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

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

Jude Bennison
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Signature .... Date ....

Report authorised by:

Dr Tim O'Neill
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Signature .... Date ....

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Grower Summary

Headline

- Improved understanding of the life-cycle of the blackberry leaf midge in protected blackberry has been gained in year 1 of this project.

Background and expected deliverables

To meet consumer demand for soft fruit over an extended season, there has been a substantial increase in UK production of blackberries and raspberries under protection, mainly using ‘Spanish’ tunnels. This has led to increased problems with insect pests that were previously considered to be ‘minor’ localised pests in outdoor rubus crops. One such pest is the blackberry leaf midge, *Dasineura plicatrix*, which has now become widespread and is damaging on blackberry crops both in fruiting and in propagation. The larvae feed on the leaf tips, causing leaf twisting and distortion, cane stunting and branching and reduced yield in the following year’s crop.

The life cycle of blackberry leaf midge on protected blackberry and raspberry is not fully understood. On protected crops, the pest seems to have more than the two generations per season reported to occur on outdoor crops. This will lead to increased midge numbers and an extended period of damage on protected crops. There is a shortage of approved, effective pesticides for use against the pest on protected rubus crops, particularly on protected blackberry. In addition, some of the pesticides available for control are not compatible with bees used for pollination, and /or biological control agents used against other pests in Integrated Pest Management (IPM) programmes. There is a need to confirm the life cycle of the pest on protected blackberry and raspberry crops and to develop integrated control methods for use in IPM programmes.

The aims and expected deliverables of this project are to confirm the location and timing of key life-stage events of blackberry leaf midge on commercial protected blackberry and raspberry crops and to test integrated control methods for use on protected blackberry, with a view to extrapolating the methods to protected raspberry.

Summary of the project and main conclusions

The work has been split into two objectives.

Objective 1: To confirm the location, timing and duration of key life-stage events of blackberry leaf midge on protected blackberry and raspberry

- The biology and life stage events of blackberry leaf midge were confirmed in two protected blackberry crops during 2009, one grown in pots (Meadow Field), the other grown in the soil (Chivers Field).

- The pest overwintered in 2008/2009 as cocoons in the soil. Most were found in soil to a depth of 3 cm, at the edge of the ground-cover matting running under the crop canopy. They were also found in the soil in the planting hole, under the polythene covering the ground between plants and in plant debris on the polythene.

- Monitoring with water traps detected the first male midge on 8 April in Meadow Field and the first females on 15 April in both Meadow and Chivers Fields.

- Sampling of leaf tips detected the first midge eggs and larvae on 15 and 22 April in Meadow and Chivers Fields respectively.

- Soil temperature data between March and June was modelled in a similar manner to the ADAS raspberry cane midge model to predict first generation blackberry leaf midge emergence and first egg-laying dates. First eggs were predicted on 20-21 April in Meadow Field and on 27-29 April in Chivers Field. These results were very promising as the predicted dates were only five days earlier than the actual dates when first eggs were found in leaf tips, i.e. 15 and 22 April in the two respective fields. As the leaf tips were only sampled weekly, the first eggs could have corresponded even more closely with the predicted dates. The data suggested that blackberry leaf midges emerge and lay eggs slightly earlier than raspberry cane midge, at an accumulative soil temperature of around 280°C days above a base temperature of 4°C.

- Numbers of midge adults remained low (below two per trap) until June and July. Mean numbers per trap peaked on 22 July in Meadow Field (24 per trap) and on 8 July in Chivers Field (132 per trap), see Figure 1.

- From late June to mid-August during peak adult activity, numbers of males trapped were much higher than those of females in both fields. This could possibly be due to differences in the behaviour of males and females rather than an uneven sex ratio in the population.

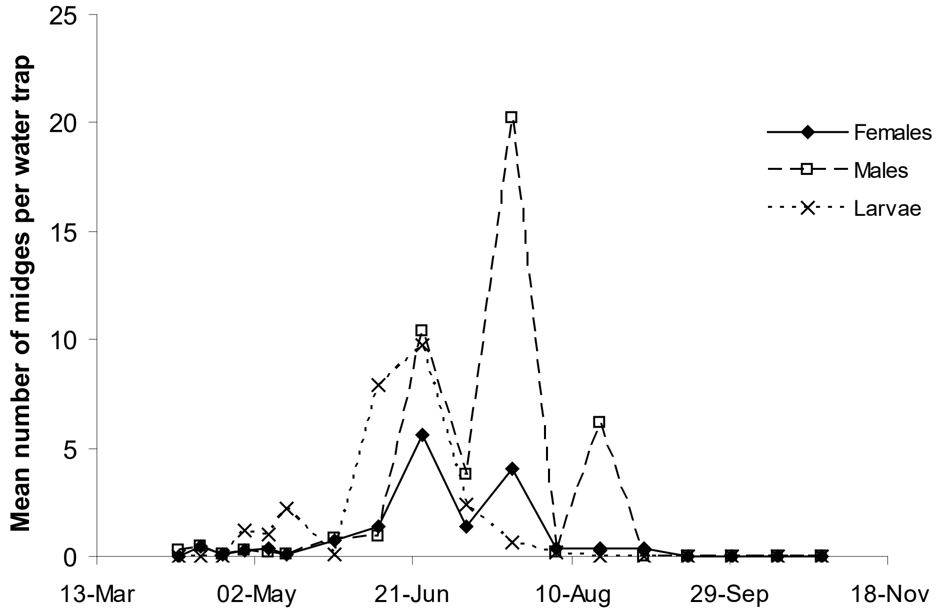

Figure 1. Meadow Field: Mean numbers of blackberry leaf midge males, females and dropped larvae per water trap.

- Following first adult emergence and egg laying, the percentage of leaf tips infested with eggs and larvae increased rapidly in both fields, from 30% and 5% in Meadow and Chivers Fields respectively in mid-April, to 60% and 55% respectively in late April and to 90% and 100% respectively in late June/early July (see Figure 2). Larval feeding activity continued until late September.

- Midge larvae fed for approximately two weeks in the leaf tips, causing them to twist. Severely damaged leaves turned brown and withered.

- When fully fed, the larvae dropped to the ground to pupate in cocoons. No pupae were ever found in the leaf tips, and dropped larvae were found in the water traps under the crop canopy that were used for monitoring adult activity (see Figure 1).

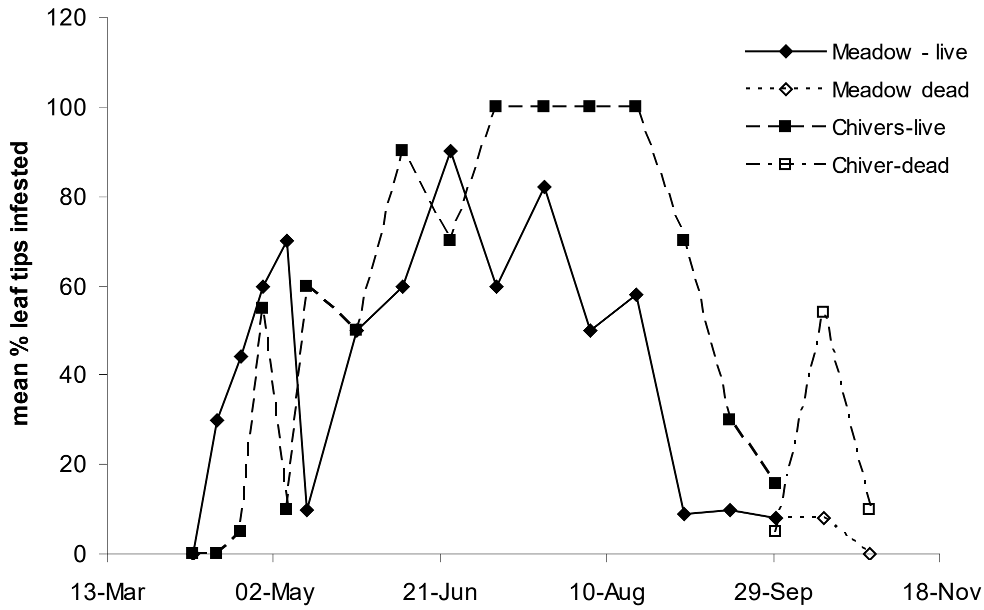

Figure 2. Percentage of leaf tips infested with eggs and/or larvae in Meadow and Chivers Fields between 8 April and 28 October.

- Monitoring of three protected raspberry crops in June confirmed that blackberry leaf midge larvae damaged raspberry leaves but the percentage of infested leaf tips was much lower than that in the protected blackberry crops at this site. This may have been due to the use of chlorpyrifos against other pests such as raspberry cane midge.

- The pattern of adult numbers in traps and that of eggs and larvae in leaf tips suggested that there were four overlapping generations in protected blackberry, between April and September, unlike on outdoor blackberry when only two generations are reported, in May/June and July/August. Thus on protected blackberry, first adult emergence is earlier, there are more generations per season and the pest is active for a longer period than on outdoor blackberry.

Objective 2: To evaluate potential integrated control methods against blackberry leaf midge, for use in IPM programmes on protected blackberry

- Preliminary laboratory experiments indicated that both the predatory mites *Amblyseius cucumeris* and *Amblyseius andersoni* predated young blackberry leaf midge larvae.

However, it was not possible to produce sufficient data for statistical analysis due to difficulties with methodology. Further work will be conducted in year 2.

- Releases of both *A. cucumeris* and *A. andersoni* to blackberry plants in slow-release sachets in research tunnels at ADAS Boxworth led to some establishment of *A. cucumeris* in the flowers but no apparent establishment of *A. andersoni*. The latter species can be difficult to find on host crops. However, following grower releases of *A. andersoni* to commercial protected blackberry plants, there was no apparent reduction in the pest when compared with untreated plants. Further work on establishment and potential control by predatory mites will be conducted at ADAS Boxworth in year 2.

- In laboratory pot experiments, neither the predatory mites *Macrocheles robustulus* nor the predatory beetles *Atheta coriaria* gave significant reductions in the numbers of blackberry leaf midge larvae that successfully completed their development in compost and emerged as adult midges. Results indicated that numbers of both predators may need to be equal to or higher than numbers of the target midge larvae in the soil to give significant control of the ground-dwelling stage of the pest. Work in year 2 will include comparing the potential of *M. robustulus* with that of the predatory mite *Hypoaspis* sp. against the ground-dwelling stages of the pest.

- Grower applications of Naturalis-L to the commercial crop did not reduce the percentage of leaf tips infested or mean numbers of live larvae per leaf tip. *Beauveria bassiana* is a contact-acting fungus and is unlikely to reach the target pest inside folded leaf tips. In a laboratory test, application of Naturalis-L to compost did not reduce the numbers of blackberry leaf midge larvae that successfully completed their development in the compost and emerged as adult midges.

- Grower applications of thiacloprid (Agrovista Reggae, SOLA 0467/2008) and abamectin (Dynamec, SOLA 2290/2007) did not reduce numbers of live midge larvae per leaf tip or percentage of infested leaf tips when compared with those in untreated plants.

- Grower application of chlorpyrifos (Alpha chlorpyrifos, label recommendation for outdoor blackberry) to outdoor blackberry reduced numbers of live midge larvae per leaf tip by 87% and reduced the percentage of infested leaf tips by 92% when compared with those in untreated plants. By extrapolation, chlorpyrifos should give some control of the pest on raspberry and various chlorpyrifos products are approved for use on both outdoor and protected raspberry. However, chlorpyrifos is not approved for use on protected blackberry and is not compatible with biological control agents used in an IPM programme.

- Further work on the potential of IPM-compatible pesticides against blackberry leaf midge will be conducted in year 2, in consultation with Vivian Powell at HDC.

- Naturally-occurring anthocorid bugs (both *Anthocoris nemorum* and *Orius* sp.) were observed feeding on blackberry leaf midge larvae in the commercial crop during July and August. Both adults and nymphs were recorded, which showed that the predatory bugs were breeding on the blackberry crop. *Orius laevigatus* are commercially available and work on its potential against the pest when released early in the season will be included in year 2.

Financial benefits

It is too early in the project to predict financial benefits.

Action points for growers

- Monitor for blackberry leaf midge on both outdoor and protected blackberry and raspberry crops.

- If the pest occurs on raspberry, extrapolation of the results in this project on outdoor blackberry indicates that chlorpyrifos should give some control of the pest. Various chlorpyrifos products have approval for use on both outdoor and protected raspberry. However, this pesticide is not approved for use on protected blackberry and is not compatible with biological control agents used in IPM.

- Keep up to date with further results in this project on potential integrated management strategies for the pest by contacting HDC or Jude Bennison: jude.bennison@adas.co.uk, Tel. 01954 268225.

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Science Section

Introduction

In order to meet consumer demand for soft fruit over an extended season, there has been a substantial increase in UK production of blackberries and raspberries under protection, mainly using 'Spanish' tunnels. This has led to increased problems with what were considered previously in outdoor rubus crops as 'minor' localised pests, including blackberry leaf midge, *Dasineura plicatrix*. This pest has now become widespread and is often very damaging, particularly on blackberry crops. The pest damages crops in propagation in addition to fruiting crops. On protected crops, the pest seems to have more than the two generations per season occurring on outdoor crops. This will lead to increased midge numbers and an extended period of damage on protected crops.

There is a shortage of approved, effective pesticides for use against the pest on protected rubus crops, particularly on protected blackberry. In addition, some of the pesticides available for control of the pest are not compatible with bees used for pollination, and /or biological control agents used against other pests in Integrated Pest Management (IPM) programmes. There is a need to confirm the life cycle of the pest on protected blackberry and raspberry crops and to develop integrated control methods for use in IPM programmes.

The chemical control options currently available to growers for control of this pest are very limited, particularly on protected blackberry. The pesticides available are either ineffective against the pest, or are limited in the timing of, or number of applications permitted, or their use is incompatible with bees used for pollination, and/or with biological control agents used against other pests within IPM programmes. For example, chlorpyrifos (e.g. Equity, Lorsban WG) and deltamethrin (Decis) only have SOLAs for use on outdoor blackberry and both these pesticides are incompatible with IPM. Thiacloprid (e.g. Calypso) has a SOLA for use on protected blackberry but can only be used three times per season, and growers use it primarily for control of aphids, capsids and increasingly, raspberry beetle, at times that may not coincide with incidence of blackberry leaf midge larvae. Bifenthrin products (e.g. Talstar 80 Flo) have SOLAs for use on both protected and outdoor blackberry crops, but commercial use, primarily for control of wingless weevil and two-spotted spider mite in these crops has indicated that it has little efficacy against blackberry leaf midge. All these pesticides have adverse and persistent effects on biological control agents used within IPM.

One UK grower has reported that abamectin (Dynamec) has given some control of blackberry leaf midge on blackberry. This pesticide has a SOLA for use on protected blackberry and raspberry, for control of spider mite and leaf and bud mite. Although Dynamec is harmful to many biological control agents, it has short persistence, so can be used in IPM programmes if timed carefully. Dynamec would be worth evaluating against blackberry leaf midge in the proposed project.

In addition to the limited options for chemical control, growers often see damage by first generation midges too late to apply any pesticide effectively, as the larvae are reported to feed in the twisted leaves for only 2-3 weeks before most of them drop to the ground to pupate. It would be useful for growers to be aware of the timing of first generation midge emergence.

An HDC-funded studentship (CP 38) at The Natural Resources Institute (NRI), led by NRI in collaboration with EMR, investigated the sex pheromones of some important midge pests of UK fruit crops. Research in this project mainly focussed on pheromones for pear midge, pear leaf midge and blackcurrant leaf midge (Hall, 2007 and 2008). The research also detected some of the pheromone components of blackberry leaf midge (Amarawardana, 2008). However, methods for the practical use of the pheromone have yet to be developed. It is possible that use of a sex pheromone lure could form part of an IPM strategy against the pest in the future and HDC have recently agreed to fund a new project with EMR to investigate this.

In this project in the meantime the ADAS raspberry cane midge emergence model will be tested to determine whether this could predict the emergence of first generation blackberry leaf midge adults. This will be done by simply monitoring daily mean soil temperatures in polythene tunnels at the commercial experimental site to determine whether first generation adult emergence is triggered in a similar manner to that of cane midge, i.e. when a particular cumulative temperature threshold is reached. It is possible that prediction of the first generation blackberry leaf midge emergence date could be used to manipulate synchronised emergence of the adults in a polythene tunnel, e.g. by increased watering of the soil, once threshold soil temperatures are reached. This could allow accurate timing of an IPM-compatible pesticide against adult midges.

An effective non-chemical strategy for control of the pest could include the establishment of one or more biological control agents in the crop, so that they are available to attack the pest at key times in the pest's life cycle. Potential biological control agents for use against blackberry leaf midge include those that target the the leaf-dwelling stages (eggs and larvae on leaves) and those that target the ground-dwelling stages (larvae that drop to the ground to pupate inside cocoons).

No research has yet been done on potential biological control agents against the leaf-dwelling stages of the pest. However, various *Amblyseius* species predatory mites, including *A. cucumeris* (used for control of thrips) and *Amblyseius swirskii* (used for control of thrips and whiteflies) are known to feed on the eggs of the predatory midge, *Aphidoletes aphidimyza*, which is used for biological control of aphids (personal communication, van der Linden, the Netherlands). Releases of *Amblyseius andersoni* (used for control of mites) are thought to have led to a reduction in blackberry leaf midge in a UK crop of protected blackberry (Helyer, personal communication).

This project will investigate the potential of *A. cucumeris* and *A. andersoni* against the eggs and young larvae of blackberry leaf midge. *A. swirskii* is another potential candidate but currently may only be released under licence in the UK in fully protected structures, thus cannot be released in 'Spanish' tunnels. In addition, this predator needs warmer temperatures to establish than the other, native *Amblyseius* species, and is unlikely to establish in the cool temperatures experienced in late spring in protected blackberry crops, when first generation midges are active. However, both *A. cucumeris* and *A. andersoni* are native to the UK and thus may be released both outdoors and in Spanish tunnels. These two species are active at cooler temperatures than *A. swirskii.* Both species can establish on crops in the absence of host prey, if pollen is available as food. Or, if flowers, and thus pollen are not yet present on the crop early in the season, both species can be released using 'controlled release sachets' which provide a food source for the mites, and allow the predators to emerge onto the crop over several weeks after the sachets are introduced to the crop. Both species would be useful on blackberry and raspberry crops, as they would also contribute to control of thrips (*A. cucumeris*), spider mites (*A. andersoni*) and other mite pests such as raspberry leaf and bud mite and blackberry mite (both *Amblyseius* species).

Recent Dutch laboratory research on biological control of the ground-dwelling stages of blackberry leaf midge showed that although three species of entomopathogenic nematodes were ineffective against the larvae in laboratory studies, the ground-dwelling predatory mites, *Hypoaspis aculeifer* and the predatory beetles, *Atheta coriaria* showed potential for control of the pest (Wenneker, 2008 and personal communication). These biological control agents are commercially available in the UK. The Dutch laboratory studies indicated that either higher numbers of *Hypoaspis* or *Atheta* than those tested would be needed for effective control, or a more aggressive predator would be needed, as the midge larvae are only available for predation before they spin a cocoon in the soil.

It could be possible for growers to rear their own supplies of *Atheta* for cost-effective use of high release rates of the beetles against blackberry leaf midge. Recent HDC-funded research led by ADAS in project PC 239 and PC 239a developed a method for growers of protected herbs and ornamentals to rear large numbers of *Atheta* on their own nurseries, for low-cost biological control of sciarid and shore flies (Bennison, 2007, 2008, 2009 and 2010).

The results would be relevant for growers of protected blackberry should *Atheta* prove to have practical potential against blackberry leaf midge. The project will aim to build on and complement the results of both PC 239 and PC 239a and the Dutch research on using *Atheta* for biological control of this pest.

Recent Dutch research has demonstrated the potential of a large, agressive soil-dwelling predatory mite species, *Macrocheles robustulus*, against the ground-based life stages of western flower thrips (WFT) (Messelink & van Holstein-Saj, 2008). The results showed that *Macrocheles* gave better control of WFT than *Hypoaspis* species. *M. robustulus* is known to feed on various soil-dwelling prey and could have potential against the larvae of blackberry leaf midge. *M. robustulus* is native to the UK and has been found naturally occurring in large numbers in various commercial and research glasshouses (Bennison, unpublished). The predator is not yet commercially available but is likely to be available in the future, as it is easy to rear and has potential against a range of key soil-dwelling pests. This project will investigate the potential of *M. robustulus* against blackberry leaf midge larvae in the soil or substrate.

An entomopathogenic fungus, *Beauveria bassiana* (Naturalis-L), was approved for use on all protected crops in the UK during 2009 and will be available in spring 2010. The product may have potential for control of blackberry leaf midge as it can infect a wide range of invertebrate pests. The HDC Soft Fruit panel requested that this product should be tested for efficacy against the pest in this project.

Overall aim of project

The two aims of this project are to confirm the location and timing of key life-stage events of blackberry leaf midge on commercial protected blackberry and raspberry crops and to test integrated control methods for use on protected blackberry, with a view to extrapolating the methods to protected raspberry.

Objective 1: Confirm the location, timing and duration of key life-stage events

Materials and Methods

Experimental site: Sunclose Farm, Milton, Cambridge.

Experimental crops: Two blackberry crops grown in polythene tunnels. One crop grown in pots in 'Spanish' tunnels (Meadow Field) and one grown in the soil in fully covered tunnels

(Chivers Field). The tunnels in Meadow Field were covered with polythene on 5-6 February and those in Chivers Field were covered between 6 and 12 March 2009.

Variety: Loch Ness.

Both crops had a history of damage by the pest. The biology and life cycle of blackberry leaf midge was monitored in detail between February and October 2009 in both crops. Some monitoring was also done in protected raspberry crops at the same site.

Overwintering cocoons

Soil samples were taken from both fields on 18 February from the following positions:

Meadow Field: compost from the pots, plant debris on and underneath the polythene covering the ground under the pots, and soil to a depth of 3 cm from the soil path in between the plant rows, at the edge of the ground-cover matting running under the crop canopy.

Chivers Field: soil in the planting hole, under polythene covering the ground between the plants, and both plant debris and soil to a depth of 3 cm from the soil path in between the plant rows, at the edge of the polythene.

Further soil samples were taken on 17 March and 9 April from Meadow Field only, from the soil at the edge of the ground-cover matting.

The soil samples were kept in polythene bags in the cold store until they were processed for midge cocoon extraction in the laboratory. The extraction and examination procedure was very time consuming and thus only a few representative samples from each sampling position could be processed. Each sample was soaked in water to help break up any lumps of soil to enable the cocoons to float free. In order to recognise the cocoons when extracted, soaking was also needed to help remove the coating of soil particles that the midge larvae wrapped around the cocoons,. The samples were soaked for approximately four hours or overnight, depending on sample size and soil structure. The samples were gently stirred to help break down any lumps. The samples were then gently washed in small amounts through a deep sided 250 µm sieve to remove as much soil as possible. This sieve was placed in a container of concentrated magnesium sulphate solution. Any cocoons floated to the surface where they were picked off onto filter paper using a fine paint brush. The cocoons were then examined under a binocular microscope for an initial identification.

Adult emergence and number and duration of generations

Adult emergence was monitored initially with both water traps and sticky traps in one tunnel in each of Meadow and Chivers Fields.

Water traps: Ten water traps were set up in each field on 11 March. The water traps were white, circular plastic dishes, 16.5 cm diameter and 6 cm deep. Five traps were placed on the floor beneath the crop canopy and five traps were placed on crates 27 cm high, to raise the traps to the height of the lower crop canopy. The traps were placed at equal distances along the length of the row of plants, with the 'floor' traps alternating with the 'crate' traps along the row. From 8 July, the five 'crate' traps were discontinued in each field as monitoring ten traps per field proved too time-consuming and there was no apparent difference between numbers of adults in traps on the floor or on crates. The traps were filled to 1.5 cm below the top with water mixed with a drop of detergent ('Tween') to break the surface tension so that midges could not escape once trapped. One 'Campden' tablet was added to each trap to help preserve the fragile midges until collection. The trap contents were collected weekly from 19 March until 12 May, then fortnightly until 28 October. This was done by pouring and rinsing the contents of each trap through a 250 µm sieve, then washing the contents of the sieve with water into a labelled screw-top jar.

In the laboratory the contents of the jars were either examined on the day of collection or, if necessary, refrigerated for a few days until they could be examined. The contents of each jar were poured through a 250 µm sieve. Any large insects and blackberry fruit retained on the sieve were washed on the sieve to remove any possible midges and were then discarded. The contents of the sieve were then washed with water into a Petri dish and examined under a binocular microscope. On some trapping dates there were large numbers of petals in the traps. These were examined in the Petri dish in alcohol before disposal, to ensure that no midges were attached to them. Numbers of male and female adult blackberry leaf midges were then recorded per trap.

Sticky traps: Yellow sticky traps were set up in both Meadow and Chivers Fields on 11 March. In each field, 10 traps were attached to the tops of canes, positioned along a row of plants so that the traps were at crop height. An additional 10 traps were placed in the bases of strawberry punnets and the punnets were then placed on the soil at the edge of the ground-cover matting or polythene running under the crop canopy. The punnets were secured with pieces of wire positioned as 'staples' over the top of the punnets and pushed into the soil at each side. These were used as 'emergence' traps with the aim of catching midges emerging from the soil. The traps were collected weekly until 22 April, when they were discontinued in favour of the water traps. No midge adults were caught in the 'emergence' traps and the midges caught on the sticky traps at crop height could not be identified as the wing venation (a key diagnostic character) could not be seen easily once the wings had absorbed the trap glue.

Prediction of adult emergence from soil temperatures

Daily mean soil temperatures at two depths (3 and 20 cm) were recorded between 11 March and 10 June in the monitoring tunnels in both Meadow and Chivers Fields. This was done in order to determine whether first generation blackberry leaf midge emergence occurs when a particular cumulative temperature is reached, as with raspberry cane midge. Two replicate 'Tinytalk' dataloggers were buried at each depth in each tunnel. The data was used to model first generation blackberry leaf midge emergence and first egg-laying dates in a similar manner to the ADAS raspberry cane midge model.

Eggs and larvae

Monitoring of leaf tips for midge eggs and larvae was done on the same sampling dates as the water traps, from 1 April to 28 October. Twenty random leaf tips were collected from each of the 'monitoring' tunnels, one in Meadow Field and one in Chivers Field. The tunnel remained untreated for blackberry leaf midge throughout the season. The leaf tips comprised a group of unfolded leaves at the growing tip, the number of individual leaves varied between two and eight. The leaf tips were placed into labelled plastic boxes which were placed in a cool box and returned to the laboratory. In the laboratory either 20, or more often ten, leaf tips were examined from each field, as the procedure was very time-consuming. Each individual folded leaf was examined under a binocular microscope and checked for midge eggs at the base of the hairs on the outside (under-surface) of the folded leaf. Then each folded leaf was gently unfolded using fine forceps and checked for midge larvae, which feed on the inside of the folded leaves. Larvae dropping from the leaves to the ground to pupate were monitored with the same water traps used for monitoring adult midge activity.

On 9 June, three crops of protected raspberry (Georgia, Glen Ample and Polka) were sampled for blackberry midge eggs and larvae, using the same method as used for blackberry. Ten twisted leaf tips with damage symptoms of the pest were sampled from each crop.

Results and Discussion

Overwintering cocoons

No midge cocoons were recovered from the compost in the pots in Meadow Field. This could have been due to the plants having very dense root systems throughout the depth of the pot.

This made it very difficult to extract compost from the pots without using force, and the force used could have damaged any cocoons around the roots in the upper layer of compost.

In the soil samples taken on 18 February, cocoons were found in all the positions sampled, with most being recovered from the soil taken from the edge of the ground-cover matting. In five such soil samples from Meadow Field, totals of 395 empty cocoons, 265 cocoons with larvae, 14 free larvae and six free pupae were found (i.e. 58% of the total cocoons were empty). The cocoons were off-white or a dirty cream in colour, once the soil particles had been removed by washing, and were approximately 1.75 – 2 mm long and 1 mm wide. It is possible that the extraction procedure rubbed off the cocoon cases from the larvae and pupae. At this stage, although the cocoons were suspected to be those of blackberry leaf midge, the species could not be confirmed due the lack of a published description of *Dasineura plicatrix* life stages. Thus samples of occupied cocoons (those with larvae inside) were kept on damp filter paper in Petri dishes or Perspex boxes in the laboratory, to allow the adults to emerge for identification.

The first adult midges emerged from cocoons in the laboratory on 13 March. When ready to emerge, the pupae broke through the wall of the cocoons and, after adult emergence, the empty pupal case was left attached to the outside of the cocoon. The midge species could still not be confirmed due the lack of a full published description of *D. plicatrix*. However, the species was retrospectively identified as blackberry leaf midge, once large numbers of similar adults were being found in water traps beneath the crop canopy and midge eggs and larvae were being found in the blackberry leaves.

Due to the lengthy time needed for cocoon extraction, only one of the soil samples could be processed from those taken from the edge of the ground-cover matting in Meadow Field on each of 17 March and 9 April. These were processed to determine whether a higher proportion of midge cocoons were empty than in earlier samples, due to adult midge emergence. In the sample collected on 17 March, 129 empty cocoons and 77 cocoons with larvae were extracted, i.e. 63% of the cocoons were empty. In the sample collected on 9 April, 36 empty cocoons and seven cocoons with larvae were extracted (84% were empty). Although a higher proportion of empty cocoons were found in the sample taken on 9 April, this result should be treated with caution as there was a large variability in numbers of empty and occupied cocoons per sample.

Adult emergence and number of generations

Blackberry leaf midge adults are small, delicate midges with pale pink abdomens, long legs and long beaded antennae. The beads of the antennae are close together in the females but are separated by short narrow sections in the males. The males are slightly smaller (1.5 mm long) than the females (2 mm long). The males have a pair of claspers at the end of the abdomen and the females have a long, pointed ovipositor. The wings of both sexes are paddle-shaped and are covered in short dark hairs. There are only a few wing veins, with the top vein ending at the upper edge of the wing, rather than at the tip of the wing as in raspberry cane midge.

The mean numbers of male and female blackberry leaf midges per water trap in Meadow and Chivers Fields are shown in Figures 1 and 2 respectively. The first adults (two males) were caught in a water trap in Meadow Field in a trap collected on 8 April. Males and females (means of 0.5 per trap) were caught in traps collected on 15 April in both Meadow and Chivers Fields. Numbers of midge adults remained low (below two per trap) until June and July, when numbers of adults peaked on 22 July in Meadow Field (mean 24 adults per trap, 4 females and 20 males) and on 8 July in Chivers Field (mean 132 per trap, 3 females and 129 males), see Figures 2 and 3. The trend for numbers of females and males trapped was similar in both fields from late June through to mid-August, when numbers of trapped adults increased and numbers of males were much higher than females. The predominance of males in the traps could have been partly due to their behaviour, e.g. males may be more attracted to the white traps than the females, or they may fly more actively and thus get caught in traps in higher numbers. Numbers of adults caught in Chivers Field were higher than in Meadow Field, particularly during June and July when peak numbers were recorded.

Following the detection of the first adult midges in water traps, on 8 and 15 April respectively in Meadow and Chivers Fields, adults were found in traps in both fields on every collection date until 2 September (Table 1 and Figures 1 and 2). The pattern of numbers of adults in water traps in each field suggested that there may have been four generations in 2009; the first in April/May and the second, third and fourth in June, July and August/September respectively (Figures 1 and 2). The generations were not discrete, but overlapped so that midge activity extended from April to September. On outdoor blackberry only two generations are reported, with adults active in May/June and July/August (Alford 1984). Thus on protected blackberry first adult emergence is earlier, there are more generations per season and the pest is active for a longer period than on outdoor blackberry.

Table 1. Mean numbers of adult male and female blackberry leaf midges per water trap in Meadow and Chivers Field tunnels.

Date	Meadow Field		Chivers Field	
	Females	Males	Females	Males
8 April	0	0.2	0	0
15 April	0.5	0.5	0.4	0.4
22 April	0.1	0.1	0.3	0.7
29 April	0.3	0.3	0.6	0.7
6 May	0.4	0.2	0.5	0.3
12 May	0.1	0.1	0.4	0.2
27 May	0.7	0.8	0.7	0.9
10 June	1.4	0.9	6.7	26.2
24 June	5.6	10.4	1.1	1.3
8 July	1.4	3.8	3	129
22 July	4	20.2	6	33.4
5 Aug	0.4	0.2	2.2	8.4
19 Aug	0.4	6.2	2.2	8
2 Sep	0.4	0	0.4	2.8
16 Sep	0	0	0	0
30 Sep	0	0	0	0
14 Oct	0	0	0	0
28 Oct	0	0	0	0

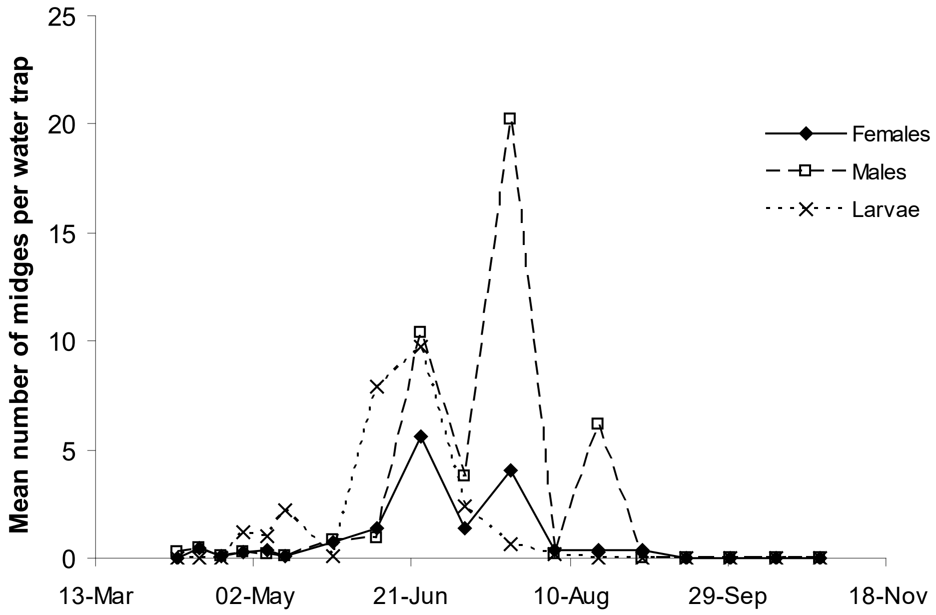

Figure 1. Meadow Field: Mean numbers of blackberry leaf midge males, females and dropped larvae per water trap.

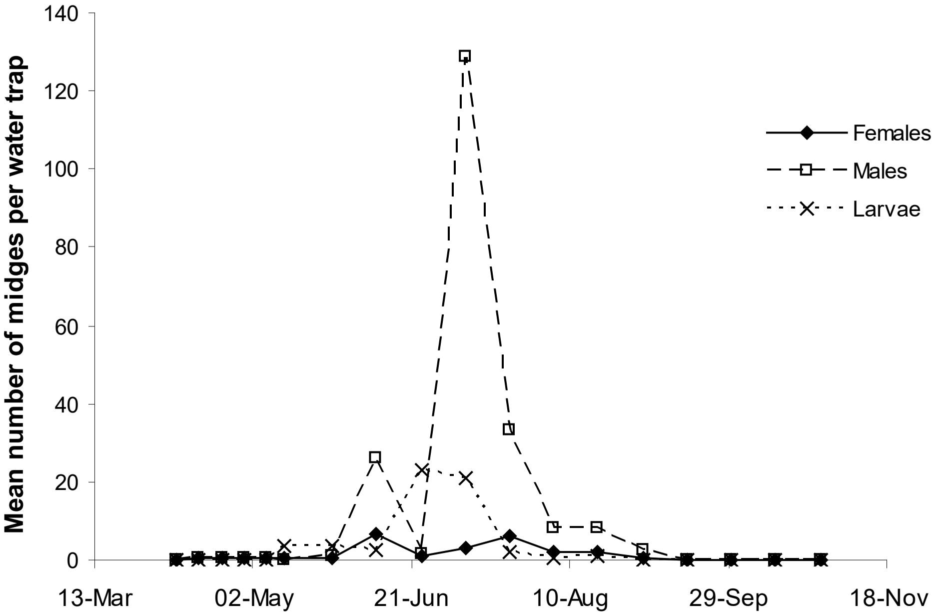

Figure 2. Chivers Field: Mean numbers of blackberry leaf midge males, females and dropped larvae per water trap.

Eggs and larvae

Blackberry leaf midge eggs and young larvae were first found on 15 April in Meadow Field, one week after the first males were detected and on the same date as the first females were detected. On this date, 30% of the leaf tips were already infested with either eggs or larvae (Figure 3). First eggs and larvae were found in Chivers Field on 22 April (5% leaf tips infested), one week after finding the first males and females. Midge larvae were found in leaf tips on every subsequent sampling occasion and the percentage of leaf tips infested increased rapidly. By 29 April, 60% and 55% leaf tips were infested in Meadow and Chivers Fields respectively (Figure 3). Percentage leaf tips infested peaked at 90% in Meadow Field on 24 June and at 100% in Chivers Field between 8 July to 19 August.

Eggs were not found on every sampling date. In Meadow Field they were found in mid-late April, late May and late June to early August (Figure 4). In Chivers Field eggs were found in late April to mid-August (Figure 5). Mean numbers of eggs and larvae per leaf tip in the same field showed similar peaks (Figures 4 and 5). These peaks corresponded with the peak numbers of adult midges in water traps, i.e. in late June and late July in Meadow Field (Figures 1, 3 and 4) and during July and early August in Chivers Field (Figures 2, 3 and 5). As with the pattern of peak adult numbers, the peak numbers of eggs and larvae per leaf tip indicated there were four overlapping generations of midges during the season and peak numbers of eggs and larvae were higher in Chivers Field than in Meadow Field. Larvae found in leaf tips during October in both fields were dead. The reason for this is unknown, as no pesticides had been applied by the grower and the larvae did not seem to have been predated (when larvae are predated, usually only a shrivelled larval skin is left behind).

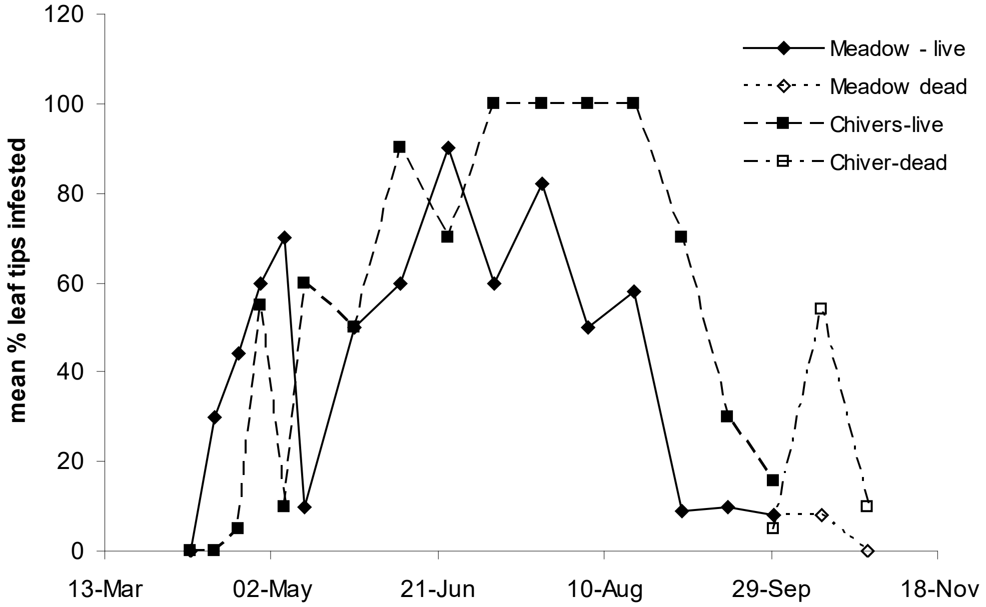

Figure 3. Percentage of leaf tips infested with eggs and/or larvae in Meadow and Chivers Fields between 8 April and 28 October.

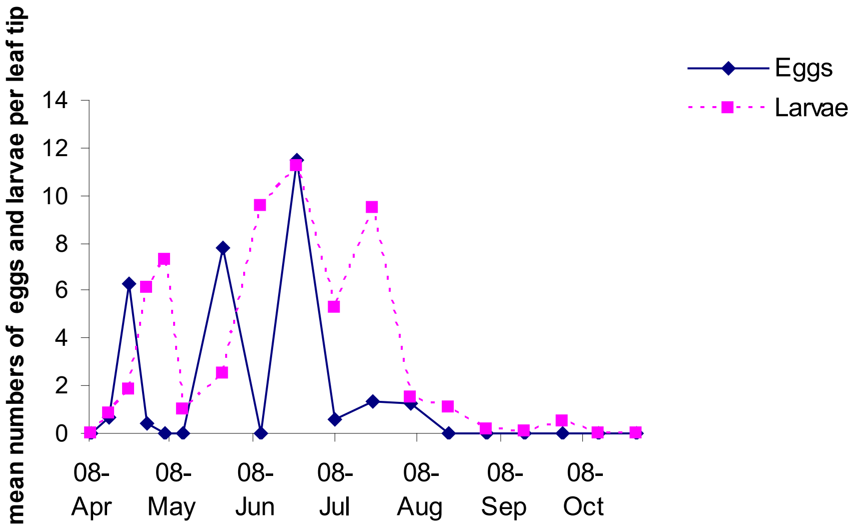

Figure 4. Mean numbers of eggs and larvae per leaf tip in Meadow Field between 8 April and 28 October.

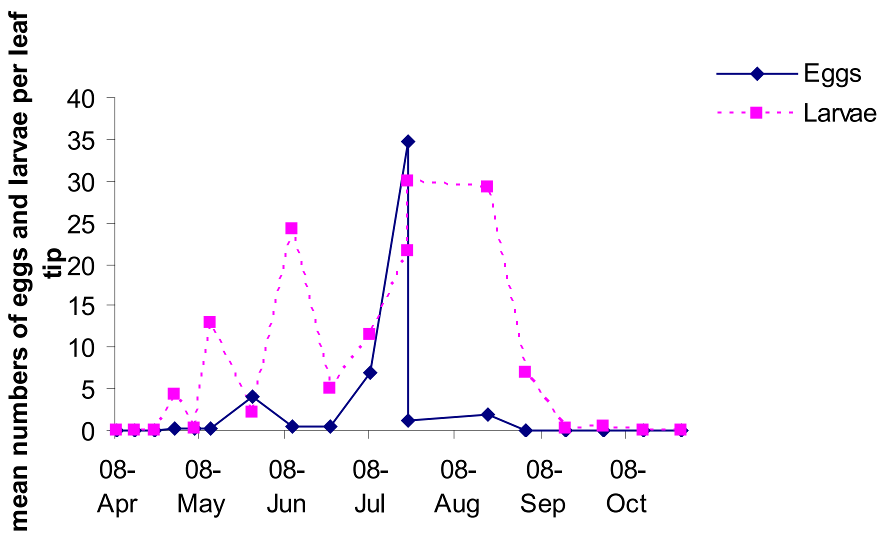

Figure 5. Mean numbers of eggs and larvae per leaf tip in Chivers Field between 8 April and 28 October.

Blackberry leaf midge eggs are small, transparent, cigar-shaped and very difficult to see as they are laid at the base of the numerous long leaf hairs or sometimes just inside the fold of the leaf. The newly hatched, transparent larvae are found in the same locations as the eggs, but they quickly move inside the folded leaves to feed. The larvae become opaque white as they grow and the final stage larvae are sometimes pale pink, a similar colour to the adult midge abdomens. Like other midge larvae, they have no legs and no obvious head and have black mouthparts at the front end of the body.

As the larvae grow they moult into the next larval stage, leaving cast skins behind in the folded leaves. Soon after the larvae start feeding, they cause the leaf mid-rib to thicken and the leaves to twist. Severely damaged leaves then turn brown and withered. When fully fed, the larvae drop to the ground to pupate in their cocoons. During the trial no pupae were ever found in the leaf tips and dropped larvae were found in the same water traps under the crop canopy that were used for adult midge monitoring (Figures 1 and 2). The first larvae in water traps were found two weeks after the first larvae were found in leaf tips in April, indicating that at this time of year the larvae fed for two weeks in the leaves before dropping to the ground to pupate. The duration of the larval stage on outdoor blackberry is reported to be approximately three weeks during May and June (Barnes, 1948; Alford 1984), thus the life cycle starts earlier and the development rate is shorter on protected blackberry.

Blackberry leaf midge larvae and cast larval skins were confirmed in samples of twisted leaf tips from the raspberry varieties Georgia and Polka on 9 June. The twisted leaf tips taken from the variety Glen Ample had symptoms of midge damage but no larvae were present due to them having already dropped to the ground to pupate. The level of infestation in the protected raspberry crops sampled was much lower than in the protected blackberry crops at this site. This may have been due to the use of chlorpyrifos against other pests such as raspberry cane midge having given some control of blackberry leaf midge populations.

Prediction of first blackberry leaf midge eggs from soil temperatures

Modelling of the soil temperature data in tunnels in both Meadow and Chivers Fields indicated that first generation blackberry leaf midge eggs would be laid at an accumulative soil temperature of around 280°C days above a base temperature of 4°C. This predicted first eggs on 20-21 April in Meadow Field and on 27-29 April in Chivers Field. These predicted dates were only five days earlier than the actual dates when first eggs were found in leaf tips, i.e. 15 and 22 April in Meadow and Chivers Fields. As the leaf tips were only sampled weekly, the first eggs could have corresponded even more closely with the predicted date. The warmer early season soil temperatures in Meadow Field, and thus the earlier predicted and actual date that first eggs were found in Meadow Field, was probably due to the tunnels in this field having been covered with polythene earlier (5-6 February) than in Chivers Field (6-12 March).

The data suggested that blackberry leaf midges emerge and lay eggs slightly earlier than raspberry cane midge, which are predicted to lay first eggs when accumulated soil temperatures reach 339°C days above a base temperature of 4°C (Gordon *et al*, 1989). The data predicting first blackberry leaf midge eggs gave very promising results during the first year of the project. Soil temperatures will be monitored again in both fields during year 2 to test the prediction of first eggs for a second season.

Conclusions from work in Objective 1

- The biology and life stage events of blackberry leaf midge were confirmed in two protected blackberry crops during 2009, one grown in pots (Meadow Field), the other grown in the soil (Chivers Field).
- The pest overwintered in 2008/2009 as cocoons in the soil. Most were found in soil to a depth of 3 cm in the path in between the plant rows, at the edge of the ground-cover matting running under the crop canopy. They were also found in the soil in the planting hole, under the polythene covering the ground between plants and in plant debris on the polythene.
- Monitoring with water traps detected the first male midge on 8 April in Meadow Field and the first females on 15 April in both Meadow and Chivers Fields. Monitoring with

sticky traps was abandoned in favour of using water traps due to difficulties in identifying the fragile midge adults on sticky traps.

- Sampling of leaf tips detected first midge eggs and larvae on 15 and 22 April in Meadow and Chivers Fields respectively.
- Soil temperature data between March and June was modelled to predict first generation blackberry leaf midge emergence and first egg-laying dates in a similar manner to the ADAS raspberry cane midge model. First eggs were predicted on 20-21 April in Meadow Field and on 27-29 April in Chivers Field. These results were very promising as the predicted dates were only five days earlier than the actual dates when first eggs were found in leaf tips, i.e. 15 and 22 April in the two respective fields. As the leaf tips were only sampled weekly, the first eggs could have corresponded even more closely with the predicted date. The data suggested that blackberry leaf midges emerge and lay eggs slightly earlier than raspberry cane midge, at an accumulative soil temperature of around 280°C days above a base temperature of 4°C.
- Numbers of midge adults remained low (below two per trap) until June and July. Mean numbers per trap peaked on 22 July in Meadow Field (24 per trap) and on 8 July in Chivers Field (132 per trap).
- From late June to mid-August during peak adult activity, numbers of males trapped were much higher than those of females in both fields. This could possibly be due to differences in the behaviour of males and females rather than an uneven sex ratio in the population.
- Following first adult emergence and egg laying, the percentage of leaf tips infested with eggs and larvae increased rapidly in both fields, from 30% and 5% in Meadow and Chivers Fields respectively in mid-April, to 60% and 55% in late April and to 90% and 100% respectively in late June/early July. Larval feeding activity continued until late September.
- Midge larvae fed for approximately two weeks in the leaf tips, causing them to twist. Severely damaged leaves turned brown and withered.
- When fully fed, the larvae dropped to the ground to pupate in cocoons. No pupae were ever found in the leaf tips, and dropped larvae were found in the water traps under the crop canopy that were use for monitoring adult activity.
- Monitoring of three protected raspberry crops in June confirmed that blackberry leaf midge larvae damaged raspberry leaves but the percentage of infested leaf tips was much lower than that in the protected blackberry crops at this site.
- The pattern of adult numbers in traps and that of eggs and larvae in leaf tips suggested that there were four overlapping generations in protected blackberry, between April and September, unlike on outdoor blackberry when only two generations are reported,

in May/June and July/August. Thus on protected blackberry, first adult emergence is earlier, there are more generations per season and the pest is active for a longer period than on outdoor blackberry.

Objective 2: Evaluate potential integrated control methods against blackberry leaf midge, for use in IPM programmes on protected blackberry

Small-scale experiments were done in the laboratory and in polythene tunnels at both ADAS Boxworth and the commercial farm to assess the potential of the following biological control agents and pesticides against blackberry leaf midge:

- *Amblyseius cucumeris* and *A. andersoni* against midge eggs and young larvae on foliage
- *Macrocheles robustulus* against midge larvae dropping to the ground
- *Beauveria bassiana* (Naturalis-L) against midge larvae on foliage and dropping to the ground
- Abamectin (Dynamec) and thiacloprid (Agrovista Reggae) compared with chlorpyrifos (Alpha chlorpyrifos) against midges on foliage

Amblyseius cucumeris and A. andersoni

Small-scale experiments were done in the laboratory and in polythene tunnels to assess the potential of the predatory mites *A. cucumeris* and *A. andersoni* against blackberry leaf midge eggs and young larvae.

Materials and Methods

Laboratory experiments

Initial attempts to determine whether the two predatory mite species predated on blackberry leaf midge eggs were inconclusive. This was due to the need to assess numbers of eggs in blackberry leaf tips before and after treatment with the predatory mites. This assessment required separating the folded leaf tips with fine forceps under a binocular microscope, in order to see the eggs at the base of the leaf hairs. This procedure could have damaged some of the delicate eggs and the data was inconclusive.

A pilot experiment was set up on 10 June 2009 to determine whether either or both species predate on young blackberry leaf midge larvae. Blackberry leaf tips infested with larvae were collected from the commercial crop monitored for work in Objective 1. Leaf tips with similar numbers of young, newly hatched larvae were selected by examining them under a binocular microscope. Individual leaf tips with known numbers of larvae were put into separate screw-top specimen tubes. Four replicate tubes were set up for each of the following treatments:

1. Untreated control
2. *A. cucumeris*
3. *A. andersoni*

Twenty predatory mites were added to each of the tubes used for treatments 2 and 3 using a 'pooter'. The tubes were left in the laboratory in natural daylength for 48 hours, then each leaf and tube was examined under a binocular microscope and the numbers of live and dead midge larvae were recorded.

Polythene tunnel experiments

A. cucumeris and *A. andersoni* were released on two dates to a row of blackberry plants, cultivar Loch Ness, grown in pots in two separate, identical polythene tunnels at ADAS Boxworth. The mites were released at the rate of one sachet per plant on 11 March 2009 and four sachets per plant on 22 April. Ten flower buds per tunnel were sampled on 22 May and placed into tubes with 70% alcohol. The buds were gently pulled apart under a binocular microscope and any predatory mites mounted on glass slides in Heinz medium. After the prepared mites had been allowed to clear for two days, they were examined under a high power microscope and any *A. cucumeris* or *A. andersoni* recorded.

Results and Discussion

Laboratory experiments

The mean numbers of live midge larvae remaining per tube at the end of the experiment are shown in Table 2.

Table 2. Mean numbers of live midge larvae per tube, 48 hours after adding predatory mites

Treatment	Mean no. live larvae per tube at set-up	Mean no. live larvae per tube 48 hrs after set-up	% live larvae remaining 48 hrs after set-up
Untreated control	5.5	4	73%
A. cucumeris	5.3	2.5	47%
A. andersoni	5.3	1.3	25%

These preliminary results indicated that both predatory mites had predated some young midge larvae. This was supported further by dead larvae (a mean of 0.5 per tube) being recorded in the tubes with *A. cucumeris* and unhealthy, punctured larvae (a mean of 0.8 per tube) in those treated with *A. andersoni*. However, the leaf tips had wilted or dried up in some of the tubes in all three treatments and this could have led to mortality of some midge larvae, due to lack of food. Therefore the results were not subjected to statistical analysis. There was insufficient time to repeat the experiment using a method to keep the leaf tips in good condition, due to the excessive time required to complete the monitoring of the pest life cycle in Objective 1. Further work on the predatory mites is justified in year 2 as various *Amblyseuis* species, including *A. cucumeris,* are known to feed on the eggs of the predatory midge, *Aphidoletes aphidimyza*, which is used for biological control of aphids (personal communication, van der Linden, the Netherlands).

Polythene tunnel experiments

In the tunnel where *A. cucumeris* was released, three predatory mites were found in the ten flower buds sampled on 22 May. Two of these were confirmed as *A. cucumeris* and the third specimen could not be confirmed to species. This result indicated some establishment of *A. cucumeris* in blackberry flowers. No predatory mites were found in the bud samples taken from the plants treated with *A. andersoni*. *A. andersoni* can be difficult to find on host crops (N. Helyer and R. Greatrex, personal communication). Releases of *Amblyseius andersoni* (used for control of mites) are thought to have led to a reduction in blackberry leaf midge in a crop of protected blackberry (N. Helyer, personal communication). However, the grower at the commercial farm hosting experiments in this project released *A. andersoni* to the blackberry plants in tunnels in Meadow Field on two occasions and there was no apparent reduction in the pest, when compared with the untreated tunnel where the pest's biology was monitored in Objective 1. Further work on establishment of the predatory mites and potential control will be done at ADAS Boxworth in year 2.

Macrocheles robustulus

Materials and Methods

A laboratory experiment was set up on 17 June to assess the potential of the predatory mite *Macrocheles robustulus* against the midge soil-dwelling life stages, i.e. larvae that drop to the ground to spin their pupal cocoons. Large, fully grown midge larvae were removed from blackberry leaf tips sampled from the commercial crop used in Objective 1. Four larvae per pot were added to 14 replicate 2cm deep Petri dishes with tight fitting lids, to which damp compost had been added to a depth of one cm. The lids of the dishes were fitted with ventilation holes screened with insect-proof mesh. Two adult *M. robustulus* per dish were added to seven of the dishes and the remaining seven were used as untreated controls. The dishes were left in a controlled temperature room at 21°C and with a photoperiod of 16 hours light, eight hours dark. The dishes were examined every 2-3 days and any adult midges that had developed were recorded and removed from each pot. The compost was dampened with a hand mister on each assessment date. The experiment was continued for four weeks until 14 July. The mean numbers of adult midges emerging per dish were statistically analysed using a t-test.

Results and Discussion

The mean numbers of adult midges emerging per dish over the 4-week period are shown in Table 3.

Table 3. Mean numbers of adult blackberry leaf midges emerging per dish treated with *Macrocheles robustulus* and per untreated dish

Treatment	Mean no. adult midges per dish	Mean % midge survival to adult stage
Untreated control	2.57	64%
Macrocheles robustulus	1.29	32%

M. robustulus reduced the numbers of midge larvae surviving to the adult stage when compared with the untreated control, but this result was not quite statistically significant (P=0.053). It is likely that if higher numbers of *M. robustulus* had been added per dish, the predators would have given significant reduction of the pest. Very few *M. robustulus* were present in the experimental sample received for the experiment. Further work is planned with the predator in year 2, when its potential against the ground-dwelling life stages of the pest will be compared with that of the similar predatory mite, *Hypoaspis* species. *M. robustulus* is not yet commercially available but is of interest to commercial biological control suppliers for the control of various pests, as it has given better control of the ground-dwelling life stages of western flower thrips than *Hypoaspis aculeifer* (Messelink & van Holstein-Saj, 2008).

***Atheta coriaria* and *Beauveria bassiana* (Naturalis-L)**

Materials and Methods

A laboratory test was set up on 27 July to test the potential of the predatory beetle *Atheta coriaria* and the entomopathogenic fungus *Beauveria bassiana* (Naturalis-L) against the ground-dwelling stages of blackberry leaf midge. Fully grown midge larvae were collected from blackberry leaf tips used for monitoring the biology of the pest in Objective 1. Nine larvae per pot were added to damp M2 compost in 20 replicate 9 cm plant pots. The following treatments were made to five replicate pots per treatment:

1. Untreated control
2. Naturalis-L at the recommended rate for a foliar spray (3 litres per ha in 1000 litres water per ha)
3. *Atheta coriaria* at 10 adults per pot
4. *Atheta coriaria* at 5 adults per pot

The Naturalis-L was left in water for two hours to allow the spores to rehydrate before application, as recommended by the supplier. The *A. coriaria* were taken from the ADAS culture of the predators. Each pot was placed into a larger white plastic pot, covered by a piece of insect-proof mesh secured by a rubber band. Prior to covering the pots treated with treatments 1 and 2, two small portions of yellow sticky trap were secured to the inside of the white outer pots using a paper clip. The pots were left in a controlled temperature room at 21°C and a photoperiod of 16 hours light, eight hours dark. Sticky traps were added to pots treated with treatments 4 and 5 on 31 July (four days after set-up) when the first midge adults were seen on the sticky traps in the untreated control pots (this was done later than in treatments 1 and 2, to avoid catching the *A. coriaria* on the traps). The pots were checked regularly for adult midges on the traps and for compost moisture. Water was added to the compost when necessary to keep it damp, using a hand-held mister. The experiment was completed on 17 September, seven weeks after set-up. Numbers of adult midges on the sticky traps were recorded. The data was subjected to statistical analysis using Analysis of Variance.

Results and Discussion

The mean numbers of adult midges per pot are shown in Table 4.

Table 4. Mean numbers of adult blackberry leaf midges emerging per pot treated with *Atheta coriaria*, *Naturalis-L* and per untreated pot

Treatment	Mean no. adult midges per pot	Mean % midge survival to adult stage
Untreated control	3.8	42%
Naturalis-L	3.6	40%
Atheta coriaria at 10 per pot	2.4	27%
Atheta coriaria at 5 per pot	2.8	31%

None of the treatments significantly reduced numbers of midge larvae surviving to the adult stage. Only 42% of the larvae reached the adult stage in the untreated pots, which was a lower survival rate than in the experiment with *Macrocheles robustulus*, when 64% survived in the untreated controls (Table 3). This made it more difficult to achieve significant reductions by the treatments. Dutch research with *A. coriaria* against blackberry leaf midge ground-dwelling life stages had shown that when five adult beetles were used with 10 or 30 midge larvae in Petri dishes, 100% of the midge larvae survived after 24 hours but only 5% survived with the *A. coriaria*. However, when five *A. coriaria* were added to pots of soil with 25 midge larvae, 30% of the larvae survived to the adult stage, compared with 60% in untreated controls (Wenneker & Helsen 2008). This result is similar to that in this project, where 31% midge larvae survived to the adult stage when five *A. coriaria* per pot were used (Table 4). However, in our experiment, the ratio of *A. coriaria* to midge larvae was 1:2 whereas in the Dutch research it was 1:5. Our results indicate that as with the *Macrocheles*, numbers of *Atheta* may need to be equal or higher than numbers of midge larvae dropping to the soil to give significant reduction of the ground-dwelling stage of the pest. The lower predation rate in soil than in Petri dishes is likely to be due to the midge larvae being protected from predators when encased in the cocoons which they spin shortly after dropping to the ground.

Grower applications of Naturalis-L and chemical pesticides

Materials and Methods

The grower applied three pesticides and one biopesticide as foliar sprays to different individual rows of blackberry in Meadow Field, on different dates. All treatments except for chlorpryrifos were applied to protected blackberry. The treatments were as follows:

- Thiacloprid (Agrovista Reggae) on 17 April at the rate recommended for protected blackberry or protected raspberry in SOLA 0467/2008 (250 ml per ha).

- Chlorpyrifos (Alpha Chlorpyrifos) on 24 April at the label recommended rate (1.5 litres per ha, applied to a row of outdoor blackberry (chlorpyrofos is not approved on protected blackberry).
- Abamectin (Dynamec) on 1 May at the rate recommended for protected blackberry or protected raspberry in SOLA 2290/2007 (50 ml per 100 litres water).
- *Beauveria bassiana* (Naturalis-L) at the label recommended rate (3 litres per ha).

The grower also applied Dynamec on 1 May with a silicon-based wetter (Paramount) to one row of protected blackberry in Chivers Field.

ADAS sampled 10 or 20 leaf tips 4-8 days after each treatment and on the same date, sampled equal numbers of leaf tips in a nearby untreated row of plants. Mean percentage of infested leaf tips and mean numbers of live midge larvae per leaf tip were recorded. The data was subjected to statistical analysis using Analysis of Variance.

Results and Discussion

The results of the different treatments cannot be directly compared as they were applied on different dates and although replicate leaf tips were sampled in both treated and untreated rows of plants, the treated areas were not fully replicated. However, the results of the treatments compared with untreated plants on individual dates gave an indication of efficacy against the pest.

The only treatment that led to significant reductions in the pest in Meadow Field was Alpha Chlorpyrifos. Four days after treatment, mean numbers of live larvae were 0.8 and 6.1 per leaf tip in treated and untreated tips respectively, i.e. 87% reduction, $P<0.05$ (Figure 6). Percentage leaf tips infested were 5% in the treated row and 60% in the untreated row, equivalent to a 92% reduction $P<0.05$ (Figure 7). By extrapolation, this pesticide should give some control of the pest on raspberry and various chlorpyrifos products are approved for use on both outdoor and protected raspberry. However, chlorpyrifos is not approved for use on protected blackberry, nor is not compatible with biological control agents used in IPM programmes.

Dynamec has translaminar action and Agrovista Reggae is systemic, but neither pesticide gave significant reduction in the pest. Although mean numbers of larvae per leaf tip were lower five days after treatment with Dynamec than in untreated leaves (Figure 6), the reduction was not significant due to the wide variation between numbers of larvae per tip. The result of the addition of the silicon-based wetter Paramount to Dynamec in Chivers Field was inconclusive as numbers of leaf midge larvae and percentage of infested leaf tips in both treated and untreated plants were very low (mean 0.2 larvae per tip and 10% tips infested in untreated plants).

Naturalis-L is contact in action and thus blackberry leaf midge is a difficult target for this biopesticide. The results of one foliar application indicated that this biopesticide is not effective against the pest (Figures 6 and 7) and this result is supported by the lack of control of larvae in the substrate in the laboratory test (Table 4).

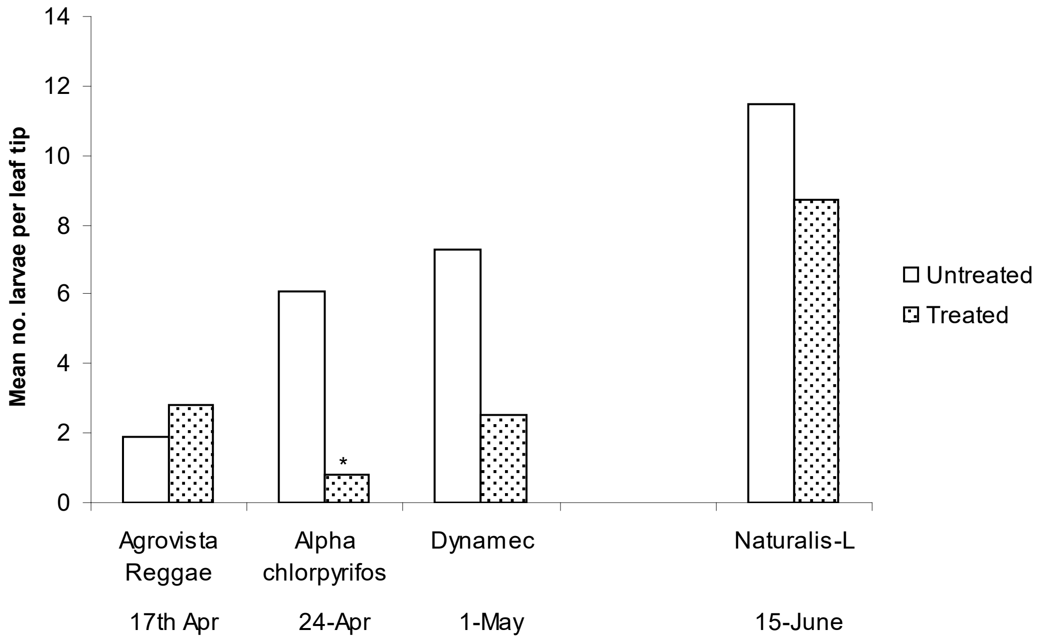

Figure 6. Mean numbers of live midge larvae per leaf tip in untreated and treated plants, 5, 4, 5 and 8 days after application of Agrovista Reggae, Alpha chlorpyrifos, Dynamec and Naturalis L respectively.

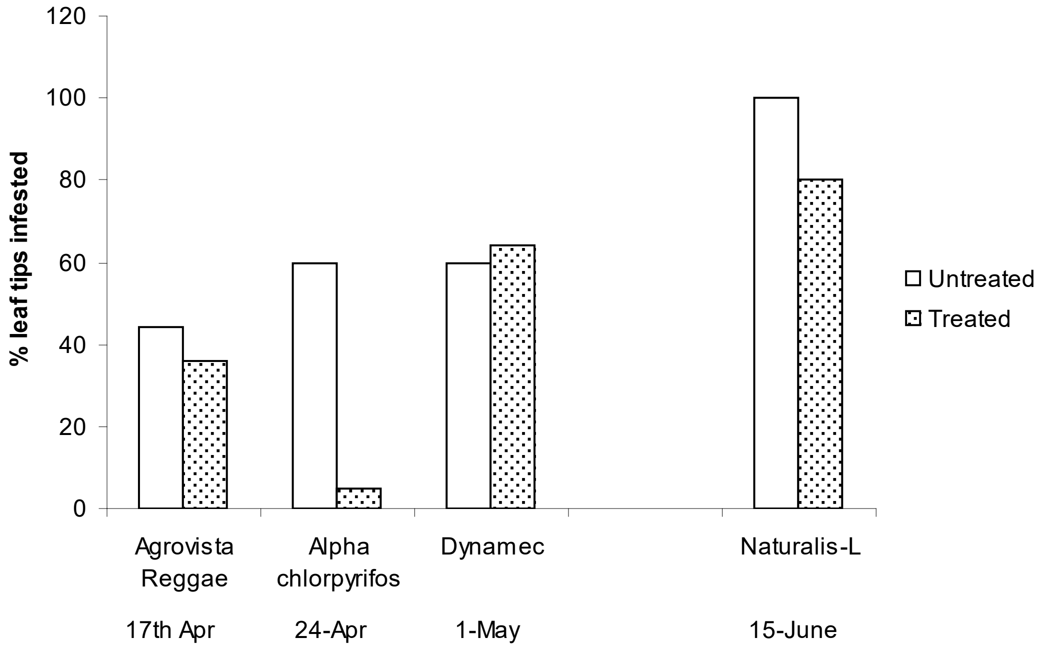

Figure 6. Percentage leaf tips infested with live midge larvae in untreated and treated plants, 5, 4, 5 and 8 days after application of Agrovista Reggae, Alpha chlorpyrifos, Dynamec and Naturalis L respectively.

Naturally-occurring anthocorid bugs

When making leaf tip and water trap assessments during the work in Objectives 1 and 2, naturally-occurring anthocorid bugs (both *Anthocoris nemorum* and *Orius* sp.) were observed. *A. nemorum* were found in water traps in Chivers Field on 15 April (mean 0.1 per trap) and in Meadow Field on 5 August (mean 1.2 per trap) and 19 August (mean 0.4 per trap). Both *A. nemorum* and *Orius* sp. (likely to be *O. laevigatus*) were found in leaf tips infested with blackberry leaf midge larvae in Chivers Field on 27 July, 5 and 19 August (means of 0.2, 0.2 and 0.5 per leaf tip on respective dates). Both adults and nymphs were recorded, which showed that the predatory bugs were breeding on the blackberry crop. Both bug species are good thrips predators and thrips were also found in the water traps on both dates and in the leaf tips on 19 August. However, the bugs will also eat other soft-bodied prey and both species were observed feeding on the blackberry leaf midge larvae. *Orius laevigatus* are commercially available and work on its potential against the pest when released early in the season will be included in year 2.

Conclusions from work in Objective 2

- Preliminary laboratory experiments indicated that both the predatory mites *Amblyseius cucumeris* and *Amblyseius andersoni* predated young blackberry leaf midge larvae. However, it was not possible to produce sufficient data for statistical analysis due to difficulties with methodology. Further work will be done in year 2.
- Releases of both *A. cucumeris* and *A. andersoni* to blackberry plants in research tunnels at ADAS Boxworth led to some establishment of *A. cucumeris* but no apparent establishment of *A. andersoni*. The latter species is difficult to find on host plants. However, following grower releases of *A. andersoni* to commercial protected blackberry plants, there was no apparent reduction in the pest when compared with untreated plants. Further work on establishment of predatory mites and potential control will be done at ADAS Boxworth in year 2.
- In laboratory pot experiments, neither the predatory mites *Macrocheles robustulus* nor the predatory beetles *Atheta coriaria* gave significant reductions in numbers of blackberry leaf midge larvae successfully completing their development in compost and emerging as adult midges. Results indicated that numbers of both predators may need to be equal to or higher than numbers of the target midge larvae in the soil to give significant control of the ground-dwelling stage of the pest. Work in year 2 will include comparing the potential of *M. robustulus* with that of the predatory mite *Hypoaspis* sp. against the ground-dwelling stages of the pest.
- Grower applications of Naturalis-L to the commercial crop did not reduce the percentage of leaf tips infested or mean numbers of live larvae per leaf tip. *Beauveria bassiana* is a contact-acting fungus and is unlikely to reach the target pest inside folded leaf tips. In a laboratory test application of Naturalis-L to compost did not reduce numbers of blackberry leaf midge larvae in the ground successfully completing their development and emerging as adult midges.
- Grower applications of thiacloprid (Agrovista Reggae, SOLA 0467/2008) and abamectin (Dynamec, SOLA 2290/2007) did not give significant reductions in numbers of live midge larvae per leaf tip or in percentage of infested leaf tips.
- Grower application of chlorpyrifos (Alpha chlorpyrifos, label recommendation for outdoor blackberry) to outdoor blackberry reduced numbers of live midge larvae per leaf tip by 87% and reduced the percentage of infested leaf tips by 92% when compared with those in untreated plants. By extrapolation, chlorpyrifos should give some control of the pest on raspberry and various chlorpyrifos products are approved for use on both outdoor and protected raspberry. However, chlorpyrifos is not approved for use on protected blackberry and is not compatible with biological control agents used in an IPM programme.

- Further work on the potential of IPM-compatible pesticides against blackberry leaf midge will be done in year 2, in consultation with HDC.
- Naturally-occurring anthocorid bugs (both *Anthocoris nemorum* and *Orius* sp.) were observed feeding on blackberry leaf midge larvae in the commercial crop during July and August. Both adults and nymphs were recorded, which showed that the predatory bugs were breeding on the blackberry crop. *Orius laevigatus* are commercially available and work on its potential against the pest when released early in the season will be included in year 2.

Technology Transfer

- Project objectives presented to ADAS soft fruit growers' discussion group, Millets Farm Centre, Oxon, 23 March 2009
- Project objectives and images of pest provided to KG growers for their in-house training day, November 2009
- Update on project results to ADAS fruit consultants, EMR, 27 January 2010
- HDC News article March 2010

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