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 89
Project leader:	Jude Bennison, ADAS
Report:	Interim, March 2012
Previous report:	-
Fellowship staff:	Jude Bennison, Senior Entomologist, ADAS Boxworth (lead Fellowship mentor) Mike Lole, Senior Entomologist, ADAS Rosemaund (mentor) Steve Ellis, Senior Entomologist, ADAS High Mowthorpe (mentor) John Buxton, Senior Entomologist (mentor) John Atwood, Senior Horticultural Consultant (mentor) Chris Dyer, Statistician, ADAS (mentor) Heather Maher, Senior Research Manager, ADAS Boxworth (mentor) Kerry Maulden, Senior Research Manager, ADAS Boxworth (mentor) Shaun Buck, Senior Research Manager, ADAS High Mowthorpe (mentor)

("Trainees")	Tom Pope, Entomologist, ADAS Boxworth (Fellowship trainee Entomologist and Project Manager) Gemma Gillies, Graduate Entomologist, ADAS Boxworth (Fellowship trainee Entomologist) Joanna Greetham, Senior Research Technician, ADAS Boxworth (Fellowship trainee scientific support staff) Tracie Evans, Research Technician, ADAS Boxworth (Fellowship trainee scientific support staff) Chloe Whiteside, Research Technician, ADAS Boxworth (Fellowship trainee scientific support staff)
Location of project:	ADAS Boxworth and commercial farms and nurseries
Industry Representative:	-
Date project commenced:	01 April 2011
Date project completed (or expected completion date):	31 March 2016

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 ....

Report authorised by:

Dr Tim O'Neill
Horticulture Research Manager
ADAS

Signature ....   Date ....

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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. Gemma Gillies joined ADAS Boxworth in October 2011. Mentoring activities included:

Visits to commercial nurseries and farms

Visits were made by Gemma Gillies and Tom Pope with Senior ADAS entomologists, Jude Bennison, John Buxton and Mike Lole and with Principal ADAS fruit/HNS consultant, John Atwood. Nurseries and farms visited included:

- Soft fruit farms (strawberry, raspberry, blackberry): consultancy visits as well as specific monitoring of thrips, aphids, vine weevil, two-spotted spider mite and tarsonemid (with Jude Bennison and John Atwood)
- Protected ornamentals: IPM strategies and biocontrol application techniques (with Jude Bennison and John Buxton)
- Hardy nursery stock: consultancy visits and specific monitoring of aphids and parasitoids (with John Buxton and Jude Bennison)

- Protected herbs: aphids and biocontrol strategies (with Jude Bennison)
- Field vegetables: cabbage root fly management (with Mike Lole) and biocontrol of aphids (with Jude Bennison)

Pest and biocontrol agent identification

Laboratory training on identification of key horticultural pests was completed by Gemma Gillies and Tom Pope as well as key members of the scientific support team at ADAS Boxworth. Training courses included:

- Thrips identification: methods for collecting, preparing and identifying the main thrips species infesting protected edibles, soft fruit and ornamental crops (training given by Jude Bennison and Mike Lole)
- Predatory mite identification: methods for collecting, preparing and identifying commercially available and certain naturally-occurring species (ADAS training given by Mike Lole, training workshop at IOBC conference was given by Sandra Mulder of Koppert BV together with other international mite specialists)
- Free living nematode identification: methods for extracting and identifying key species (training given by Steve Ellis, Shaun Buck and Heather Maher)
- Aphid, parasitoid and hyperparasitoid identification: aphid species infesting edible, soft fruit and ornamental crops, and associated parasitoids and hyperparasitoids (training given by Tom Pope and Mike Lole, parasitoid and hyperparasitoid species confirmed by the Natural History Museum).

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

Technical meetings with 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. Industry commodity group meetings and HDC research update meetings were also attended, e.g. the BHTA (British Herbs Trade Assocation) technical meeting and the HDC/EMRA soft fruit research update meeting. Scientific meetings attended included the AAB (Association of Applied Biology) conferences on Biopesticides and Advances in Biological Control, and the IOBC (International Organisation for Biological Control) conference on IPM in Protected Crops.

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

Contribution of overwintered predatory mites to pest mite control on strawberry

Numbers of tarsonemid mite and two-spotted spider mite were recorded on five crops of polytunnel-grown strawberry at a farm in Cambridgeshire between 25 May and 28 July 2011. The strawberry crops included both June-bearers and everbearers. Predatory mites were also recorded, noting whether they were associated with, and therefore likely to be feeding on, pest mites. Predatory mites recorded before predator releases by the grower were assumed to have overwintered within or close to the crop. Subsequent sampling of predatory mites provided information on population development of mite species recorded.

Overall numbers of tarsonemid mite and two-spotted spider mite were low. Tarsonemid mites were only found on unexpanded leaves and two-spotted spider mites were only found on fully expanded leaves. No mites were found in sampled flowers. Tarsonemid mites were recorded throughout the sampling period, while two-spotted spider mites were only recorded from 21 June onwards. Where tarsonemid mites were recorded, numbers remained fairly constant; while for two-spotted spider mite, numbers of mites increased towards the end of the sampling period. However, these trends must be considered in context with the IPM programme used to control mite pests. In particular, where two-spotted spider numbers were highest, on a second year crop of cv. Sonata, an application of bifenazate (Floramite 240 SC) on 13 July was effective in controlling this pest. Similarly, an application of abamectin (Dynamec) may have been effective in controlling tarsonemid on first year crops of cv. Jubilee. Predatory mites were not released by the grower until the end of the sampling period, except on the two first year Jubilee crops where *Neoseiulus* (*Amblyseius*) *cucumeris* was applied on 11 June and 20 July.

Overwintered predatory mites were recorded from three of the five crops sampled. Only eight predatory mites were recorded throughout the sampling period. These predators were only found associated with either tarsonemid mites or two-spotted spider mites. All of the predatory mites recorded were species of *Neoseiulus*. Of the predatory mites associated with tarsonemid mites, only those from a planting of cv. Christine were adults and thus could be identified to species, i.e. a single *Neoseiulus aurescens* and four *Neoseiulus californicus*. Two predatory mites were recorded associated with two-spotted spider mite, these were *Neoseiulus californicus* and *Neoseiulus cucumeris*. Unidentifiable (juvenile) predatory mites were recorded on the first year crops of Jubilee associated with two-spotted spider mite, but these were only found following releases of *Neoseiulus cucumeris* to these crops. Thus, these mites could have been either released or had overwintered.

These results were consistent with the results of HDC project SF 115 in that *Neoseiulus californicus* was the most frequently found predatory mite overwintering on strawberry. *Neoseiulus aurescens* and *N. cucumeris* were also found to have overwintered on strawberry. The fact that these mites were only found associated with either tarsonemid mites or two-spotted spider mite indicates that overwintered predatory mites may provide useful early season control of these pests. However, it is not clear from these results how populations of these predators would respond to higher pest pressures.

Aphid hyperparasitoids on protected edibles, soft fruit and ornamentals

Aphid hyperparasitoids were collected from a protected strawberry crop in Cambridgeshire, a hardy nursery stock (HNS) site in Norfolk and a sweet pepper crop in Essex. The grower at each site used regular releases of aphid parasitoids in their IPM programmes. At the sweet pepper site, a mix of *Aphidius colemani*, *Aphidius ervi* and *Aphelinus abdominalis* was used. At the strawberry and HNS sites, a new aphid parasitoid mix available from BCP Certis was used, which included the three parasitoid species above, as well as three 'new' species, *Aphidius matricariae*, *Praon volucre* and *Ephedrus cerasicola*.

Each site was sampled on two occasions and parasitised (mummified) aphids were collected. Where possible, the aphid species and primary parasitoid genus were identified from the appearance of the 'mummy'. Evidence of primary parasitoid emergence (indicated by a neat circular exit hole) or hyperparasitoid emergence (indicated by a ragged emergence hole) was also recorded. Where there was no emergence hole, the mummified aphids were kept in the laboratory until either a primary or a hyperparasitoid emerged. Emerging hyperparasitoids were sent to the Natural History Museum for identification.

Hyperparasitism occurred in protected strawberry and HNS as well as in sweet pepper, on a range of aphid species parasitised by both *Aphidius* spp. and *Praon* spp. The hyperparasitoid species were similar to those recorded in PC 295 and 295a:

Protected strawberry: No hyperparasitism was recorded on 24 June, 5% hyperparasitism was recorded on 19 October. The aphid species was the potato aphid, *Macrosiphum euphorbiae* and the hyperparasitoid species were *Asaphes suspensus*, *Dendrocerus laticeps* and *Pachyneuron* sp.

Protected HNS: Hyperparasitism of aphids on selected plant species was 21% on 19 August and 32% on 26 September. The aphid species were the melon-cotton aphid, *Aphis gossypii*, the violet aphid, *Myzus ornatus* and the potato aphid, *Macrosiphum euphorbiae*. The parasitoid species were *Aphidius* spp. and *Praon* spp. and the hyperparasitoid species were *Asaphes suspensus, Asaphes vulgaris* and *Dendrocerus carpenteri*.

Protected sweet pepper: Hyperparasitism was 25% on 24 August but 0% on 19 October**.** The aphid species was the peach-potato aphid, *Myzus persicae* and the hyperparasitoid species was *Asaphes vulgaris*.

Monitoring of hyperparasitism on various crops will continue in year 2 of the project, including on outdoor lettuce, where biocontrol of aphids by parasitoids will be monitored.

Biological control of aphids on lettuce

Tom Pope and Jude Bennison visited a key lettuce grower in East Anglia on 22 August. Current IPM practices on outdoor lettuce were discussed with the grower. The grower agreed to host monitoring work during Year 2. This work will start in May 2012.

Efficacy of entomopathogenic nematodes against vine weevil

Suppliers of entomopathogenic nematodes were consulted regarding efficacy of currently available species against vine weevil. An experiment has been planned testing selected nematode species with or without *Metarhizium anisopliae* (Met52) on protected strawberry and this will start in May 2012.

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

Gemma Gillies was not in post long enough to deliver knowledge transfer in year 1 of this project. Knowledge transfer activities delivered by Tom Pope were related both to this project, and also to other horticultural projects, and included:

Publications (with input from experienced ADAS colleagues):

- HDC Factsheet on midge, mite and caterpillar pests of cane fruit crops (in prep).
- HDC News articles on vine weevil research (HDC project SF HNS 112 and CRD project PS2134) and the leaf miner *Scaptomyza flava* (HDC project FV 376 and CRD project PS2718)
- IOBC paper on side-effect testing of novel powdery mildew fungicides against biological control agents (CRD project PS2125).

Presentations :

- Summary of the Fellowship project at the HDC Annual Studentship Conference
- Research results on Improved biological control of problem herb aphid species (HDC project PE 006) at the BHTA Technical Meeting
- Insecticide resistance talk at the BOPP Technical Seminar.

Scientific Conferences:

- AAB Advances in Biological Control meeting; the vine weevil results (CRD project PS2134) were presented.
- The IOBC Working Group meeting 'Integrated control in protected crops'; the side-effect testing work was presented (CRD project PS2125).

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 on a wide range of horticultural projects over the last year. These included:

- HDC-funded project PE 006 - Protected herbs: improved biological control of aphids.
- HDC-funded project SF HNS 112 - Evaluation of insecticides for control of adult vine weevil under controlled conditions.
- CRD-funded project PS2134 - Use of refuge traps to disseminate entomopathogenic fungi for the control of adult vine weevil.
- CRD-funded project PS2135 - A desk study of current knowledge on the combined use of microbial biopesticides and chemical pesticides in Integrated Pest Management.
- CRD-funded project PS2125 - Novel strategies for optimising powdery mildew management on outdoor cucurbits and protected herbs.
- HortLINK project HL001107 - Biological, semiochemical and selective chemical management methods for insecticide resistant western flower thrips on protected strawberry.

In addition to the technical skills learnt through involvement on these projects, this work has provided several knowledge transfer opportunities. These activities were delivered by Tom Pope as Gemma Gillies was not in post long enough to contribute to these projects:

Examples of publications:

Allen, J., Pope, T., Bennison, J., Birch, N. and Gordon, S. (in prep.) Midge, mite and caterpillar pests of cane fruit crops. *HDC Factsheet*.

Pope, T. (2012) Vine weevils run out of places to hide. *HDC News.* March 2012: 22-23.

Pope, T. W., Maulden, K., Bennison, J. and Green, G. (2011) Side-effect testing of novel powdery mildew fungicides against biological control agents. *IOBC/wprs Bulletin*. 68: 145-148.

Pope, T. (2011) Why some leaves need to cover up. *HDC News*. November 2011: 20-21.

Examples of presentations: Pope, T. Potential of entomopathogenic fungi to control adult vine weevil. *AAB Advances in biological control*. 30 November 2011. Marston, Lincolnshire. Bennison, J. and Pope, T. (2011) Protected herbs: improved biological control of aphids (PE 006, 2011-2012). *BHTA Technical Meeting*. 11 October 2011. Harper Adams University College. Shropshire. Pope, T. W., Maulden, K., Bennison, J. and Green, G. (2011) Side-effect testing of novel powdery mildew fungicides against biological control agents. *IOBC/wprs Working Group 'Integrated control in protected crops, temperate climate'*. 18-22 September 2011. Sutton Scotney, Hampshire. Pope, T. (2011) Insecticide resistance demystified and preservation of chemical controls. *BOPP Technical Seminar*. 15 September 2011. Sutton Bonington Campus, University of Nottingham, Nottinghamshire. Pope, T. (2011) Insecticide Resistance Action Group (IRAG). *EPPO Meeting*. 7 September 2011. Rothamsted Research, Hertfordshire.

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

- Predatory mites, including *Neoseiulus californicus* and *Neoseiulus cucumeris*, can overwinter in strawberry crops and may contribute to early season control of tarsonemids and two-spotted spider mites.
- Hyperparasitism can occur in any crop where aphid parasitoids are used to control aphid pests.

Background

Contribution of overwintered predatory mites to pest mite control on strawberry

ADAS fruit consultants have observed predatory mites within soft fruit crops in early spring on some farms before releases of these predators have been made. Subsequent work (HDC-funded project SF 115) found *Neoseiulus* (*Amblyseius*) *californicus* to be the most commonly found overwintering species, although this species was only found on strawberry. *Neoseiulus californicus* is currently regarded as a non-native species and the current licence for release allows release on fully protected crops but prohibits its use on outdoor or polytunnel crops. Another predatory mite species, *Amblyseius andersoni*, was also found on strawberry. Both *N. californicus* and *A. andersoni* are predators of important mite pests of strawberry e.g. two-spotted spider mite (*Tetranychus urticae*) and tarsonemid mite (*Phytonemus pallidus*).

The role that these overwintering predatory mites play in controlling mite pests on strawberry crops is unknown. In particular, work completed in SF 115 did not record whether the predatory mites collected were associated with a pest or whether, and to what extent, populations of predatory mites increased during the season. Therefore, the aim of this project was to assess the role of overwintering predatory mites in controlling mite pests on strawberry.

Aphid hyperparasitoids on protected edibles, soft fruit and ornamentals

The aphid parasitoids *Aphidius colemani*, *Aphidius ervi* and *Aphelinus abdominalis* are used successfully in IPM programmes in a range of crops, including sweet pepper and protected ornamentals. Parasitoids are released preventively each week from early in the season to ensure that they are present before arrival of aphids. Monitoring of aphid numbers and parasitism then allows parasitoid release strategies to be amended accordingly. Parasitoids have been found to give good control of aphid populations on sweet pepper until mid-summer. However, recent HDC funded research (PC 295a) found that on some nurseries, breakdown in control provided by aphid parasitoids occurred from mid-summer onwards, predominantly due to the presence of hyperparasitoids. High levels of hyperparasitism were found both within the crop itself on *Aphidius*-parasitised peach-potato aphid (*Myzus persicae*) and in open rearing units (ORUs or 'banker plants') producing *Aphelinus abdominalis* on cereals infested with grain aphid (*Sitobion avenae*).

Recently, a new aphid parasitoid mix became available from BCP Certis. This mix of aphid parasitoids includes three newly available species in addition to the three species named above. The 'new' species are *Aphidius matricariae*, *Praon volucre* and *Ephedrus cerasicola*. The mix has given good control of a wide range of 'difficult' aphid species on strawberry, ornamental pot plants and hardy nursery stock (Clare Sampson, personal communication). The greater range of aphid pests that may now be successfully controlled is likely to lead to increased use of aphid parasitoids by growers. This in turn may mean that hyperaparasitism becomes a problem in a wider range of crops than has previously been reported. Therefore, the aim of this project was to record whether hyperparasitism occurred in other horticultural crops in addition to in sweet pepper.

Summary

Contribution of overwintered predatory mites to pest mite control on strawberry

Numbers of tarsonemid mite and two-spotted spider mite were recorded on five crops of polytunnel-grown strawberry at a farm in Cambridgeshire between 25 May and 28 July 2011. The strawberry crops included both June-bearers and everbearers. Predatory mites were also recorded, noting whether they were associated with, and therefore likely to be feeding on, pest mites. Predatory mites recorded before predator releases by the grower were assumed to have overwintered within or close to the crop. Subsequent sampling of predatory mites provided information on population development of mite species recorded.

Overall numbers of tarsonemid mite and two-spotted spider mite were low. Tarsonemid mites were only found on unexpanded leaves and two-spotted spider mites were only found on fully expanded leaves. No mites were found in sampled flowers. Tarsonemid mites were recorded throughout the sampling period, while two-spotted spider mites were only recorded from 21 June onwards. Where tarsonemid mites were recorded, numbers remained fairly constant; while for two-spotted spider mite, numbers of mites increased towards the end of the sampling period. However, these trends must be considered in context with the IPM programme used to control mite pests. In particular, where two-spotted spider numbers were highest, on a second year crop of cv. Sonata, an application of bifenazate (Floramite 240 SC) on 13 July was effective in controlling this pest. Similarly, an application of abamectin (Dynamec) may have been effective in controlling tarsonemid on first year crops of cv. Jubilee. Predatory mites were not released by the grower until the end of the sampling period, except on the two first year Jubilee crops where *Neoseiulus* (*Amblyseius*) *cucumeris* was applied on 11 June and 20 July.

Overwintered predatory mites were recorded from three of the five crops sampled. Only eight predatory mites were recorded throughout the sampling period. These predators were only found associated with either tarsonemid mites or two-spotted spider mites. All of the predatory mites recorded were species of *Neoseiulus*. Of the predatory mites associated with tarsonemid mites, only those from a planting of cv. Christine were adults and thus could be identified to species, i.e. a single *Neoseiulus aurescens* and four *Neoseiulus californicus*. Two predatory mites were recorded associated with two-spotted spider mite, these were *Neoseiulus californicus* and *Neoseiulus cucumeris*. Unidentifiable (juvenile) predatory mites were recorded on the first year crops of Jubilee associated with two-spotted spider mite, but these were only found following releases of *Neoseiulus cucumeris* to these crops. Thus, these mites could have been either released or had overwintered.

These results were consistent with the results of HDC project SF 115 in that *Neoseiulus californicus* was the most frequently found predatory mite overwintering on strawberry. *Neoseiulus aurescens* and *N. cucumeris* were also found to have overwintered on strawberry. The fact that these mites were only found associated with either tarsonemid mites or two-spotted spider mite indicates that overwintered predatory mites may provide useful early season control of these pests. However, it is not clear from these results how populations of these predators would respond to higher pest pressures.

Aphid hyperparasitoids on protected edibles, soft fruit and ornamentals

Aphid hyperparasitoids were collected from a protected strawberry crop in Cambridgeshire, a hardy nursery stock (HNS) site in Norfolk and a sweet pepper crop in Essex. The grower at each site used regular releases of aphid parasitoids in their IPM programmes. At the sweet pepper site, a mix of *Aphidius colemani*, *Aphidius ervi* and *Aphelinus abdominalis* was used. At the strawberry and HNS sites, a new aphid parasitoid mix available from BCP Certis was used, which included the three parasitoid species above, as well as three 'new' species, *Aphidius matricariae*, *Praon volucre* and *Ephedrus cerasicola*.

Each site was sampled on two occasions and parasitised (mummified) aphids were collected. Where possible, the aphid species and primary parasitoid genus were identified from the appearance of the 'mummy'. Evidence of primary parasitoid emergence (indicated by a neat circular exit hole) or hyperparasitoid emergence (indicated by a ragged emergence hole) was also recorded. Where there was no emergence hole, the mummified aphids were kept in the laboratory until either a primary or a hyperparasitoid emerged. Emerging hyperparasitoids were sent to the Natural History Museum for identification.

Hyperparasitism occurred in protected strawberry and HNS as well as in sweet pepper, on a range of aphid species parasitised by both *Aphidius* spp. and *Praon* spp. The hyperparasitoid species were similar to those recorded in PC 295 and 295a:

Protected strawberry: No hyperparasitism was recorded on 24 June, 5% hyperparasitism was recorded on 19 October. The aphid species was the potato aphid, *Macrosiphum euphorbiae* and the hyperparasitoid species were *Asaphes suspensus*, *Dendrocerus laticeps* and *Pachyneuron* sp.

Protected HNS: Hyperparasitism of aphids on selected plant species was 21% on 19 August and 32% on 26 September. The aphid species were the melon-cotton aphid, *Aphis gossypii*, the violet aphid, *Myzus ornatus* and the potato aphid, *Macrosiphum euphorbiae*. The parasitoid species were *Aphidius* spp. and *Praon* spp. and the hyperparasitoid species were *Asaphes suspensus, Asaphes vulgaris* and *Dendrocerus carpenteri*.

Protected sweet pepper: Hyperparasitism of the peach-potato aphid, *Myzus persicae* was 25% on 24 August but 0% on 19 October. The hyperparasitoid species was *Asaphes vulgaris*. Aphid parasitoid 'banker plants' were not being used in the crop.

Monitoring of hyperparasitism on various crops will continue in year 2 of the project, including on outdoor lettuce, where biocontrol of aphids by parasitoids will be monitored.

Financial benefits

- Biocontrol of tarsonemid mite and two-spotted spider mite is most effective when releases of predatory mites are made before pest populations begin to increase. However, predator releases may need to be delayed due to temperatures and pesticide applications. Results in this project indicated that overwintered predatory mites may provide useful early season control of tarsonemids and two-spotted spider mite on strawberry, to complement control by released predatory mites.
- Biocontrol of aphids usually requires regular releases of parasitoids. High proportions of aphid hyperparasitoids reduce the effectiveness of these parasitoids, resulting in increased losses caused by aphids. This has been demonstrated in sweet pepper in HDC projects PC 295 and 295a. Results in this Fellowship project confirmed that aphid hyperparasitism occurred in protected HNS and strawberry as well as in sweet pepper. Growers will benefit from being aware of this risk on a range of horticultural crops so that they can adapt their IPM programmes if needed.

Action points

- Soft fruit growers should be aware that predatory mites including *Neoseiulus californicus* and *Neoseiulus cucumeris* can overwinter in strawberry crops and may contribute to early season control of tarsonemids and two-spotted spider mites.
- Growers should be aware that *Neoseiulus californicus* is regarded by Defra as a non-native species and is only licensed for release to crops grown under full protection (not those grown in 'Spanish' tunnels).
- Growers using aphid parasitoids in any crop should be aware that aphid hyperparasitism may occur. Look out for ragged emergence holes in aphid 'mummies' as an indicator that hyperparasitoids are present.
- Seek advice from your biocontrol supplier or IPM consultant if there are high levels of aphid hyperparasitism. It is likely that you will need to switch from using aphid parasitoids to aphid predators, and/or IPM-compatible pesticides.

SCIENCE SECTION

Introduction

Contribution of overwintered predatory mites to pest mite control on strawberry

Observations by ADAS fruit consultants have indicated that predatory mites are present in early spring on some farms before releases of these predators have been made. Subsequent work completed as part of HDC funded project SF 115 recorded predatory mites in 51 out of a total of 55 samples collected at sites before predators had been released that year. The most common species overall was *Neoseiulus* (*Amblyseius*) *californicus*; although this species was only found on strawberry. *Neoseiulus californicus* is currently regarded as a non-native species and the current licence for release allows release on fully protected crops but prohibits its use on outdoor or polytunnel crops. Another predatory mite species, *Amblyseius andersoni*, was also found on strawberry. Both *N. californicus* and *A. andersoni* are predators of important mite pests of strawberry e.g. two-spotted spider mite (*Tetranychus urticae*) and tarsonemid mite (*Phytonemus pallidus*).

The role that these overwintering predatory mites play in controlling mite pests on strawberry crops is unknown. In particular, work completed in SF 115 did not record whether the predatory mites collected were associated with a pest or whether, and to what extent, populations of predatory mites increased during the season.

The aim of this project was to assess the role of overwintering predatory mites in controlling mite pests on strawberry. Specific objectives were:

- Record numbers of two-spotted spider mite and tarsonemid mites on strawberry crops and whether overwintering predatory mites were found associated with these pest populations.
- Identify species of predatory mite successfully overwintering on strawberry crops.

Aphid hyperparasitoids on protected edibles, soft fruit and ornamentals

Until recently, biological control of aphids on protected crops relied mainly on three aphid parasitoid species:

- *Aphidius colemani* for control of e.g. the peach-potato aphid, *Myzus persicae* and the melon-cotton aphid, *Aphis gossypii*.
- *Aphidius ervi* and *Aphelinus abdominalis* for control of e.g. the potato aphid, *Macrosiphum euphorbiae* and the glasshouse-potato aphid, *Aulacorthum solani*.

These parasitoid species have been successfully used in IPM programmes in a range of crops, including sweet pepper and protected ornamentals. Parasitoids are released preventively each week from early in the season to ensure that they are present before arrival of aphids. Monitoring of aphid numbers and parasitism then allows parasitoid release strategies to be amended accordingly. Parasitoids have been found to give good control of aphid populations on sweet pepper until mid-summer. However, recent HDC funded research (PC 295a) found that on some nurseries, breakdown in control provided by aphid parasitoids occurred from mid-summer onwards, predominantly due to the presence of hyperparasitoids. Levels of hyperaparsitism of *Aphidius*-parasitised *Myzus persicae* recorded within sweet pepper crops ranged from 8 to 63%. (Jacobson, 2010). Five hyperparasitoid species of the genera *Dendrocerus*, *Asaphes* and *Pachyneuron* were found. In addition, hyperparsitism was recorded in open rearing unit (ORUs or 'banker plants') producing *Aphelinus abdominalis* within the crop. These ORUs were based on cereal plants infested with the grain aphid, *Sitobion avenae*. Seventy-two percent hyperparasitism was recorded by three species from the genera *Dendrocerus* and *Alloxysta*.

Recently, a new aphid parasitoid mix became available from BCP Certis. This mix of aphid parasitoids includes three newly available species in addition to the three species named above. The 'new' species are *Aphidius matricariae*, *Praon volucre* and *Ephedrus cerasicola*. The mix has given good control of a wide range of 'difficult' aphid species on strawberry, ornamental pot plants and hardy nursery stock (Clare Sampson, personal communication). There is also ongoing research (extension of PE 006) investigating the potential of these parasitoid species against 'problem' aphid species on protected herbs. The greater range of aphid pests that may now be successfully controlled is likely to lead to increased use of aphid parasitoids by growers. This in turn may mean that hyperaparasitism becomes a problem in a wider range of crops than has previously been reported.

The aim of this project was to record whether hyperparasitism occurred in other horticultural crops in addition to in sweet pepper. Specific objectives were to:

- Record presence and initial data on levels of hyperparasitism within sweet pepper, protected strawberry and hardy nursery stock crops.
- Identify the species responsible for any hyperparasitism seen.

Materials and methods

Contribution of overwintered predatory mites to pest mite control on strawberry

Site selection: a fruit farm in Cambridgeshire where overwintering predatory mites had been recorded on strawberry crops as part of HDC funded project SF 115 was selected. An initial visit to the farm was completed together with John Atwood, ADAS senior horticultural consultant. Based on this visit, and subsequent discussions with John and the grower, a range of plantings were selected for monitoring (Table 1).

Table 1. Strawberry plantings monitored for over wintering predatory mites and mite pests.

Strawberry variety	June bearer/everbearer
Jubilee – site 1	Everbearer
Jubilee – site 2	Everbearer
Christine	June-bearer
Evie 2	Everbearer
Sonata	June-bearer

Sampling: this consisted of collecting small, unexpanded leaves; large, fully expanded leaves; and open flowers. The small, unexpanded leaves were collected primarily to record numbers of tarsonemid mites and any associated predatory mites. Similarly, open flowers were collected in order to record the presence of tarsonemid mites and predatory mites. The large expanded leaves were collected primarily to record numbers of two-spotted mites and their associated predators. Sampling was completed from late-May to late-July (Table 2).

Table 2. Sampling dates when leaves and flowers were collected.

Date
25 May
8 June
21 June
4 July
28 July

Identification: collected leaves and flowers were checked using a binocular microscope at ADAS Boxworth in order to record mite numbers. Any predatory mites found were mounted on glass microscope slides using Heinz Mounting Medium and cleared for approximately 24 hours using a hotplate. Cleared mounted species were identified with the assistance of Mike Lole, Senior Entomologist, ADAS Rosemaund.

Aphid hyperaparsitoids on protected edibles, soft fruit and ornamentals

Site selection: three sites were selected on which to monitor for the presence of aphid hyperparasitoids. These included a polytunnel-grown strawberry crop in Cambridgeshire; a hardy nursery stock site in Norfolk; and a sweet pepper nursery in Essex. The grower at each selected site was using an IPM programme that included regular releases of aphid parasitoids. The growers of strawberry and hardy nursery stock were releasing a mix of six parasitoid species produced by Viradixis and supplied by BCP Certis (Table 3). The pepper producer was releasing three of these species: *Aphidius colemani*, *Aphidius ervi* and *Aphelinus abdominalis*.

Table 3. Primary parasitoid species.

Parasitoid species
Aphidius ervi
Aphidius colemani
Aphidius matricariae
Praon volucre
Ephedrus cerasicola
Aphelinus abdominalis

Sampling and identification: at each site, aphids were sampled on two separate occasions. Numbers of mummified (parasitised) aphids, numbers of mummified aphids with a neat round emergence hole (indicating that a primary parasitoid had emerged) and numbers of mummified aphids with a ragged emergence hole (indicating that a hyperparasitoid had emerged) were recorded. Where no emergence hole was found, aphid mummies were placed in glass Petri dishes in the laboratory at approximately 20°C, recording whether a primary or a hyperparasitoid emerged. Emerging hyperparasitoids were identified to species at the Natural History Museum. In addition, wherever possible aphid species and primary parasitoid genus (based on aphid mummy morphology e.g. *Aphidius* sp., *Praon* sp. or *Aphelinus* sp. / *Ephedrus* sp.) was recorded.

Results and discussion

Contribution of overwintering predatory mites to pest mite control on strawberry

Numbers of tarsonemid mites and two-spotted spider mites were low. Tarsonemid mites were only found on unexpanded leaves. Two-spotted spider mites were only found on fully expanded leaves. No mites were found on the flowers sampled. Data for each of the five plantings sampled is as follows:

Jubilee – Site 1:

Few tarsonemid mites were recorded in this planting, with just four infested leaves collected during the sampling period (Figure 1). There was no evidence of a build-up in numbers of tarsonemid mites throughout this period. No predatory mites were found on infested or clean leaves collected from this planting, despite the fact that *Neoseiulus cucumeris* was released on 11 June at approx. 300 per m^2 and on 20 July at approx. 200 per m^2. *Phytoseiulus persimilis* was applied on 24 July at approx. 3 per m^2. Throughout this period various fungicide and insecticide applications were made including abamectin (Dynamec) on 1 June, which may, along with the releases of *N. cucumeris*, explain why numbers of tarsonemid remained low after 25 May.

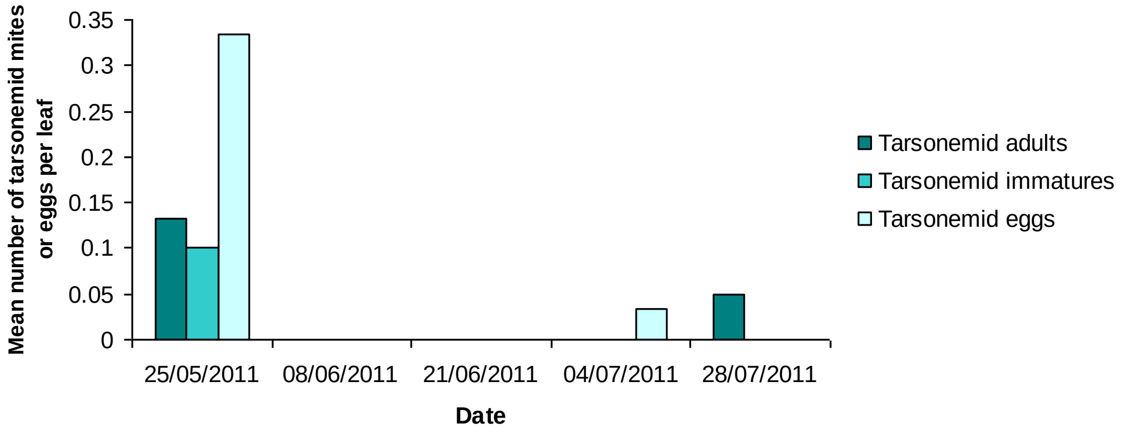

Figure 1. Mean numbers of tarsonemid mites per unexpanded leaf.

Two-spotted spider mites were not recorded on this planting until 4 July, but numbers then increased rapidly (Figure 2). Two unidentified juvenile predatory mites were found associated with the two-spotted spider mites on 28 July.

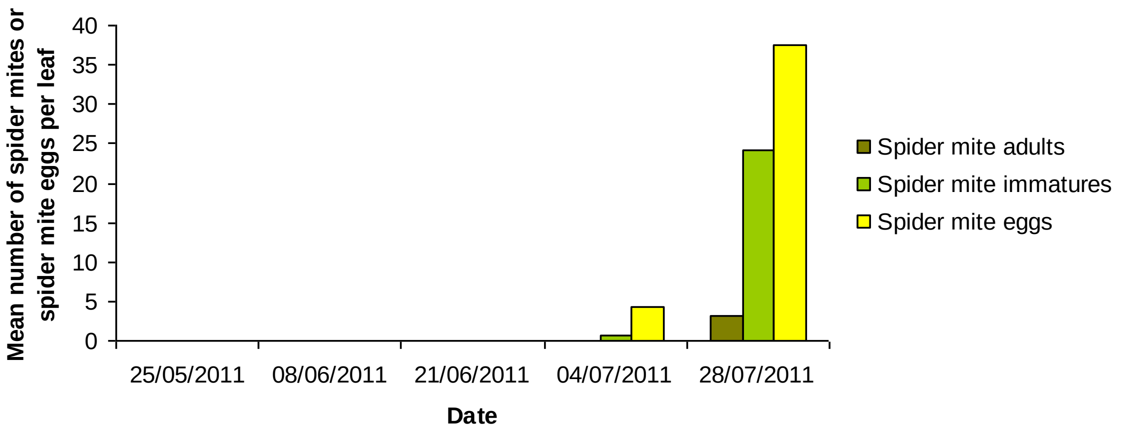

Figure 2. Mean numbers of two-spotted spider mite per fully expanded leaf.

Jubilee – Site 2:

Few tarsonemid mites were recorded on unexpanded leaves in this planting, with just four infested leaves collected during the sampling period (Figure 3). There was no clear evidence of a build-up in numbers of tarsonemid mites throughout this period. No predatory mites were found on infested or clean leaves collected from this planting, despite the fact that the same releases of *Neoseiulus cucumeris* and *Phytoseiulus persimilis* were applied to this planting as were applied to Jubilee - Site 1. Fungicide and insecticide applications were the same as in Site 1.

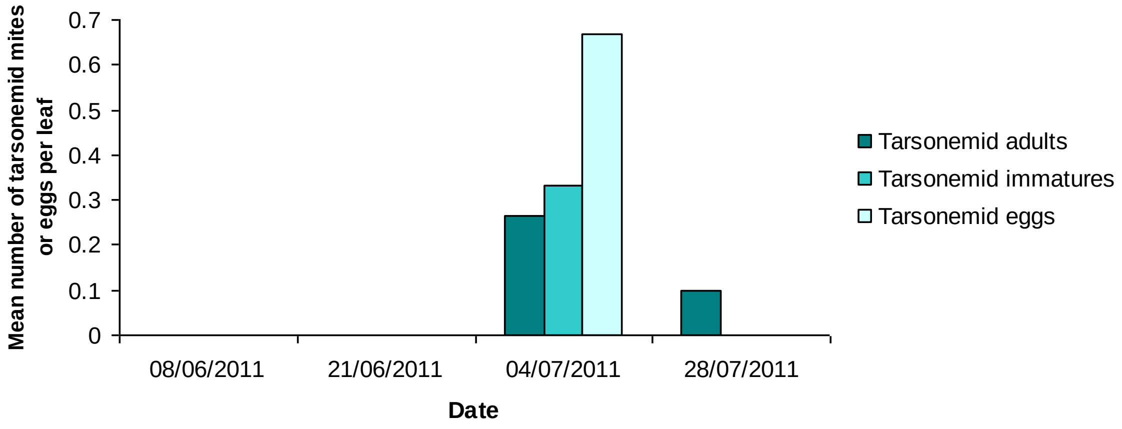

Figure 3. Mean numbers of tarsonemid mites per unexpanded leaf.

Two-spotted spider mites were not recorded on this planting until 28 July (Figure 4). No predatory mites were found associated with the two-spotted spider mite.

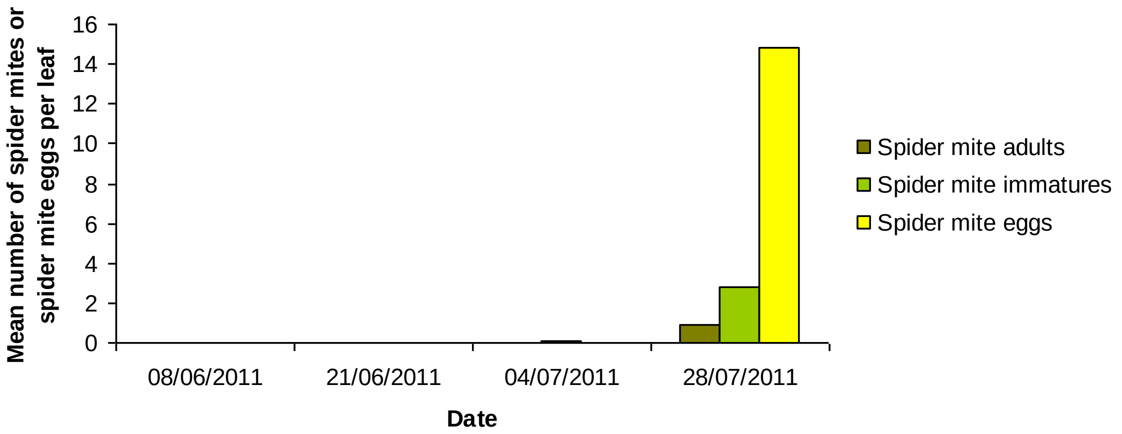

Figure 4. Mean numbers of two-spotted spider mite per fully expanded leaf.

Christine:

Large numbers of tarsonemid mites were recorded on unexpanded leaves collected from this planting (Figure 5). There was also evidence of a sharp increase in numbers of mites between 25 May and 8 June. Six adult or juvenile predatory mites were recorded associated with tarsonemid mites. All of the predatory mites were species of *Neoseiulus*. Of the adult predatory mites identified to species, there was one *Neoseiulus aurescens* and four *Neoseiulus californicus*. The two immature predatory mites could only be identified to genus. In addition, predatory mite eggs were recorded. The planting was grubbed at the end of June.

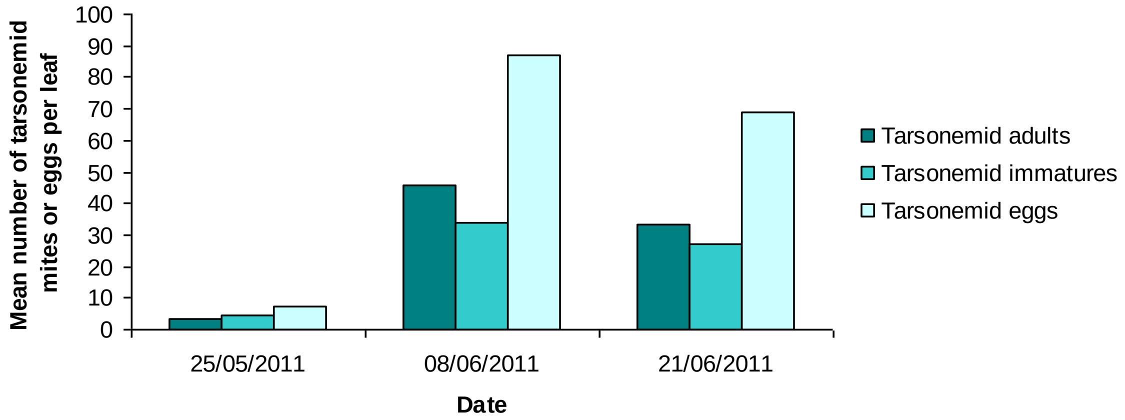

Figure 5. Mean numbers of tarsonemid mites per unexpanded leaf.

Fully expanded leaves were not collected from this planting.

Evie 2:

Tarsonemid mites were recorded on unexpanded leaves collected from this planting (Figure 6). Interestingly, numbers of tarsonemid mites dipped between 21 June and 28 July. Two insecticide/acaricide applications were made during this period: thiacloprid (Calypso) and pirimicarb (Aphox) on 27 June and Floramite on 7 July, but neither application would be expected to control tarsonemid mite. A single adult *Neoseiulus cucumeris* was recorded associated with tarsonemid mites on 28 July.

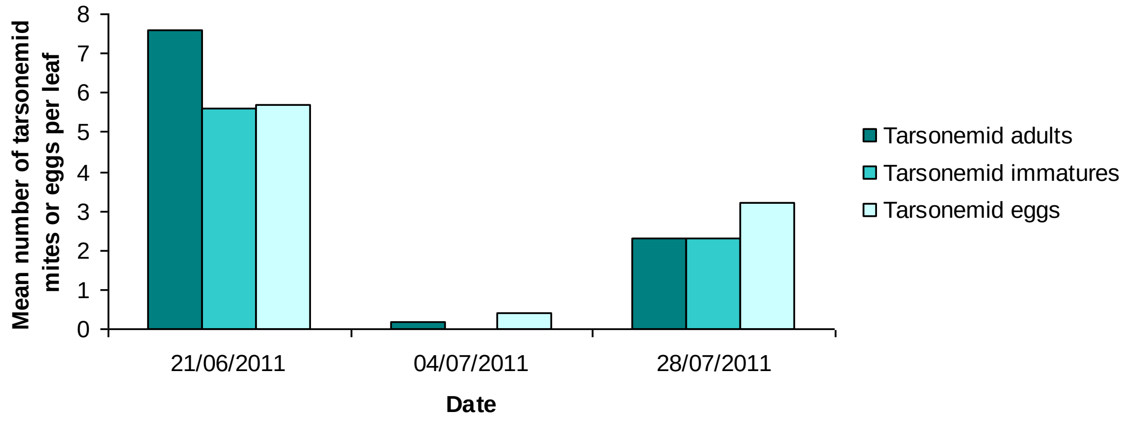

Figure 6. Mean numbers of tarsonemid mites per unexpanded leaf.

No two-spotted spider mites were recorded on fully expanded leaves collected from this planting until the final assessment (Figure 7). No predatory mites were recorded from this planting.

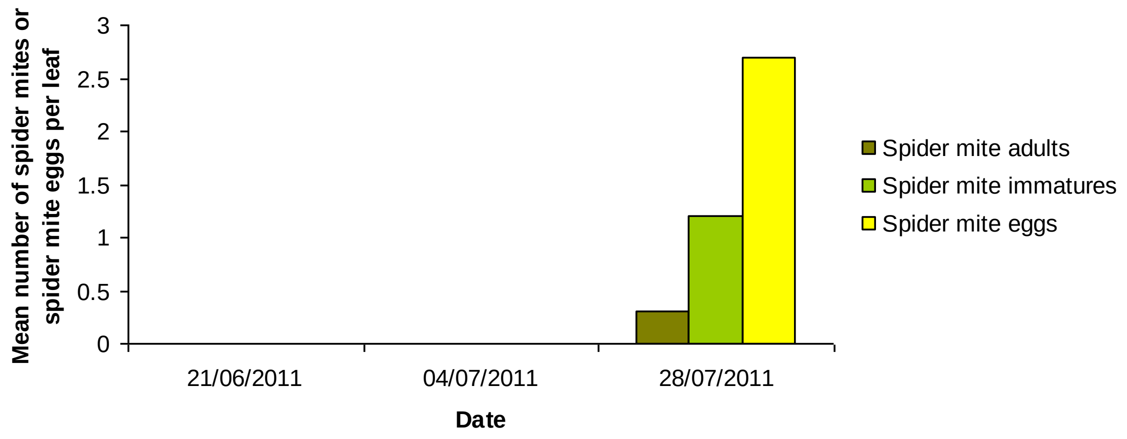

Figure 7. Mean numbers of two-spotted spider mite per fully expanded leaf.

Sonata:

Unexpanded leaves were not collected from this site and no tarsonemid mites were recorded. However, large numbers of two-spotted spider mite were found on fully expanded leaves collected from this planting (Figure 8). Numbers of mites increased between 21 June and 4 July but then decreased by 28 July. No predator releases were made until after 28 July, but an application of bifenazate (Floramite) was made on 17 July, which appears to explain the reduction in mite numbers. A single *Neoseiulus* species of predatory mite was recorded associated with the two-spotted spider mite on 21 June.

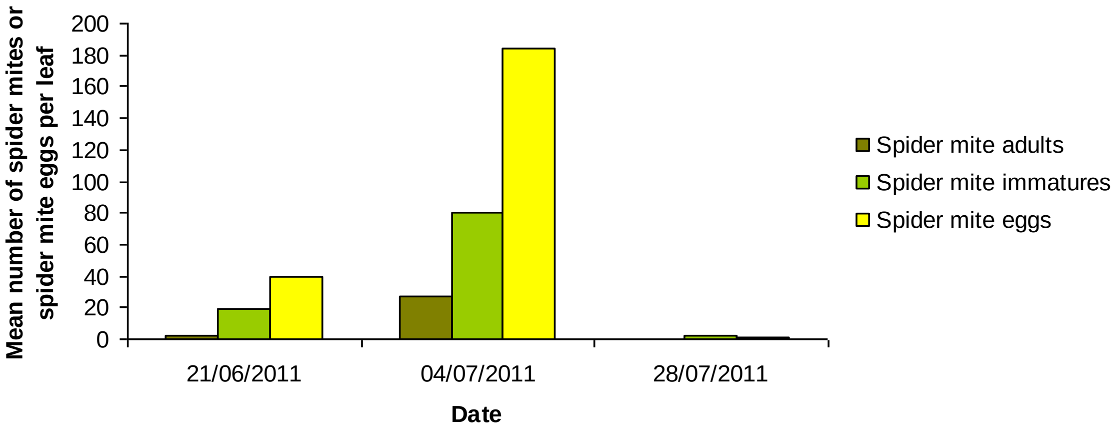

Figure 8. Mean numbers of two-spotted spider mite per fully expanded leaf.

Results from this study are consistent with those of SF 115, where *Neoseiulus californicus* was recorded as the most frequently found predatory mite overwintering on strawberry. *Neoseiulus californicus* was found associated with both tarsonemid mites and two-spotted spider mites. In addition, a single *Neoseiulus aurescens* was found associated with tarsonemid mites and a single *Neoseiulus cucumeris* was found associated with two-spotted spider mite. The fact that predatory mites were only found associated with either tarsonemid mites or two-spotted spider mite indicates that overwintered predatory mites may provide useful early season control of these pests. Indeed, the highest number of predatory mites was found in the Christine planting, where there was the highest number of tarsonemid mites. However, there was no evidence that numbers of predatory mites were increasing. Other factors may also be important in explaining the presence of overwintering predatory mites. These factors include the age of the planting; position of the site; availability of overwintering refuges etc.

Aphid hyperparasitoids on protected edibles, soft fruit and ornamentals

Data on hyperparasitism in a strawberry crop in Cambridgeshire, hardy nursery stock site in Norfolk, and a sweet pepper crop in Essex were collected. Each site was visited on two occasions.

Protected strawberry crop:

Relatively large numbers of mummified aphids were recorded on both occasions on which the crop was sampled (Table 4). Primary aphid parasitoids had already emerged from most of the mummified aphids collected on both assessment dates (Figure 9). No evidence of hyperparasitism was recorded in the crop, however, a small number of mummified aphids from which a parasitoid had not emerged were returned to the laboratory. From these mummified aphids, five were found to be hyperparasitised. All of the hyperparasitised aphids were identified as the potato aphid, *Macrosiphum euphoribiae*, that had been parasitised by a species of *Aphidius*. The hyperparasitoids emerging from these aphids were identified by the Natural History Museum as *Asaphes suspensus* (Figure 10), *Dendrocerus laticeps* and *Pachyneuron* sp.

Table 4. Numbers of mummified aphids and percentage hyperparasitised on a protected strawberry crop.

Date sampled	No. of mummified aphids	Aphid species	Primary parasitoid	% Parasitoid emergence	% Hyperparasitism
24/06/2011	113	*Macrosiphum euphorbiae*	*Aphidius*, *Praon* and *Aphelinus*	-	0
19/10/2011	99	*Macrosiphum euphorbiae*	*Aphidius*, *Praon* and *Aphelinus*	-	5

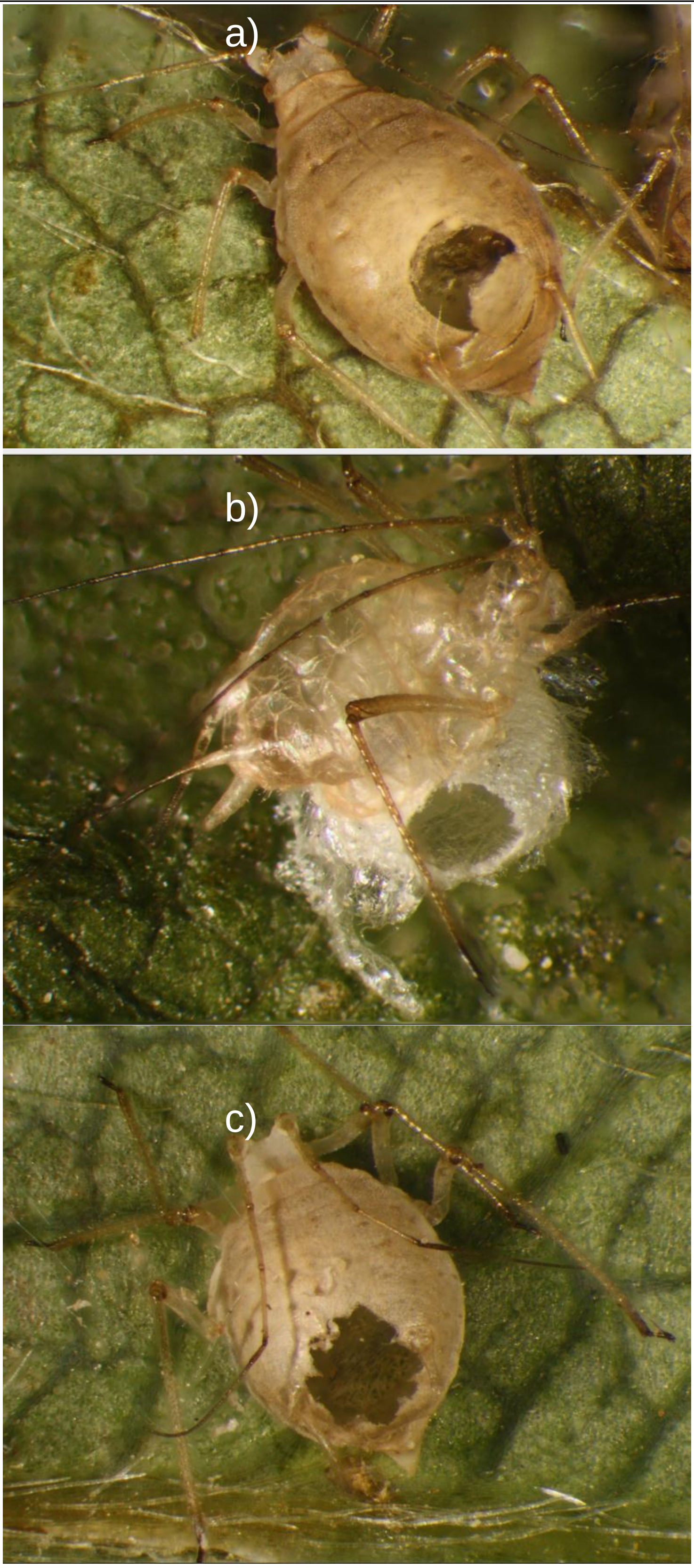

Figure 9. Typical emergence hole produced by; a) primary aphid parasitoid (*Aphidius* sp.), b) primary aphid parasitoid (*Praon* sp.) and c) aphid hyperparasitoid.

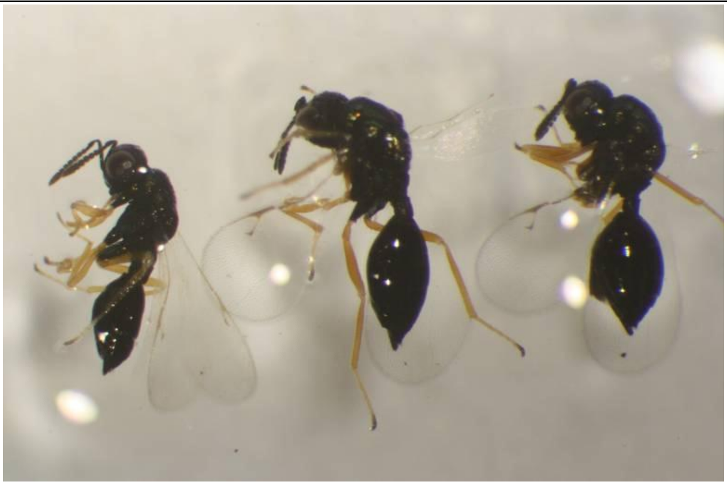

Figure 10. *Asaphes suspensus.*

Hardy nursery stock site:

Mummified aphids were collected from a range of hardy nursery stock crops (Table 5), including *Hebe* sp., *Coronilla glavea*, *Clematis* sp., *Photinia* sp., *Euonymus* sp., and *Lavender* sp. On 19 August, most mummified aphids were collected from *Euonymus* sp. (15) with the remainder collected from *Hebe* sp. The dominant aphid species were the melon-cotton aphid, *Aphis gossypii* and a large unidentified species*.* On 26 September, most aphids were collected from *Coronilla glavea* (86), with smaller numbers collected from *Photinia* sp. (13), *Lavender* sp. (10), *Hebe* sp. (3) and *Clematis* sp. (2). The dominant aphid were the potato aphid, *Macrosiphum euphoribiae* and the violet aphid, *Myzus ornatus*. Of the hyperparasitoids emerging from these aphids, most were identified by the Natural History Museum as *Asaphes suspensus* (Figure 9) and *Asaphes vulgaris* (Figure 11) as well as a single *Dendrocerus carpenteri* (Figure 12).

Table 5. Numbers of mummified aphids and percentage hyperparasitised on hardy nursery stock crops.

Date sampled	No. of mummified aphids	Aphid species	Primary parasitoid	% Parasitoid emergence	% Hyperparasitism
19/08/2011	19	*Aphis gossypii* and an unidentified species.	*Aphidius* and *Aphelinus*	79	21
26/09/2011	114	*Macrosiphum euphorbiae*	*Aphidius*, *Praon* and *Aphelinus*	69	32

Figure 11. *Asaphes vulgaris*.

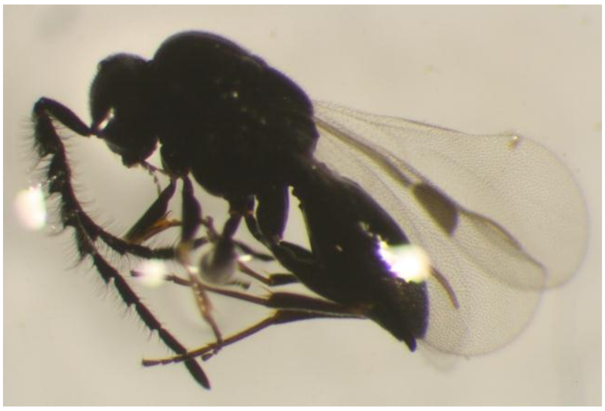

Figure 12. *Dendrocerus carpenteri*.

Sweet pepper crop:

Relatively few mummified aphids were collected from the sweet pepper crop (Table 6). All of the mummified aphids were *Myzus persicae,* and all had been parasitised by *Aphidius* sp. Only a single hyperparasitoid emerged from these mummified aphids and this was identified by the Natural History Museum as *Asaphes suspensus* (Figure 10).

Table 6. Numbers of mummified aphids and percentage hyperparasitised on sweet pepper.

Date sampled	No. of mummified aphids	Aphid species	Primary parasitoid	% Parasitoid emergence	% Hyperparasitism
24/08/2011	4	*Myzus persicae*	*Aphidius*	100	25
19/10/2011	42	*Myzus persicae*	*Aphidius*	91	0

A summary of the aphid species, primary parasitoid genus and hyperparasitoid species found in the sampled crops is given in Table 7.

Table 7. Hyperparasitoid, primary parasitoid and aphid associations recorded in different horticultural crops.

Insect Species			**Crop**		
Hyperparasitoid	**Primary Parasitoid**	**Aphid**	**Pepper**	**Strawberry**	**HNS**
Asaphes suspensus	*?*	*Macrosiphum euphorbiae*		✓	
Asaphes suspensus	*Praon* sp.	*?*			✓
Asaphes suspensus	*?*	*Myzus ornatus*			✓
Asaphes vulgaris	*Aphidius* sp.	*Myzus persicae*	✓		
Asaphes vulgaris	*Aphidius* sp.	*Macrosiphum euphorbiae*			✓
Asaphes vulgaris	*Praon* sp.	*?*			✓
Asaphes vulgaris	*?*	*Myzus ornatus*			✓
Dendrocerus carpenteri	*Praon* sp.	*Macrosiphum euphorbiae*			✓
Dendrocerus laticeps	*?*	*Macrosiphum euphorbiae*		✓	
Pachyneuron sp.	?	?		✓	

NB: Hyperparasitism of *Aphis gossypii* was recorded based on the ragged emergence holes only and no hyperparasitoids were collected for species identification.

Results from this study built on the recent work of Rob Jacobson in HDC funded projects PC 295 and PC 295a. These two HDC projects were focused solely on sweet pepper production and found hyperparasitism of the peach-potato aphid, *Myzus persicae* (on sweet pepper) and the grain aphid, *Sitobion avenae* (on 'banker plants'). In this Fellowship project, hyperparasitism was found in *Myzus persicae* as well as in the violet aphid, *Myzus ornatus* on HNS and the potato aphid, *Macrosiphum euphorbiae* on both HNS and strawberry. In PC

295 and PC 295a, hyperparasitised aphids had been parasitized by *Aphidius* sp. or *Aphelinus abominalis*. In this study, hyperparasitised aphids had been parasitised by *Aphidius* sp. and *Praon* sp. The hyperparasitoid species identified in this study were similar to those identified in PC 295 and PC 295a.

Levels of hyperparasitism of *Aphidius*-parasitised *M. persicae* recorded within sweet pepper crops ranged from 8 to 63% in PC 295 and PC 295a. By contrast, in this study hyperparasitism of *Aphidius*-parasitised *M. persicae* recorded within sweet pepper crops ranged from 0 to 25%. The grower was not using aphid parasitoid 'banker plants' at the nursery visited in this study. This could explain the lower percentage hyperparasitism than that recorded in PC 295 and PC 295a. However, the percentage hyperparasitism recorded in this study was based on relatively small numbers of mummified aphids collected. Levels of hyperparasitism in the strawberry crop were even lower, ranging from 0 to 5% but at the hardy nursery stock site were higher and ranged from 21 to 32% on the plant species monitored. However, biological control of aphids on the HNS crops was not disrupted. These results confirm that aphid hyperparasitism seems to be widespread and may be found in a range of crops. Hyperparasitism could represent a threat to biological control of aphids on various horticultural crops in the future. Monitoring of hyperparasitism will continue in Year 2.

Conclusions

- *Neoseiulus californicus* was recorded as the most frequently found species of overwintering predatory mite in strawberry. Overwintering predatory mites were only found together with tarsonemid mites and two-spotted spider mites indicating that these predators provide useful early season control of these pests.
- Hyperparasitism was found in a polytunnel grown strawberry crop, hardy nursery stock site and at a sweet pepper nursery. Levels of hyperparasitism recorded did not threaten biological control of aphids, but if aphid parasitoids are increasingly used to control aphid pests this may become an increasing problem. Hyperparasitism will continue to be monitored on a range of crops in Year 2.

Knowledge and technology transfer

The results of each research project were discussed informally with the growers hosting the studies on predatory mites and aphid hyperparasitism.

Bennison, J. and Pope, T. (2011). Summary of objectives and progress to date in the ADAS IPM Fellowship. *HDC Annual Studentship Conference*. 6 July 2011. East Malling Research, Kent.

Glossary

Hyperparasitism – when a primary parasitoid developing within its host is attacked by a secondary parasitoid. Here, this refers to naturally occurring secondary parasitoids which attack the primary aphid parasitoids being used as biological control agents to control aphid pests.

References

Irving, R. (2011) Identification of overwintering predatory mites in strawberry and cane fruit, and investigation of on-farm production. *HDC Project SF 115 Final Report*.

Jacobson, R. (2010) Sweet pepper: further development of IPM solutions for aphid infestations. *HDC Project PC 295a Final Report*.

Jacobson, R. (2009) Sweet pepper: short-term solutions for leafhopper and aphid infestations. *HDC Project PC 295 Final Report*.

