitoring *Thrips fuscipennis* at commercial sites

During 2014 an ADAS fruit consultant sent in samples of thrips which were damaging everbearer fruit at a commercial site. It was confirmed that the thrips species responsible was *Thrips fuscipennis*. Visits were made to the site to monitor thrips numbers.

The first visit was made on 17 July 2014 and 20 flowers were sampled randomly across the crop to determine the mean number of thrips per flower. One medium-aged flower sticking up from the top of the plant was selected and visual counts of thrips adults and larvae were then carried out. Following the initial visit on 17 July the grower treated half the crop with spinosad (Tracer) and the other half with a release of the predatory bug *Orius laevigatus.* Following the treatment, a return visit was made on 1 August 2014 and 24 flowers were sampled from each treatment area to determine the mean number of thrips and *O. laevigatus* per flower. Twenty four flowers were sampled systematically and some were brought back to ADAS, Boxworth so the thrips species could be identified. .

On the first visit prior to treatment a mean of six thrips adults per flower was recorded.

O. laevigatus treatment area

Following releases of *O. laevigatus*, there was an average of 1.1 and 0.25 thrips adults and larvae per flower respectively. There was also a mean of 0.04 *O. laevigatus* adults per flower (equivalent to one every 25 flowers) and 0.21 *O. laevigatus* nymphs per flower (equivalent to one every five flowers) which is equivalent to 25% of the flowers sampled having *O. laevigatus.*

Tracer treatment area

Following treatment with spinosad (Tracer) there was a mean of 1.17 and 0.21 thrips adults and larvae per flower respectively in the Tracer treatment area. There was also a mean of 0.13 (equivalent to one every 7.7 flowers) *O. laevigatus* adults and 0.13 *O. laevigatus* nymphs per flower which is equivalent to 25% of the flowers sampled had *O. laevigatus* on.

The numbers of thrips per flower and *O. laevigatus* per flower was similar between the treatments indicating that there was no difference between the two treatments. The data suggested that both treatments were effective in reducing the numbers of thrips per flower, as the numbers of thrips adults reduced from six per flower prior to treatment, to around one per flower following treatment in both treatment areas. However at the same time as this crop was being monitored, thrips species were also being monitored on other commercial crops, where growers who had experienced high numbers of thrips including *T. fuscipennis* were reporting a natural decline in thrips numbers. Therefore, it is cannot be confirmed whether the decline in thrips numbers was a treatment effect or a natural population change. This work did confirm that *O. laevigatus* provided control of *T. fuscipennis* as it was present throughout the monitoring period and was observed predating thrips on the strawberry flowers. It also confirmed that *T. fuscipennis* was reproducing on strawberry as larvae were present.

A literature review on current knowledge of *T. fuscipennis* biology, overwintering sites and natural enemies

Distribution and host range

Thrips fuscipennis, commonly known as rose thrips, is widely distributed across Europe and further afield including China and western North America. It has a wide host range including various ornamentals, fruit crops, legumes and cucumbers. Specific fruit crops include blackberry, strawberry and various fruit trees but *T. fuscipennis* has not previously been considered an important pest on these crops, with control measures considered unnecessary. Other important hosts include hedge weeds commonly found surrounding fruit crops such as bind weed (*Calystegias sepium*) and meadowsweet (*Filipendula ulmaria)*.

Biology and recognition

Thrips fuscipennis is reported to have up to four generations per year and is often found in association with *Thrips major* populations. *Thrips fuscipennis* adults are dark brown in colour and have seven antennal segments compared to those of *Frankliniella occidentalis* (western flower thrips) which is lighter in colour with eight antennal segments. Other *Thrips* species e.g. *T. major* can also occur in strawberry flowers and distinguishing *T. fuscipennis* from other *Thrips* species requires detailed examination of various morphological features under a high powered microscope using a diagnostic key.

In spring, the *T. fuscipennis* adults emerge from their overwintering sites which include the trunks of trees and amongst herbage. It has also been recorded overwintering together with *Thrips major* in bark crevices e.g. of chestnut. Once the adults have emerged they lay eggs on host plants from May onwards and the adults and larvae feed on leaves, shoots and in flowers until September. Males are reported to be present between June and October.

Control

Monitoring of *T. fuscipennis* is reported to be effective using blue traps and can be combined with Lurem-TR® which is a semiochemical (methyl isonicotinate) attractive to both males and female thrips species including *T. fuscipennis*. Work carried out in strawberry crops in the Netherlands indicated that *Thrips major* was the main species found on blue sticky traps with the Lurem-TR® attractant, although small numbers of *T. fuscipennis* were present in some sampling weeks.

Currently, *T. fuscipennis* remains susceptible to applications of spinosad (Tracer). However, growers of strawberry are concerned that this species may develop resistance to spinosad and are keen for a biological control solution.

Biological control agents are available for controlling thrips, such as the predatory mite *Neoseiulus cucumeris* which is widely used for WFT control on strawberry and on protected edible and ornamental crops. However, there is no published information on whether these also predate *T. fuscipennis* larvae. ADAS work in this project (CP 89) indicated that *Orius laevigatus* provided control of *T. fuscipennis* on a protected strawberry crop in 2014.

Overall there is very little published information available on this species with regard to its biology and control. Further knowledge on its biology would help to inform the development of effective integrated management strategies.

Comparing damage by *Thrips fuscipennis* (rose thrips) with *Frankliniella occidentalis* (western flowers thrips)

Following reports of *Thrips fuscipennis* causing damage on strawberry crops during 2014, a trial was carried out to confirm that *T. fuscipennis* causes damage on strawberry and whether the damage differs to that caused by western flower thrips. The experiment consisted of three treatments consisting of replicate thrips-proof mesh cages containing either western flower thrips (*Frankliniella occidentalis*), rose thrips (*Thrips fuscipennis*) or no thrips (control).

Each cage contained four strawberry plants. Before adding the plants to the cages the plants were grown under horticultural fleece in a polytunnel to stop natural infestation of thrips occurring.

Once the strawberry plants were put into the thrips- proof cages, *T. fuscipennis* was collected from a commercial site on 17 July and 10 were released into each *T. fuscipennis* cage on 18 July. Ten western flower thrips were also released into each of the WFT cages which were collected from the ADAS laboratory culture. An additional 15 of each thrips species were released into the cages on 1 August. Assessments were carried out on 15, 29 August and 12 September where the number of flowers, ripe fruit, thrips per flower and damage was assessed. Although no thrips had been released to the untreated cages, thrips were found on the plants with a mean of 0.01, 0.6 and 0.5 per flower on 15, 29 August and 12 September respectively. The untreated cages were always sampled first to prevent cross contamination with the other cages and therefore the plants must have been infested when they were covered with fleece while growing in the polytunnel. On the final sampling date, samples of the thrips were taken from the cages and it was confirmed that 100% of the seven thrips collected from the untreated cages were the onion thrips, *Thrips tabaci*. This confirms that the plants were naturally infested prior to them being moved into the thrips-proof cages as *T. tabaci* was not released in this experiment.

In the WFT cages, the numbers of thrips per flower increased at each sampling date with 0.01, 0.6 and 1.1 thrips per flower on 15, 29 August and 12 September respectively. In the

WFT cages, 62.5% of the eight thrips collected were WFT and 37.5% were *T. tabaci*. No cross contamination between WFT and *T. fuscipennis* occurred in the WFT cages.

In the *T. fuscipennis* cages, the numbers of thrips per flower increased at each sampling date with 0.06, 0.5 and 1.4 thrips per flower on 15, 29 August and 12 September respectively. When thrips samples were taken, it was confirmed that 30% of the 10 thrips collected were *T. tabaci* and 60% were *T. fuscipennis*. In one of the cages one potential WFT/ *Frankliniella intonsa* was also identified (10%).

Due to the natural contamination of the plants with *T. tabaci* it was very difficult to compare fruit damage caused by WFT and *T. fuscipennis* as it may have been caused by *T. tabaci. Thrips tabaci* is known to cause fruit damage on strawberry and this was confirmed in the untreated cages where damage was observed by the final assessment. It was also difficult to interpret the reproductive rate of *T. fuscipennis* and WFT on the strawberry plants as the *Thrips* species larvae could have been *T. tabaci.*

Potential of the predatory beetle Atheta coriaria for biological control of vine weevil larvae

Laboratory experiments carried out in the CRD-funded project PS 2130 demonstrated that *A. coriaria* adults and larvae predated a mean of 6.5 and 3.3 vine weevil larvae respectively over a three day period when offered eight 1-4 day-old vine weevil larvae.

An experiment was conducted in this project to assess whether vine weevil control could be achieved in more realistic conditions. Potted fuchsia plants were infested with vine weevil eggs and *A. coriaria* were applied at vine weevil egg hatch. The experiment consisted of two treatments; an untreated control (fuchsia plants infested with vine weevils) and an *A. coriaria* treatment (infested fuchsia plants treated with *A. coriaria*). Each plant was covered with an insect-proof mesh cage to prevent *A. coriaria* moving between plants and other pests or predators reaching the plant.

On 7 August each fuschia plants were infested with 15 vine weevil eggs. In total 30 adult and 30 larval *A. coriaria* were then released to each plant with five adults and larvae being released on 15 August, 10 adults and larvae being released on 16 August and a final 15 adults and larvae being released on 20 August.

Assessment of the plants took place on 21 October when they were assessed for numbers and weights of vine weevil larvae, number of *A. coriaria*, plant and root vigour and root weight.

There were no significant differences between the treatments in the number or weight of vine weevils, plant or root vigour, or root weight, indicating that *A. coriaria* did not provide control of vine weevil larvae in this experiment.

Financial Benefits

- Growers and agronomists will benefit from being aware that both WFT and *T. fuscipennis* can damage strawberry fruit.
- Soft fruit agronomists have already benefitted from the training in recognition of thrips species that can occur in strawberry flowers given at the HDC soft fruit agronomist's day on 12 February 2015.
- Growers and agronomists will benefit from being aware that *T. fuscipennis* is currently susceptible to spinosad (Tracer), unlike many populations of WFT on soft fruit farms.
- Improved knowledge of thrips recognition will reduce the unnecessary use of Tracer against spinosad-resistant WFT populations and allow growers to reserve the permitted number of applications of Tracer per year for control of spotted wing drosophila (SWD) if required.
- Growers and agronomists will benefit from the results of this project which showed that during late July and August 2014, *Orius laevigatus* established in strawberry flowers infested with *T. fuscipennis* where the predators were observed eating thrips and numbers of thrips per flower were reduced.

Action Points

- Strawberry growers and agronomists should be aware that different thrips species can infest strawberry flowers and both WFT and *T. fuscipennis* can damage fruit.
- Use a preventive programme of the predatory mites *Neoseiulus cucumeris* from first flowers in the spring.
- Consider starting releases *Orius laevigatus* to supplement control by *N. cucumeris* once temperatures are above 15°C (preferably above 20°C) for a few hours each day and during a flower flush to help them establish.

- Get your thrips species confirmed by an Entomologist. ADAS can help with this, contact gemma.hough@adas.co.uk or jude.bennison@adas.co.uk for details of the samples required. Species confirmation will help to plan an appropriate insecticide if needed as a back-up to biological control agents in your IPM programme.
- Hardy nursery stock growers using *Atheta coriaria* for the control of sciarid and shore flies may gain some incidental control of young vine weevil larvae, but *A. coriaria* should not be relied upon for biological control of vine weevil.

SCIENCE SECTION

Introduction

Rose thrips, Thrips fuscipennis

Knowledge gained by ADAS during 2013/14 in the IPM Fellowship confirmed that native thrips species were causing strawberry fruit damage in various commercial crops and geographic locations. The rose thrips, *Thrips fuscipennis* was identified in both 2013 and 2014 as commonly occurring in large numbers associated with rapidly-occurring fruit bronzing, in crops where WFT had been well controlled by *Neoseiulus cucumeris.* Growers have often applied spinosad (Tracer) which has given effective control. However, growers are concerned about the risk of insecticide resistance and would like a biological control option. In addition, growers are likely to wish to reserve Tracer for use against spotted wing drosophila (SWD) if needed, as the number of applications per crops are currently limited to four per year on protected strawberry. Some growers consider that as these species seem to migrate into the crop as adults in large numbers they are not controlled by *N. cucumeris* which only feeds on WFT larvae. It is unknown whether *N. cucumeris* can successfully predate *T. fuscipennis* larvae

In this year's Fellowship the following work has been carried out by Gemma Hough on *Thrips fuscipennis*:

- Monitoring *T. fuscipennis* at commercial sites
- A literature review on current knowledge of *T. fuscipennis* biology, overwintering sites and natural enemies
- Comparing damage by *T fuscipennis* (rose thrips) with *Frankliniella occidentalis* (western flowers thrips)

Potential of the predatory beetle Atheta coriaria for biological control of vine weevil

Vine weevil (*Otiorhynchus sulcatus*) is one of the most serious pest problems in both soft fruit and hardy nursery stock crops. Adult weevil damage to leaves and the presence of larvae around roots can make containerised ornamental plants unmarketable. Root damage caused by larvae in both ornamental and soft fruit crops leads to reduced plant vigour and yields and if damage is severe, to plant death.

Growers of susceptible soft fruit crops such as strawberry and raspberry commonly use entomopathogenic nematodes for vine weevil control, usually applied through drip-irrigation systems. This method is usually effective in substrate-grown crops but not in field-grown crops. Growers of containerised hardy ornamentals have until recently largely relied on the use of persistent insecticides in the growing media for vine weevil control. However, the choice of insecticides is now very limited due to recent EC restrictions on the use of neonicotinoid insecticides and in addition, growers are under pressure to reduce reliance on pesticides in favour of IPM. Entomopathogenic nematodes are used in containerised ornamentals for vine weevil control but drip irrigation is little used in these crops, therefore nematodes have to be applied using a drench. This method is labour-intensive and drenching can be less effective on large, closely spaced plants, when much of the drench can end up on the floor rather than on the target substrate in the pots. The entomopathogenic fungus *Metarhizium anisopliae* (Met52) is available for incorporation in growing media for vine weevil control, but its temperature requirements limits its use in ornamentals and the current formulation is impractical for use in soft fruit.

There is a need to improve biological control of vine weevil and a potential candidate for supplementing other biological control methods is the predatory beetle *Atheta coriaria*. This predator is commercially available for biological control of sciarid and shore flies in protected crops, where it feeds on both eggs and larval stages. In CRD-funded project PS 2130, ADAS demonstrated that in the laboratory, both *A. coriaria* adults and larvae predated young vine weevil larvae, although they did not feed on the eggs (Bennison *et. al*. 2011). The predator was investigated further in a semi-field experiment by Sacha White during 2014 as part of the Horticultural IPM Fellowship project.

Materials and methods

Monitoring Thrips fuscipennis at commercial sites

During 2014 ADAS fruit consultant Janet Allen sent in samples of thrips which were damaging everbearer fruit at a commercial site. It was confirmed that the thrips responsible were *Thrips fuscipennis*. Visits were made to the site to monitor the thrips numbers. The PYO crop consisted of eight rows of table top substrate-grown strawberries which were divided width ways by a walkway (Figure 2).

On the first visit made on 17 July 2014, 20 flowers were sampled randomly across the crop to determine the mean number of thrips per flower. On each sampling plant, one medium-aged flower sticking up from the top of the plant was selected. Medium-aged flowers are described as having fresh-looking petals but the pollen has dropped from the anthers so the anthers look brown rather than yellow (Figure 1). Visual in-field counts of thrips adults and larvae were then carried out using a head magnifier and carefully pulling down the petals on each side of the flower to expose the thrips

Young flower	Medium aged flower	Senescent flower
(yellow anthers)	(brown anthers)	(dropped petals)

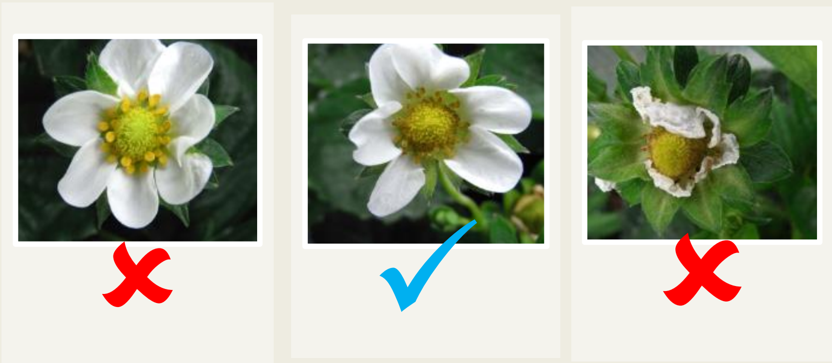

Figure 1 Determining young, medium aged and senescent flowers for thrips sampling.

Following the initial visit on 17 July the grower treated half the crop on one side of the walkway with spinosad (Tracer) and the other half with a release of *Orius laevigatus*. Following the treatment, a return visit was made on 1 August 2014 and 24 flowers were sampled from each treatment area to determine the mean number of thrips and *O. laevigatus* per flower. Twenty four flowers were sampled systematically from each area with three flowers being sampled in each row (Figure 2). Flower samples were also brought back to ADAS, Boxworth where the thrips species were identified.

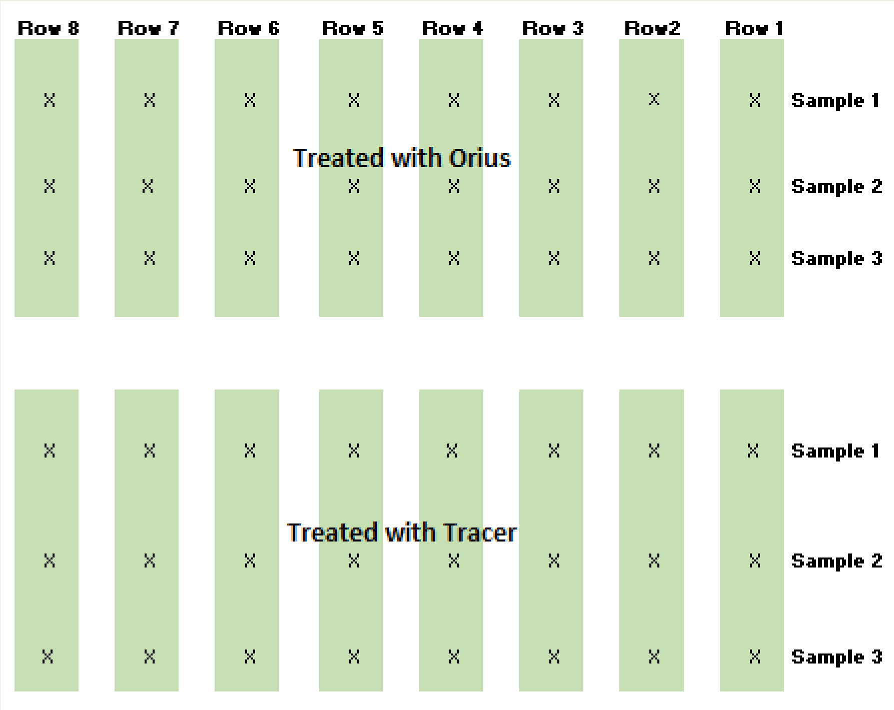

Figure 2 Strawberry crop layout consisting of eight rows of table top strawberries divided into two sections by a walkway. X represents the area flowers were sampled from following treatment with Tracer and *O. laevigatus.*

Review of Thrips fuscipennis

A review of the literature was carried out to summarise the current knowledge available on the biology, overwintering and control of *T. fuscipennis*. General internet searches and searches via Web of Science of the scientific literature relating to *T. fuscipennis* or rose thrips (without any date restrictions) were carried out.

Comparing damage by Thrips fuscipennis (rose thrips) with Frankliniella occidentalis (western flowers thrips)

Following reports of *Thrips fuscipennis* causing damage on strawberry crops during 2014, an experiment was carried out to confirm that *T. fuscipennis* causes damage on strawberry and to determine whether the damage differs to that caused by western flower thrips.

The experiment consisted of three treatments (Table 1) of either western flower thrips (*Frankliniella occidentalis*), rose thrips (*Thrips fuscipennis*) or no thrips (control). Each treatment had five replicates with each replicate consisting of a thrips-proof cage containing two small sections of a growbag each with two strawberry plants (variety Calypso) to give four plants per cage (Figure 3). The cages were arranged in a randomised design in a polytunnel.

Table 1 Treatments

Treatment	Thrips species
1	Untreated (no thrips)
2	Western flower thrips (*Frankliniella occidentalis*)
3	Rose thrips (*Thrips fuscipennis*)

Figure 3 Each thrips-proof cage contained two sections of a grow bag containing two strawberry plants each.

Plant propagation: On 28 May the strawberry plants to use in the experiment were planted into tomato grow bags (also suitable for strawberries) in a polytunnel and covered with horticultural fleece to reduce the risk of a natural infestation of thrips occurring (Figure 4). Drip irrigation was used to water the plants. On 18 July the grow bags were cut up into sections each containing two strawberry plants and two sections were added per thrips-proof cage (four plants per cage, Figure 3). The floor of the cages were lined with capillary matting so the strawberry plants could be watered using sub-irrigation. The bottom of the grow bags were slit to allow water to be taken up.

Figure 4 Strawberry plants grown under horticultural fleece

Thrips infestation: Once the plants were in the cages and were flowering, thrips adults were used to infest the plants. Western flower thrips were sourced from the ADAS laboratory culture (Figure 5b) and *T. fuscipennis* was sourced from a commercial site (Figure 5a) where it had been confirmed there was a pure population (all samples collected were confirmed as *T. fuscipennis*).

Once the strawberry plants were put into the thrips-proof cages, *T. fuscipennis* was collected from the commercial site on 17 July and 10 were released into each *T. fuscipennis* cage on 18 July. Ten western flower thrips were also released into the WFT cage which were collected from the ADAS culture. An additional fifteen of each thrips species were released into the cages on 1 August. Prior to the second release of thrips, some flowers were removed (including buds that were starting to open) to make sure there were only two flowers per cage. This was done to provide the same number of flowers per cage when a high density of thrips were released, to ensure the thrips were given the best opportunity to cause damage.. Flowers which were removed were tapped over the plants with the remaining two flowers to make sure any released thrips remained in the cage.

Figure 5a Rose thrips, *Thrips fuscipennes* (left) **5b** western flower thrips, *Frankliniella occidentalis* (right)

Assessments: Assessments were carried out on 15, 29 August and 12 September when the numbers of flowers ripe fruit, thrips per flower and fruit and damage were assessed.

Potential of the predatory beetle Atheta coriaria for biological control of vine weevil

Petri dish experiments carried out in the CRD-funded project PS 2130 demonstrated that *A. coriaria* adults and larvae predated a mean of 6.5 and 3.3 vine weevil larvae respectively over a three day period when offered eight 1-4 day-old vine weevil larvae (Bennison, 2011).

An experiment was conducted to assess whether vine weevil control could be achieved in more realistic conditions. Potted fuchsia plants were infested with vine weevil eggs and *A. coriaria* were applied at vine weevil egg hatch. The experiment consisted of two treatments; an untreated control (T1 - fuchsia plants infested with vine weevils) and an *A. coriaria* treatment (T2 - infested fuchsia plants treated with *A. coriaria*).

Plant propogation

On 11 July 2014 24 potted fuchsia plants were potted up and placed in a polytunnel. Plants were watered overhead. Each plant was covered with a fabric insect-proof cage to prevent *A. coriaria* moving between plants and other pests or predators reaching the plant (Figure 6). Sticky tape was also placed on the ground-cover matting around the trial area to prevent infestation of the plants with any wild vine weevils. Twelve plants were randomly allocated to each treatment.

Figure 6 *Atheta* trial with fuchsia plants covered with a fabric cage to prevent *A. coriaria* moving between plants.

Vine weevil culturing

Adult weevils were obtained from a commercial strawberry crop during 2014. Adult vine weevils were kept in 1.5 l plastic pots. The lids of these pots were perforated in order to provide ventilation. The base of each pot was lined with damp tissue paper (source of moisture), and an additional ball of dry tissue paper was provided as a refuge. Twenty to 30 weevils were placed into each pot, which in turn were placed in a controlled temperature room at 20°C. Pots were cleaned on a weekly basis and fresh yew leaves (*Taxus baccata*) were provided as a food source

***Atheta coriaria* culturing**

Atheta coriaria were reared using methods developed as part of the HDC Project PC 239 and available in HDC Factsheet 06/10. *Atheta coriaria* were reared in 3 litre plastic boxes with snap-on lids. Two ventilations holes were cut in lid of each box and covered with insect -proof mesh. A substrate of 1:1 coir and vermiculite was added to each box (approx. 1.5 litres) and mixed. Water was added to the substrate to ensure it was damp. *Atheta coriaria* were then added to the each box to start the cultures. *Atheta coriaria* to start the cultures were kindly provided by Richard Greatrex at Syngenta Bioline.

The cultures were kept at room temperature. Every week approx. 15g of ground pelleted chicken food was added to each culture. Water was added if necessary to ensure the substrate remained damp.

Vine weevil infestation

Vine weevil eggs were collected from the cultures on 6 August 2014. On 7 August ,15 eggs were applied to each fuchsia plant. This was done by washing the eggs off filter paper into a small hole in the compost at the base of each plant. Once complete the hole was covered over with compost. The eggs were an orange-brown colour, indicating that they were close to hatch. Twenty eggs were also kept at room temperature on damp filter paper in a Petri dish and monitored daily for egg hatch. On 14 August 20% of eggs had hatched and 15 August 60% of eggs had hatched. Maximum egg hatch was 85%.

***Atheta coriaria* infestation**

On 15 August, once over 50% of the vine weevil eggs had hatched, five adult *A. coriaria* and five larvae were released to the compost at the base of each plant in T2. On 16 August a further 10 adults and 10 larvae were added to each T2 plant. On 20 August the final release of 15 adults and 15 larve were added to each T2 plant. In total 30 adult and 30 larval *A. coriaria* were added to each plant, using staggered releases to coincide with vine weevil egg hatch and to avoid *A. coriaria* cannibalism should insufficient other prey be available.

Assessments

On 21 October, the plant root systems and compost were assessed for numbers of vinse weevil larvae (vine weevils separated into small, medium and large categories), number of *A. coriaria* adults and larvae, plant and root vigour (1 to 5 scale, 1 = poor) and root weight.

Results and Discussion

Monitoring Thrips fuscipennis at commercial sites

On the initial visit, prior to the grower treating the crop with Tracer and *Orius laevigatus* a mean number of six thrips adults per flower were recorded (20 flowers sampled). Samples of the thrips on the strawberry flowers were taken and brought to ADAS Boxworth where they were identified as *T. fuscipennis*. High numbers of thrips were also observed in hedgerows surrounding the strawberry crop, particularly in bind weed (*Calystegia sepium*) and wild blackberries and these were also confirmed as *T. fuscipennis*. Kirk (1985a) confirmed that *T. fuscipennis* aggregates and mates in bind weed flowers once they open at dawn, from where they continue to actively disperse during the day.

On the second visit following the treatment of half the crop with *O. laevigatus* and the other half with Tracer, 24 flowers were sampled in each treatment area.

O. laevigatus treatment area

Following the releases of *O. laevigatus*, there was an average of 1.1 and 0.25 thrips adults and larvae per flower respectively (Figure 7). There was also a mean of 0.04 *O. laevigatus* adults per flower (equivalent to 1 every 25 flowers) and 0.21 *O. laevigatus* nymphs per flower (equivalent to 1 every 5 flowers) which is equivalent to *O. laevigatus* being present in 25% of the flowers sampled (Figure 8).

Tracer treatment area

Following treatment with spinosad (Tracer) there was a mean of 1.17 and 0.21 thrips adults and larvae per flower respectively in the Tracer treatment area (Figure 7). There was also a mean of 0.13 (equivalent to one every 7.7 flowers) *O. laevigatus* adults and 0.13 *O. laevigatus* nymphs per flower which again meant 25% of the flowers sampled had *O. laevigatus* on (Figure 8).

The numbers of thrips and *O. laevigatus* per flower were similar in each treatment indicating that there was no difference between the two treatments. A two sample T-test was carried out on the data and no significant differences between the mean numbers of thrips and *O. laevigatus* in each treatment area was observed (P= n.s.). The data suggested that both treatments were effective in reducing the mean numbers of thrips per flower from six per flower prior to treatment, to around one per flower following treatment in both treatment areas, However, during the same period (August 2014) other growers in different areas of the UK who had experienced high *Thrips* species numbers (confirmed to be species mixes including *T. fuscipennis*) were reporting a natural decline in thrips numbers. Therefore, it cannot be confirmed whether the decline in thrips numbers was a treatment effect or a natural population change. However, this work did confirm that *O. laevigatus* had established in strawberry flowers infested with *T. fuscipennis* as it was present throughout the monitoring period and was observed eating thrips on the strawberry flowers. It also confirmed that *T. fuscipennis* was reproducing on strawberry as larvae were present in addition to adults

Orius treatment

	Row 8	Row 7	Row 6	Row 5	Row 4	Row 3	Row 2	Row 1
Sample 1	3 adults	0	2 adults 1 larvae	1 adult	1 adult	0	1 larvae	0
Sample 2	3 adults	1 adult	2 adults 1 larvae	0	2 adults	1 adult	1 larvae	1 larvae
Sample 3	2 adults	0	3 adults	1 adult	4 adults 1 larvae	1 adult	0	0

Tracer treatment

	Row 8	Row 7	Row 6	Row 5	Row 4	Row 3	Row 2	Row 1
Sample 1	5 adults 1 larvae	0	1 larvae	1 dead adult	2 adults	1 adult	1 adult	0
Sample 2	0	2 adults	1 adult	2 adults	2 adults	1 larvae	0	0
Sample 3	2 adults	0	3 adults	0	3 adults	2 larvae	3 adults	1 adult

Figure 7 Number of thrips larvae and adults recorded on each of the 24 flowers sampled from each treatment area.

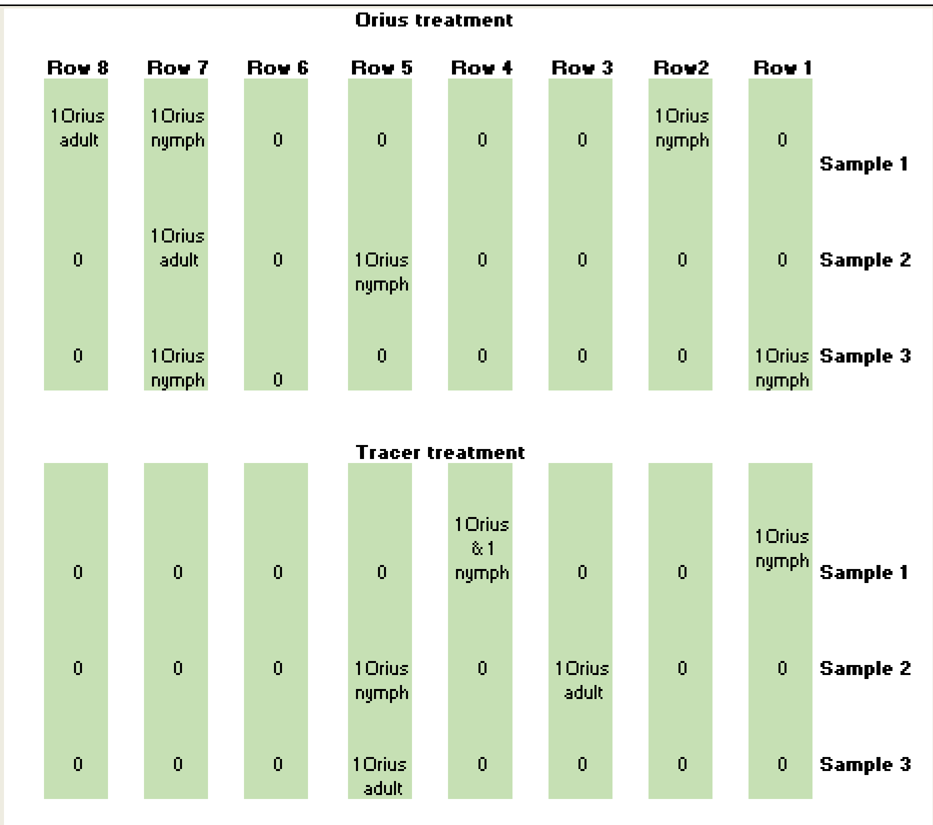

Figure 8 Number of *O. laevigatus* adults and larvae recorded on each of the 24 flowers sampled from each treatment area.

Review of Thrips fuscipennis

Thrips fuscipennis, commonly known as the rose thrips, is widely distributed across Europe (Poland, Britain, Italy, Turkey) and further afield including China and western North America (Nakahara, 1994). In the UK, it is reported to be more abundant in the East and South and reaches as far north as the southern boundary of the Highland Boundary Fault (traverses Scotland from Arran and Helensburgh) (Morison, 1957). It has a wide host range including various ornamentals (Alford 1991), fruit crops (Alford, 1984), legumes and cucumber (Lewis, 1997). Specific fruit crops include blackberry, strawberry and various fruit trees (Alford, 1984). Hedge weeds commonly found surrounding fruit crops are also suitable hosts such as bind weed (*Calystegia sepium*) and meadowsweet (*Filipendula ulmaria)* (Kirk, 1985a).

Biology

Thrips fuscipennis is reported to have up to four generations per year (Alford, 1984) and is often found in association with *Thrips major* populations (ADAS data, unpublished, van Kruistum (2013), Morison, 1957).

In spring, the adults emerge from their overwintering sites which include the trunks of trees and amongst herbage (Morison, 1957). It is also recorded overwintering together with *Thrips major* in bark crevices e.g. of chestnut (Speyer, 1938). Once the adults have emerged they lay eggs from May onwards and after egg hatch the larvae feed on leaves, shoots and in flowers until September (Alford, D., 1984). Males are reported to be present between June and October (Alford, 1984). Work on the oviposition rate of *T. fuscipennis* has shown that its population can be regulated by oviposition decreasing with an increase in population density (Kirk, 1994).

Identification

Thrips fuscipennis is dark brown in colour and has seven antennal segments compared with *Frankliniella occidentalis* (western flower thrips) which is lighter in colour with eight antennal segments. Distinguishing *Thrips fuscipennis* from other *Thrips* species requires detailed examination of various morphological features under a high powered microscope using a diagnostic key (Mound *et al*., 1976). As previously mentioned *T. major* and *T. fuscipennis* are often found together and it is possible that misidentification of these two species may sometimes have occurred as the main distinguishing feature is whether there are three (*T. major*) or four (*T. fuscipennis*) hairs on the tergite (See glossary) of abdominal segment two on the dorsal side (top side) which can often be difficult to see depending on the quality of the mounted specimen.

Information to aid molecular identification is available including genetic profiles of *T. fuscipennis* produced by gel electrophoresis in response to four primer pairs (CS249/CS250; 18SMP/28SMP; 18J/O1; P1/28Z) using the restriction enzymes Rsa I, Hae III, Msp I, Hinf I and Alu I, (Thripsnet, 2015).

Control

Thrips cause direct plant damage by piercing and sucking out the contents of plant cells which results in a silvery appearance on leaves and WFT and *T. fuscipennis* can also cause bronzing on fruit. *Thrips fuscipennis* also feed on the contents of pollen grains but are capable of reproducing on leaves in the absence of pollen (Kirk, 1984; Kirk 1995). However, the presence of pollen resulted in significantly more eggs being laid by *T. fuscipennis* compared with when other floral tissues were provided or no food was given (Kirk, 1985b). *Thrips Fuscipennis* has not been previously considered as an important pest on fruit crops and control has been considered unnecessary (Alford, D., 1984).

Monitoring of *T. fuscipennis* is reported to be effective using blue traps and these can be combined with Lurem-TR® which is a semiochemical, methyl isonicotinate, attractive to both males and females of many thrips species including *T. fuscipennis* (Koppert, 2006; Teulon et al, 2011). Work carried out by van Kruistum (2013) in the Netherlands indicated that *Thrips major* was the main species found on blue sticky traps with the Lurem-TR attractant in strawberry in weeks 24, 28 and 31, although small number of *T. fuscipennis* were present in week 34. These results may be due to more *T. major* than *T. fuscipennis* being present in the crop, rather than the traps and lures being more attractive to *T. major*. In Horticulture LINK project HL1107 (SF 120), in an ADAS trial evaluating the use of blue roller traps for thrips control in a strawberry crop where *T. major* was the predominant species, the traps did not lead to significantly fewer thrips adults per flower when numbers per flower peaked in late July, but did lead to significantly fewer thrips larvae per flower than in plots without blue roller traps (Cross *et al*., 2015).

Other compounds have also been identified which are attractive to thrips, including *p*-anisaldehyde (a volatile secondary plant compound) which was found to capture *T. fuscipennis* as well as other flower thrips when added to various types of traps (Teulon *et al.*, 1993).

Currently, unlike western flower thrips, *T. fuscipennis* remains susceptible to applications of spinosad (Tracer).

The predatory mite *Neoseiulus cucumeris* is widely used for control of WFT on many protected crops and on strawberry, but no published information is available as to whether these predate *T. fuscipennis* larvae. ADAS work in this project, CP 89 indicated that *Orius laevigatus* provided control of *T. fuscipennis* on a protected strawberry crop in 2014.

Overall there is very little published information available on this species with regard to its biology, particularly developmental biology, and control. Further knowledge on its biology would help to inform the development of effective integrated management strategies.

Comparing damage by Thrips fuscipennis (rose thrips) with Frankliniella occidentalis (western flowers thrips)

Figure 9 shows the mean number of thrips per flower for each treatment. Although thrips were not released in the untreated cages, thrips were found on the untreated plants with a mean of 0.01, 0.6 and 0.5 per flower on 15, 29 August and 12 September respectively. The untreated cages were always sampled first to prevent cross contamination with the other cages and therefore the plants must have been naturally infested when they were covered with fleece while growing in the polytunnel. On the final sampling date, samples of the thrips were taken from the cages and it was confirmed that 100% of the seven thrips collected from the untreated cages were the onion thrips, *Thrips tabaci*. This confirms that the plants were naturally infested prior to them being moved into the thrips-proof cages as *T. tabaci* was not released in this experiment.

In the WFT cages, the numbers of thrips per flower increased at each sampling date with 0.01, 0.6 and 1.1 thrips per flower on 15, 29 August and 12 September respectively. In the WFT cages, 62.5% of the eight thrips collected were WFT and 37.5% were *T. tabaci*. No *T. fuscipennis* occurred in the WFT cages.

In the *T. fuscipennis* cages, the numbers of thrips per flower increased at each sampling date with 0.06, 0.5 and 1.4 thrips per flower on 15, 29 August and 12 September respectively. When thrips samples were taken, it was confirmed that 30% of the 10 collected were *T. tabaci* and 60% were *T. fuscipennis*. In one of the cages one individual which could have been either WFT or *Frankliniella intonsa* (difficult to see diagnostic features for identification) was also present (10% of the thrips collected).

On the first assessment on 15 August, it was evident that the strawberry plants were not taking up enough water via the capillary matting in the cages and as a result they were wilting and the developing buds and fruit had started to abort which may explain the reduction in the mean number of flowers per cage on the last two sampling dates. The numbers of thrips per flower could have been influenced by the number of available flowers (Figure 11) i.e. where cages had fewer flowers the mean numbers of thrips per flower would be higher as they would aggregate in those few remaining flowers.

Due to the natural contamination of the plants with *T. tabaci* it was very difficult to compare the damage caused by WFT and *T. fuscipennis* as it may also have been caused by *T. tabaci* (Figure 10). *Thrips tabaci* is known to cause fruit damage on strawberry and damage occurred by the final assessment in the untreated cages (where only *T. tabaci* was confirmed). It was also difficult to interpret whether *T. fuscipennis* reproduced on the strawberry plants as the larvae found could also have been *T. tabaci.* For the reasons discussed statistical analysis was not carried out on the data as significant results could be misleading.

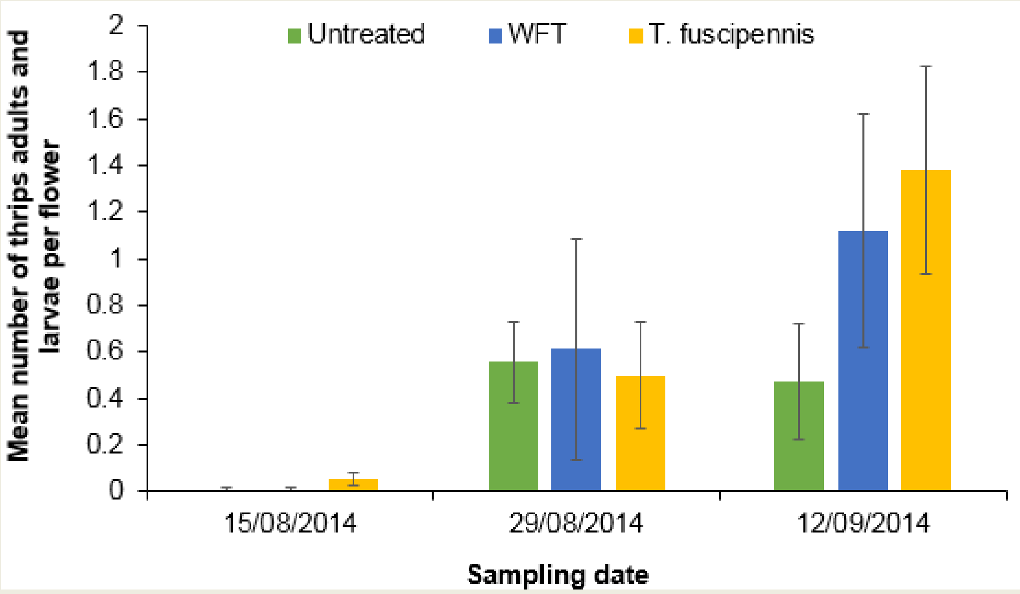

Figure 9 Mean number of thrips and larvae per flower in untreated cages and those where either WFT or *T. fuscipennis* were released (with standard error).

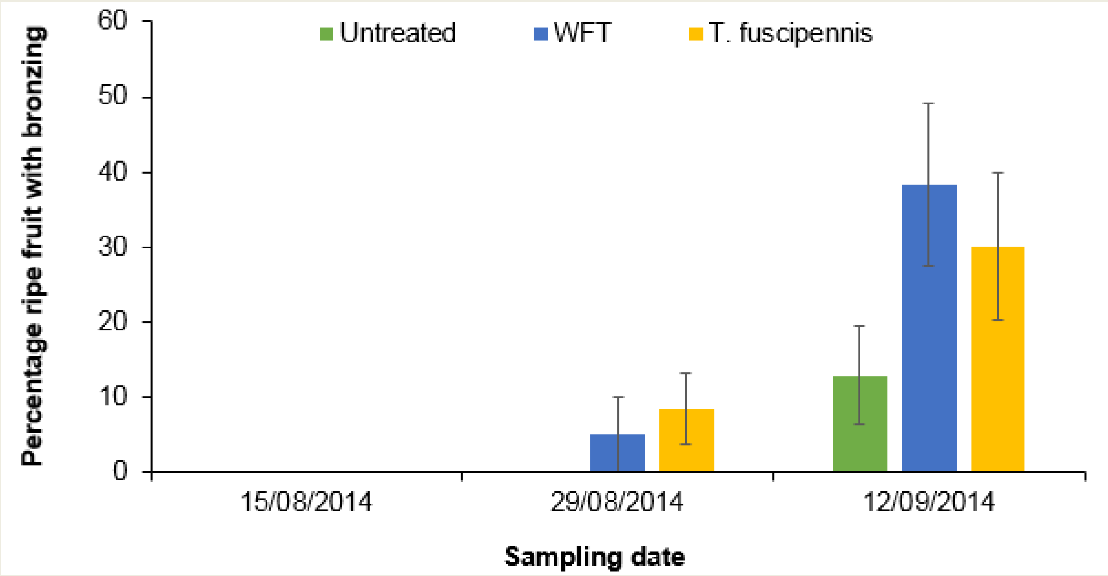

Figure 10 Mean percentage of ripe fruit with bronzing in untreated cages and those where either WFT or *T. fuscipennis* were released (with standard error).

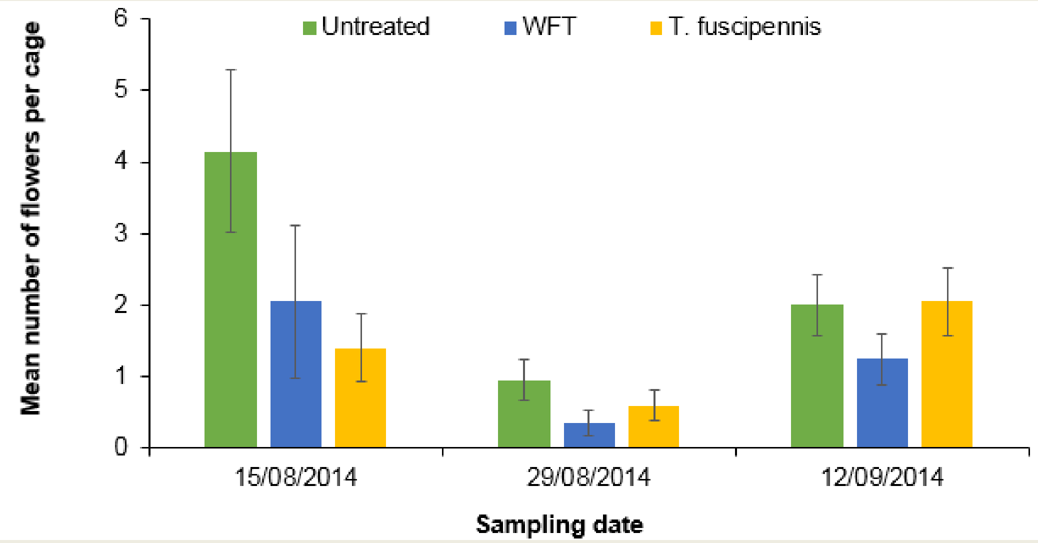

Figure 11 Mean number of flowers per cage in untreated cages and those where either WFT or *T. fuscipennis* were released (with standard error).

Potential of the predatory beetle Atheta coriaria for biological control of vine weevil

Two-sample t-tests were carried out on the data. There were no significant differences between the treatments in the number or weight of vine weevils (P = n.s.) (Fig. 12), plant or root vigour (P = n.s.) (Fig. 13), or root weight (P = n.s.) (Figure 14).

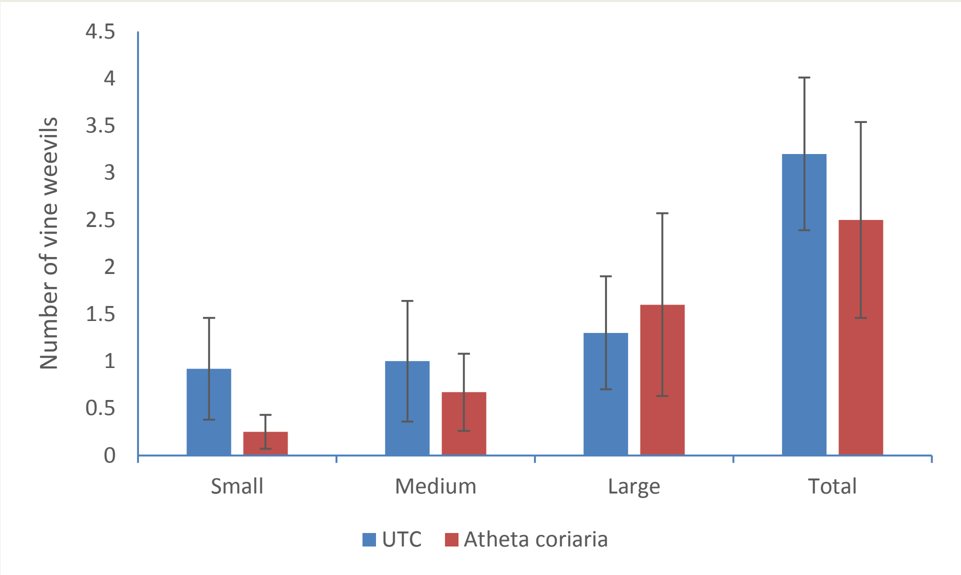

Fig. 12 Number of vine weevil in each size category and total number in the untreated control (UTC) and *Atheta coriaria* treatments. Bars indicate the standard error of the mean.

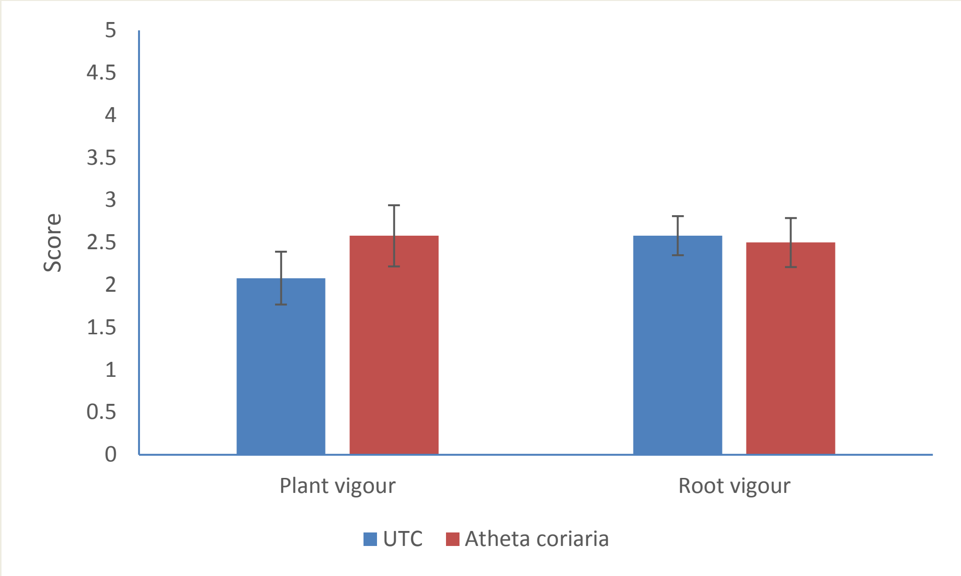

Fig. 13 Plant and root vigour (scored 1 to 5, 1 = poor condition) in the untreated control (UTC) and *Atheta coriaria* treatments. Bars indicate the standard error of the mean.

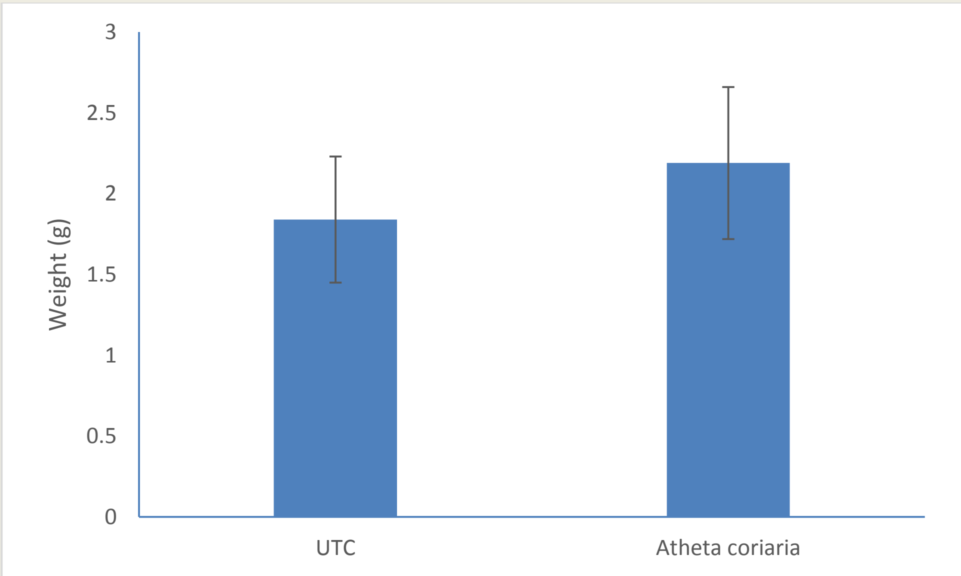

Fig. 14 Root weight (g) in the untreated control (UTC) and *Atheta coriaria* treatments. Bars indicate the standard error of the mean.

Conclusions

Monitoring Thrips fuscipennis at commercial sites

● *Thrips fuscipennis* can damage strawberry fruit.

● Bind weed and wild blackberry flowers can be a source of *T. fuscipennis.*

● *Orius laevigatus* predates *T. fuscipennis*

● A natural decline in thrips numbers made it difficult to determine the effect of the treatments of Tracer and the release of *O. laevigatus.*

Review of Thrips fuscipennis

●Very little published information is available on this species and further knowledge on its biology will help to inform the development of effective integrated management strategies.

●Hedge weeds commonly found surrounding fruit crops are also suitable hosts for *T. fuscipennis* such as bind weed (*Calystegias sepium*) and meadowsweet (*Filipendula ulmaria)*

●*Thrips fuscipennis* is reported to have up to four generations per year and is often found in association with *Thrips major* populations

● Monitoring of *T. fuscipennis* is reported to be effective using blue traps and can be combined with Lurem-TR

● *T. fuscipennis* currently remains susceptible to applications of spinosad (Tracer).

●No published information is available as to whether *Neoseiulus cucumeris* predates *T. fuscipennis* larvae. *Orius laevigatus* predates *T. fuscipennis.*

Comparing damage by Thrips fuscipennis (rose thrips) with Frankliniella occidentalis (western flowers thrips)

● Due to the natural contamination of the plants with *T. tabaci* it was very difficult to compare the damage caused by WFT and *T. fuscipennis* as some damage may have been caused by *T. tabaci*

● It was difficult to interpret the comparative reproductive rate of *T. fuscipennis* and WFT on the strawberry plants as some of the larvae could have been *T. tabaci.*

Potential of the predatory beetle Atheta coriaria for biological control of vine weevil

● *A. coriaria* did not effectively control vine weevil in the pot experiments. However, there were relatively low numbers of vine weevil larvae in the untreated controls.

● Springtails were found in abundance in the compost. *Atheta coriaria* are known to feed on various soil-dwelling invertebrates including springtails and it is possible that they predated these rather than the vine weevil larvae. The availability of alternative food sources for biological control agents are known to interfere with biological control programmes, as they can preferentially feed on these rather than the target pest.

Knowledge and Technology Transfer

The results of each research project were discussed informally with the growers hosting the trial.

Publications (with input from experienced ADAS colleagues):

● Gemma Hough and Sacha White published HDC News articles on the Entomology Fellowship (CP 89)

Scientific conferences:

●Gemma Hough presented and published a paper on Biological control of vine weevil larvae on protected strawberry. IOBC Integrated protection of fruit crops Subgroup “Soft Fruits” 25-30 May 2014

● Sacha White co-presented a paper with Jude Bennison on thePotential of the predatory beetle *Atheta coriaria* for biological control of vine weevil. AAB conferenceAdvances in IPM 2014, Olde Barn Hotel, Marston, Lincolnshire, 19-20 November 2014.

Glossary

Tergite- a hardened plate forming the tergum of a segment (Oxford dictionaries).

Tergum - A thickened dorsal plate on each segment of the body of an arthropod (Oxford dictionaries).

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