Project Title	Protected bedding and pot plants: evaluation of *Atheta coriaria* using an on-nursery rearing system.
Project number:	PC 261
Project leader:	Jude Bennison, ADAS
Report:	Final report, August 2006
Previous report	None
Key staff:	Jude Bennison, Study Director Kerry Maulden, Site Manager
Location of project:	ADAS Boxworth
Project coordinator:	Fay Richardson, Coletta & Tyson, 324, Hull Road, Woodmansey, Beverley, East Yorks, HU17 ORU
Date project commenced:	1 April 2006
Date completed:	26 August 2006
Key words:	Western flower thrips, WFT, *Frankliniella occidentalis*, biological control, predatory beetles, *Atheta coriaria*, *Impatiens*.

The results and conclusions in this report are based on a series of experiments conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

AUTHENTICATION

I declare that this work was done under my 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
Project Leader

Signature ..... Date .....

Report authorised by:

Jon Oakley
Principal Research Entomologist
ADAS

Signature ..... Date .....

CONTENTS

Grower Summary

Headline

- Atheta coriaria significantly reduced numbers of WFT on potted Impatiens over a 6-week period when released in small research glasshouses using the on-nursery rearing/release units being developed in project PC 239 but future work is needed before recommendation on optimising their use can be provided.

Background and expected deliverables

Western flower thrips (WFT) remains one of the major pests of UK protected crops, including ornamental bedding and pot plants. Biological control strategies for WFT within Integrated Pest Management (IPM) programmes currently rely mainly on the predatory mite, *Amblyseius cucumeris* which feeds on young thrips larvae on leaves and in buds and flowers. Although *A. cucumeris* gives successful control of WFT on most bedding and pot plants, control can be unreliable under high thrips pressure on particularly susceptible flowering plants. Some growers use the ground-dwelling predatory mites, *Hypoaspis miles* or *H. aculeifer* to supplement biological control of thrips by *A. cucumeris. Hypoaspis* spp. are marketed primarily for control of sciarid flies but they will also feed on other ground-dwelling invertebrates, including WFT larvae and pupae (most WFT larvae drop from the host plant to the ground to pupate). Other growers, particularly growers of pot chrysanthemums, use sprays of entomopathogenic nematodes, *Steinernema feltiae* ('Nemasys F') for control of WFT.

An opportunity has arisen to test the potential for the predatory beetle, *Atheta coriaria* for low-cost biological control of WFT in bedding/pot plants. Laboratory work in Canada has shown that *Atheta* are voracious predators of WFT larvae and pupae. The potential of *Atheta* for control of thrips has not been fully tested in glasshouse crops. ADAS is leading an HDC-funded project on developing an on-nursery rearing system for *Atheta* for reduced cost biological control of sciarid and shore flies on protected ornamentals, herbs and celery (PC 239). If the system could also contribute to WFT control at no extra cost to the grower, this would be added benefit to the grower and would add value to project PC 239.

The expected deliverable of this pilot project was to evaluate control of WFT on ornamental bedding/pot plants by *Atheta* when reared in glasshouses using the system developed in PC 239.

Summary of the project and main conclusions

- An experiment was done on WFT-infested *Impatiens* in three insect-screened glasshouse compartments at ADAS Boxworth, Cambridge.
- One *Atheta* rearing/release unit was placed in the middle of each of two compartments and the third compartment was used as an untreated control. Each unit had been prepared with 60 adult *Atheta* which had been allowed to breed in the laboratory at 25°C for 26 days before placing in the glasshouse compartments.
- The estimated numbers of *Atheta* in each rearing unit when placed in the glasshouse compartments were 1143 and 1351 respectively in treated compartments 1 and 2. These were equivalent to initial release rates of 71 and 84 *Atheta* per m^2 of glasshouse space in the two compartments.
- The experiment lasted for six weeks, from 8 May when the WFT were added to the plants and the *Atheta* units were put in place, to 20 June when the final numbers of WFT were assessed on the plants.
- *Atheta* adults and larvae were found in bait pots placed amongst the plants throughout the experiment, demonstrating that the beetles dispersed from the rearing units and entered the pots. *Atheta* adults were also frequently observed on the damp capillary matting underneath the pots.
- At the end of the experiment, mean numbers of WFT (38 and 97 per plant respectively) in the two compartments treated with *Atheta* rearing units were significantly lower than in the untreated compartment (209 per plant), Figure 1. *Atheta* reduced numbers of WFT by 82% and 53% respectively in the two treated compartments, compared with the untreated control compartment.

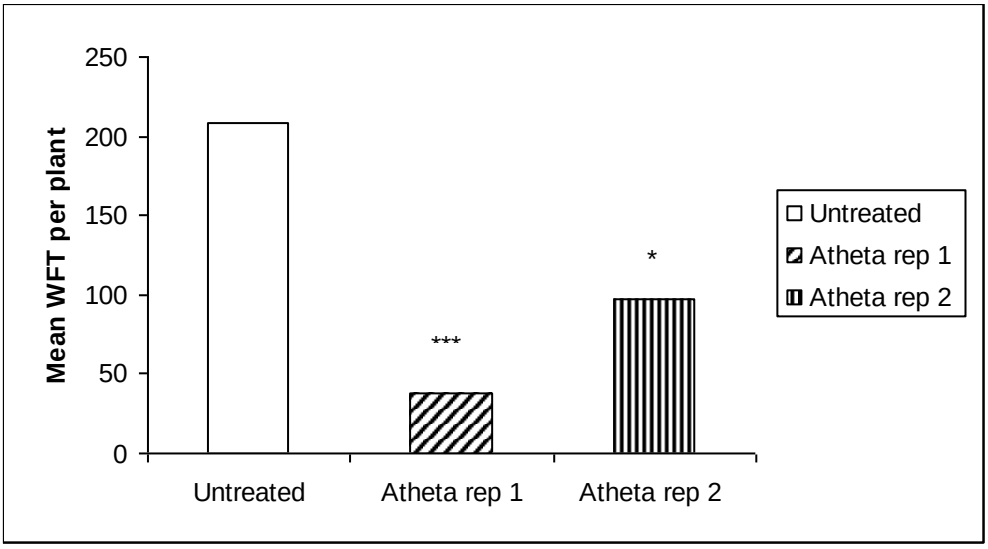

Figure 1. Mean numbers of WFT per plant in the untreated glasshouse and in the two glasshouses with *Atheta* rearing units, 6 weeks after experiment set up.

- Very few WFT pupae were found on the *Impatiens* plants in the destructive assessments for thrips counts. It is concluded that as already demonstrated on pot chrysanthemum and cucumber, most WFT drop from *Impatiens* plants to pupate in the ground or in the compost in the pots. It is concluded that the reductions in WFT

numbers were due to *Atheta* predating WFT ground-dwelling stages (older larvae and pupae).

- Naturally-occurring predatory mites (*Macrocheles* sp.) became established in the rearing units after 4-6 weeks and may have contributed to the reduction of *Atheta* in the rearing units over time. *Macrocheles* sp. mites can also feed on WFT ground-dwelling stages and may possibly have contributed to the reduction in WFT numbers.
- Although *Atheta* led to significant reductions in WFT, the level of control at the high thrips infestation level used in the experiment was not sufficient to be able to recommend that growers use the rearing/release unit system as the sole method for biological control of WFT. However, use of the rearing units might give better control of WFT at lower densities than those used in this experiment. In addition, adding higher numbers of *Atheta* adults to the units when preparing them might lead to better WFT control. However, use of similar units to those tested in this experiment could be used to supplement the control given by other biological control agents e.g. *Amblyseius cucumeris*.
- The *Atheta* rearing/release units may give different results to those given in this pilot project, when used in larger glasshouses, or in crops not grown on capillary matting, or in longer-term pot plants e.g. cyclamen, or on crops on which the pupation behaviour of WFT has not been recorded. The optimum number of *Atheta* units per unit area of glasshouse space has not yet been determined, when using the system for control of WFT or other ground-dwelling pests. Further research would be needed to fill these gaps in knowledge.

Financial benefits

- The efficacy, practicality and cost-benefits of using *Atheta* rearing/release units on a commercial scale for the control of sciarid and shore flies are being tested in project PC 239, in crops of protected herbs, celery and ornamentals. PC 239 will also provide further information on the likely lifespan of the rearing units, any potential problems with other invertebrates invading the rearing units, and interactions with other ground-dwelling biological control agents.
- The financial benefits of using *Atheta* on-nursery rearing units will be fully discussed in the final report for PC 239, (due February 2008). The cost-benefits of the system will depend on many factors including:
  - How many ground-dwelling pests *Atheta* are reducing.
  - Whether *Atheta* are bought in to set up the units or are 'recycled' from growers' own rearing units.
  - The size and number of rearing units used per unit area of glasshouse (the size of the units used in this pilot project are likely to be scaled up for commercial use).
  - The lifespan, production rate and release rate of the units.

Action points for growers

- Growers should not rely on *Atheta coriaria* as the sole biological control agent for WFT, either as beetles released direct from suppliers or used in the rearing/release system used in this project.

- Growers could try the prototype rearing/release units described in this report as a supplement to WFT control by other biological control agents, in crops in which WFT are known to pupate mainly on the ground. However, it is recommended that the full results of Project PC 239 are awaited before the system is considered for adoption on a large scale.
- A factsheet will be prepared for growers at the end of project PC 239 (February 2008) which will summarise the results of PC 239 and give recommendations on how to use the on-nursery rearing units for *Atheta* on a range of protected crops.

Science Section

Introduction

Western flower thrips (WFT) remains one of the major pests of UK protected crops, including ornamental bedding and pot plants. Biological control strategies for WFT within Integrated Pest Management (IPM) programmes currently rely mainly on the predatory mite, *Amblyseius cucumeris* which feeds on young thrips larvae on leaves and in buds and flowers. Although *A. cucumeris* gives successful control of WFT on most bedding and pot plants, control can be unreliable under high thrips pressure on particularly susceptible flowering plants. Some growers use the ground-dwelling predatory mites, *Hypoaspis miles* or *H. aculeifer* to supplement biological control of thrips by *A. cucumeris. Hypoaspis* spp. are marketed primarily for control of sciarid flies but they will also feed on other ground-dwelling invertebrates, including WFT larvae and pupae (Bennison *et al*, 2002). It has been shown in recent Defra-funded research (HH3102TPC) that on pot chrysanthemum and cucumber, most WFT larvae drop from the plants to the ground to pupate and will thus be vulnerable to ground-active biological control agents (Bennison *et al*, 2005). This behaviour is likely to be similar on other host plants. Some growers, particularly growers of pot chrysanthemums, use sprays of entomopathogenic nematodes, *Steinernema feltiae* ('Nemasys F') for control of WFT and it has been shown in the same Defra-funded project (HH3102TPC) that control of WFT populations by Nemasys F is partly due to killing WFT larvae and pupae in the ground or compost (Bennison *et al*, 2005, 2006).

An opportunity has arisen to test the potential for the predatory beetle, *Atheta coriaria* for low-cost biological control of WFT in bedding/pot plants. Laboratory work in Canada has shown that *Atheta* are voracious predators of WFT larvae and pupae; each adult beetle can kill up to 95 WFT larvae or 78 pupae per day (Carney *et al*, 2002). The potential of *Atheta* for control of thrips has not been fully tested in glasshouse crops, as usually they are released for control of sciarid or shore flies together with biological control agents for other pests including thrips. However, there is evidence from Canada that *Atheta* reduced numbers of WFT in glasshouse roses (G. Murphy, personal communication). In a UK cyclamen crop (at WJ Findon & Son) where experimental *Atheta* rearing units were used for sciarid fly control and no thrips biological control agents were used, WFT caused no problems on the crop (R. Woodcock, personal communication).

ADAS is leading an HDC-funded project on developing an on-nursery rearing system for *Atheta* for reduced cost biological control of sciarid and shore flies on protected ornamentals, herbs and celery (PC 239). If the system could also contribute to WFT control at no extra cost to the grower, this would be added benefit to the grower and would add value to project PC 239.

The overall objective of this pilot project was to evaluate control of WFT on ornamental bedding/pot plants by *Atheta* when reared in glasshouses using the system developed in PC 239.

Materials and Methods

Experiment location and plant material

The experiment was done in three insect-screened glasshouse compartments at ADAS Boxworth, Cambridge. Each compartment measured 16 m^2. The plants used were *Impatiens*, supplied as young plants in plugs on 24 April 2006 and potted into 13 cm pots using M2 compost. The plants had not been treated with biological control agents for thrips at the propagation nursery and had not received any pesticides. The plants were kept in thrips-proof cages in a glasshouse at Boxworth, to grow on for two weeks before the experiment was set up.

Preparation of Atheta rearing units

Four *Atheta* rearing units were prepared on 12 April 2006, using the method developed in PC 239. Each rearing unit consisted of a plastic box (3 litre capacity) sealed with a tight fitting snap-on lid with two ventilation holes covered with insect-proof mesh. Each box contained 1.5 litres of a coir and vermiculite (1:1 mix) substrate. The substrate was dampened with 150 ml water per litre substrate before adding to the boxes. Sixty *Atheta* adults (a mixture of females and males) were added to each box. Turkey starter crumbs (used for rearing young turkey chicks) were provided as a food source for the *Atheta*, by sprinkling 2.5 g of the crumbs on top of the substrate in each box, and rotating the boxes through 360° to incorporate the crumbs into the substrate. Every 3-4 days, 5-10ml of water (as required, to maintain the dampness of the substrate) and 2.5g of turkey crumbs were incorporated into the substrate. The rearing units were kept in a controlled temperature laboratory at 25°C, with a photoperiod of 16:8 hours light:dark for 26 days (until 8 May 2006).

Estimation of Atheta numbers in rearing units at start of experiment

On 8 May, three replicate 60 ml sub-samples of the substrate were taken from each of the four boxes and turned onto a large white plastic tray and the numbers of *Atheta* adults and larvae counted (pupae are not recognisable in the substrate as they are a similar colour as the substrate). The total numbers of *Atheta* adults and larvae per box were estimated from the sub-sample counts and the two boxes with the most similar numbers were selected as the rearing units to use in the experiment.

Experiment design

On 8 May 2006, 48 *Impatiens* plants were placed on capillary matting on the floor in each of the three glasshouse compartments, as shown in Figure 2, Appendix I.

WFT infestation

On 8 May 2006, ten plants in each compartment were infested with six WFT larvae per plant. This gave an infestation of 60 WFT larvae per compartment and an overall mean of 1.3 WFT larvae per *Impatiens* plant. The WFT larvae were reared on French bean pods in the laboratory and were transferred to the *Impatiens* plants with a fine paintbrush.

Experiment treatments

1. *Atheta coriaria*, released in one rearing unit per glasshouse compartment, in two replicate compartments.
2. No *Atheta coriaria* (untreated control), in one compartment.*

*It was originally intended to use two replicate compartments for the untreated controls. However, 'indicator' *Impatiens* plants, placed in the second control compartment before the experiment was set up, quickly developed symptoms of *tomato spotted wilt virus* (TSWV) which is spread by WFT. This indicated that viruliferous WFT were still present in the compartment, following a previous Defra-funded experiment with WFT and TSWV (project HH1758SPC). Despite a thorough clean-up procedure having been put in place, it was decided not to use this compartment as a replicate control for the experiment in this project, as it could have put the experimental plants in all compartments at risk of virus infection and early senescence.

Plant husbandry

The glasshouse environmental conditions were automatically controlled by the glasshouse computer as follows:

- Temperatures were set at minimum 18°C night and day, venting at 21°C.
- The plants were watered using drip irrigation lines on the capillary matting.

The aphid parasitoids *Aphidius colemani* were released every week in each compartment, as a precaution against the peach-potato aphid, *Myzus persicae*, which commonly infests *Impatiens*.

Assessments

Compost temperatures

Compost temperatures were monitored in each glasshouse compartment throughout the experiment period using a Tinytalk® datalogger, placed in an extra pot with M2 compost and an *Impatiens* plant.

Bait pots to monitor Atheta dispersal from rearing units

Two 'bait' pots (9 cm pots containing damp M2 compost with turkey grower mash incorporated) were used in each of the compartments with *Atheta* rearing units, to check that *Atheta* were leaving the units and dispersing throughout the compartments and entering the pots. The bait pots were set up on the capillary matting in the positions indicated in Figure 2, Appendix I on 9 May 2006 at the start of the experiment and were assessed and replaced one, three, five and six weeks later. The assessment procedure was the same as that used for the estimation of *Atheta* in the rearing units, i.e. turning the pots out onto a large white plastic tray and counting the numbers of *Atheta* adults and larvae.

Estimation of Atheta numbers in rearing units at end of experiment

At the the end of the experiment on 22 June 2006 (six weeks after placing the *Atheta*

rearing units in the compartments), six replicate 30 ml samples of substrate were taken from each of the rearing units. Numbers of *Atheta* adults and larvae in each sub-sample were counted and the estimated total numbers of *Atheta* per rearing unit were calculated, using the same method as described for the pre-release counts.

Assessment of numbers of WFT per plant at end of experiment
At the end of the experiment on 20 June 2006, numbers of WFT per plant were assessed on the same ten plants per compartment that had been used as release sites for the WFT larvae six weeks earlier. Each assessment plant was carefully cut off at compost level and washed in a large beaker containing 70% alcohol. The alcohol was poured through a 150 μm sieve to retain the thrips and the plant washing and alcohol sieving procedure was repeated for a second time to ensure that all thrips had been removed. The thrips were washed from the sieve with 70% alcohol into screw-top tubes. In the laboratory, the contents of each tube were emptied into a 'Doncaster' counting dish and numbers of WFT adults, larvae, prepupae and pupae were counted under a binocular microscope.

Statistical analysis

Total numbers of WFT (all life stages) per plant in each compartment were analysed by paired t-test.

Results and Discussion

WFT life stages on Impatiens plants
Mean numbers of WFT per plant in each glasshouse compartment are given in Table 1. Most of the WFT life stages recovered from the plants were adults and larvae (Table 1). Very few pupal stages were found, with a total of only one prepupa and four pupae being found on all thirty assessment plants. This indicates that as already demonstrated on pot chrysanthemum and cucumber (Bennison *et al*, 2004; Bennison, 2006), most WFT larvae drop from *Impatiens* plants to the compost or ground to pupate, and are thus available to ground-dwelling biological control agents, including *Atheta*. Similar results were given in American research, where the majority of WFT immature stages found on *Impatiens* were larvae (Ugine *et al*, 2006), with only one pupa being found on 80 *Impatiens* stems with leaves and flowers, whereas 145 larvae were found (Ugine, personal communication).

Table 1. Mean numbers of WFT life stages per plant in the glasshouse compartments treated with or without *Atheta* rearing units.

Treatment	Mean nos WFT larvae/ plant	Mean nos WFT prepupae/ plant	Mean nos WFT pupae/ plant	Mean nos WFT adults/ plant	Mean total WFT life stages/ plant	Mean % reduction in WFT compared with controls
Untreated control	175.5	0.1	0	33.2	208.8	
Atheta compart. 1	33.3	0	0.1	4.1	37.5***	82%
Atheta compart. 2	84.8	0	0.3	12.1	97.2*	53%

* significantly less WFT than in untreated control glasshouse, $P<0.05$
*** significantly less WFT than in untreated control glasshouse, $P<0.001$

Reduction of WFT numbers by Atheta

Mean numbers of WFT per plant (all combined life stages) in both compartments with *Atheta* rearing units were significantly lower than in the untreated compartment. Mean numbers of WFT per plant were 82% lower in the *Atheta* compartment replicate 1 than in the untreated compartment ($P<0.001$) and 53% lower in the *Atheta* compartment replicate 2 ($P<0.05$), Table 1 and Figure 1. There were no significant differences between numbers of WFT per plant in the two replicate *Atheta* compartments.

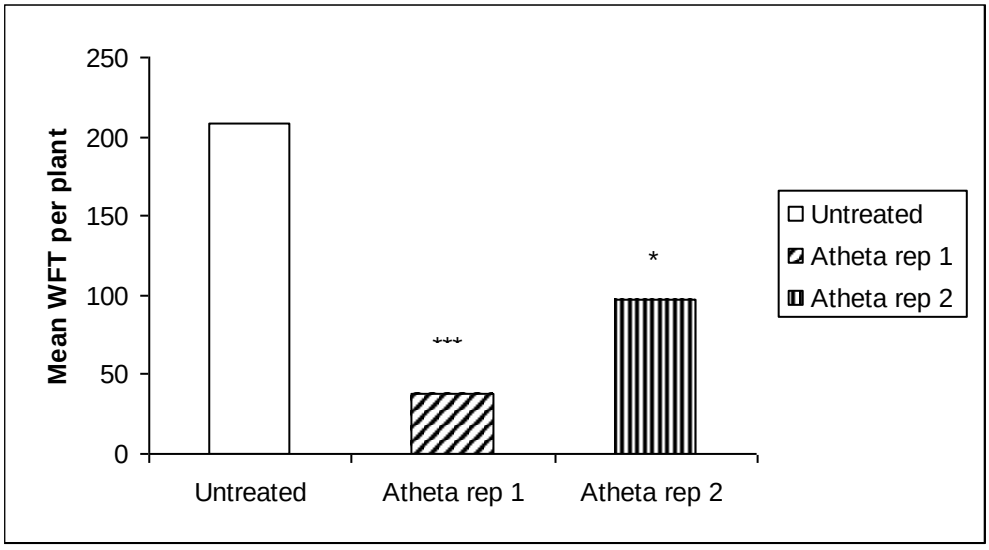

Figure 1. Mean numbers of WFT (all life stages) per plant in the untreated glasshouse and in the 2 replicate glasshouses with *Atheta* rearing units on 20 June, 6 weeks after WFT infestation and introduction of *Atheta* units.

* significantly less WFT than in untreated control glasshouse, $P<0.05$
*** significantly less WFT than in untreated control glasshouse, $P<0.001$

These results indicate that *Atheta* could contribute to control of WFT when released in glasshouses using the rearing units being developed in project PC 239. However, the results indicate that at the thrips and *Atheta* densities used in this experiment, they should not be relied upon as the sole biological control agents for WFT. The predatory mite *Amblyseius cucumeris* usually gives successful control of WFT on bedding plants and this was demonstrated on *Impatiens* in Defra-funded project HH1758SPC, 'Epidemiology of viruses on crops grown under protection' (Bennison *et al*, 2001). However, it is possible that *Atheta* could supplement the control given by *A. cucumeris* under conditions of high thrips pressure, or in crops where *A. cucumeris* is less reliable, e.g. chrysanthemum and some hardy nursery stock species. Use of the rearing unit system could offer a cost-effective method for using *Atheta*.

Estimated numbers of Atheta in rearing units at start and end of experiment

Numbers at start of experiment
Mean numbers of estimated *Atheta* adults and larvae per rearing unit (based on sub-samples of substrate) used in the two replicate compartments treated with *Atheta* are shown in Table 2. At the start of the experiment on 8 May, the two rearing units had very similar numbers of *Atheta* adults and larvae. When the rearing units were prepared on 12 April, 60 *Atheta* adults were added to each unit recorded and 26 days later on 8 May, the total numbers of *Atheta* per unit were 1143 and 1351 respectively (Table 2). These totals would be an under-estimate, as *Atheta* pupae were not recorded owing to them being indistinguishable from substrate particles when the sub-samples of substrate were examined. Thus the mean multiplication rate in the two rearing units over the 26 days in the laboratory at 25°C was x21. This result was similar to the *Atheta* multiplication determined given in experiments in PC 239, when a mean of x20 multiplication was given when 30 adults per box were incubated for 23 days at 25°C (annual report 2006).

The numbers of *Atheta* per rearing unit at the start of the experiment, when the rearing units were placed in the glasshouse compartments, (area 16 $m^{2)}$, were equivalent to 71 and 84 *Atheta* per m^2 in compartments 1 and 2 respectively. Not all the *Atheta* would disperse from the rearing units immediately, but this potential release rate was much higher than the maximum commercial product release rate recommended for *Atheta* mixed life stages (10 per m^2) if used for the control of sciarid or shore flies.

Numbers at end of experiment
Estimated total numbers of *Atheta* per rearing unit were lower at the end of the experiment than at the beginning (Table 2). This must have been due partly to the *Atheta* dispersing from the *Atheta* units faster than they were developing inside the units, over the six week period of the experiment (see next section). However, it is also thought that some *Atheta* eggs and young larvae may have been killed by naturally occurring predatory mites, as from 14 June, *Macrocheles* sp. mites were noticed in the rearing units, particularly in *Atheta* compartment 2. These mites have been found in large numbers in both research and commercial glasshouses where IPM is practiced (Jude Bennison & Mike Lole, unpublished data). *Macrocheles* sp. can enter glasshouses and disperse by 'hitching a ride' on insects, including beetles. The mites feed on a range of invertebrates, including insect eggs and larvae (Hughes, 1976) and thus may have been partly responsible for the lower numbers of *Atheta* in the rearing unit in compartment 2 than in compartment 1 at the end of the experiment (Table 2). Recent research in The Netherlands has shown that *Macrocheles*

spp. can also reduce WFT populations by feeding on the ground-dwelling stages (Messelink & Kogel, 2005). Thus the *Macrocheles* found in the *Atheta* rearing boxes in this experiment could possibly have contributed to the reduction of WFT numbers, but this is not possible to verify from the data collected during the experiment. The mites were only recorded in the *Atheta* rearing units and not in the pots or on the capillary matting in both the untreated and *Atheta*-treated glasshouse compartments. The interactions between pests and both released and naturally-occurring biological control agents are very complex and not easily understood in simple experiments such as this. The occurrence of naturally-occurring invertebrates in the *Atheta* rearing units being used on commercial nurseries in PC 239 is being recorded, and this information may give a further indication of the potential impact of any naturally-occurring predators on *Atheta* densities in the rearing units.

Table 2. Mean estimated *Atheta* adults, larvae and total *Atheta* per rearing unit used in the glasshouse compartments, at the start and end of the experiment.

***Atheta* rearing unit**	**Mean estimated numbers of *Atheta* at start of experiment on 8 May 06**	**Mean estimated numbers of *Atheta* at end of experiment on 22 June 06**
Used in replicate compartment 1	850 adults 293 larvae **1143 total**	290 adults 275 larvae **565 total**
Used in replicate compartment 2	958 adults 393 larvae **1351 total**	115 adults 65 larvae **185 total**

Dispersal of Atheta from rearing units

Mean numbers of *Atheta* adults and larvae found in the two bait pots per compartment on each assessment date are given in Table 3. No *Atheta* were found on any date in the bait pots in the untreated compartment, which indicated that the insect screening system in the compartments and staff precautions when entering the glasshouses had successfully prevented the beetles from migrating between compartments. Both *Atheta* adults and larvae were found in the bait pots on each assessment date, between one and six weeks after the rearing units were placed in the compartments (Table 3). These results demonstrated that *Atheta* were dispersing from the release units and entering the pots. *Atheta* adults were also frequently observed sheltering on the damp capillary matting underneath the *Impatiens* pots during the day, when pots were lifted for inspection. It is likely that the *Atheta* were also using the pots as breeding sites, as some very young larvae were recorded in the bait pots.

Table 3. Mean numbers of *Atheta* adults and larvae per bait pot in each of the two replicate glasshouse compartments treated with an *Atheta* rearing unit on 8 May 2006

Date	***Atheta* replicate compartment**	**Mean no. *Atheta* adults per bait pot**	**Mean no. *Atheta* larvae per bait pot**	**Mean no. total *Atheta* per bait pot**
16 May	1	7	0	7
	2	8	6.5	14.5
31 May	1	7.5	3	10.5
	2	15.5	0.5	16
14 June	1	12	9	21
	2	3	3	6
20 June	1	2	2.5	4.5
	2	0.5	0.5	1

Compost temperatures

The weather during the experiment period during May and June was unusually hot. Mean, maximum and minimum compost temperatures in the two glasshouse compartments treated with *Atheta* were 20-26°C, 23-30°C and 16-23°C respectively (Figures 3-5, Appendix I). *Atheta coriaria* have been recorded as completing their life cycle at various temperatures between 15.6 and 32.2°C, with development rates being faster with increasing temperatures (Miller & Williams, 1983). Temperatures outside the 15.6 - 32.2°C range were not tested in Miller & Williams' research, so it is possible that *Atheta* could develop at lower or higher temperatures than those reported. However, the compost temperatures recorded in our glasshouse compartments treated with *Atheta* were within the known *A. coriaria* development range.

Conclusions

- *Atheta coriaria* significantly reduced numbers of WFT on potted *Impatiens* when released in two glasshouse compartments in the rearing units being developed in project PC 239. Mean percentage reductions in WFT numbers per plant compared with those in the untreated control compartment were 82% reduction in compartment 1 and 53% reduction in compartment 2.
- The control of WFT was by *Atheta* predation of the ground-dwelling stages of WFT (late larval and pupal stages).
- On *Impatiens*, most WFT larvae drop to the ground to pupate, as has already been demonstrated in pot chrysanthemum and cucumber.
- Use of the on-nursery rearing system for *Atheta* should not be relied upon on its own for thrips control, but should lead to some control of WFT on crops grown on capillary matting and in crops on which WFT lavae drop to the ground to pupate.
- Naturally-occurring predatory mites (*Macrocheles* sp.) became established in the rearing units after 4-6 weeks and may have contributed to the reduction of *Atheta* in the rearing units over time. *Macrocheles* sp. mites can also feed on WFT ground-dwelling stages and may possibly have contributed to the reduction in WFT numbers.

- The *Atheta* rearing/release system was only tested in small research glasshouses in this project, on *Impatiens* over a 6-week period. Further research would be necessary to test the system for WFT control in longer-term pot plant crops e.g. cyclamen, in larger glasshouses and in growing systems other than capillary matting, e.g. ebb and flood benching. These factors are likely to affect the viability of the rearing units and *Atheta* dispersal and behaviour in the crop.
- Use of the on-nursery rearing system for *Atheta* against sciarid and shore flies in initial trials on commercial crops of protected herbs, celery and ornamentals will be reported in the annual report for PC 239, (2006).
- Growers should await the final results of PC 239 (due February 2008) when a factsheet will be provided, summarising the results of PC 239 and giving recommendations on how to use the on-nursery rearing units for *Atheta* on a range of protected crops.

Technology transfer

- Jude Bennison presented the aims of the project in a presentation on 'Advances in biological pest control' at the BOPP AGM, 28 June 2006.
- The results of the project will be summarized in an article in HDC News.
- With the approval of HDC, the results of the project will be published in the 'Grower' and/or in a scientific journal.

Acknowledgements

Thanks are due to:

- WG Findon, for supplying the *Impatiens* plugs free of charge.
- Syngenta Bioline, for supplying the original *Atheta* culture for the rearing units in PC 239 free of charge.

References

Bennison, J., Maulden, K., Barker, I., Morris, J., Boonham, N., Smith, P. and Spence, N. (2001). Reducing spread of TSWV on ornamentals by biological control of western flower thrips. *Thrips and Tospoviruses: Proceedings of the 7th International Symposium on Thysanoptera*, Reggio Calabria, Italy, 215-219.

Bennison, J., Maulden, K. & Maher, H. (2002). Choice of predatory mites for biological control of ground-dwelling stages of western flower thrips within a 'push-pull' strategy on pot chrysanthemum. *IOBC/wprs Bulletin* **25(1)**, 9-12.

Bennison, J.A., Broadbent, A.B., Kirk, W.D.J., Maulden, K.A. & Shipp, J.L. (2004). Western flower thrips pupation behaviour on greenhouse chrysanthemums and implications for integrated control. Abstract proceedings, XXII International Congress of Entomology, Brisbane, August 2004.

Bennison, J.A. (2006). Defra final report for project HH3102TPC 'Exploiting knowledge of WFT behaviour to improve efficacy of biological control measures'.

Carney, V.A., Diamond, J.C., Murphy, G.D. & Marshall, D. (2002). The potential of *Atheta coriaria* Kraatz (Coleoptera: Staphylinidae), as a biological control agent for use in greenhouse crops. *IOBC/wprs Bulletin* **25(1)**, 37-40.

Hughes, A.M. (1976). The mites of stored food and houses. *MAFF Technical Bulletin 9.* Her Majesty's Stationary Office, London, 356-357.

Messelink, G.J. & de Kogel, W.J. (2005). Impact of chrysanthemum cultivar, fertilization and soil-dwelling predatory mites on *Frankliniella occidentalis*. *Proc. Neth. Entomol. Soc. Meeting* **16**, 101-107.

Miller, K.V. & Williams, R.N. (1983). Biology and host preference of *Atheta coriaria* (Coleoptera: Staphylinidae), an egg predator of Nitidulidae and Muscidae. *Annual Entomological Society of America* **76**, 158-161.

Ugine, T.A., Sanderson, J.P. & Wraight, S.P. (2006). Within-plant and temporal distribution of nymphal and adult western flower thrips, *Frankliniella occidentalis* (Thysanoptera: Thripidae), on flowers and foliage of greenhouse Impatiens, *Impatiens wallerana*, and implications for pest population sampling. *Environmental Entomology* **35(2)**, 507-515.

Appendix I

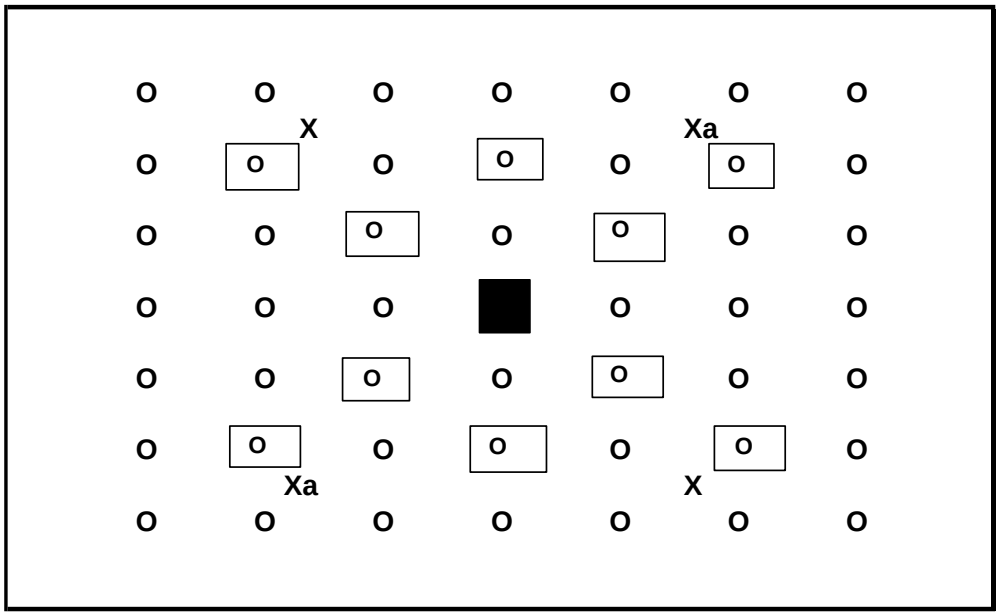

Figure 1. Experiment layout in each of the compartments treated with an *Atheta* rearing unit.

O = *Impatiens* plant

O = *Impatiens* plant with 6 WFT larvae added at start of experiment

X = position of bait pots in weeks 1 and 5

Xa = position of bait pots in weeks 3 and 6

= *Atheta* rearing unit

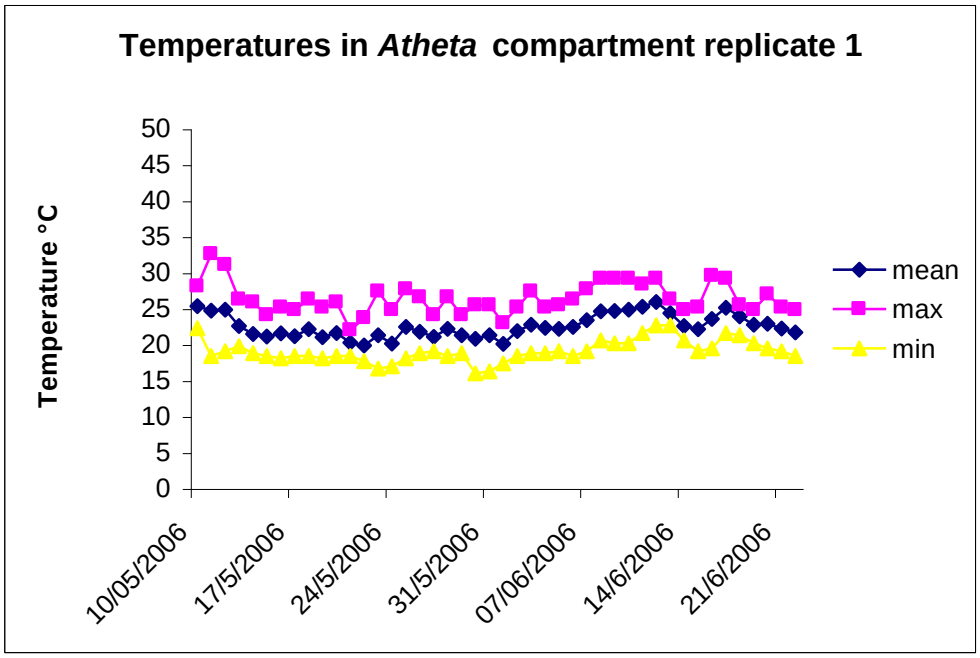

Figure 2. Mean, minimum and maximum compost temperatures in the glasshouse compartment treated with *Atheta* rearing unit, replicate 1.

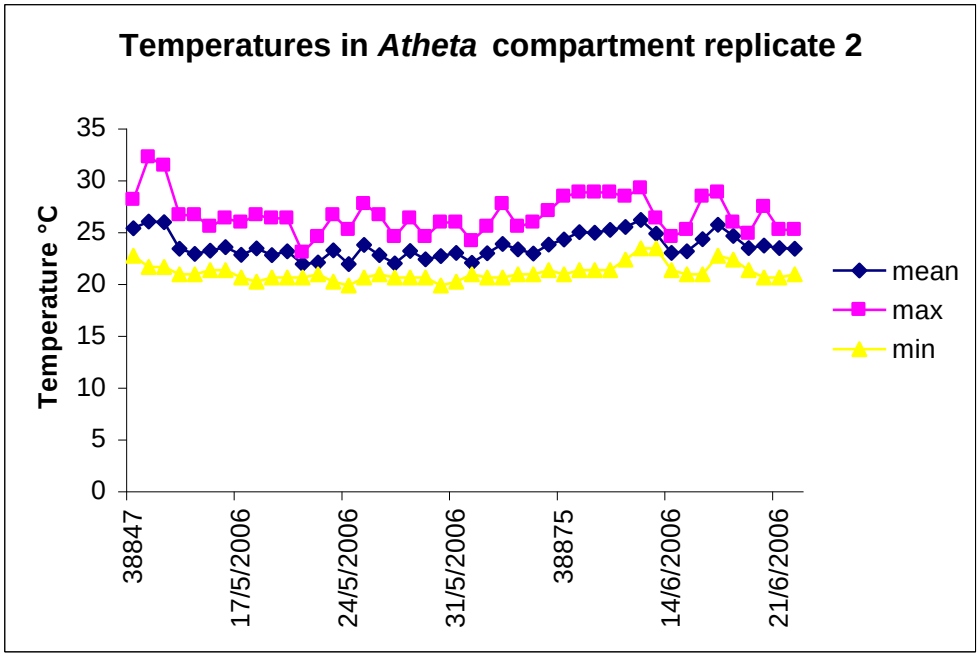

Figure 3. Mean, minimum and maximum compost temperatures in the glasshouse compartment treated with *Atheta* rearing unit, replicate 2.

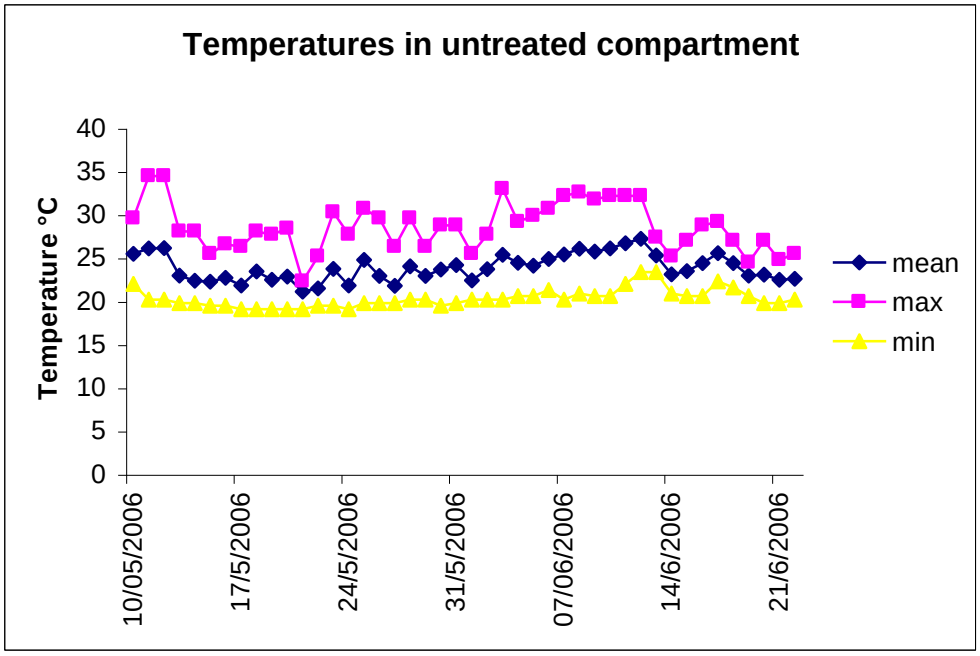

Figure 4. Mean, minimum and maximum compost temperatures in the glasshouse compartment without an *Atheta* rearing unit (untreated control).