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The results and conclusions in this report are based on an investigation conducted over one year. The conditions under which the experiment was carried out and the results obtained 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.

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GROWER SUMMARY

TF 145 Evaluation of insecticides for control of selected apple and pear pests

Headline

Three replicated orchard experiments in 2003 screened insecticides for control of pear midge, woolly aphid and *Blastobasis decolorella*. No meaningful results were obtained for pear midge. A post blossom spray of Dursban or Aphox controlled woolly aphid without significantly affecting key natural enemies. Calypso and Aztec were ineffective. Dursban, Runner and Tracer (contains spinosad, <u>not</u> approved for use on pome fruit in the UK) gave good control of *Blastobasis* when applied in early June.

Background and deliverables

Effective pesticide products need to be identified for control of several pome fruit pests, including pear midge, woolly aphid and caterpillars of the moth *Blastobasis decolorella*. Since the withdrawal of HCH and carbaryl, no effective treatment has been identified for pear midge which is a localised pest in some pear orchards, notably of the variety Comice. Woolly aphid was a serious problem in 2002 and many growers struggled to control it. Comparisons of the efficacy of existing approved products are needed, including the benefits of pre- versus post-blossom treatment and possible harmful effects on the key natural enemies of woolly aphid, earwigs and the parasitoid *Aphelinus mali*. *Blastobasis* is a localised but very damaging pest of apple, particularly Bramley and Egremont russet and other short-stalked varieties. Growers have relied on routine sprays of chlorpyrifos (Dursban etc) to control this pest. The efficacy of the newer Insect Growth Regulators Insegar and Runner needed to be investigated as well as optimum timing for spraying.

The expected deliverables from this project are:

- Identification of appropriate pesticide treatments for control of pear midge, woolly aphid and *Blastobasis*

Approval may be needed for some of the products identified.

Summary of the project and main conclusions

In 2003, three replicated orchard experiments were conducted in commercial orchards in Kent to evaluate insecticides for control of pear midge, woolly aphid and the moth *Blastobasis decolorella*. The aim was to identify effective insecticide treatments for each of the pests.

Pear midge

Two foliar sprays (500 l/ha) of Talstar, Dursban 4, Tracer (contains spinosad), Calypso, Derris, Toppel, XL All 95% nicotine and Hallmark were applied to Comice at the green and white bud growth stages on 27 March and 11 April 2003, respectively.

Only a very light infestation of pear midge developed in the trial, insufficient to test the efficacy of the treatments and draw sound conclusions**.** Derris, Toppel and Nicotine had similar or greater total numbers of infested fruitlets compared to the untreated control**.** The smallest total number of infested fruitlets was found on the plots treated with Calypso. The trial needs to be repeated

Woolly aphid

Single foliar sprays (200 l/ha) of Dursban 4, Orosorb oil, Aphox, Calypso or Aztec, were applied either preventively pre-blossom on 15 April 2003 or curatively post blossom on 18 June 2003 when woolly aphid populations were increasing rapidly.

The pre-blossom sprays did not control woolly aphid infestations, probably because the bulk of the population was present in burr knots on the rootstocks above ground level at this time where the colonies were inaccessible. Post blossom applications of Dursban 4 or of Aphox significantly reduced infestations of woolly aphid by over 50% compared to the untreated control. Aztec, Calypso or Orosorb oil were ineffective.

None of the treatments adversely affected parasitism by *Aphelinus mali*. Levels of parasitism increased markedly on all plots. Pre-blossom application of Orosorb oil significantly reduced numbers of earwigs in artificial refuges but none of the other treatments significantly affected earwig numbers. Laboratory work to investigate possible harmful affects of pesticides to *A. mali* and earwigs is recommended.

Blastobasis

Single foliar sprays (300 l/ha) of Dipel, Dursban 4, Insegar, Runner and Tracer (contains spinosad) were applied to Bramley at two timings of application 1) on 19 June at the beginning of the egg hatch period 2) on 4 August when the caterpillars were semi-developed and fruit injury was starting to occur.

Dursban, Runner and Tracer gave good control of *Blastobasis* when applied in early June, about the time of the start of egg hatch of Blastobasis caterpillars. Sprays applied in early August were considerably less effective in preventing fruit damage,

though they did give partial control. Dipel and Insegar had some activity, but were less effective than the other products.

Financial benefits

Use of ineffective treatments for control of any of these pests could result in substantial losses in yield and quality. In the extreme, the entire crop from a particular orchard might be lost, though typical losses are usually less than 10%. A 10% loss from a 20 tonne/ha Cox crop worth £400/tonne to the grower would cost the grower £800/ha.

Action points for growers

- This work identifies chlorpyrifos (Dursban etc) and Aphox as the most effective treatments for control of woolly aphid. Further work to confirm these findings is needed.
- This work identifies Runner as an approved and effective product for control of *Blastobasis*. Sprays should be applied during egg hatch and the early stages of caterpillar development and not be left until caterpillars are semi-mature in August. Further work to confirm these findings is needed.

Note

Some of the pesticides used in this trial are not legally approved for use on pome fruit in the UK. Always check the approval status of pesticides before considering their use.

SCIENCE SECTION

I Evaluation of insecticides for control of pear midge 2003

Summary

A single replicated small plot orchard experiment in a pear orchard (cv Comice) at Wanshurst Farm, Marden, Kent evaluated Talstar, Dursban 4, Tracer (contains spinosad), Calypso, Derris, Toppel, XL All 95% nicotine and Hallmark for control of pear midge. Two foliar sprays (500 l/ha) of each product were applied at the green and white bud growth stages on 27 March and 11 April 2003, respectively. The number of pear fruitlets infested with pear midge larvae was counted on 21 May 2003.

Only a very light infestation of pear midge developed in the trial, insufficient to test the efficacy of the treatments and draw sound conclusions**.** Derris, Toppel and Nicotine had similar or greater total numbers of infested fruitlets to the control**.** The smallest total number of infested fruitlets was found on the plots treated with Calypso.

Introduction

Pear midge (*Contarinia pyrivora* (Riley)) is a widespread though usually only a minor pest of pear in the UK. Biology, pest status and control are reported by Antonin (1984), Anon. (1983) and Frankenhuyzen (1985). There has been surprisingly little research into this pest reported in the literature in recent years.

Pear is the only host of the pear midge. There are considerable differences in varietal susceptibility though all varieties may be attacked. Of the varieties grown commonly in the UK, Williams Bon Chretien is the most susceptible, followed by Doyenne du Comice. Conference and Concorde are much less susceptible and are rarely attacked severely.

Pear midge is a widespread pest of pears but is virtually absent from many commercial orchards. Where it does occur, it occurs year after year, usually in orchards of more susceptible varieties. It is a common pest on garden trees, especially those of susceptible varieties.

Pear midge attacks are usually recognised by the characteristic damage caused to young developing fruitlets which are infested with pear midge larvae (see below). When the infested fruitlets are cut open they are found to contain several to many whitish midge larvae up to 4-5 mm long with a conspicuous brownish spatula. Like most midge larvae, pear midge larvae are somewhat flattened dorso-ventrally and have a spatula mark on their abdomen. Larvae are able to jump by flexing and suddenly straightening their body. Adult female pear midges can be seen ovipositing into pear flower buds on warm, still days at the green to white bud growth stage. The female characteristically arches her abdomen to insert her long ovipositor. Adults are 2.5-4.0 mm long with a greyish black body with a pair of pale longitudinal stripes on the thorax, wings dusky. Eggs are very small, cigar shaped, whitish and semitransparent and are usually placed in groups on the anther.

Pear midge causes damage by larvae infesting fruitlets which fail to develop into fruits. During early fruitlet development until about 2 weeks after petal fall, infested fruitlets grow more rapidly than healthy ones and become noticeably rounded or malformed. However, they cease development when about 15-20 mm diameter and develop large black patches on their surface. If attacks are light, the loss of a small proportion of young fruitlets is often of little consequence. Unfortunately, attacks are occasionally more severe, especially on susceptible varieties in unsprayed or organic orchards. A large proportion of the fruitlets may be lost, substantially reducing yield.

Pear midge has one generation per annum. Adults emerge in late March to early May, usually at the green to white bud stage of mid-season pear varieties. After mating, females insert eggs into the flower buds or sometimes in open flowers. Eggs are placed in groups of 10-30 on the anthers. Eggs hatch in about 6 days and the larvae feed within the flesh of the developing fruitlet forming a black cavity. Larvae are fully fed in about 6 weeks. They then force their way out of the fruitlet (which may have dropped to the ground) and enter the soil to spin silken cocoons at a depth of 5-8 cm. Here they overwinter, eventually pupating in the spring.

Pear midge spends most of its life inside pear fruitlets or in the soil where it is largely protected from non-specialised natural enemies.

No formal assessment methods or economic thresholds have been determined for pear midge. The easiest way to monitor pear midge is to assess the severity of fruitlet damage 3-4 weeks after petal fall. If the pest is present one year, a damaging attack can be expected the next. It is also possible to monitor oviposition activity by adult females at the green to white bud stage. However, this method is difficult and unreliable as it is easy to miss the correct time period of oviposition in conducive weather conditions.

Temperature based forecasting models have not been developed for pear midge though it is probable that such a model could be developed to predict timing of emergence of adults in spring. Spring emergence appears to be well synchronised with the green to white bud stage of susceptible varieties such as Williams and Comice.

Careful removal and destruction of infested fruitlets before they fall to the ground and larvae start to exit to pupate in the soil should theoretically break the life cycle. However, such removal on a commercial scale is labour intensive and unlikely to be economic. Furthermore, it may be necessary to remove all the infested fruitlets for at least two successive seasons as it is possible that a proportion of larvae in cocoons persist for more than one season in the soil before emerging. Cultivation of the soil under the tree to destroy larvae and pupae is impractical because the depth at which they occur is too great.

Insecticide sprays to control pear midge are targeted against adults at the green to white bud stage. Eggs and larvae inside the flowers and developing fruitlets are inaccessible to chemical sprays. No pesticide product available in the UK is recommended by the manufacturer for control of pear midge.

Objective of this work

Here we report the results of a single replicated orchard experiment done in 2003 to evaluate the efficacy of 8 insecticide products for preventive control of pear midge.

Methods and materials

A single replicated orchard experiment comparing the efficacy of two sprays of 8 different pesticide products was conducted at a single site in 2003 as follows:

Site

The experiment was conducted in the central part of a commercial pear orchard located at Wanshurst Farm, Wanshurst Green, Marden, Kent (GR TQ 761454 by kind permission of the owner, Mr Richard Carpenter). The orchard was fully established and had alternate rows of Comice and Conference trees. The variety Comice was used for the experiment, the Conference acting as guard rows between the treatment plots. The row spacing was 4.57m and the tree spacing in the row was 2.29 m. Thus, the tree density was 957 trees/ha. The trees were approximately 3m tall. Visual inspection in comparison with pictogram of relative tree area density revealed that the orchard had a CAF factor of 0.5 at this growth stage. This orchard had a history of recent pear midge infestation the attack being most severe in the central area of the orchard used for the experiment.

Treatments

Each treatment comprised two applications of each insecticide product, the first at green cluster and the second at white bud growth stage on 27 March and 11 April 2003, respectively (Table 1). The observation of active adult midge in the crop assisted with the selection of the optimum timing for each spray application.

Table 1. Treatments evaluated in the pear midge efficacy testing experiment in 2003. Two applications of each product were made on 27 March and 11 April 2003 at the green and white bud growth stages, respectively.

Treat no.	Active substance and formulation	Product	Product Dose l/ha	Concentration ml/l
1	Bifenthrin 100 g/l EC	Talstar	0.5	1.0
2	Chlorpyriphos 480 g/l EC	Dursban 4	1.0	2.0
3	Spinosad 480 g/l SC	Tracer †	0.6	1.2
4	Thiacloprid 480 g/l SC	Calypso	0.125	0.25
5	Rotenone 50 g/l EC	Derris	0.625	1.25
6	Cypermethrin 100 g/l EC	Toppel 10	0.35	0.7
7	Nicotine 950 g/l LI	XL- Nicotine 95%	0.665	1.33
8	Lambda-cyhalothrin 100 g/l CS	Hallmark	0.09	0.18
9	Untreated*	-	-	-

* The untreated control was double replicated, there being two untreated plots in each block
† Tracer is not approved for use on pome fruit in the UK

Spray Application

Sprays were applied with a Hardi Tornado Mister (MRY) motorised air-assisted knapsack sprayer at a volume rate of 500 litres water /ha. An in-line red Micron flow rate restrictor was fitted to the sprayer to provide a flow rate of 0.55 litres per minute. Measurement of the volume of spray solution remaining in the tank after spray application showed that application rates were within 7% of those required.

Experimental design and layout

A randomised complete block design with 5 replicates was used. Plots consisted of 4 adjacent trees in a row. Five rows of Comice trees were used for the experiment, one row for each block. The plots in any one block were arranged end to end and separated by 2 guard trees. Each row was separated from the next by an intervening row of trees of the variety Conference.

Meteorological records

Wet and dry bulb temperature and wind speed were measured with a whirling psychrometer and a hand held whirling cup anemometer (at 2m height above ground) before, during and after spraying. For the first spray application on 27 March 2003, the dry bulb temperature at the start of spray application at 09.30 hrs was 14.0 ˚C rising to 16.5 ˚C at 11.50 hrs and falling to 15.8 ˚C at 15.00 hrs when the spray application treatments were completed. The corresponding wet bulb temperatures were 10.0, 13.8 and 11.0 ˚C respectively. The wind was from an easterly direction and the windspeed was 1-2 kmh at the start rising to 6 kmh at the end of spray applications. For the second spray application on 11 April 2003 the dry bulb temperature at the start at 08.25 hrs of spray application was – 0.25 ˚C rising to 4.5 ˚C at 10.00 hrs, 12.2 ˚C at 11.00 hrs and 10.5 ˚C at 13.30 hrs when the spray application was completed. The corresponding wet bulb temperatures were – 0.25, 4.2, 9.5 and 7.5 ˚C respectively. The windspeed did not exceed 2 km/h.

Assessments

The numbers and proportions of fruits damaged by pear midge on each of the four trees per plot was recorded when maximum fruitlet damage was evident on 21 May 2003.

Statistical analyses

The incidence of pear midge infested fruitlets was very low and erratic. Treatment total for all 5 replicate plots of 4 trees were calculated. Statistical analysis of the data was inappropriate.

Results

Only a very light infestation of pear midge developed in 2003. Numbers of infested fruitlets recorded on 21 May 2003 were very small. Derris, Toppel and Nicotine had similar or greater numbers of infested fruitlets than the control. The smallest total number of infested fruitlets was found on the plots treated with Calypso. It is not possible to draw sound conclusions from these results.

Table 2. Total number of pear fruitlets per treatment infested by pear midge on 21 May 2003. Totals are for 5 replicate 4 tree plots

Treat no.	Product	Grand total number of infested pear fruitlets recorded
1	Talstar	5
2	Dursban 4	7
3	Tracer	5
4	Calypso	2
5	Derris	20
6	Toppel 10	10
7	XL- Nicotine 95%	12
8	Hallmark	6
9	Untreated	10
10	Untreated	16

Conclusions

- Only a very light infestation of pear midge developed in the trial, insufficient to test the efficacy of the treatments and draw sound conclusions
- Derris, Toppel and Nicotine had similar or greater numbers of infested fruitlets than the control
- The smallest total number of infested fruitlets was found on the plots treated with Calypso

II Evaluation of insecticides for control of woolly aphid 2003

Summary

A replicated experiment in a Cox orchard at Bayfield farm, Painter's Forstal, Kent in 2003 evaluated single foliar sprays (200 l/ha) of Dursban 4, Orosorb oil, Aphox, Calypso or Aztec, applied either preventively pre-blossom or curatively post blossom, for control of woolly aphid. The pre-blossom sprays did not control woolly aphid infestations, probably because the bulk of the population was present in burr knots on the rootstocks above ground level at this time where the colonies were inaccessible.
Post blossom applications of Dursban 4 or of Aphox both significantly reduced infestations of woolly aphid by over 50% compared to the untreated control. Aztec, Calypso or Orosorb oil were ineffective.

None of the treatments adversely affected parasitism by *Aphelinus mali*. Levels of parasitism increased markedly on all plots during July. Pre-blossom application of Orosorb oil significantly reduced numbers of earwigs in artificial refuges but none of the other treatments significantly affected earwig numbers.

Possible harmful affects of pesticides to *A. mali* and earwigs would better be investigated in laboratory experiments where the timing, method and duration of exposure of different life stages to pesticides could be precisely controlled and investigated.

Introduction

Woolly aphid

Woolly aphid was first observed in Britain in 1787; the source is assumed to be the USA. The aphid feeds on the wood of apple trees, particularly on the spurs and branches where the bark is cracked. This feeding often causes galling and hypertrophy of the wood (Geoffrion, 1985) which is disfiguring but is probably not serious in established trees. In America, Australasia and South Africa breeding colonies also occur on the roots. Until recently, this was not thought to occur in the UK. However, localised root infestations have now been found in the UK. Root colonies damage the roots leading to a restriction of scion growth (Brown & Scmitt, 1990) and also serve as a source of re-infestation for the aerial parts of the tree. In spring and summer, the aphid spreads from overwintering sites on the main trunk and branches onto the young growth. Woolly aphid is a serious pest of apple (Weber & Brown, 1988). Population increase can be very rapid and huge colonies can form entirely enveloping the bark. Wool, cast skins, honeydew and dead aphids contaminate the fruits which become unsaleable. Because of the waxy 'wool' secreted by the aphids, colonies are conspicuous.

Woolly aphid was very effectively controlled by systemic organophosphorus insecticides especially vamidothion (Kilval) which was outstanding and demeton-S-methyl (Metasystox). These OP insecticides are no longer available in the UK. The only remaining approved aphicides for control of woolly aphid are the carbamates pirimicarb (Aphox) and triazamate (Aztec) which are partially systemic and at best only partially effective. Although pirimicarb is considered to be fairly safe to the key natural enemies of woolly aphid. The effects of triazamate have not been determined. Chlorpyrifos, though not specifically applied for woolly aphid control, was the most widely used insecticide on apple and early season sprays probably helped keep woolly aphid populations in check. The decline in use of chlorpyrifos may be a factor in the increased incidence of woolly aphid outbreaks in recent years. The chloronicotinyl insecticide thiacloprid (Calypso) has recently been approved for use on apple in the UK and is very effective for control of rosy apple aphid. Unfortunately, it is ineffective against woolly aphid and more worryingly, there is evidence that it may be harmful to earwigs, which are important natural enemies of woolly aphid. If thiacloprid is applied early in the season before earwigs are present in the canopy, possible harmful effects are likely to be minimised. Harmful effects of thiacloprid on earwigs are another possible contributory factor in the increased incidence of woolly aphid in UK apple orchards.

Woolly aphid has two key natural enemies in UK apple orchards, the parasitoid *Aphelinus mali* and the common European earwig, *Forficula auricularia,* an important generalist predator.

Parasitoid Aphelinus mali

Details of the life history of *A. mali* are given by Bonnemaison (1965, 1974). Females lay a single egg in each host, with a preference for third instar nymphs (Mueller et al., 1992). Records of the numbers of generations of the parasitoid per annum in temperate Europe range from 5-7 versus 11-12 of its host (Bonnemaison, 1965; Evenhuis, 1958). First adults emerge during bloom. Rates of parasitism vary with environment conditions, e.g. *A. mali* is not favoured by humid conditions. Adult *A. mali* are more cold-hardy than their host but the aphid will develop at a lower temperature than the parasitoid.

The biology and ecology of the interactions between the parasitoid and its host have been studied extensively. Although *A. mali* has been released to control woolly apple aphid for a number of decades (e.g. it was introduced into America in the 1920's (Marchal, 1921) the results of studies to date on the interaction between the aphid and this parasitoid indicate that it is rarely able to control the aphid in the field. Using a multi-species simulation model, research in the Netherlands (Mols, 1996) estimated the relative densities of *A. mali* required to suppress the woolly aphid over ten years. It was concluded that the numbers of parasitoids would have to be, on average, 23 times more than those of its host at the time of adult emergence in May for control of the pest to be achieved. In addition to the slower reproductive rate of *A. mali* compared to its host, the parasitoid also emerges later than the aphid in spring and has a greater vulnerability to insecticides (Massee, 1943; Blommers, 1992). Levels of parasitism have been shown to be inversely proportional to the size of aphid colonies (Mueller et al., 1992) and hyperparasitoids may limit the performance of *A. mali* (Kölger, 1989).

In contrast, high levels of parasitism by *A. mali* have been observed and in some cases populations of the aphid have been reduced to very low levels (Blommers, 1994). When this occurs, however, it seems likely that other predators, e.g. velvet mites, ladybirds or earwigs, also impact on the aphid population. In addition, water stress or partial host-plant resistance may also be important in regulating aphid populations (Blommers, 1994).

The extensive use of *A. mali* against woolly apple aphid throughout the world has produced a variety of conflicting reports as to its effectiveness and tolerance of insecticide programmes. Research in Hungary (Jenser, 1983) showed that *A. mali* in colonies on the roots and root collars of apple trees were able to survive in orchards treated with broad-spectrum insecticides, later migrating to the canopy to regulate populations of woolly aphid. However, if there is a consensus, it would appear to suggest a move is necessary towards selective insecticide use to encourage the development of natural or released populations of this and other parasitoid species. Conclusions from studies on the impact of the parasitic wasp *A. mali* on the woolly aphid have been mixed, but have suggested mostly that biological control using this parasitoid is insufficient and should instead be included as a component in an integrated approach to controlling the aphid.

The common European earwig

The common European earwig, *Forficula auricularia,* is an omnivorous insect which feeds on apple but also on a wide range of arthropod prey (Buxton, 1974). They are abundant on apple trees having developed a high level of resistance to many broad-spectrum pesticides (Cross et al., 1999)). Woolly aphid numbers increase in orchards that had received applications of diflubenzuron (Ravensburg, 1981) – an insect growth regulator that is toxic to earwigs but not to woolly aphid. A simulation model of earwig predation on woolly aphid from laboratory and other published work predicted that earwigs could destroy a field population of woolly aphid (Noppert et al., 1987). It has also been demonstrated (Stapp et al., 1987; Mueller et al., 1988) that woolly aphid numbers remain low in trees where earwigs are present compared to trees where earwigs are excluded; 30-35% of new shoots were infested in earwig-excluded trees compared to 10% where earwigs were present. New colonies of woolly aphid were generally discovered within 2 weeks. However, in the USA it has been found that earwigs may be unable to control woolly aphid in apple stool beds (Carrol et al., 1985). Work at HRI-East Malling (Solomon et al., 2000) developed artificial refuges to enhance earwig populations on pear trees showing that where earwig numbers had been enhanced, numbers of pear sucker larvae were reduced to below 50% of the numbers in trees from which earwigs had been removed.

Possibilities of biocontrol with entomopathogenic fungi

Aphids are highly susceptible to entomopathogenic fungi and a range of species has been investigated as mycoinsecticides (Milner, 1997). For example, Vertalec (Koppert BV, Netherlands), which is based on *Verticillium lecanii* and was developed by HRI, has been sold in the UK, Netherlands and some other European countries for many years for the control of aphids on glasshouse crops (Shah & Goettel, 1999). Entomopathogenic fungi require freely available water at the insect surface for infection, and consequently mycoinsecticides work best in high humidity environments which in the UK has restricted their use to glasshouse environments (Milner & Lutton, 1986; Helyer et al., 1992). However, new formulations of mycoinsecticides are now available which enable pest control at low humidities (Bateman et al., 1993; Ibrahim et al., 1999) and offer the prospect of insect control on field crops. Examples include the *Beauveria bassiana* – based mycoinsecticides Naturalis (Troy Biosciences Inc., USA) and BotaniGard (Mycotech Corp, USA). Both products are sold in the USA although Naturalis is undergoing registration with the Pesticides Safety Directorate in the UK. Naturalis has been reported to control aphids (*M. persicae* and *Aphis gossypii*). The GHA strain of *B. bassiana* (the active constituent of BotaniGard) has been used to control a variety of pests in glasshouse and field experiments, including *M. persicae* (Olson & Oetting, 1999) and the brown citrus aphid, *Toxoptera citricida* (Poprawski et al., 1999). A new formulation of *V. lecanii* has also been developed by Koppert to improve infection at low humidities. Finally, PFR-97 (Certis USA) is based on the Apopka 97 strain of *Paecilomyces fumosoroseus* and is sold for the control of aphids, whitefly, thrips and spidermites in glasshouse crops. It is available in the USA and is reported to have been registered in the European Union in 1997 (it was the first biopesticide to pass the EU unified registration requirements) but is not available in the UK. Entomopathogenic fungi do not appear to have been investigated as potential biocontrol agents of woolly aphid.

Integrated pest management approaches

The increase in the incidence of woolly aphid is probably caused by changes in pesticide use, particularly the decline in the use of chlorpyrifos, increased use of Insect Growth Regulators and possible harmful effects of new pesticides to earwigs, coupled with changes in weather conditions. The cause of the problem needs to be identified by gaining a better understanding of the effects of commonly used pesticides on key natural enemies of woolly aphid so that harmful treatments can be avoided or minimised. New, more effective selective aphicides need to be identified. Enhancement of earwigs and/or the use of biopesticides could provide a valuable means of alleviating the problem without recourse to pesticide application.

Objectives of this work

Here we report the results of a single replicated orchard experiment done in 2003 to evaluate the efficacy of 5 insecticide products for control of woolly aphid on apple. Preventive treatment before blossom was compared with curative treatment post-blossom against established infestations in May - June. An important additional objective was to determine whether any of the treatments tested adversely affected numbers of earwigs or the proportion of aphids parasitised by the parasitoid *Aphelinus mali*.

Methods and materials

A single replicated experiment was done in one commercial orchard in 2003 as follows:

Site

The experiment was done in 'Unit 6' Cox orchard at Bayfield farm, Painter's Forstal, Faversham, Kent (by kind agreement with Mr Martin Harman, A. R. Neaves, Little Sharsted Farm, Doddington, Kent). The orchard was approximately 25 years old, in single rows spaced 3.96 m apart and with a tree spacing in the row of 1.83 m. The tree density was thus 1380 trees/ha. The variety was Cox and the rootstock M9 with an MM106 interstock. The high incidence of burr knots on the rootstock above ground level but below the union with the interstock provided many good feeding sites for overwintering woolly aphid populations. The orchard thus had a history of woolly aphid infestation and had been severely infested in 2002. The orchard had received a typical conventional pesticide management over many years which included sprays of broad spectrum OP pesticides, mainly of chlorpyrifos.

Treatments

Treatments (Table 3) were single foliar sprays of 5 different products. The products were chosen because they were approved pesticides for aphid control on apple in the UK (Dursban, Aphox, Calypso, Aztec) or in the case of Orosorb oil, an adjuvant oil, because it was considered by the manufacturer/supplier to possibly be efficacious. Dose rates used were the full rate recommended by the manufacturer. Two timings of application of the single sprays of each pesticide product were compared as separate treatments as follows: Timing A) was before blossom application at the green cluster growth stage on 15 April 2003. This application timing was aimed at reducing early season populations so preventing/reducing subsequent increase of the pest in summer. Timing B) was curative application post blossom on 18 June 2003 when the woolly aphid populations were starting to increase and cause crop damage.

Table 3. Treatments applied in woolly aphid trial on 15 April (timing A) or 18 June (timing B) 2003.

Treat no.	a.i.	Product	Dose product (/ha)	Conc. (ml/l)	Timing†
1	Chlorpyrifos 480 g/l EC	Dursban 4	1.0 l	5 ml	A
2	Orange oil	Orosorb	2.0 l	10 ml	A
3	Pirimicarb 50% w/w WG	Aphox	560 g	2.8 g	A
4	Thiacloprid 480 g/l SC	Calypso	375 ml	1.875 ml	A
5	Triazamate 140 g/l EW	Aztec	500 ml	2.5 ml	A
6	Chlorpyrifos 480 g/l EC	Dursban 4	2.0 l	10 ml	B
7	Orange oil	Orosorb	2.0 l	10 ml	B
8	Pirimicarb 50% w/w WG	Aphox	560 g	2.8 g	B
9	Thiacloprid 480 g/l SC	Calypso	375 ml	0.375	B
10	Triazamate 140 g/l EW	Aztec	500 ml	2.5 ml	B
11	Untreated*	-	-	-	-

*The untreated control was double replicated, there being two untreated plots in each block
†Timings: A = Preventive treatment pre-blossom at the late green cluster stage on 15 April 2003. B = Curative treatment when damaging infestations started to develop on 18 June 2003

Spray application

Sprays were applied with a Hardi Tornado Mister (MRY) motorised air-assisted knapsack sprayer at a volume rate of 200 litres water /ha. This volume was chosen as it represented a typical volume rate used for low volume spraying in apple trees in the UK. It was lower than the minimum label recommended spray volume of 400 l/ha for Aphox or 1000 l/ha for Calypso. An in-line orange Micron flow rate restrictor was fitted to the sprayer to provide a flow rate of 0.38 litres per minute. Measurement of the volume of spray solution remaining in the tank after spray application showed that application rates were within 20% of those required. The Crop Adjustment Factor (CAF) for PACE was estimated as 0.5 at the first application on 15 April and 0.75 at the second application on 18 June 2003.

Experimental design and layout

A randomised complete block design with 5 replicates was used. Plots consisted of 6 adjacent trees in a row. They were arranged in two long rows of the orchard, with six plots in the block in one row and the other six plots alongside in the adjacent row.

Meteorological records

Wet and dry bulb temperature and wind speed were measured with a whirling psychrometer and a hand held whirling cup anemometer (at 2m height above ground) before and after spraying. For the first spray application timing A on 15 April 2003 the dry bulb temperature at the start at 08.45 hrs of spray application was 15.5 °C rising to 21.0 C at 12.00 hrs when the spray application treatments were completed. The corresponding wet bulb temperatures were 10.0 and 13.0 °C respectively. For the second spray application timing B on 18 June 2003 the dry bulb temperature at the start at 15.00 hrs of spray application was 21 °C staying more or less constant during application of the treatments. The corresponding wet bulb temperatures was 16.5 °C.

Assessments

Populations of woolly aphid, percentage parasitism by *A. mali* and numbers of earwigs in artificial refuges (see below) were assessed on 1-6 July 2003 and again on 21-22 July 2003, 13-18 and 33-34 days after the second date of spray application respectively.

For woolly aphid, the number of nodes infested with woolly aphid on each of the current years extension shoots that emanated from the main trunk were counted on each of the central 4 trees in each plot. The number of shoots assessed on each tree was also counted and the total number of nodes on each shoot was counted on a sub-sample of 100 shoots so that the percentage nodes infested could be estimated.

For *Aphelinus mali,* one or two woolly aphid colonies containing roughly 50 aphids were selected on each assessed tree. The wax was blown away so that the bodies of the individual aphids were visible. The number of aphids in each colony and the numbers parasitised by *A. mali* were counted, recording the numbers of mummies from which the parasite had emerged and from which it had not emerged separately. The percentages of aphids parasitised were calculated.

For earwigs, one tree in each plot was furnished with a bottle refuge shortly after the second sprays had been applied. The refuges consisted of 2l plastic drinks bottles with their bases cut away and loosely filled with a roll of corrugated cardboard. One refuge was taped to the trunk of one tree in each plot. The refuges were orientated vertically with their open orifices facing down. The numbers of earwig males, females and nymphs in each artificial refuges were counted on each assessment date. The earwigs were returned to the tree after counting.

Statistical analysis

The percentage of nodes infested with woolly aphid on each assessed tree was calculated. Analyses of variance of the numbers of nodes infested with woolly aphid, the percentage nodes, the percentage parasitism by *A. mali* and the numbers of earwigs present in the refuges were done after angular transformation ($\sin^{-1}(x^{1/2})$) of the percentage parasitism data and square root transformation of the earwig counts. In the first instance, the analyses of variance were done with the 11 different treatments as a treatment factor. The analyses were repeated separating the contrasts between the two timings and the untreated control and the different chemical products.

Results

Woolly aphid

The analyses of variance revealed highly significant differences between the 11 different treatments at the first assessment (P=0.007) and very nearly significant treatment differences at the second assessment (P=0.052) (Table 4). None of the pre-blossom treatments significantly reduced the numbers of nodes infested with woolly aphid compared to the untreated control at either assessment date. However, the post blossom applications of Dursban 4 or of Aphox both significantly reduced the numbers of nodes infected by aphids by 66% and 67% respectively at the first assessment and by 70% and 51% respectively at the second assessment. Aztec, Calypso nor Orosorb significantly reduced, or increased aphid populations compared to the untreated control at either assessment. The analyses of variance separating the contrasts between the two timings and the untreated control and the different chemical products revealed that timing was a statistically significant factor (P=0.007) but that the interaction between timing and product was not statistically significant (P=0.077).

Percentage parasitism by Aphelinus mali

The grand mean total % parasitism at the first assessment was 15.5%. At the second it was 65.6%, a 4.2 fold increase. At the first assessment, the majority of the parasites had not emerged. At the second assessment, the parasite had emerged from the majority of aphid mummies. There were no statistically significant treatment affects on the percentages of aphids parasitised by *A. mali* at either the first or the second assessment (Table 5). Indeed, the lowest mean value for the total % parasitism was recorded on the untreated control at the first assessment. However, the value for the untreated control was in the middle of the range of the other treatments at the second assessment. At the first assessment, a Students T test suggested that the mean for the Dursban treatment was greater than the mean for the untreated control (P<0.01). However, this difference between the highest and the lowest value cannot be regarded as a valid difference, particularly as the analysis of variance did not reveal any statistically significant treatment affects. Thus, no adverse or beneficial affects of the treatments on parasitism by *A. mali* were detected in the experiment. Parasitism levels increased markedly over the 14-21 day period between the two assessments.

Earwig populations

The analyses of variance revealed highly significant differences between the 11 different treatments in the total (square root transformed) numbers of earwigs at the first assessment (P=0.006), but treatment differences were not significant at the second assessment (P=0.113) (Table 6). At the first assessment, the pre-blossom spray of Orosorb (treatment 2) had significantly fewer earwigs than the untreated control but the post blossom spray of Orosorb (treatment 7) did not. Both timings of Dursban application had numbers boardering on significantly less than the control at the first assessment.

Discussion

Woolly aphid

In this experiment, the pre-blossom sprays were ineffective. Although woolly aphid colonies were visible at this time they were principally among the burr knots on the rootstock above ground level where they were inaccessible and difficult to contact directly with spray. It is also possible that many of the aphids had not emerged from other overwintering sites under loose bark etc at this time. By the second spray timing, the colonies had spread to the current year's extension shoots where they were directly intercepted by the spray treatments. Both Dursban and Aphox were effective having similar, though somewhat disappointing efficacy in reducing aphid populations. For commercially acceptable levels of control, a second application would have been required.

The lack of efficacy of Aztec in this experiment, an insecticide shown to be effective in previous experiments, is surprising. Because these results contradict previous findings and experience, caution should be exercised in reaching conclusions about the efficacy of this product on the basis of this single experiment. Further investigation is needed before conclusions can safely be drawn. Calypso was ineffective, in line with previous experiments and the manufacturer's recommendations. Disappointingly, the Orosorb oil was also ineffective.

Aphelinus mali

None of the treatments adversely affected parasitism by *A. mali* which increased markedly on all plots during the experiment with no statistically significant treatment differences. It cannot be concluded from these results that the products are harmless to *A mali,* only that they were not harmful in the circumstances of this particular trial. Broad-spectrum insecticides such are chlorpyrifos are almost certainly harmful to adult parasitoids, which are especially vulnerable. Deposits of chlorpyrifos on bark surfaces where the adult parasite forages are likely to be persistently harmful. Juvenile stages of the parasite within the aphid host are protected from the direct effects of pesticide by the host itself. Development is likely to be unaffected unless the aphid dies. It is probable that the adult stage was not present in significant numbers at the time of or shortly after the spray applications. Information of the timing of occurrence of adult *A mali,* provided by direct observations or from temperature based forecasting models would be useful in avaoiding application of broad-spectrum insecticides at critical times. Possible harmful affects of pesticides to *A.mali* would better be investigated in laboratory experiments where the timing, method and duration of exposure of different life stages of the parasite could be precisely controlled.

Earwigs

The early applications timing of Orosorb appeared to be harmful to earwigs though firm conclusions cannot safely be drawn from this single experiment. As for *A. mali*, it cannot be concluded from these results that the other products are harmless to earwigs, only that they were not harmful in the circumstances of this particular trial. Possible harmful affects of pesticides to earwigs would better be investigated in laboratory experiments where the timing, method and duration of exposure of different life stages of the parasite could be precisely controlled.

Conclusions

- In this single experiment in 2003, pre-blossom sprays of Aphox, Dursban, Aztec, Calypso or Orosorb oil did not control woolly aphid infestations, probably because the bulk of the population was present in burr knots on the rootstocks above ground level at this time where the colonies were inaccessible to sprays.
- Post blossom applications of Dursban 4 or of Aphox (in 200 l/ha) both significantly reduced infestations of woolly aphid by over 50% compared to the untreated control. Aztec, Calypso or Orosorb oil were ineffective.
- None of the treatments adversely affected parasitism by the parasitoid *Aphelinus mali* in the circumstances of this experiment. Levels of parasitism increased markedly on all plots during July. However, it is likely that broad-spectrum pesticides are persistently harmful to adults of this parasitoid as they forage on the bark.
- Pre-blossom application of Orosorb oil significantly reduced numbers of earwigs in artificial refuges. None of the other treatments significantly affected earwig numbers.
- Possible harmful affects of pesticides to *A. mali* and earwigs would better be investigated in laboratory experiments where the timing, method and duration of exposure of different life stages could be precisely controlled and investigated.

Table 4. Mean numbers and percentages of nodes infested with woolly aphid per tree.

Treatment		Timing	First assessment 1-6 July 2003 no. nodes	First assessment 1-6 July 2003 % nodes	Second assessment 21-22 July 2003 no. nodes	Second assessment 21-22 July 2003 % nodes
1	Dursban 4	A (15 April)	19.5	24.7	18.4	23.3
2	Orosorb	A (15 April)	21.9	27.7	18.6	23.5
3	Aphox	A (15 April)	27.5	34.8	22.4	28.4
4	Calypso	A (15 April)	29.7	37.6	18.6	23.5
5	Aztec	A (15 April)	25.7	32.5	16.7	21.1
6	Dursban 4	B (18 June)	8.6	10.9	4.5	5.7
7	Orosorb	B (18 June)	26.5	33.5	15.3	19.4
8	Aphox	B (18 June)	8.4	10.6	7.4	9.4
9	Calypso	B (18 June)	18.8	23.8	14.5	18.4
10	Aztec	B (18 June)	23.5	29.7	22.4	28.4
11	Untreated	-	25.3	32.0	15.2	19.2
		-				
	Fprob		0.007	0.007	0.052	0.052
	SED (44df) – comparisons with control		5.26	6.66	4.81	6.09
		- other comparisons	6.07	7.68	5.56	7.04

Table 5. Mean percentage and mean angular transformed (Ang) percentage of aphids parasitised by *Aphelinus mali*

Treatment		Timing	First assessment 1-6 July 2003 % not emerged	% emerged	Total %	Ang (Total %)	Second assessment 21-22 July 2003 % not emerged	% emerged	Total %	Ang (Total %)
1	Dursban 4	A (15 April)	11.0	1.6	12.6	18.1	12.8	40.1	52.9	46.7
2	Orosorb	A (15 April)	6.6	3.9	10.4	17.6	27.3	42.4	69.8	57.6
3	Aphox	A (15 April)	15.3	3.4	18.6	20.3	9.0	63.6	72.5	59.9
4	Calypso	A (15 April)	6.6	4.8	11.4	19.2	10.1	57.9	68.0	59.1
5	Aztec	A (15 April)	13.1	2.0	15.0	19.4	15.7	45.3	61.0	51.5
6	Dursban 4	B (18 June)	15.9	17.0	32.9	33.9	18.4	54.6	73.0	62.2
7	Orosorb	B (18 June)	10.6	5.4	16.0	22.8	9.8	65.8	75.6	60.9
8	Aphox	B (18 June)	11.1	7.3	18.4	24.7	13.0	45.0	58.0	50.4
9	Calypso	B (18 June)	9.7	1.87	11.5	19.2	16.9	46.6	63.5	52.9
10	Aztec	B (18 June)	9.4	6.5	15.9	22.1	18.2	45.7	62.4	52.5
11	Untreated	-	5.9	1.7	7.6	12.8	14.0	50.9	64.8	55.3
	Fprob					0.128				0.648
	SED (45df) – comparisons with control					5.60				6.89
		- other comparisons				6.46				7.96

Table 6. Mean numbers of earwig females, males, nymphs and total and square root transformed total numbers of earwigs recorded in artificial refuges.

Treatment		Timing	First assessment 1-6 July 2003					Second assessment 21-22 July 2003				
			males	females	nymphs	total	√total	males	females	nymphs	total	√total
1	Dursban 4	A (15 April)	1.6	2.4	2.4	6.4	2.5	0.8	2.4	0.2	3.4	1.3
2	Orosorb	A (15 April)	0.8	1.2	2.4	4.4	1.7	0.0	1.4	0.2	1.6	0.8
3	Aphox	A (15 April)	2.2	4.2	2.6	9.0	2.5	1.6	6.2	0.4	8.2	2.3
4	Calypso	A (15 April)	4.4	7.0	10.6	22.0	4.5	1.4	4.8	0.4	6.6	2.5
5	Aztec	A (15 April)	4.2	8.0	10.0	22.2	4.4	2.6	10.0	1.2	13.8	3.3
6	Dursban 4	B (18 June)	1.4	3.6	3.0	8.0	2.4	1.2	3.2	0.0	4.4	1.7
7	Orosorb	B (18 June)	3.0	6.4	7.2	16.6	3.9	3.0	8.0	0.8	11.8	3.4
8	Aphox	B (18 June)	1.0	3.2	7.0	11.2	3.0	4.4	4.4	0.4	9.2	2.4
9	Calypso	B (18 June)	1.6	4.2	2.2	8.0	2.5	0.8	4.0	1.8	6.6	1.8
10	Aztec	B (18 June)	3.6	10.6	10.6	24.8	4.9	3.6	4.8	0.6	9.0	2.8
11	Untreated	-	2.5	8.5	6.0	17.0	3.9	1.9	6.0	0.6	8.5	2.4
		-										
	Fprob						0.006					0.113
	SED (45df) – comparisons with control						0.77					0.75
		- other comparisons					0.88					0.86

III Evaluation of insecticides for control of Blastobasis 2003

Summary

A replicated orchard experiment was conducted in a Bramley orchard at Upper Goldstone Farm, Ash in 2003 to evaluate the efficacy of single foliar sprays (300 l/ha) of Dipel, Dursban 4, Insegar, Runner and Tracer (contains spinosad) for control of *Blastobasis decolorella*. Two timings of application were compared 1) on 19 June at the beginning of the egg hatch period 2) on 4 August when the caterpillars were semi developed and fruit injury was starting to occur.

- Dursban, Runner and Tracer gave good control of Blastobasis when applied in early June, about the time of the start of egg hatch of Blastobasis caterpillars.
- Sprays applied in early August were considerably less effective in preventing fruit damage, though they did give partial control.
- Dipel and Insegar had some activity, but were less effective than the other products.

Introduction

Blastobasis decolorella is a serious but local pest of apple, especially Bramley (Alford, 1980). It attacks foliage and fruit. Apple and beech appear to be the main hosts in the field. The pest can be abundant in beech hedges, which can act as a source of infestation for apple orchards. In the laboratory, the larvae will feed on the leaves of a wide range of plants including alder, beech, blackcurrant, bramble, cherry, *Cotoneaster*, dock, hawthorn, field maple, pear, plum, rose, sallow (*Salix* spp.), and strawberry. They can also be reared to adult on rose hips, hawthorn berries and dead leaves and flowers of apple trees. It is probable that all apple varieties may be attacked but there are considerable differences in the susceptibility of different varieties. Varieties with fruits that are short stalked and/or which hang in clusters and where dead leaf and flower debris accumulates round the stalks, tend to suffer the most damage. Bramley and Egremont russet are amongst the most susceptible, Cox and Worcester are moderately susceptible, Golden Delicious is less susceptible.

Blastobasis is a native of Madeira, and was first found in Britain in 1946 initially restricted to the London area. It is now widely distributed and locally common especially in beech hedges and apple orchards in some localities. Larvae feed on the flesh of apple fruits around the stalks or where fruits are touching or where fruits are in contact with leaves or branches. Large areas of skin and flesh are removed wounds tending to weep and becoming covered by a sticky mass of black frass. They are usually surface feeders but sometimes penetrate more deeply into the flesh. Crop losses can be very high, approaching 100%. Larvae also feed on the bark of branches and the wounds may become infected with canker.

The biology of Blastobasis is reported by Easterbrook (1985). There is one generation per annum in the UK with a very small partial second flight of adults in the autumn and early winter. Adults of the first, main generation fly in June and July, about the same time as codling moth. Eggs are laid (on average 70 per female at a rate of 20 per day) on foliage or amongst debris on the tree. Eggs kept at constant temperatures of 8, 18 or 25 ˚C hatch after 44, 7 and 4 days respectively. Larvae occur from July to October. Initially, they feed on debris such as in the rolled edge of a dead leaf, in a dead flower or burrowed into shrivelled fruitlets. Older larvae construct a shelter of dead leaves and flowers webbed together. Damage to fruits occurs from late July onwards consisting initially of small single holes. As the larvae grow the damage becomes more extensive. When fully fed in the autumn or early winter, larvae leave their feeding sites and move to the soil or amongst debris on the ground where they form a silken cocoon in which they pupate. A small proportion of very early maturing larvae pupate and emerge the same year, giving rise to a small second flight in the autumn or early winter. If eggs are laid, they are unlikely to develop successfully.

Little is known about the natural enemies of Blastobasis. No parasitic wasps have been reared from samples of larvae collected in the field. It is probable that a wide range of generalist insect predators such as anthocorids, mirids, lacewing larvae, earwigs etc feeds on eggs and young larvae. Numerous earwigs are often present in the vicinity of semi-mature caterpillars feeding in shelters amongst fruits and leaves. The shelters appear to provide good protection against them but sometimes, vacant shelters occupied by earwigs are found giving the impression that earwigs might be important predators of Blastobasis.

Work in progress at HRI-East Malling and NRI, Chatham has partially identified the sex pheromone of Blastobasis. Two chemical components, a mono-unsaturated C16 acetate and the corresponding aldehyde, have been identified by linked electrophysiology and gas chromatography. The exact structure of these components has not been determined to date and field tests of combinations of the possible isomers at different relative release rate have not been successful. Further work to identify the components more precisely and to seek other possible missing components is still in progress.

Unlike most moths, adult Blastobasis can be sampled using the beating method, as when dislodged from the vegetation they do not fly but fall onto the beating tray, where they either lie still or scuttle around on their backs. Beating should be used to determine the flight period. For each beat sample, a sharp tap should be made to a branch with a beater over a beating tray (see ‘Pest and disease assessment’). No economic thresholds have been developed but presence of the moth is probably sufficient to justify the application of insecticide treatment.

Forecasting methods for Blastobasis have not been developed. However, limited information indicates that the first adult flight starts at approximately 130 day degrees above 10 ˚C and the peak flight occurs at approximately 240 day degrees.

Cultural control options for this pest are limited. Beech hedges often harbour the pest so removal of these if the pest is present is likely to be helpful. Thinning fruits so that they only occur singly will also reduce damage substantially. Where larvae are found on fruits during picking at harvest, they should be killed.

Blastobasis often goes unnoticed until harvest when the damage is done and it is too late to take remedial action for the current season. Insecticidal controls need to be timed to control caterpillars as they hatch from eggs. Unfortunately, sprays of *Bacillus thuringiensis* have only limited efficacy against the pest. The organophosphorus insecticide chlorpyrifos (Dursban etc), and several pyrethroid insecticides are approved for control of codling and tortrix moth and other caterpillars in apple and pear orchards in the UK and have been shown to be effective against Blastobasis. (Easterbrook et al., 1985). However, pyrethroid insecticides, which are very effective, should be avoided because they are harmful to predatory mites and other natural enemies. Where Blastobasis was a problem the previous year or where adult moths have been collected by beating, one or two sprays of chlorpyrifos (Dursban etc) (possibly 3 sprays in extreme circumstances) may be applied in June and July, at the same time as for codling and fruit tree tortrix moth. Use of chlorpyrifos (Dursban etc) for codling and tortrix moth control will give incidental control of Blastobasis, though it is wise to extend the insecticidal protection into July where there is a serious Blastobasis problem. The aim is to apply the chlorpyrifos (Dursban) timed to coincide with the onset of egg hatch. Beat sampling will indicate the start and duration of the flight. The insecticidal protection should be maintained continuously by spraying chlorpyrifos at 2-3 week intervals until 2-3 weeks after the end of the flight period, remembering that the maximum number of applications of this insecticide per season is 3. *Bacillus thuringiensis* and diflubenzuron (Dimilin) are largely ineffective against Blastobasis. The effectiveness or otherwise of fenoxycarb (Insegar) or of ecdysone agonist insecticides (moulting accelerating compounds) is unknown. No insecticides with this latter mode of action are approved in the UK currently.

Objectives of this work

The objective of the work reported here was to conduct one field experiment in 2003 to evaluate 5 insecticides, applied either at egg hatch or against semi-mature caterpillars before harvest, for control of *Blastobasis decolorella*.

Methods and materials

A single replicated experiment was done in one commercial orchard in 2003 as follows:

Site

The experiment was done in Bramley orchard no. 20, Upper Goldstone Farm, Cop Street, Ash, Kent (by kind permission of Mr Graham Foat). The orchard was planted in single rows spaced 11’ x 5’ (= 3.35 x 1.52 m, tree density = 1964 trees/ha) in 1983. The main cropping variety was Bramley’s Seedling. Every 3rd tree in every 3rd row was a pollinator, variety Discovery.

Treatments

Treatments (Table 7) were single foliar sprays of Dipel, Dursban 4, Runner, Insegar or Tracer applied on 19 June 2003 at the estimated start of egg hatch or approximately 6 weeks later on 4 August 2003 when caterpillars were semi-mature. Beat sampling the foliage on 19 June 2003 revealed that small numbers (approximately 1/20 beats) of adult Blastobasis moths were present in the foliage before treatments were applied.

Table 7. Treatments applied in the Blastobasis efficacy testing experiment 2003.

Trt no.	a.i.	Product	Product dose (/ha)	Harvest interval (days)	Applica-tion date (2003)
1	*Bacillus thuringiensis 32000 IU/mg*	Dipel	1.0 kg	0	19 Jun
2	Chlorpyrifos 480 g/l EC	Dursban	2.0 l	14	19 Jun
3	Methoxyfenozide 240 g/l SC	Runner	0.6 l	14	19 Jun
4	Fenoxycarb 25% w/w WG	Insegar	0.6 kg	42	19 Jun
5	Spinosad 480 g/l SC	Tracer	0.45 l	7	19 Jun
6	*Bacillus thuringiensis 32000 IU/mg*	Dipel	1.0 kg	0	4 Aug
7	Chlorpyrifos 480 g/l EC	Dursban	2.0 l	14	4 Aug
8	Methoxyfenozide 240 g/l SC	Runner	0.6 l	14	4 Aug
9	Fenoxycarb 25% w/w WG	Insegar	0.6 kg	42	4 Aug
10	Spinosad 480 g/l SC	Tracer	0.45 l	7	4 Aug
11	Untreated				

<u>Spray application</u>

Sprays were applied with a Hardi Tornado Mister (MRY) motorised air-assisted knapsack sprayer at a volume rate of 300 litres water /ha. This volume was chosen as it represented a typical volume rate used for low volume spraying in apple trees in the UK. An in-line orange Micron flow rate restrictor was fitted to the sprayer to provide a flow rate of 0.38 litres per minute. Measurement of the volume of spray solution remaining in the tank after spray application showed that application rates were within 10% of those required. The Crop Adjustment Factor (CAF) for PACE was estimated as 1.0 for both spray applications.

<u>Experimental design and layout</u>

Randomised complete block with 5 replicate plots of 24 trees, arranged in 3 rows of 8, for each treatment.

<u>Meteorological records</u>

Wet and dry bulb temperature and wind speed were measured with an aspirated psychrometer and a hand held whirling cup anemometer (at 2m height above ground) before and after spraying. For the first spray application on 19 June 2003 the dry bulb temperature at the start at 06.00 hrs of spray application was 17 °C rising to 22 °C at 14.15 hrs when the spray application treatments were completed. The corresponding wet bulb temperatures were 15 and 22 °C respectively. The windspeed was measured as 1 km/h. For the second spray application on 4 August 2003 the dry bulb temperature at the start at 09.00 hrs of spray application was 25 °C rising to 28 °C at 12.30 hrs when the spray application treatments were completed. The corresponding wet bulb temperatures were 15 and 25 °C respectively.

Assessments

The grower harvested the largest fruits from the plots on 5 August 2003, immediately before the second spray applications. He recorded the total number of large fruits harvested from each plot and the numbers that had been damaged by tortrix or Blastobasis caterpillars (the cause was not distinguished). A sample of 300 fruits per plot (20 from each of 15 trees, 5 in the centre of each of the three rows of each plot) was sampled by HRI-East Malling staff on 28 August 2003. Where caterpillars were not present or the cause of the damage not obvious, it was impossible to distinguish between Blastobasis or tortrix caterpillars as the cause of damage to many fruits. Therefore, the numbers of fruits definitely damaged and the numbers infested with Blastobasis caterpillars, the numbers of fruits definitely damaged and the numbers infested with tortrix caterpillars and the numbers damaged by Blastobasis or tortrix but where the exact cause could not be determined, were recorded separately.

Statistical analysis

The percentages of fruits damaged by Blastobasis, tortrix caterpillars or where the cause was uncertain, were calculated. Analyses of variance were done on the percentages after angular transformation ($\sin^{-1}x^{1/2}$).

Results

Both Blastobasis and tortrix caterpillars caused damage to the fruits at harvest and for many individual fruits it was not possible to distinguish the cause of damage with certainty.

At the first spray timing, all the 5 products significantly reduced the percentage fruits damaged by either Blastobasis or tortrix caterpillars (Table 8). Dursban, Runner and Tracer had the lowest mean values, all significantly lower than Insegar. Dipel was intermediate.

All 5 products also significantly reduced the amount of damage at the second spray timing, but the second timing was significantly less effective than the first. At the second timing, the Dursban and Tracer had the lowest mean values but they were not significantly less than the other treatments.

The same treatment effects and trends were apparent in the results where the cause of damage had definitely been identified as Blastobasis. The first application timing was more effective than the second. Dursban, Runner and Tracer were the most effective treatments with Dipel and Insegar less effective.

Conclusions

- Dursban, Runner and Tracer gave good control of Blastobasis when applied in early June, about the time of the start of egg hatch of Blastobasis caterpillars.
- Sprays applied in early August were considerably less effective in preventing fruit damage, though they did give partial control.
- Dipel and Insegar had some activity, but were less effective than the other products.

Table 8. Mean and mean angular transformed ($\sin^{-1} x^{1/2}$) percentages of fruits definitely damaged by a *Blastobasis* caterpillar, definitely damaged by a tortrix caterpillar or damaged either by a *Blastobasis* or a tortrix caterpillar but where the cause could not be diagnosed with certainty.

Treatment			Definitely *Blastobasis*		Definitely tortrix		*Blastobasis* or tortrix	
Number	Product	Application date	%	Ang (%)	%	Ang (%)	%	Ang (%)
1	Dipel	19 Jun	0.3	2.5	0.0	0.0	2.3	8.7
2	Dursban 4	19 Jun	0.0	0.0	0.0	0.0	1.3	6.6
3	Runner	19 Jun	0.0	0.0	0.0	0.0	1.4	6.9
4	Insegar	19 Jun	0.5	3.7	0.0	0.0	3.6	10.8
5	Tracer	19 Jun	0.0	0.0	0.0	0.0	0.6	4.3
6	Dipel	4 Aug	0.5	3.2	0.0	0.0	3.9	11.1
7	Dursban	4 Aug	0.5	3.2	0.1	0.7	3.1	9.6
8	Runner	4 Aug	0.7	3.6	0.1	0.7	4.5	12.1
9	Insegar	4 Aug	0.9	4.5	0.0	0.0	4.2	11.6
10	Tracer	4 Aug	0.4	2.3	0.0	0.0	2.9	9.8
11	Untreated		1.1	5.2	0.3	2.0	7.2	15.4
	Fprob		-	0.823†	-	-	<0.001	<0.001
	SED((40 df)		-	1.90†	-	-	0.88	1.27

† analysis conducted with treatments with mean values of zero (treatment numbers 2, 3 and 5) excluded

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References

ALFORD, D. V. 1980. *Blastobasis decolorella* (Wollaston) (Lepidoptera: Blastobasidae), a potentially serious apple pest. *Plant Pathology* 29, 145-146.

ANON. 1983. Apple and pear midges. *Leaflet, Ministry of Agriculture, Fisheries and Food, UK. No. 26, 8 pp. 5 ref.*

ANTONIN, P. 1984 Cecidomyiids of the leaves (*Dasyneura pyri* Bch.) and immature pears (*Contarinia pyrivora* Riley). [French] *Revue Suisse de Viticulture, d'Arboriculture et d'Horticulture 16: 2, 101-102.*

BATEMAN, R.P., CAREY, M., MOORE, D & PRIOR, C. (1993). The enhanced infectivity of *Metarhizium flavoviride* in oil formulations to desert locusts at low humidities. *Annals of Applied Biology* **122**, 145-152.

BLOMMERS, L. (1992). Selective package and natural control in orchard IPM. *Acta Phytopathologica et Entomologica Hungarica* **27,** 127-134.

BLOMMERS, L.H.M. (1994). Integrated Pest Management in European Apple and Pear Orchards. *Annual Review of Entomology* **39,** 213-241.

BONNEMAISON, L. (1965). Observations écologiques sur *Aphelinus mali* Haldeman, parasite du puceron lanigère *(Eriosoma lanigerum* Haussmann). *Annals of the French Entomological Society* **1,** 143-176.

BONNEMAISON, L. (1974). Aphelinides. Les organisms auxiliaires en verger de pommiers. *IOBC/WPRS Bulletin* **3,** 87-88.

BROWN, M. W. & SCMITT, J. J. (1990) Growth reduction in non-bearing apple trees by woolly apple aphids (Homoptera: Aphididae) on roots. *Journal of Economic Entomology* 83, 1526-1530.

BUXTON, J. (1974). The biologiy of the common European earwig, *Forficula auricularia* L. with reference to its predatory activities on the damson-hop aphid, *Phorodon humuli* (Schrank). PhD Thesis, University of London.

CARROLL, D. P., WALKEWR, J. T. S. & HOYT, S. C. (1985). European earwigs (Dermaptera: Forficulidae) fail to control apple aphids on bearing apple trees and woolly apple aphids (Homoptera: Aphididae) in apple rootstock stool beds. *Journal of Economic Entomology* **78**, 972-974.

CROSS, J. V., FAULKNER, H. E. & JAY, C. N. (1999). Susceptibility of *Adoxophyes orana*, *Cydia pomonella* and *Forficula auricularia* in UK apple orchards to insecticides. *IOBC/WPRS Bulletin* **22 (7),** 169-176.

EASTERBROOK, M. A. 1985. The biology of *Blastobasis decolorella* (Wollaston) (Lepidoptera: Blastobasidae) a potentially serious pest of apple. *Entomologist's Gazette* 36, 167-172.

EASTERBROOK, M. A., SOLOMON, M. G. & FITZGERALD, J. D. 1985. Control of *Blastobasis decolorella* (Lepidoptera: Blastobasidae), a new pest of apple. *Journal of Horticultural Science* 60, 33-36

EVENHUIS, H.H. (1958). Ecological studies on the woolly aphid and its parasite in The Netherlands. *Tijdschr Plantenziekten* **64,** 1-103.

FRANKENHUYZEN, A. VAN. 1985. The pear midge. Life history and control. *Fruitteelt 75: 13, 330-333*

GEOFFRION, R. (1985). Le puceron lanigere du pommier. *Phytoma* **369,** 25-27.

HELYER, N., GILL, G., BYWATER, A. & CHAMBERS, R. (1992). Elevated humidities for control of chrysanthemum pests with *Verticillium lecanii*. *Pesticide Science* **36**, 373-378.

IBRAHIM, L., BUTT, T.M., BECKETT, A. & CLARK, S.J. (1999). The germination of oil-formulated conidia of the insect pathogen, *Metarhizium anisopliae*. *Mycological Research* **103**, 901-907.

KÖGLER, T. (1989). The parasitoids of the woolly apple aphid *(Eriosoma lanigerum* Hausmann) (Hom.: Aphididae) and their distribution in palatinate. *Anzeiger für Schädlingskunde, Pflanzenschutz, Umweltschutz* **62,** 25-31.

JENSER, G. (1983). The woolly aphis colonies on roots and root collars in treated orchards. *Proceedings of the International Conference on Integrated Plant Protection, Budapest, 4-9 July 1983*.**2**, 40-42.

MARCHAL, P. (1921). Introduction en France d'un parasite Américain du puceron lanigère du pommier, l'Aphelinus mali Haldeman. *Comptes Rendus Academie d'Agriculture de France:* pp.619-625 (cited by Evenhuis, 1958).

MASSEE, A.M. (1943). Further notes on the woolly aphid parasite *(Aphelinus mali* Hald.). *Annual Report East Malling Research Station* **27,** 65-67.

MILNER, R. J. (1997). Prospects for biopesticides for aphid control. *Entomophaga*, **42**, 227 – 239.

MILNER, R.J. & LUTTON, G.G. (1986). Dependence of *Verticillium lecanii* (Fungi: Hyphomycetes) on high humidities for infection and sporulation using *Myzus persicae* (Homoptera: Aphididae) as host. *Environmental Entomology* **15**, 380-382.

MOLS, P.J.M. (1996). Do natural enemies control woolly apple aphid. *IOBC/WPRS Bulletin* **19,** 203-207.

MUELLER, T. F., BLOMMERS, L. H. M. & MOLS, P. J. M. (1988). Earwig (*Forficula auricularia* L.) predation on the woolly apple aphid, *Eriosoma lanigerum*. *Entomologia Experimentalis et Applicata* **47**,145-152.

MUELLER, T.F., BLOMMERS, L.H.M. & MOLS, P.J.M. (1992). Woolly apple aphid *(Eriosoma lanigerum* Hausm.) (Hom.: Aphididae) parasitism by *Aphelinus mali* Hal. (Hym.: Aphelinidae) in relation to host stage and host colony size, shape and location. *Journal of Applied Entomology* **114,** 143-154.

NOPPERT, F., SMITS, J. D. & MOLS, P. J. M. (1987). A laboratory evaluation of the European earwig (*Forficula auricularia* L.) as a predator of the woolly apple aphid (*Eriosoma lanigerum* Hausm.). *Mededelingen van de Faculteit Landbouwwetenschappen Rijksuniversiteit Gent* **52**,413-422.

OLSON, D. L. & OETTING, R. D. (1999). Compatibility of insect growth regulators and *Beauveria Bassiana* (Balsamo) Vuillemin in controlling green peach aphid (Homoptera: Aphididae) on greenhouse chrysanthemums. *Journal of Entomological Science* **34**, 286 – 294.

POPRAWSKI, T. J., PARKER, P. E. & TSAI, J. H. (1999). Laboratory and field evaluation of hyphomycete insect pathogenic fungi for control of brown citrus aphid (Homoptera: Aphididae). *Environmental Entomology* **28**, 315 – 321.

RAVENSBURG, W. J. (1981). The natural enemies of the woolly apple aphid, *Eriosoma lanigerum* (Hausm.) (Homoptera: Aphididae) and their susceptibility to diflubenzuron. *Mededelingen van de Faculteit Landbouwwetenschappen Rijksuniversiteit Gent* **46**, 437-411.

SHAH, P. A. & GOETTEL, M. S. (1999). *Directory of microbial control products and services*. Society for Invertebrate Pathology, Gainseville, Florida, USA.

SOLOMON, M. G., FITZGERALD, J. D. & JOLLY, R. (2000) Artificial refuges and flowering plants to enhance predator populations in orchards. *IOBC/WPRS Bulletin* **22(7)**, 31-37.

STAPP, J. S. MUELLER, T. F., DRUCKER, B., BLOM, J VAN DER, MOLS, P. J. M., BLOMMERS, L. H. M. & VAN DER BLOM, J. (1987) Field studies on the European earwig (*Forficula auricularia* L.) as predator of the woolly apple aphid (*Eriosoma lanigerum* Hausm.) *Mededelingen van de Faculteit Landbouwwetenschappen Rijksuniversiteit Gent* **25**, *423-431.*

WEBER, D.C. & BROWN, M.W. (1988). Impact of woolly apple aphid (Homoptera: Aphididae) on the growth of potted apple trees. *Journal of Economic Entomology* **81,** 1170-1177.