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

AUTHENTICATION

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

Dr Angela Berrie, East Malling Research

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

CONTENTS

TF 164 PRODUCING APPLES FREE FROM PESTICIDE RESIDUES

GROWERS' SUMMARY

Headline

- The zero pesticide residue management system (ZRMS) is feasible for commercial production.

- Scab control in the ZRMS was acceptable but the ZRM system is not suitable for orchards with a moderate to high incidence of primary mildew and powdery mildew control must be restored by conventional means before adopting the system in these orchards.

- Pest control under the ZRMS is variable, but in general similar to commercial control.

Background and expected deliverables

Consumers expect perfect apples that contain no pesticide residues. This project addresses this consumer demand and hence Defra policy objective of producing apples with minimal pesticide residues, of high quality and produced using methods safe to the environment. The zero pesticide residue management system (ZRMS), which was developed in Defra project HH2502STF and which is based on the use of conventional pesticides up to petal fall and post harvest, will be further evaluated on fruit farms to assess its practical and economical suitability for use in commercial orchards. The long term effects of the reduced pesticide inputs of the system on pests and diseases, (including storage rots) and beneficial insects will be examined by maintaining the experimental plots at EMR (EMR) established under project HH2502STF.

There is also a need to develop alternative methods of control for the key pests and diseases which are mainly active post-bloom. These include rosy apple aphid (*Dysaphis plantaginea*), powdery mildew (*Podosphaera leucotricha*) and storage rots. The experimental approach to be used in the study also offers the opportunity to study the arthropod and microbial biodiversity on apple trees under the different pesticide management systems. Particular attention will be paid to delivering the project outputs as advice to growers through revised sections in the Defra Apple Best Practice Guide on methods to produce apples free of pesticide residues, alternative methods for mildew control, elimination of over-wintering scab and alternative methods for control of rosy apple aphid.

Overall objective

The overall objective is to develop a management strategy that produces apples free of pesticide residues without loss in fruit quality. Specific objectives are:

1. To (a) test and demonstrate the zero residue strategy under a range of conditions on commercial farms to identify any problems and to ensure uptake

of the system by fruit growers and (b) to undertake a desk study to produce guidelines for use of fungicides and insecticides post bloom to ensure that fruit at harvest are free of pesticide residues
2. To identify the long term effects of the zero pesticide residue strategy on pest and disease incidence and on pest and disease control
3. To develop effective alternative methods for control of powdery mildew
4. To evaluate two entomopathogenic fungi as biocontrol agents of rosy apple aphid in the orchard in the spring and autumn, identifying any factors which limit efficacy
5. To identify methods that eliminate apple scab on overwintering leaf litter in Bramley orchards
6. To evaluate the longer term effects of the zero pesticide residue strategy on (a) arthropod populations in apple trees compared to a broad-spectrum routine programme and untreated and (b) on microbial populations in apple trees compared to those of a broadspectrum routine programme or untreated
7. To demonstrate to fruit growers the feasibility of the zero residue strategy and to encourage uptake by providing advice through the Apple Best Practice Guide and HDC Fact Sheets

Summary of the project and main conclusions

In 2004 to 2006, trials were conducted in four commercial orchards in Kent (two on Cox and two on Gala) in which the pest and disease control achieved by the zero pesticide residue management system (ZRMS) established in half the orchard was compared to that in the other half receiving the grower's standard pesticide programme. In general, scab control in the ZRMS was acceptable and as good as in the grower plots. Where scab occurred at higher incidence it was not attributable to the ZRMS approach. Powdery mildew was the main disease problem encountered in three of the sites due to a high incidence of primary mildew at the start of the trial. In such circumstances reduced dose sulphur gave poor control. The ZRM system is not suitable for orchards with a moderate to high incidence of primary mildew and powdery mildew control must be restored by conventional means before adopting the system in these orchards. In the trial sites control of storage rots was similar in both plots, but none of the orchards were stored long-term for the system to be thoroughly tested. Pest control, in the ZRMS in the four orchard sites was variable, but in general similar to that in the growers half. These trials have demonstrated the practical feasibility of the system.

A desk study was conducted on pesticide use post-bloom on apple and the risk of reportable residues. Based on information provided by pesticide companies and fruit cooperatives guidance is given on harvest intervals that minimise the risk of residues above reporting limits.

In a large, replicated orchard experiment at EMR the ZRM system was applied to established plots (MS, MR) containing scab susceptible (Cox, Gala, Fiesta, Discovery) or scab resistant cultivars (Saturn, Ahra, Discovery) and compared with conventionally (CS, CR) sprayed or unsprayed (US/UR) plots of the same cultivars. Both 2004 and 2006 were high risk years for scab with 56-89% (2004) and 24-92% (2006) scabbed fruit recorded at harvest in untreated plots (US). Despite this, the

scab control achieved in ZRMS plots (MS/MR) in 2004 (<1% scabbed fruit) and in 2006 (0.2-5.8%), was as good as or better than that in CS/CR plots (<1% scabbed fruit in 2004 and 0.7-6.2% scabbed fruit in 2006) which had received season-long fungicides.

The risk of powdery mildew was high in all three years (up to 100% mildewed shoots in US/UR plots), but the control achieved by the managed programme, based on elimination of primary mildew and fungicides pre-bloom combined with low dose sulphur sprays post-bloom, applied to MS/MR plots was as good as that achieved by the conventional programme of sprays applied to CS/CR plots. Losses due to rots in store were generally less in fruit from MS/MR plots, where the emphasis had been on cultural control, rot risk assessment and selective picking, than in CS/CR plots that had received pre harvest captan or tolylfluanid sprays only, or US/UR plots, that were untreated.

Rhynchites weevil (*Coenorhinus aequatus*), Totrix moth (*Adoxophes orana, Archips podana*) and rosy apple aphid (*Dysaphis plantaginea*) were the main pests recorded at damaging levels in untreated plots. Pest control in MS/MR plots was based on IPM monitoring and treatment pre-bloom and at petal fall with selective insecticides and with granulosis virus for codling control in summer and was as good as that achieved in CS/CR plots where control was based on conventional pesticides (including organophosphate insecticides) pre- and post-blossom.

Fruit russet was similar in both MS/MR plots and CS/CR plots, indicating that there was no effect of sulphur on the fruit quality. In all three seasons there were savings in the cost of fungicides in MS/MR plots of around £100/ha, but these were offset by the higher costs of the selective insecticides used resulting in most cases in similar costs in the MS/MR and CS/CR programmes. Additional costs were incurred in MS/MR plots for pest and disease monitoring, inoculum removal and selective harvesting. No residues were detected (analysed to limit of detection) in fruit sampled at harvest from MS/MR plots. In these trial plots the ZRM system has given comparable pest and disease control to that in the conventional system. The key to the success has been the emphasis on control in the dormant season and pre-bloom, meaning that minimal problems have been carried to the post bloom period.

Two approaches were explored for control of powdery mildew as alternatives to sulphur. In the first, B11, a naturally occurring isolate and AQ10 a commercially available isolate of the biocontrol agent *Ampelomyces quisqualis* (AQ), were evaluated in an apple orchard of cv. Cox. Both isolates failed to establish on mildewed trees in the orchard trial. This result combined with that from other trials, indicates that AQ is unlikely to be active enough as a biocontrol agent to be relied upon for orchard mildew control. In a second approach potassium bicarbonate and potassium phosphite (Farmfos) were evaluated in orchard trials for control of powdery mildew. None of the alternative chemicals tested were consistently as effective as sulphur in controlling mildew, but both did reduce the incidence of secondary mildew and could be used in conjunction with sulphur as part of a programme for mildew control post-blossom. Most important is ensuring that the incidence of primary mildew remains low.

The possibility of using entomopathogenic fungi as an alternative approach for control of rosy apple aphid (RAA) was explored. Foliar sprays of commercially available formulations of the entomopathgenic fungi *Beauveria bassiana* (BotaniGard and Naturalis) and *Paecilomyces fumosoroseus* (PFR) were evaluated in the field for control of RAA and other aphids. None of the products were successful in field trials. Use of entomopathogenic fungi does not appear to be a promising IPM approach for control of RAA and other aphids. The effect of exclusion or supplementary honey feeding of the common black ant (*Lasius niger*) on populations of aphids and natural enemies on apple was also investigated. Exclusion of ants resulted in increased populations of predators and rapid decreases in aphid populations and a useful tool in apple IPM.

Elimination of overwintering apple scab inoculum is one of the key factors in the ZRM system. Three separate experiments were conducted between 2004 and 2006 to evaluate possible alternatives to myclobutanil and urea that are currently used post harvest to disrupt the development of the scab sexual overwintering state and to encourage leaf degradation. All treatments (urea, myclobutanil, tebuconazole, pyrimethanil and potassium bicarbonate) except fenbuconazole reduced the numbers of scab ascospores and could be used as post harvest treatments to reduce or eliminate overwintering scab.

The approach used in the development of the ZRMS in Wiseman's orchard at EMR gave the opportunity for comparing the long-term effects of the broad-spectrum pesticide programme (CS/CR) and the managed programme (MS/MR) on arthropod and microbial biodiversity compared to the untreated plots (US/UR). During the four year study, a total of 8,305 individual spiders (Araneae) of 69 species was collected and identified. 5,958 individuals comprising 51 species were collected in the canopy and these were significantly reduced both in abundance and species richness by the CS/CR and MS/MR treatments compared to the US/UR plots in all years. 1,412 individuals comprising 41 species were collected in the herb layer and their abundance was similarly significantly higher in the US/UR plots. Seventy species of Auchenorrhyncha (leaf hoppers and cicadas) were collected and the MS/MR and CS/CR programmes similarly reduced significantly the number of leafhoppers in the canopy and also effected the density of cicadas in the ground herbage layer. A total of 90 species of Heteroptera (plant bugs) were recorded, of which 11 species comprised 80% of the total bug abundance. The composition of bug communities differed between years and between the plots subject to different insecticide regimes.

The microbial biodiversity on leaf and fruit surfaces in the different apple plots in the Wiseman's orchard at EMR was investigated using a combination of traditional plating techniques and genetic methods to analyse the total DNA extracted from leaf or fruit washings. Bacteria and yeasts were the most numerous microorganisms recorded on plates, but generally restricted to three or four commonly occurring types. There were differences in types of bacteria, yeasts and other fungi at different times of the season but these were not consistent between years or related to rainfall. Filamentous fungi generally occurred at much lower incidence compared to yeasts and bacteria but were more diverse in types with up to 33 different types recorded on plates during the course of the study. There was no consistent effect of pesticide programme on the incidence of bacteria, yeasts or other fungi. Problems were encountered with the molecular method developed for characterising the plant

surface microflora which could not be resolved within this project. It is clear that this technique offers a powerful tool for analysis of microbial biodiversity on plant surfaces but requires some further development.

Particular attention has been paid to delivering the project outputs as advice to growers. A total of 21 visits to trial sites or talks to growers, mainly on the ZRM system were delivered in the course of the project, together with 14 articles for grower publications.

Conclusions

- The zero pesticide residue management system (ZRMS) is feasible for commercial production.

- Scab control in the ZRMS was acceptable but the ZRM system is not suitable for orchards with a moderate to high incidence of primary mildew and powdery mildew control must be restored by conventional means before adopting the system in these orchards.

- Pest control under the ZRMS is variable, but in general similar to commercial control.

Financial Benefits

Routine monitoring for pest and disease would be done in the conventional system, but with fewer visits. Additional monitoring is needed particularly at petal fall when searches for apple scab are important.

Fungicide costs are usually lower by around £100 per hectare, because of the use of sulphur post bloom. Insecticide costs are generally higher because of the more intensive insecticide use pre-bloom, the use of more selective products rather than the broad spectrum organophosphate insecticide chlorpyrifos and additional aphicide used in October.

The offset of reduced fungicides costs against the increased insecticides costs results in similar overall costs for ZRMS managed and conventional programmes. However differences in the cost of insecticides between the ZRMS system and the conventional system are declining as the use of selective insecticides in conventional system is increasing so it is likely that in time the ZRMS will be cheaper.

Action points for growers

- Consider trialling the zero pesticide residue management system (ZRMS) in Gala orchards that are already not troubled by scab and in particular mildew.

- Depending on the findings of the HDC project TF 173, consider trialling the ZRMS on other varieties.

SCIENCE SECTION

Introduction

Consumers expect perfect apples that contain no pesticide residues. This project addresses this consumer demand and hence Defra policy objective of producing apples with minimal pesticide residues, of high quality and produced using methods safe to the environment. The zero pesticide residue management system, which was developed in project HH2502STF and which is based on the use of conventional pesticides up to petal fall and post harvest, will be further evaluated on fruit farms to assess its practical and economical suitability for use in commercial orchards. The long term effects of the reduced pesticide inputs of the system on pests and diseases, (including storage rots) and beneficial insects will be examined by maintaining the experimental plots at EMR (EMR) established under project HH2502STF. There is also a need to develop alternative methods of control for the key pests and diseases which are mainly active post-bloom. These include rosy apple aphid (*Dysaphis plantaginea*), powdery mildew (*Podosphaera leucotricha*) and storage rots. The experimental approach to be used in the study also offers the opportunity to study the arthropod and microbial biodiversity on apple trees under the different pesticide management systems. Particular attention will be paid to delivering the project outputs as advice to growers through revised sections in the Defra Apple Best Practice Guide on methods to produce apples free of pesticide residues, alternative methods for mildew control, elimination of overwintering scab and alternative methods for control of rosy apple aphid.

Objectives

The overall objective is to develop a management strategy that produces apples free of pesticide residues without loss in fruit quality. Specific objectives are:

1 To (a) test and demonstrate the zero residue strategy under a range of conditions on commercial farms to identify any problems and to ensure uptake of the system by fruit growers and (b) to undertake a desk study to produce guidelines for use of fungicides and insecticides post bloom to ensure that fruit at harvest are free of pesticide residues
2 To identify the long term effects of the zero pesticide residue strategy on pest and disease incidence and on pest and disease control
3 To develop effective alternative methods for control of powdery mildew
4 To evaluate two entomopathogenic fungi as biocontrol agents of rosy apple aphid in the orchard in the spring and autumn, identifying any factors which limit efficacy
5 To identify methods that eliminate apple scab on overwintering leaf litter in Bramley orchards
6 To evaluate the longer term effects of the zero pesticide residue strategy on (a) arthropod populations in apple trees compared to a broad-spectrum routine programme and untreated and (b) on microbial populations in apple trees compared to those of a broadspectrum routine programme or untreated

7 To demonstrate to fruit growers the feasibility of the zero residue strategy and to encourage uptake by providing advice through the Apple Best Practice Guide and HDC Fact Sheets

Objective 1a – Evaluation of zero residue system on commercial farms

The plan was to establish zero residue orchards on four commercial farms on cv. Cox or Gala. The purpose of these sites was to evaluate the system under a range of conditions in a commercial situation, to identify problems and to provide demonstration sites for growers to visit.

Materials and methods

In 2004, in collaboration with World Wide Fruit, trial sites were established in two Cox orchards and two Gala orchards on four commercial farms in Kent. In each orchard the zero residue management system (ZRMS) (Berrie, 2004) (Table 1) was applied to half the orchard and compared to the grower's standard programme in the other half. Standard nutrient programmes were applied to both plots. Dormant season treatments were not applied to the ZRMS plots in year 1 as the trial did not start until April 2004, but were applied post harvest in 2004 and 2005 prior to the start of years 2 and 3 of the project. Pest and disease incidence was assessed at standard key times (Cross & Berrie, 2001) and pheromone traps used to assist in decisions on pesticde use. Any adjustments to the ZRMS programme were communicated to the growers by phone or email. Leaf litter incidence was assessed using a point transect method (Gadoury & MacHardy, 1986) at each site in April as an indication of overwintering scab potential. Full assessments of key pests and scab and mildew incidence (Cross & Berrie, 1995) were made pre bloom, at petal fall and at monthly intervals to harvest. At harvest, pest and disease incidence was assessed on a random sample of 1000 fruit from 50 trees per plot. Ten fruit bins were labelled from each plot and the fruit stored and assessed for rot incidence and fruit quality at the end of the storage period. At harvest a random sample of 25 fruit were taken from each plot and analysed for pesticide residues. Records were kept of the pesticide costs and labour inputs to both plots to obtain an economic appraisal of the two systems.

The trials were continued for two further seasons to obtain extensive data under different weather conditions and identify any new problems.

Results and Discussion

2004

Leaf litter (Table 3) had almost disappeared from the orchard at site 2, but present at moderate to high incidence in both plots at the other three sites. In 2004 weather conditions indicated a moderate risk of apple scab in the early part of the season (Table 2). Scab was recorded at Broadwater 'Gala' in both the ZRMS and grower plots pre bloom during the period when conventional pesticides were applied and was the result of a faulty sprayer rather than the treatments applied (Table 3). Consequently use of conventional fungicides for scab control was continued after blossom and the ZRMS used only for powdery mildew and storage rots at this site. Apart from this pest and disease levels were mainly low and similar in ZRMS and grower plots. The main disease problem was powdery mildew. The incidence of

secondary mildew was high at sites 2-4 due to a high incidence of primary mildew in these orchards, particularly at site 2, which was not expected (Table 4). Primary mildew was removed by hand at site 1 to reduce the inoculum, but had little impact on the subsequent epidemic (Table 4). Use of sulphur, at 50% of the full recommended rate, post bloom was only partially effective in controlling the mildew at this high incidence. The incidence of rots in 'Gala' stored from sites 1 and 3 until December or February 2005 was similar in fruit from ZRMS and grower plots (Table 5). The incidence of codling moth was above threshold at site 3 but was well controlled post bloom by the use of codling moth granulosis virus (Table 6). Control of tortrix was poor at site 1 in ZRMS the plot, but better than that in the conventional plot.

2005

Dormant season treatments to encourage leaf rotting were applied post-harvest in 2004. In general, leaf litter incidence was similar to that in 2004, but generally lower in the ZRMS managed plots (Table 7). Weather conditions in spring were again only of moderate risk for scab (Table 2) and the incidence at all four sites remained very low throughout the season with <1% of fruit with scab recorded at harvest. The main disease problem was again powdery mildew. The incidence of secondary mildew was high at sites 2-4 due to a high incidence of primary mildew in these orchards (Table 8). Primary mildew was removed by hand at sites 2 and 4 but appeared to have little impact on subsequent mildew development. Use of sulphur post bloom was again only partially effective in controlling the mildew. The incidence of rots in 'Gala' stored from sites 1 and 3 until December or February and in 'Cox' from site 2 stored until January was <1% and similar in fruit from ZRMS and grower plots (Table 9 & 10). Pest incidence was mainly low and similar in ZRMS and grower plots (Table 11). The incidence of codling moth was above threshold at site 3 but was well controlled post-bloom by the use of codling moth granulosis virus. Damage due to tortrix moth caterpillars was low at harvest (Table 11) in both plots. Use of methoxyfenozide at early green cluster followed by fenoxycarb at pink bud and petal fall gave effective control of this pest early in the season. Woolly aphid incidence increased post-bloom in orchards at site 4 and site 3 and this pest could pose problems for control in ZRMS. However, at site 3 frequent use of sprays of magnesium sulphate appeared to suppress development of the pest.

2006

January and February 2006 were exceptionally dry, such that there was little breakdown of leaf litter in this period. Consequently, there was in general a higher incidence of leaf litter present in apple orchards at bud burst than in the previous two seasons, particularly at site 3. The amount of leaf litter was mainly lower in the ZRMS plots (Table 12) and, as in the previous two seasons, most leaf litter had disappeared at site 2. The weather in April and May was exceptionally favourable for apple scab (Table 2). Scab was not recorded at any of the sites in May and remained similar and at a low incidence at sites 1, 3 and 4. However, at site 2 by July a high incidence of scab was recorded in both ZRMS plots and the grower plot. Fruit set was also poor in the orchard such that additional scab control was not applied to the ZRMS plot whilst being continued in the grower plot. At harvest >50% of the fruit in ZRMS plot were scabbed, compared to 6% in the grower plot. As scab control at the other three sites in the ZRMS plots was satisfactory it is difficult to explain why the strategy failed at site 2, especially as this site had very little leaf litter present at bud burst and had had

the lowest scab incidence in previous years. The control of scab on the whole farm at site 2 was very poor in 2006 due to extended gaps in the spray schedule enforced by the exceptional rain fall in May. The trial orchard was adjacent to an apple orchard of cv. 'Jonagold' which is more susceptible to scab and in which there was a high incidence of leaf litter. It is likely that the scab in the trial orchard had spread from the adjacent Jonagold orchard during exceptionally favourable conditions in May. Weather conditions in September and October were warm and wet, favouring continued tree growth and late scab development (Table 2 & Table 12) giving a high potential scab carryover into 2007. Primary mildew incidence was lower at the four sites than in the previous two seasons, but still at a moderate level at sites 2 and 4 (Table 13). The incidence of secondary mildew was again high throughout the season at these two sites and not contained by sprays of reduced dose sulphur. Only fruit from site 1 was stored and only until November 2006. Rot incidence recorded was very low <0.2% (Table 14) and similar in fruit from both plots. Pest damage to fruit at harvest was higher than in previous years at all sites (Table 15). At site 1 and 4 pest damage was greater in the ZRMS plots than in the grower plots; at site 3, greater pest damage was recorded in the grower plot and at site 2 pest damage was similar in both plots. There was no consistent reason for the damage at any site. At site 4 where the highest pest damage was recorded in the ZRMS plot, much of this was due to caterpillars (Codling, tortrix and early caterpillar) and earwigs. The incidence of codling moth was above threshold at sites 3 and 4 but was well controlled post bloom by the use of codling moth granulosis virus at site 3. Control of codling moth with granulosis virus was less successful at site 4.

Pesticide residues

Multi-residue screen with additional analyses for specific pesticides (dithianon, methoxyfenozide, thiacloprid, flonicamid, carbendazim) was conducted on fruit samples taken from both plots. No residues were detected in the samples taken from ZRMS plots at sites 2 and 4 in any of the 3 years. Tolylfluanid was detected in ZRMS plot at site 1 in 2004 when additional treatments for scab were applied. Various pesticide residues were detected in ZRMS fruit in 2004 and 2005 at site 4. Investigations indicated that the protocol supplied for the trial had not been followed and conventional pesticide treatments applied post-bloom in 2004 and 2005. The protocol was strictly adhered to in 2006 and no residues were detected in apple samples analysed in 2006. Various pesticide residues were detected in fruit from the grower plots but none above the MRL (Table 16).

Economics

Most additional labour inputs noted by the participating growers were associated with the trial rather than the system. Additional monitoring is needed particularly at petal fall when searches for apple scab are important. Pesticide costs are usually lower by around £100 per hectare, because of the use of sulphur post bloom. Insecticide costs are generally higher because of the more intensive insecticide use pre-bloom, the use of more selective products rather than the broad spectrum organophosphate insecticide chlorpyrifos and additional aphicide used in October. However differences in the cost of insecticides between the ZRMS system and the conventional system are declining as the use of selective insecticides in conventional system is increasing.

Conclusions

- In general. scab control in the ZRMS was acceptable and as good as in the grower plots. Where scab occurred at higher incidence it was not attributable to the ZRMS approach. Overwintering leaf litter of 'Cox' and 'Gala' tends to degrade fairly rapidly over the winter such that little remains by the following spring (Berrie, 2006). However, overwintering leaves of 'Bramley' and 'Jonagold' degrade more slowly and could still be a source of scab inoculum after blossom, particularly following a dry spring. Potentially the ZRMS could be more challenging on these varieties. Studies under objective 5 of this project have examined the possibility of eliminating overwintering scab
- Control of powdery mildew was the main disease problem encountered. At the start of the trial the incidence of primary mildew in three of the four sites was moderate to high resulting in a high incidence of secondary mildew. In such circumstances reduced dose sulphur gave poor control. In the experimental plots at EMR control of powdery mildew by reduced dose sulphur sprays was adequate and did not result in an increased incidence of primary mildew in the first three years of the trial. However in these plots the incidence of primary mildew was very low and reduced dose sulphur gave sufficient control to maintain the mildew at a low level. It is clear that ZRMS system is not suitable for orchards with a moderate to high incidence of primary mildew. Before adopting the system in such orchards the control of powdery mildew needs to be restored
- In the trial sites control of storage rots was similar in both plots, but none of the orchards were stored long term for the system to be thoroughly tested
- Pest control in the 4 orchard sites was variable and worst in 2006. The cause of the damage to fruit at harvest varied between sites and could not clearly be attributed to the principles of the ZRMS, but more likely to seasonal variation in pest incidence, choice of insecticide and insecticide timing
- The use of an aphicide post harvest in October to control rosy apple aphid returning to apple trees to lay eggs appeared to be successful as rosy apple aphid was not a problem in the ZRMS plots at any of the four sites.
- Granulosis virus (CGV) appeared to give effective control of codling moth in all three years at site 3 where the incidence was the highest and control was better than that achieved in the grower plots where conventional insecticides were used. Control at site 4 in 2006 was less effective compared to the grower plot. Reasons for this are not clear. CGV is not as fast acting as conventional insecticides in killing codling moth larvae, leading to skin blemishes on the fruit (stings). However, this did not appear to be a problem. CGV is not yet approved for use on apples in the UK and was used under an experimental approval in these trials. Registration is currently underway. The product when approved is likely to be more expensive than the conventional alternatives.

The key factors in the ZRM system are dormant and early season pest and disease control and pest and disease monitoring. However, it is important to remember that the system is not fixed, but is presented as a viable system with the minimal risk of detectable residues in fruit at harvest. It is vital to assess pest and disease incidence at petal fall in order to decide whether to proceed and to continue monitoring during the summer so that likely pest or disease problems are detected early and control methods considered.

Objective 1b. Desk study on pesticide use post bloom on apple and the risk of reportable residues

In this desk study, for each major pest and disease likely to be a problem post-bloom on apple in the UK, the risks of not using conventional pesticides for their control and the risk of significant losses occurring have been considered. Alternative treatments which avoid the use of pesticides that leave residues have been identified. Conventional pesticides generally used for their control have been considered and guidelines provided for their use post bloom to avoid residues in fruit at harvest. Pesticides that frequently result in residues in fruit have been identified from the UK pesticide residue survey. Ways to avoid the occurrence of residues above reporting limits have been identified based on guidance given by Agrochemical companies and a leading producer cooperative.

The occurrence of pesticide residues in UK produced apples

The Pesticides Residues Committee conducts regular retail surveillance of pesticide residues in samples of fresh produce. The results are published quarterly and are available on the PSD website. Apples, an important dietary constituent, are surveyed every year. In 2003 and 2005 for instance, 82 and 30 samples, respectively, of UK produced apples were taken from retail outlets and analysed for residues of >100 pesticides. In 2003, 71% of the samples contained residues above the reporting limits (5.3% had two residues, 5.0% had 3 residues, 3% had 4 residues and 1% had 5 residues). A number of pesticides are found at contamination above the accepted reporting limits in UK produced fruit (see Tables 17 and 18 for 2003 and 2005 respectively). In all cases, these reported residues are well within accepted legal limits and such fruit is safe to be consumed. Amounts below the reporting limit are regarded as zero, even though trace amounts might be present which could be measured by a more sensitive method of analysis than the standard methods.

The results showed a substantive reduction in the incidence of residues from post-harvest treatments to fruit compared to earlier surveys, but an increase in the incidence of chlorpyrifos residues. In both years, the highest incidence of reportable residues was for chlorpyrifos, followed by captan and carbendazim. Note that the reporting limit for captan was reduced from 0.05 mg/kg in 2003 to 0.02 mg/kg in 2005. Chlorpyrifos is used for pest control and it is suspected that most residues were the result of applications targeted the second generation attack of codling moth in late July and August. Captan and carbendazim treatments are applied against storage rots either as sprays immediately pre harvest or as drenches post harvest.

Risks of not treating with pesticides between petal fall and harvest

Scab

The 6-year trial in Wiseman orchard at EMR showed that, providing the management practices ensure that overwintering scab inoculum was very low and excellent scab control was achieved early in the season by a thorough, targeted fungicide programme, then scab will not pose a significant risk even if no protection with scab fungicides is applied post blossom.

Mildew

Mildew risk occurs throughout the season, as long as shoots are growing. Our work has demonstrated that providing the levels of primary inoculum are very low, and that a thorough early season programme is applied up to petal fall, then adequate control of mildew can be achieved with a low dose programme of sulphur sprays during fruit development. Sulphur occurs naturally in plant tissue and thus has a very high reporting limit (5 mg/kg) and no MRL. Where high levels of primary inoculum are present and the risk of mildew infection is very high, then use of a programme of conventional fungicides between petal fall and harvest will be essential.

Storage rots

A high proportion of the residues detected above reporting limits were caused by fungicide treatments (carbendazim, captan) for post harvest rots, either as sprays applied in the orchard shortly before harvest, or post- harvest drenches to the harvested fruit in bins. Any such treatment inevitably results in residues so such treatments are not compatible with zero residue apple production. Our work in this and its predecessor project have clearly demonstrated that rot risk assessment coupled with cultural control methods and applications of fungicides at blossom and petal fall can give good control of storage rots without the use of late fungicide treatments. It is unlikely that biocontrol agents that mainly control wound pathogens such as *Penicillium* and *Botrytis* will be of use in controlling apple rots in the UK as most of these rots are the result of orchard infections pre harvest.

Codling moth

Codling moth is a highly damaging pest of apples which attacks the fruit directly causing serious losses at low population densities. A high standard of control is essential. Climate change has resulted in two generations of the moth occurring in most years, one in May - June, the second in July - August shortly before harvest. The second generation attack is particularly damaging because the fruit is more susceptible. Use of chlorpyrifos to control the second generation attack is the cause of the high occurrence of reportable residues in the pesticide residues surveillance (Tables 17 and 18). Several multiple retailers are now requiring that chlorpyrifos is not used post-blossom

Codling moth can be controlled by a spray programme of the codling moth granulovirus, which received approval in the UK in May 2007. This is a vital tool for zero residue apple production. However, the virus alone is only likely to give adequate control where populations are initially low. Where populations are higher, use of granulovirus could be combined with pheromone mating disruption (e.g. the Approved Exosex system) though this is costly. The combined use of these two approaches has not been investigated. Alternatively, Insect Growth Regulator (IGR) insecticides (methoxyfenozide, indoxacarb, fenoxycarb) could be used against the first generation in May-June. Such a strategy would also reduce the risk of strains of codling moth resistant to the granulovirus developing.

Other caterpillar pests

We have demonstrated that early season use of highly effective IGRs such as fenoxycarb and methoxyfenozide gives excellent control of winter and tortrix moths. If adequate control is not achieved then this can be supplemented by sprays of *Bacillus thuringiensis* during fruit development, timed according to pheromone trap catches.

Rosy apple aphid
Work under this project has demonstrated that excellent control of rosy apple aphid can be achieved by early season and post harvest use of insecticides (e.g. thiacloprid, pirimicarb, flonicamid). Use of these insecticides during fruit development may not necessarily result in residues in harvested fruit particularly if application is confined to the early part of the fruit development period (see below).

Woolly aphid
Control of woolly aphid is a weak point in the EMR strategy of zero residues apple production. The pest did not occur in the field trials done in this project and possible control approaches have not been tested. The logical control strategy is to inspect orchards and determine the incidence of the pest before blossom, then where the pest is present to reduce populations to the lowest level possible by early season use of flonicamid. Growers claim some success with high dose sprays of magnesium sulphate. Earwigs and the parasitic wasp *Aphelinus mali* are important natural regulators of woolly aphid populations and these should be conserved and treatments with broad-spectrum insecticides harmful to them avoided.

Other aphids
Apple grass aphid is readily controlled by early season or post harvest aphicide sprays. Green apple aphid migrations into orchards can occur during fruit development. In a zero residue production system these could not be controlled by use of aphicides as they usually occur in mid and late summer close to harvest. The only option would be physical removal.

Mussel scale
This pest is a potentially serious problem if pesticides are not used between petal fall and harvest. Current work for the HDC has shown that the mussel scale has a protracted migration period starting during or towards the end of blossom and lasting 3-4 weeks. It is unlikely that a single spray of a suitable insecticide (e.g. thiacloprid) at petal fall would not be sufficiently persistent to control the pest over the entire migration period. Use of an insecticide spray up to 4 weeks after petal fall is likely to be needed. If the correct insecticide is chosen, such applications may not result in a significant risk of reportable residues.

Mite pests
Extensive work has shown that fruit tree red spider mite and apple rust mite are rarely significant problems providing the orchard predatory mite *Typhlodromus pyri* is conserved.

Superficial scald
Bramley fruit in particular, is susceptible to the physiological disorder superficial scald and historically most harvested fruit at risk was drenched post-harvest in an anti-oxidant (diphenylamine or ethoxyquin). Strictly speaking, these materials are classed as food additives, not pesticides, but such treatment inevitably results in reportable residues. Surveillance monitoring by the Pesticides Residues Committee has found a significant frequency of such residues in the past, though these materials have not

been consistently analysed for. However, a successful alternative treatment has been instigated by the industry which precludes the need for post-harvest treatment with anti-oxidants. Fruits at risk from superficial scald are stored in CA storage (5% CO_2, 1%O_2) and treated in store with 1-methylcyclopropene, a gas which inhibits ethylene production and which does not leave residues.

Harvest intervals that minimise the risk of residues above reporting limits

Statutory harvest intervals are designed to ensure that residues are below MRLs. Increased intervals are likely to be required to ensure that residues are below reporting limits. Residue decline studies for registration purposes are conducted with the intention of determining statutory harvest intervals. Often, the interval required to eliminate reportable limits is not explored and there is no direct data available. Theoretically, it should be possible to extrapolate such intervals from existing data. However, the data is evidently often highly variable and such extrapolations outside the data range are subject to large errors. Furthermore, the data is confidential to the parent company of the pesticide.

In 2005, a letter was written to the seven parent companies of 12 of the active ingredients most commonly used in apple production during fruit development, asking for a recommendation on how the harvest interval should be extended to minimise the risk of a a reportable residue. A mixed response was obtained, but a helpful recommendation was obtained for some active ingredients, as summarised in Table 19. An alternative way of estimating harvest intervals for zero residues is to examine the data from routine pesticides residues monitoring conducted by producer cooperatives and to marry it in with grower application records. A leading producer cooperative was asked to examine residue data and attendant pesticide application records and indicate what interval would be needed to greatly reduce the incidence, ideally to eliminate, reportable residues. The recommendations made are summarised in Table 20.

Conclusions

Pesticide use in apple can largely be avoided during fruit development, greatly reducing the risk of the occurrence of reportable residues. Furthermore, several pesticides present only a very low risk of reportable residues even if they are used during fruit development. However, captan and dithiocarbamates appear to pose a risk whenever they are used. Use of these products would need to be avoided to totally eliminate reportable residues, though the risk from small numbers of early season applications is probably low. Good alternative methods have been developed for control of storage rots and the post harvest physiological disorder superficial scald and late season pesticide use is no longer required for these problems. The recent registration of codling moth granulovirus provides a vital solution for codling moth but this biocontrol agent will need to be supplemented with other approaches, possibly including use of pesticides against the first generation in May-June, in orchards where populations are high. Insecticide use during the early stages of fruit development may also be required for woolly aphid and mussel scale.

Many of the above practices have recently been implemented in commercial apple production in the UK and it is expected that the incidence of reportable residues will fall sharply.

Objective 2. Long-term effects of zero residue management system

The plan was to continue the large plot orchard trial established in Wiseman's orchard at EMR in 2001 to enable the long term effects of the ZRMS on pests, beneficials, disease and microflora populations and on fruit quality to be evaluated to ensure the system is sustainable.

Material and methods

The trial was conducted on established plots of disease susceptible apples (Cox, Gala, Fiesta) and scab resistant apples (Saturn, Ahra). The variety Discovery was common to both sets of plots. Each plot consisted of 144 trees on M9 rootstock and was separated from adjacent plots by alder windbreaks. In these plots the pest and disease control achieved following a routine conventional pesticide programme (CS/CR) was compared to that achieved following the zero residue management system (MS/MR). Untreated plots of disease susceptible and resistant varieties were included. Each treatment was replicated twice in a randomised block design. Details of the experimental design are given in Table 21 and of the ZRMS (MS/MR) in Table 1. The main features of the ZRMS are that use of conventional pesticides was restricted to the period up to petal fall and after harvest and that only biocontrol agents or sulphur were used during apple development. Treatments applied during the dormant season to minimise overwintering inoculum are an essential component of the ZRM system.

In the ZRM system, pest control was based on IPM monitoring including pheromone traps and treatment with the pesticides given in Table 1. Disease control pre-bloom was based on the use of conventional fungicides (Table 1) in conjunction with weather forecasts and key-stage system to determine frequency of spraying (Berrie & Xu). The final conventional pesticides were applied at petal fall. Fungicides for scab control were applied to MR plots only at bud burst and petal fall (key stages). Fungicides for mildew control in MR plots were applied at other times up to petal fall. Control of storage rots was based on cultural measures such as inoculum removal and mulching, to limit exposure of fruit to soil, selective picking, use of carbendazim at blossom and petal fall and the use of rot risk assessment (Cross & Berrie, 2001) to determine suitability for long-term storage (Table 1). In the conventional control (CS/CR) pesticide inputs were applied from bud burst to harvest as necessary based on monitoring and standard commercial practice as documented in the Defra Apple Best Practice guide (Cross & Berrie, 2001). As in MR plots scab fungicides were only applied in CR plots at bud burst and petal fall. Fungicides for mildew control were applied at other times. Control of storage rots was based on use of captan or tolylfluanid applied 28 and 14 days pre-harvest. No pest or disease controls were applied to untreated plots. Treatments for nutrients (including calcium sprays) and for weed control were applied to all plots.

Pests and diseases were assessed using standard methods (Cross & Berrie, 1995) at standard IPM timings of green cluster/pink bud, petal fall and at monthly intervals to harvest in order to make decisions on pesticide use and to assess the success of the management systems. At harvest records of fruit yield, quality (russet) and pest and disease incidence on the fruit were taken. Russet was assessed on a random sample of 100 apples taken at harvest using a key of 0-4 where 0 = no russet, 1 = russet around stalk and calyx, 2 = russet around as 1 but also on fruit

cheek, 3 = rough russet and 4 = rough russet and cracking. Fruit in russet categories 0-2 are acceptable in Class 1 grade.

At harvest a random sample of 25 Cox fruit were taken from MS and CS plots and sent to QTS Analytical for analysis for pesticide residues. Analysis was carried out to the limit of detection (LoD) rather than the reporting limit (RL).

At harvest fruit from each treatment (at least one bulk bin of fruit per cv. per plot) was stored in a commercial controlled atmosphere (3.5^0C; 1.25% O_2; < 1% CO_2) store and the incidence of rotting recorded in February or March. During the trial records were kept of timings for cultural, monitoring and other management inputs such that an economic appraisal of the systems could be made.

Results and Discussion

Apple scab

2004 was a high risk scab year with frequent rain at critical times pre-blossom (Table 2), resulting in 56-89% scabbed fruit in untreated plots at harvest (Table 22). Scab incidence on fruit at harvest was <1% in CS and MS plots and no storage scab was observed on fruit post store. The incidence of late scab on leaves sampled from the MS plots in October was very low indicating low scab inoculum in the post blossom period compared to the CS and US plots. A low incidence of scab was recorded on cv. Ahra (Vf scab resistant) trees in May, but no scab was recorded on the fruit at harvest (Tables 22 and 23). The weather conditions pre petal fall in 2005 were relatively drier (Table 2) compared to 2004 and consequently the scab risk was lower with 23-70% scabbed fruit in untreated plots at harvest, compared to <1% in MS plots and 0.3-1.2% in CS plots. A low incidence of scab (<1%) was recorded on cv. Ahra fruit at harvest. The wet weather and high humidity recorded pre harvest were very favourable for scab infection on the fruit. After six months in store <1% storage scab was recorded on cv. Gala from MS plots compared to 2% and 70% recorded on stored Gala from conventional and untreated plots respectively. This result demonstrates that the incidence of scab inoculum in MS plots was very low, compared to CS plots where the incidence of storage scab was higher despite the late sprays applied for scab control. In 2006 January to March was exceptionally dry with little opportunity for leaf litter breakdown to occur so that leaf litter incidence in April and hence the risk of disease-carryover was higher than in the previous years in most of the plots. Weather conditions pre-, during and post-petal fall (April-May Table 23) were wet and exceptionally favourable for scab. Bud burst was around the end of March, about two weeks later than 2004 and 2005, meaning that the trees were at an critical early stage of development during the wet weather, also increasing the risk of scab infection. The wet weather in May also disrupted the spray schedule leaving extended gaps in the programme. The combination of all these factors resulted in a higher incidence of scab (0.2-5.8% scabbed fruit at harvest) in the managed plots (Table 24) than had been recorded in the previous five years, but still commercially acceptable and similar to that recorded in conventionally sprayed plots (0.7-6.2% scabbed fruit at harvest). Scab incidence on fruit at harvest in the untreated plots ranged from 24-92%. The high risk scab season was also reflected in the higher incidence of scab recorded on cv. Discovery, compared to 2004 and 2005, particularly in the resistant cultivar plots where scab sprays were only applied at bud burst and petal fall. Weather conditions before harvest were again favourable for late scab infection on fruit. The incidence of fruit assessed after six months in store

ranged from 0.2-4.0 % scabbed fruit from MS plots compared to 0.1-6.1% on fruit from CS plots and 0.04-68% on fruit from untreated plots. A very low incidence of storage scab was also recorded on Saturn (0.04% scabbed fruit).The weather conditions in October and November delayed leaf fall and encouraged the development of late leaf scab, resulting in high incidence recorded on leaves from all treatments sampled in October and indicating a potentially high inoculum carryover for 2007.

The scab control achieved in the ZRMS susceptible variety plots has been as good as or better than that in conventional plots, even in seasons exceptionally favourable to scab, suggesting that the strategy used has worked well. One of the concerns of growers has been that this type of approach would result in a build-up of inoculum over several seasons and a gradual decline in scab control. The incidence of scab on apple cv. Gala (most scab susceptible cultivar) at harvest over the six years of the trial is shown in Table 25. The incidence varies from year to year but there is on obvious build up of scab from 2001 to 2006. Variation in scab incidence is more likely related to seasonal weather conditions.

Powdery mildew

The incidence of primary and secondary mildew in the MS /MR plots in each of the years (Tables 26-28), was similar to that in the CS / CR plots. The incidence of secondary mildew did not exceed 20% of shoots mildewed. In contrast the incidence of primary mildew in the untreated plots was moderate to high, especially on cv. Ahra where 20% or more blossoms or emerging shoots were mildewed. Over the season the incidence of secondary mildew on shoots steadily increased reaching almost 100% shoots mildewed by June or July on untreated plots. The primary mildew in MS / MR plots at the start of 2002, 2003, 2004, 2005 and 2006 was negligible, indicating that the system was not resulting in a build up of primary mildew and similarly secondary mildew recorded in June / July (Table 29) . This demonstrates that, provided the primary mildew incidence in an orchard is low, adequate control can be achieved by the use of sulphur at reduced dose (30-50% of label recommendation).

Other orchard diseases

Phoma leaf spot and sooty blotch were present in most plots, especially the untreated but so far only at a low incidence.

Storage rots

The rot risk assessed in the plots pre-harvest each year is given in Table 30. There was a high risk of brown rot (*Monilinia fructigena*) determined in each year and brown rot was the main cause of losses due to rots in store in most seasons, particularly on cv. Cox (Tables 31-33). The high incidence of brown rot was primarily due to the presence of cv Discovery in each plot. Discovery is harvested in August. Unpicked or fallen fruit are rapidly colonised by *M fructigena* and provide a large source of spores for infecting the later picked fruit. In the MS / MR plots all Discovery, including fallen fruit, were removed from the plot during the harvest to minimise *Monilinia* inoculum.

This combined with selective picking to avoid damaged fruit being stored gave effective control of brown rot. In none of the years was there sufficient rain fall to create a high risk for phytophthora rot and this rot was only recorded at low incidence (Tables 31-33). The lowest incidence of phytophthora rot was always in the MS/MR plots, indicating that selective picking was also a successful method of rot control. Nectria canker was present on the trees, especially Gala and Fiesta in every plot. In 2005 and 2006, the rainfall recorded from blossom to harvest indicated a moderate and high nectria risk respectively. There was a high incidence of Nectria rot in fruit from untreated plots in both 2005 and 2006 (Tables 31-33). Carbendazim applied at late bloom to MS/MR plots and removal of young cankers in the summer reduced the incidence of Nectria rot in store compared to the other treatments. Fungicide treatments applied to the CS/CR plots were also effective in controlling storage rots.

In general, the incidence of rots recorded post store in the MS/MR have been less or similar to that in CS/ CR plots which have received pre-harvest applications of captan or tolylfluanid. This indicates that the strategy for control of storage rot in ZRMS is effective. The losses due to rots recorded in this trial were high compared to commercial practice. However, given the rot risk assessment result, none of the fruit was suitable for storage until March in any of the years and was only stored until March to enable evaluation of the system. Similarly, the plots have a high proportion of low hanging fruit which increases the phytophthora rot risk. In practice such low branches could be removed to reduce the risk, but are retained here for trials purposes. Early harvested cultivars such as Discovery are also best avoided as pollinators for later harvested fruit destined for storage.

Pests

The total damage recorded on fruit at harvest for each of the three years is shown in Tables 34-36. Damage due to pests in fruit from untreated plots varied from 48-60% in 2005 to nearly 90% of fruit in 2006. Highest incidence of pest damage over the three years was also recorded on the fruit from commercial orchards in 2006. Reasons for the higher incidence of pest damage in 2006 are not clear, but most likely related to the hot dry summer and the fact that the wet conditions around blossom and petal fall in May probably delayed insecticide application at a critical timing for control. Rhynchites weevil (*Coenorhinus aequatus*) was a significant problem in untreated plots in all years but was well controlled by thiacloprid applied to the treated plots at petal fall. Other pests causing damage to fruit at critical levels in untreated plots included Totrix moth (*Adoxophes orana, Archips podana*) and Rosy apple aphid (*Dysaphis plantaginea*). In all three years pre blossom and petal fall treatments applied to MS/ MR plots (methoxyfenozide, fenoxycarb) and CS/CR plots (chlorpyrifos, fenoxycarb) gave good control of tortrix moth early in the season such that pheromone trap catches in summer never reached threshold and no further treatments were required. The incidence of rosy apple aphid varied with high numbers of damaged fruit in untreated plots in 2004 and 2006, but around 1-2% damaged fruit in 2005. In all three years rosy apple aphid was well controlled in MS/MR plots by a combination of post-harvest treatment with pirimicarb in October to control adult aphids returning to the apple trees to oviposit, and use of thiacloprid pre-blossom and petal-fall in spring. Similar control was achieved in CS/CR plots using chlorpyrifos pre-blossom and thiacloprid at petal fall. The numbers of rosy apple aphid recorded on MS/MR plots in spring following the autumn treatment was generally very low so two application of thiacloprid may not have been required if

aphids were the only target. However, thiacloprid is also applied for control of other pests such as rhynchites weevil and sawfly (*Hoplocampa testudinea*). In 2004 and 2005 pheromone trap catches of codling moth (*Cydia pomonella*) did not reach threshold and no treatments were applied post blossom. Fruit damaged by codling moth was however starting to increase in untreated plots – 4-4.5% in 2004 and 5-6% in 2005 (Tables 34 and 35). In 2007, pheromone trap catches exceeded threshold and codling moth granulosis virus (CERI 020, Certis Ltd) was applied on three occasions for control. Fruit damage due to codling moth at harvest was similar in MS/MR plots to that in CS/CR plots where methoxyfenozide had been used (Table 36). Other pests recorded in untreated plots included winter moth (*Operphtera brumata*), apple sucker (Psylla mali), green apple aphid (*Aphis pomi*), capsid (*Lygocoris pabulinus, Lygus rugulipennis*) and apple leaf midge (*Dasineura mali*).

Economics

A summary of the fungicide programmes applied is given in tables 37-39. In all three seasons there were savings in the cost of fungicide sprays in managed plots of around £100/hectare, but these were offset by the higher costs of the selective insecticides used (Tables 40-42) resulting in most cases in similar costs in managed and conventional programmes. CERI 020 (codling moth granulosis virus) was supplied free of charge for the trial by Certis Ltd and at present only has trials clearance for use in the UK so the cost of this product is not known. The product is currently undergoing registration in the UK. Additional costs incurred included monitoring of pest and disease incidence for decision making of around 30 mins per plot per 2 weeks plus removal of *Nectria* canker and brown rot inoculum, which was done every 10-14 days from petal fall to harvest, again at 30 mins per plot. Routine monitoring for pest and disease would also be done in the conventional system, but possibly with fewer visits.

Fruit quality

Yield data was recorded for each variety and each plot. Yield varied considerably between season, cultivar and treatment so it is difficult to draw any robust conclusions from it. The data has not been included in the report. Russet data is shown in Tables 42-45 as percentage fruit in Class 1. The russet score varied between cultivars and season with the worst russet score in 2005 (Table 44) and on the cvs Discovery and Ahra. The lowest percentage of fruit in Class 1 was recorded in untreated plots, particularly of varieties Cox, Ahra and Discovery. This was most likely due to the high incidence of mildew recorded in these plots. Ahra is particularly susceptible to mildew and russet present on the fruit in the untreated plots is typical of that caused by mildew. The use of sulphur post bloom in MS and MR plots appears to have had no effect on fruit finish. The fruit quality of Discovery was poor in each year with no consistent pattern related to treatments. The high russet incidence is most probably related to weather conditions in particular the high temperatures and erratic water supply in summer.

Pesticide residues

Residue analysis for all pesticides used in the trial plots was carried out each year by QTS Analytical, based at EMR. Residues were below the limit of detection in fruit from MS plots in all of the three years (Table 16). In 2004, residues of tolylfluanid and penconazole were detected in fruit from CS plots, though not above the MRL. A residue of tolylfluanid (Elvaron Multi) was not unexpected as it was used pre harvest for control of storage rots. However, the residue of penconazole is more difficult to explain as this chemical was not used on the plots. Bupirimate (Nimrod) was used near harvest for mildew control. No residues were detected on CS plots in 2005 and 2006.

Conclusions

- The zero residue management system used for diseases with the emphasis on dormant season disease control and cultural measures continues to be successful in this experimental system with no obvious build up of scab or powdery mildew inoculum. At the end of the last project (HH2502STF) there were concerns regarding a possible increase in incidence of sooty blotch and the leaf spot considered to be a *Phyllosticta* species. Both these fungi have been recorded in the current project but at this site have not so far increased to damaging levels
- The use of sulphur for mildew control post-bloom did not result in poor fruit finish as feared. However there are concerns about the use of sulphur so it is important to identify an alternative strategy
- The management system employed for control of storage rots appears to have been successful in this experimental system. The storage rots *Botryosphaeria* and *Diaporthe* appear to be increasing in incidence, but this is probably more related to weather conditions than the ZRMS
- The management strategy used for pest control also appears to be successful. The incidence of codling moth which was always been low in the plots, built up to threshold levels in 2006 and codling moth granulosis virus (CGV) gave adequate control. Codling moth is a significant problem in commercial orchards so success of the ZRMS is dependent on the commercial availability of CGV in the UK. The product CERI 020 used in the trial will receive approval in the UK in May 2007. Other potential pest problems such as mussel scale (*Lepidosaphes ulmi*) and woolly aphid (*Eriosoma lanigerum*) did not build up in the trial plots, but remain a possible problem for commercial orchards
- The total cost of the pesticide programme was similar in the managed system to that in the conventional, as the additional costs of selective insecticides was offset by savings in fungicide costs. Additional management costs were incurred for pest and disease monitoring, inoculum removal and selective harvesting of fruit. However, market demands mean that these practices are now becoming part of the conventional system for many growers and so in future such costs will not be considered as extra
- None of the pesticides applied to MS/MR plots appeared as detectable residues. There may be concerns in the future about use of captan at petal-fall as this pesticide can be persistent and has been detected in other tests following petal-fall use. Possible alternatives will be tried in future projects

Objective 3. Alternative methods for control of powdery mildew

In the current ZRMS mildew control post blossom relies on applications of reduced dose sulphur. Although this chemical is accepted in organic production there are disadvantages to its use. The plan was to explore alternative methods of control including the use of alternative chemicals and biocontrol agents. Evaluation of surfactants as methods to eliminate mildew overwintering in apple buds and minimise primary mildew in spring was conducted separately with funding from HDC (Berrie, 2006).

Evaluation of biocontrol agents

Material and methods

In early June 2004, two isolates of the mildew hyper-parasite *Ampelomyces quisqualis* (AQ) – isolate B11 a naturally occurring isolate from apple orchards identified under project HH2502STF and AQ10 – a commercially available isolate – were used to inoculate branches in an apple orchard cv. Cox at EMR which had a high incidence of powdery mildew. A spore suspension of each isolate was prepared and applied to run-off to labelled branches, which had previously been dampened with water. Four shoots on each of four trees per isolate were inoculated. The trees were inoculated in the early evening when the humidity was higher and on a day when the forecast was for cooler temperatures with showers for the following two days, to give the hyper-parasite the maximum chance of establishing on the mildew. The primary mildewed blossoms and shoots on the labelled trees were checked for the biocontrol agent in spring 2005.

Results and discussion

It was hoped that AQ isolates would establish on the powdery mildew on the shoots in June and overwinter with the mildew in the buds. However in spring 2005 there was no evidence of either AQ isolate on the inoculated trees. The previous project HH2502STF demonstrated that AQ significantly reduced the rate of increase of powdery mildew on potted apple rootstocks in experiments conducted in CE cabinets where conditions of humidity and temperature were optimal (15^{o}C/75%RH in day; 10^{o}C, 95%RH in night). Even under these ideal conditions the control achieved was only partial. In this experiment the AQ isolates failed to establish on the tree Further experiments were not conducted. There are now other commercially available hyper-parasites of powdery mildew (eg *Verticillium leucanii* as Vertalec or Mycotal or *Pseudozyma flocculosa* as Sporodex) which are reported to be more effective and may be worth evaluating in a future project.

Evaluation of alternative chemicals

Materials and methods

In 2004, in a small plot orchard trial at EMR on cv. Cox the efficacy of potassium bicarbonate alone, or in combination with sulphur or Farmfos (potassium phosphate (Farm-Fos 44), supplied by Farmfos Ltd, Herefordshire) in controlling secondary mildew was compared with that of Farmfos and Crop life (citrus and coconut extract). Sulphur treated and an untreated plots were included as controls (Table 46). Each

plot consisted of four trees and treatments were replicated four times in a randomised block design. Treatments were applied on three occasions between early June and early July using a self-propelled air-assisted Solo mini sprayer at 500L/ha.The incidence of secondary mildew was assessed on the middle two trees of each plot as the percentage of mildewed leaves in the top five youngest leaves on each of ten shoots per plot.
In 2005, potassium bicarbonate and Farmfos were further evaluated for their efficacy in controlling secondary mildew in a large plot orchard trial at EMR on cv. Cox. Sulphur treated and untreated plots were included as controls (Table 47). Each treatment was replicated twice and applied every 10 days from early June to late July using a tractor trailed orchard air blast sprayer. The incidence of secondary mildew was assessed as above on five shoots on each of five trees per plot. This trial was largely repeated in 2006 except potassium bicarbonate + Wetcit (citrus extract, supplied by Plant Solutions Ltd, Cobham, Surrey) was included as an additional treatment in place of sulphur (Table 48).

In all years the trial orchard received a standard programme for control of scab, powdery mildew and insect pests up to the start of the trial.

Results and discussion

In 2004, secondary mildew was assessed on three occasions in the small plot trial starting 5 days after the first treatment application. None of the treatments were completely effective in controlling mildew. The incidence of secondary mildew was high reaching almost 100% mildewed leaves on untreated plots by early July. Only sulphur was consistently effective in reducing secondary mildew, but the incidence recorded was more than 70% infected leaves which was commercially unacceptable (Table 46).

In 2005, the incidence of secondary mildew was assessed once at the end of June. The incidence of secondary mildew was again almost 100% mildewed leaves on untreated plots (Table 47). The mildew incidence was reduced on plots treated with sulphur, but was still commercially unacceptable at almost 80% mildewed leaves. No further mildew assessments were possible due to an infestation of apple leaf midge (*Daiyneura mali*) in the shoot tips that effectively stopped shoot growth.

In 2006, the incidence of secondary mildew was assessed on three occasions with the first assessment at the start of the treatment programme (Table 48) when the incidence of mildew was between 42 and 51% mildewed leaves in the plots. Thereafter mildew incidence increased to more than 80% mildewed leaves in the untreated plots, but remained at 42 to 56% mildewed leaves in treated plots indicating that all treatments showed some efficacy in controlling secondary mildew.

In the trials over the 3 years, sulphur was the most consistent in reducing secondary mildew compared to the untreated. Only in 2006 did potassium bicarbonate and Farmfos show consistent efficacy in controlling mildew, possibly because the mildew incidence at the start of the trial was lower than in the previous years. None of these treatments were however sufficiently effective to be relied upon for mildew control alone, but could be used in a programme with sulphur.

Conclusions

- AQ isolates did not establish on mildewed trees in the orchard trial. This experience combined with that from other trials indicates that AQ is unlikely to be

sufficiently active enough as a biocontrol agent to be relied upon for mildew control

- None of the alternative chemicals evaluated were consistently as effective as sulphur in controlling mildew. However the trials in 2006 did show that both potassium bicarbonate and Farmfos could reduce the incidence of secondary mildew most likely because the mildew incidence at the start of the trial was much lower than in the previous years
- Both potassium bicarbonate and Farmfos have been used in commercial orchards with some success. Therefore they could be used in conjunction with sulphur as part of a programme for mildew control in the ZRMS system post blossom. Most important is ensuring that the incidence of primary mildew remains low.

Objective 4. Entomopathogenic fungi for control of rosy apple aphid

Rosy apple aphid, *Dysaphis plantaginea* (Passerini), is a serious pest of apples in the UK. Whilst there are several entomopathogenic fungi developed for biological control of aphids, their efficacy against the rosy apple aphid (RAA) in the field is unknown. This work evaluated foliar sprays of commercially available formulations of the entomopathogenic fungi, *Beauvaria bassiana* and *Paecilomyces fumosoroseus,* in the field for control of RAA in the spring versus and autumn. Other products, based on the fungus *Verticillium lecanii* (e.g. Vertalec, Mycotal) were disregarded as being too overtly dependant on high humidity to be of use in field conditions.

Control of RAA during Spring 2004 and ant exclusion

Materials and methods

This trial evaluated foliar sprays of commercially available formulations of the entomopathogenic fungi (EPF) *B. bassiana* (BotaniGard 0.25% and Naturalis 0.3%) and *P. fumosoroseus* (PFR 0.1%) in the field for control of RAA in the spring. Eight treatments were applied; 2 x BotaniGard (11.3 % containing 2 x 10^{11} conidia/g 'ES') at 2.0/3.0 kg/ha; 2 x Naturalis (7.16% containing 2.3 x 10^{7} spores/ml) at 2.4-3.6 kg/ha; 2 x PFR at 0.8-1.2 kg/ha; and 2 x untreated controls. The effect of exclusion of ants on the RAA population, and their possible use as a vector to carry EPF to the aphid was also investigated. One of each treatment was ant-excluded by placing sticky banding around the tree-trunk (Oecotak on PVC tape).

A single small plot replicated field experiment was done at EMR apple plots WM132 and WM142 (6 rows cv. Fiesta) untreated with any other pesticide. Sprays were applied with a motorised air assisted backpack sprayer in a water volume of 1 l/tree on 24 and 31 May 2004. Three assessments of RAA populations and the proportions of aphids infected by EPFs were made after the pre spray assessment (21 May) on 7, 10 and 18 June 2004. For each assessment, the number of RAA infested leaves in each marked colony and an estimate of RAA numbers was made.

Results

Intensive application of sprays with a hand lance into individual colonies caused considerable mortality of aphids by physical means but no mycosis was observed in the field. Culturing in the laboratory showed that fungal spores were present on dead aphid bodies but this did not provide evidence that aphid mortality was caused by the EPF applied. No quantitative effects of exclusion of ants were demonstrated.

Autumn sprays in 2004 for RAA control during spring 2005

Materials and methods
The work evaluated foliar sprays of BotaniGard (1.2 kg/ha) and Naturalis (3.4 kg/ha) (B. Bassiana) in the field with and without an oil-based adjuvant (Codacide oil 3 l/ha), including an adjuvant treatment alone. An untreated control was also included at EMR (orchard no. DM153, mainly 'Bramley', with 'Greensleeves' on M9). The treatments were applied with a motorised air assisted backpack sprayer in a water volume of 1.5 l/tree (1000 l/ha) as two foliar sprays (12 and 22 October 2004).

Results
The number of colonies of aphids formed on the trees was counted and identified on 2 June 2005. The populations of aphids that developed were very small (mean = 5 RAA colonies on untreated plots). There were no RAA colonies present on plots where the EPF formulations were used in admixture with the adjuvant oil. Intermediate colony numbers (2-4 colonies) were present on plots where the adjuvant and EPF treatments had been used alone. The numbers of colonies were small and not testable statistically.

Autumn sprays in 2005 for RAA control during spring 2006

Materials and methods
The work evaluated foliar sprays of BotaniGard (*B. bassiana* 3.75 l/ha) in the field for control of RAA in the autumn with and without an oil-based adjuvant (Codacide oil 3.75 l/ha) compared to Calypso (thiacloprid 480g/l at 0.25 l product/ha). An untreated control was included. Two sprays (14 and 27 October) were applied with an air assisted motorised backpack sprayer at a rate of 500 l/ha (0.75 l/tree).

Results
In spring 2006, the number of colonies of RAA formed on the trees were counted. At the pre-spray assessment (26 October 2005) there were no significant differences in the number of RAA colonies between the plots (P=0.154). At the post-spray assessment (2 May 2006) ANOVA on $\log_{10}$ transformed data showed that the Calypso treated trees had significantly fewer RAA colonies (means; BotaniGard+Codacide 0.81, Control 0.91, Calypso 0.31, BotaniGard 0.86) than the other treatments (P <0.001). There were no other significant differences between the treatments.

Spring sprays in 2006 for RAA control during summer 2006

Materials and methods
The plots were re-randomised and foliar sprays of BotaniGard (*B. bassiana* 3.75 l/ha) evaluated in the field for control of RAA in the summer, with and without a rapeseed oil based adjuvant and Calypso and an untreated control (as above). Two sprays (4 and 18 May 2006) were applied with an air assisted motorised backpack sprayer at a rate of 500 l/ha (0.75 l/tree).

Results

On 29 June 2006, the number of RAA colonies formed on two trees per plot were counted. The number of leaves in every RAA colony located was recorded as were the number of aphids infected with fungus. There was no significant difference between the number of aphid infested leaves between any of the treatments (*P* =0.461). It is postulated that the assessment may have been carried out too late and that aphids had already migrated to their secondary host (Plantain). No EMF infected aphids were observed.

Autumn sprays in 2006 for RAA control during spring 2007

Materials and methods
The treatments were the same as the previous trial. Two sprays were applied (3 and 10 October). An attempt was made to apply a third spray, but this was not possible due to earlier than expected freezing weather conditions, unsuitable for the EPF to be effective.

Results
The number of RAA and green apple aphid (*Aphid pomi* - DeGeer), colonies were counted on three trees in each plot in spring 2007. There were no significant differences between the BotaniGard treatments and the untreated control (Fig. 1). Only Calypso significantly reduced the number of green apple aphid colonies (*P* <0.01). Calypso did not reduce significantly the number of RAA colonies (*P* =0.185).

Conclusion
The use of EPFs was not successful in the field and did not appear to be a promising IPM approach for control of RAA and other aphids.

Effects of exclusion or supplementary honey feeding of the common black ant, Lasius niger *(L.), on aphid populations and natural enemies on apple*

Materials and methods
Two replicated experiments were conducted in an unsprayed apple orchard (WM132 and WM142, c. Discovery) at EMR in 2006 to evaluate the effects of the common black ant, *Lasius niger* (L.), on populations of RAA, and green apple aphid. Ants were either excluded from trees by a sticky barrier band round the base of the trunk (experiment 1) or provided with honey baits at the base of the trunk or in the canopy (experiment 2). Trees where ants had free access and trees without artificial baits were provided for experimental controls.

Results
Exclusion of ants resulted in increased populations of predators (Coccinellidae adults and larvae, predatory Heteroptera, Syrphidae larvae, Dermaptera, Neuroptera larvae and Araneae) and rapid decreases in the populations of both aphid species. In comparison, populations of both aphids increased rapidly on control trees where ants had not been excluded and where predator populations were lower. Thus, exclusion of ants greatly reduced crop damage due to both aphid species. Provision of artificial baits, either at the base or in the canopy of the trees, also caused reductions in RAA numbers and their tending ants, but the effects were weaker. The influence on green apple aphid and their tending ants was small, and effects on predators were unclear. On trees where no aphids were present or where aphid numbers were small, ants fed

on the artificial baits allowing aphid colonies, where present, to increase in size. On trees with numerous aphids, ants showed a preference for feeding in aphid colonies and visited the artificial baits in smaller numbers having limited impact on aphid populations.

Conclusion
This study demonstrated that manipulation of ants could provide a valuable tool in apple IPM.

Objective 5. Identify methods to eliminate overwintering scab in Bramley

Elimination of overwintering scab inoculum is one of the key factors in the ZRMS. Bramley leaf litter is slow to degrade, even when treated with urea and often can be found in orchards after blossom suggesting that the ZRM system may be difficult to achieve on cv. Bramley. In the current ZRM system both myclobutanil and urea are used post harvest to disrupt the development of the scab sexual state and encourage leaf rotting. There are concerns that use of myclobutanil in this way may encourage the development of fungicide resistance. The purpose of this study was to identify other fungicides or chemicals that could also disrupt the sexual state development and minimise overwintering inoculum.

Materials and methods

Three separate experiments were conducted between 2004 and 2006 to test the effect of chemicals on formation of scab ascospores. In each experiment urea treated and untreated leaves were included as controls. For each experiment scabby 'Bramley' leaves were collected from orchards at EMR or from an organic orchard at Robertsbridge, East Sussex in early November and stored at 4^{o}C in a fridge until required. In December, aqueous solutions or suspensions of the test chemicals or fungicides were prepared (Table 4). Four replicate nets of 30 leaves of cv Bramley were dipped into each treatment for 30 secs. with stirring to ensure thorough mixing. Four replicate nets were left untreated. Additional nets of untreated scabby Bramley leaves were also retained such that these leaves could be removed at intervals from February onwards to check for stage of ascospore development so that the effect of the treatments could be assessed once the ascospores were mature. The day after treatment the nets of leaves were placed in plastic crates (to exclude earthworms) secured in place by metal pins outside on grass at EMR in a randomised block design and left to overwinter to allow the scab sexual state to develop.

In November 2006, the same treatments were applied as foliar sprays to large orchard plots of cv. Bramley with a high incidence of apple scab using a tractor trailed orchard tunnel sprayer at 500 l/ha. The following day a random sample of 30 scabby leaves were collected from each plot and placed in nets. Three further nets were similarly collected from each plot giving four replicate nets of 30 leaves per orchard treatment. These leaves were stored at 4^{o}C until December when they were similarly overwintered outside on grass as above.

In spring, when monitoring of the 'Bramley' leaves indicated that the ascospores were mature, the netted leaves were collected and the ascospores extracted and counted. The leaves from each net were mashed into small pieces, placed in a flask with distilled water and shaken for 1-2 hours to allow the ascospores to be released from the pseudothecia. The samples were then strained through muslim and then

centrifuged. The supernatant fluid was discarded and the deposit resuspended in water and retained. The numbers of ascospores in each sample were counted on a haemocytometer slide and expressed as ascospores per ml.

Results and discussion

In 2004/05, the numbers of ascospores recovered in the spring assessment was low, even in leaves from untreated plots, suggesting that the assessment was probably conducted after many of the ascospores had been released. In most treatments ascospores were only detected in one or two replicates. Highest numbers of ascospores were found in leaves from untreated plots, but because of the low numbers of ascospores found no real meaningful conclusions can be drawn (Table 49).

In 2005/06, the late winter and spring were exceptionally dry and mature ascospores were not found in the monitoring samples until mid April. High numbers of ascopspores were recorded in leaves from untreated plots (Table 49). All the dip treatments significantly reduced the numbers of ascospores and in almost all treatments ascospores were only found in one of the four replicates.

In 2006/07, weather conditions during the late winter were much wetter than the previous year, such that mature ascospores were present in leaf samples at the end of March. The leaf plots were collected in mid April and ascospore numbers assessed. Numbers of ascospores recorded in the leaf samples from the foliar spray treatments were in general low, particularly in the untreated, so it is difficult to draw any conclusions from the experiment. The highest numbers of ascospores were found in leaves treated with fenbuconazole. A higher number of ascospores were recorded in untreated leaves from the dip treatments. All treatments significantly reduced ascospore numbers apart from those treated with fenbuconazole where numbers of ascospores were similar to that in the untreated (Table 50).

The method used to evaluate treatments is not ideal. Treatments are tested on naturally infected scabby leaves so it is unlikely that all leaves have a similar incidence of scab. Dipping the leaves in the test chemical ensures that a good cover of the test chemical for the purpose of identifying effective treatments but in practice such treatments would be applied to trees as foliar sprays post harvest and spray cover would not be so extensive. In 2006 the addition of the foliar spray experiment should have given an indication of efficacy more related to commercial practice. However, the very low numbers of ascospores recorded in the untreated leaf samples from the orchard spray trial prevented any firm comparison.In the leaf dip experiments in 2005 and 2006 all treatments apart from fenbuconazole reduced numbers of ascospores compared to the untreated and could be used as post-harvest treatments to eliminate or reduce overwintering scab inoculum. It is difficult to explain why in both 2005 and 2006 the highest numbers of ascospores were recorded in leaves treated with fenbuconazole, a triazole, while both tebuconazole and myclobutanil, which are also triazoles both reduced numbers of ascospores. None of the treatments completely eliminated ascospores consistently, but in practice multiple treatments would be applied post-harvest (Table 1).

Conclusions

- In the dip experiments all treatments apart from fenbuconazole reduced numbers of ascospores and could be used as post harvest treatments to reduce or eliminate overwintering scab
- No conclusions could be drawn from the foliar spray experiment

Objective 6a. Long-term effects of the zero pesticide residue strategy on arthropod populations in apple trees compared to a broad-spectrum routine programme and untreated

The plan was to continue the work done in the previous project (HH2502STF) in order to gain longer term data on the effects of pesticides on arthropod biodiversity. Only the objectives and summary are given here. The full report is given in appendix B.

Objectives

The objectives of the study were:

1. To assess of the biodiversity of Coleoptera, Heteroptera, Auchenorhyncha, Neuroptera, Formicidae and Araneae, including an estimation of the total Arthropoda diversity of an experimental apple orchard at EMR.
2. To investigate the effects of different pest management programs (conventional treatment based on routine use of broad-spectrum insecticides, a pest and disease management program based on early spring and post harvest treatments designed to give zero pesticide residue on fruits at harvest and control untreated plots) on the biodiversity, structure and organisation of Coleoptera, Heteroptera, Auchenorhyncha, Neuroptera, Dermaptera, Formicidae and Araneae assemblages and some pest populations.

Summary

The long-term effects of different intensities of pesticide management on the biodiversity of arthropods in an apple orchard ecosystem were studied in the Wiseman IPM experimental orchard at EMR. The arthropod biodiversity in each of the 12 plots of the IPM experiment was estimated in 2001, 2002, 2004 and 2006 (years 1, 2 4 and 6 of the experiment) so that the effects of the different treatments on biodiversity could be compared. This was a continuation of the study started under the previous project for two further sampling years. In the trial, 3 different IPM treatments, ‘Conventional (CONV) = full routine pesticide programme’ (CS/CR), ‘Zero residues (ZERO) = no pesticides between petal fall and harvest’ (MS/MR) and ‘Untreated (UNTR) = no pesticides or other pest management treatments’ (US/UR) were compared in a randomised block design with four replicates. Arthropod groups (Coleoptera, Heteroptera, Auchenorhyncha, Neuroptera, Formicidae and Araneae) representing phytophagous, predatory and benign guilds were quantified in each plot in each of the years using the same regular structured sampling regime with four sampling methods (beat sampling, sweep netting, sticky traps and pitfall traps) from April to September. 83,549 individuals in the Coleoptera, Heteroptera, Auchenorrhyncha and Aranae were collected, counted and sorted into taxa, and then identified to group and species. The data was collated in full in excel data bases and subjected to statistical analysis.

During the four-year study, a total of 8,305 individual spiders (Araneae) of 69 species was collected and identified. 5,958 individuals comprising 51 species were collected in the canopy. Both the CONV and ZERO treatments significantly reduced the total arboreal spider abundance compared to the UNTR plots in all years. Similar tendencies were found in the case of the species richness. 1,412 individuals comprising 41 species were collected in the herb layer. The abundance of the herb layer spiders was significantly higher in the UNTR plots than in the CONV and ZERO plots which were not different. The four year's total abundance decreased by 35.8% and 33.5% of the UNTR plots in the CONV and ZERO treatments respectively. The similar values in the canopy were 44.4% and 45.4% suggesting that the negative effects of the treatments on the spiders were stronger in the canopy. The species richness of herb layer spider assemblages was slightly lower in the CONV plots than in the other two treatments, but the difference was not significant. Thus, the composition of spiders was very similar in the insecticide treated and untreated plots suggesting that the common spider species in the canopies of apple orchards are not agrobionts. The effect of insecticides was especially negative on orchard canopy spiders as the treatments concur with the peak of adults in May, early June. Our results showed that the pesticide treatments affect mainly the females. The juveniles and especially males compensate better for the toxic effects of pesticides probably by higher immigration. As a result, the sex ratio shifts to a male bias in pesticide treated plots. The early season treatments of less harmful pesticides did not result more abundant spider assemblages during the year, both in the canopy and in the herb layer. The substantial differences in the composition of adult and juvenile spider assemblages both in the canopy and in the herb layer suggests significant restructuring in spider assemblages during the season, i.e. different number of offspring, different mortality rates and/or movement between the adult and juvenile habitats in case of different spider species.

Seventy species of Auchenorrhyncha were collected. The methods applied for the collection substantially determined the size and species composition of the samples, the relative abundance of the species and proportion of males. *Empoasca decipiens*, *Edwardsiana rosae, Ribautiana debilis, Eupteryx atropunctata, Zygina flammigera, Edwardsiana crataegi*, *Empoasca vitis* and *Alnetoidia alneti* were common cicada species in the canopy. A species of leafhopper, *Zyginella pulchra* Löw, not previously recorded in the UK, was found in 2001. *Z. pulchra* is the only representative of the genus *Zyginella* in the UK The species is widely distributed in the Palaearctic region, including France, so its discovery in southern England is not surprising. The investigations demonstrated that the ZERO programme and the CONV treatment similarly reduced significantly the number of leafhoppers in the canopy. Males were affected more than the females, with the proportion of the males increasing in the insecticide treatments. Among the species known as apple pests, the treatments had a greater affect on the populations of *E. crataegi* than on *E. rosae* overwintering in intra- and extra-orchard habitats. The effect of pesticide treatments, which were directed to the canopy, on the density of cicadas was less perceptible in the ground herbage layer, but the treatments did modify the structure of these cicada assemblages to some degree.

The proportion of parasitisation in the genus *Edwardsiana* increased significantly in the second half of the season and both the ZERO and CONV treatments reduced the level of parasitism compared to the untreated control. In contrast, in the genus *Empoasca*, the proportion of parasitised specimens was higher

in the first half of the season and there was no difference in parasitisation among the differently treated plots.

A total of 90 species of Heteroptera were recorded. In the canopy layer the abundant species, in decreasing order of their relative abundance, were *Orius vicinus*, *Atractotomus mali*, *Anthocoris nemorum*, *Heterotoma planicornis*, *Phytocoris reuteri*, *Lygus rugulipennis*, *Phytocoris longipennis*, *Palomena prasina*, *Orthotylus marginalis*, *Blepharidopterus angulatus* and *Deraeocoris ruber.* These 11 species comprised at least 80% of the total Heteroptera abundance in the canopy in each apple orchard. The composition of bug communities differed between years and between the plots subject to different insecticide regimes in the experimental orchard at EMR. However, these differences were exceeded by the characteristic differences in species composition and relative abundances between the three different orchards.

Objective 6b. Effect of ZRMS on microbial populations on apple leaves and fruits

The overall plan was to continue the work started in project HH2502STF to gain longer term data on the influence of the weather and the five different pesticide programmes established under objective 2, on the microflora on the leaf and fruit surfaces of apple trees from the Wiseman's orchard plots.

Materials and methods

Sampling and plating technique

All samples were taken from cv. Discovery in each plot as this variety was common to all plots and the same trees sampled on each occasion. Rosette leaves from the plots were sampled in 2004 and 2005 at petal fall, in June (fruitlet) and pre-harvest. In 2006 the plots were sampled only once pre-harvest and fruit as well as leaves were collected. One rosette leaf was removed from each of 10 labelled Discovery trees in each plot. The 10 leaves were then split in half and placed in jars in 100 ml sterile water. For fruit, one fruit was removed from each of 10 trees, peeled and the peelings added to the jars for washing. The samples in water were then shaken for 60 mins at 170 rpm at 24ºC. Five millilitres of the sample washings were then removed from each jar to Eppendorf tubes and 10 µl of this plated out on to plates of MYGP agar (for yeasts), PDA/Rif (for other fungi) and Tryptic Soy agar (for bacteria). Each plate was replicated twice. The washings were also diluted (10^{-2}) and 10 µl of this plated out as above. The remaining 95 ml was retained for DNA extraction. The plates were incubated at 20ºC for 5-10 days and then numbers and types of organisms present recorded with the help of a pictorial key (developed in projects HH2502STF and HH2603STF) containing digital photographs of the upper and lower surface of the microorganisms in culture. These were identified with code numbers.

Genetic methods

The 95ml apple washings described above for plating were further prepared for DNA analyses. Fifty millilitres of the sample washings was centrifuged at 5000 rpm at 10°C for 15 min on the same day as sampling. The supernatant was discarded and the remaining 45 ml of washings added and respun as above. The supernatant was discarded and the remaining pellet suspended in 500 ul of sterile distilled water (SDW) and transferred to Eppendorf tubes. The Eppendorf containing the 500 ul of concentrated sample was freeze thawed three times using liquid nitrogen and water

at 60°C. The sample was then centrifuged at 13000rpm for 3 min. DNA was isolated from 100 μl of the sample using a GFX PCR DNA and Gel Band Purification Kit (Amersham Pharmacia), eluted with 50 μl SDW and stored in clearly labelled tubes at -80°C.

The molecular methods used for characterisation of the microflora changed from those originally proposed. Initially Denaturing Gradient Gel Electrophoresis (DGGE) was chosen as the most suitable method for discriminating PCR products, but this system proved to be impractical, unreliable and gave poor resolution of PCR products. Similarly agarose gels also proved to be unsuitable. A method for analysis of the DNA extracted from leaf or fruit washings was therefore developed using a high resolution, high throughput DNA sequencer (AB1 3100 sequencer). The development of this method is described in the project report for HH2603STF (Berrie, 2005).

Based on experience from project HH2603STF, for prokaryotes the primers PkITSF and PkITSR were used (Fig. 2). These are based on primers ITSF and ITSReub from Cardinale *et al.* (2004). For eukaryotes it was decided to use the primer ITS1F (Fig. 3) (Anderson and Cairney, 2004) which is more suited to fungal templates, to produce fungal-biased species profiles more relevant to the microbial aims of the project (Table 51).

Automated ribosomal intergenic spacer analysis (ARISA) profiling

DNA extracted from leaf or fruit washings from the trees in Wiseman's orchard plots were PCR screened (2.5ul sample in 12.5ul PCRs) for eukaryotes and prokaryotes and run on an ABI 3100 sequencer. GS2500ROX was used as the internal size standard and data were analysed using GENESCAN and GENOTYPER software (Applied Biosystems).

Electropherograms (Figure 4) were scored by eye and the results entered into a spreadsheet for analyses. Tables 52 and 53 show examples from project HH2603STF (Berrie, 2005). Peaks, which represent discrete laser detected PCR products (and therefore a specific species presence), were scored if they were unambiguously distinct above any background noise. The base of each peak can span up to 5 base pairs, so peaks were scored as a particular size if they fell within plus/minus two bases of a modal value consistently seen among the samples. Any peaks found to be present in negative controls involving only PCRed water were excluded.

Results and discussion

The numbers of different types of bacteria, yeasts and other fungi found on plates at the various sampling times from the plots in 2004-2006 are shown in Tables 54-65. The plots were sampled on three occasions in 2004 and 2005 and once only in 2006. Only leaf samples were collected in the first 2 years, whereas both leaves and fruit were sampled on the one occasion in 2006. Sampling times, rain fall in the 7-14 days prior to sampling and fungicide treatments applied in the 2-3 weeks before sampling are shown in Tables 54, 58 and 62. Bacteria and yeasts were coded and recorded mainly according to colony colour and filamentous fungi mainly relying on the key constructed under project HH2502STF. Data for the plate counts from the leaf washings and from the diluted washings have been combined and expressed as numbers of colony forming units (cfu) per ml. Throughout the project all samples

were taken from the cv. Discovery and rosette leaves were sampled on each occasion to reduce variability due to leaf position.

Bacteria

The most commonly occurring types on plates, based on colony colour were cream (Bc), yellow (By), white (Bw) and pink (Bp). Each of the bacterial colour types may represent a number of different species, but it was beyond the scope of this project to identify bacterial species present by conventional plate methods unless they were significantly affected by the treatments applied and therefore of interest. In general Bc and By colour types were found at each sampling time and Bw and Bp less frequently depending on sampling time and year. The numbers of bacteria present were generally very high. In 2004 (Table 55) total numbers of bacteria increased with later sampling on untreated plots (US, UR), possibly related to wetter conditions prior to sampling. However, in 2005 (Table 59) when rain fall prior to each sampling was similar, highest numbers of bacteria were recorded in the August sampling. In 2006 (Table 63) numbers of bacteria on untreated plots (US, UR) were greater on fruit than on leaves. In 2004 at the sampling in May, lowest numbers of bacteria were recorded on plots which had received the highest fungicide inputs (CS, MS). In other samplings there was no obvious consistent effect of treatment on bacteria types or numbers. This is consistent with other studies that have shown bacteria populations to be little affected by pesticides or even increased (Teixido et al, 1999).

Yeasts

For yeasts the most commonly occurring types on plates, based on colony colour, were pink/cream (Ypc), red (Yr) and pink flat slime (Ypfs). White (Yw) and olive/black (Yob) were less frequent and more seasonal. In general in 2004 and 2005 (Tables 56 and 60) numbers of yeasts were lowest in the first samplings around petal fall. Greater numbers of yeasts were found on fruit than on rosette leaves (Table 64). In general there was no consistent effect of pesticide programme on numbers or types of yeast Other studies have similarly reported few effects of pesticides on yeast populations (Teixido *et al.*, 1999).

Filamentous fungi

Up to 33 different colony types of filamentous fungi were recorded on plates from various sampling dates over the three seasons. The most frequently occurring were F47, F46, F43 and Fcfs. Those identified from culture include several species of *Cladosporium* (F7, F8, F46), *Fusarium* sp (F58) and *Penicillium* sp (F41, F47). Numbers of fungi were low at any one sampling time compared to yeasts and bacteria, but there were usually many more types present. The incidence of fungal types did vary with sampling time. Numbers of types appeared to be much more numerous towards August and October (Tables 54, 57, 65). It is well known that fungal activity increases as leaves or flower parts start to senesce and that pollen encourages fungal activity (Fokkema, 1971) so it is surprising that greater numbers were not recorded at petal fall samplings, but rain fall was low in both years at this time. Types of fungi present varied with time of sampling. F46 in 2004 (Table 57) was more numerous at samplings in May and June compared to October, but in 2005 was present in greatest numbers in August than in June and October. Similarly, F12 in 2004 was only recorded in May and June. Numbers of fungi were more numerous on

the fruit than on leaves (Table 65). F46, which was one of the most numerous fungi on the leaves was not recorded on the fruit sampled at the same time. Fcfs was the most commonly found fungus on the fruit. Numbers and types of fungi found were similar to that recorded in these plots in 2002 in project HH2502STF) (Berrie, 2004). In contrast more than double the number of types of fungi (68) were recorded in project HH2603STF. In that project leaf samples were taken from cv. Cox, whereas only cv. Discovery was sampled here. It is not known whether apple variety has any effect on microflora populations. There appeared to be no relationship between treatments applied and types and numbers of fungi recorded. This is surprising as it would be expected that broad spectrum fungicides such as captan to have the greatest effect on numbers of fungi. In previous studies in projects HH2502STF (Berrie, 2004) and HH2603STF (Berrie, 2005) found that filamentous fungi were the most affected by pesticide programmes with significant reductions in numbers and types at many of the sample timings. Other studies have shown that the population of filamentous fungi is generally higher on unsprayed leaves (Teixido *et al.,* 1999).

Molecular methods for assessment of microflora

In this project we hoped to use the protocol for the molecular method developed in project HH2603STF to analyse the leaf or fruit surface washings. In that project the plating techniques, with their known limitations, showed more colony types than identified in the molecular tests. There are several possible reasons why the molecular tests did not perform as well as expected which were addressed in this project. Firstly, the DNA extraction process used may not be extracting all DNA present. The method employed in 2004 and 2005 is a standard technique, but may have needed modification for this type of procedure. An alternative method was tried on samples from leaves and fruit collected in 2006, but proved unsuccessful as no DNA was extracted, hence there are no molecular results for the 2006 data. A second way of improving the molecular analysis was to DNA fingerprint bacterial and fungal types commonly occuring on plates and run them as standards alongside the test samples to marry up the plate data with the genetic or molecular results. This was attempted but the standards failed to PCR despite repeated attempts so could not be included when the test samples were run on the sequencer. The protocol for the molecular method was conducted on the leaf washing samples from 2004 and 2005. However, the traces from the sequencer were too crowded to interpret in any meaningful way without the standards that were planned for inclusion. The samples were re PCRed and rerun on the sequencer but the problems encountered were not resolved, even though the method proved successful when used in project HH2603STF. Reasons for the crowded traces are not clear. It is possible that pollen contamination on the leaf samples could have accounted for the crowded traces but it is difficult to be certain of the cause without thorough sequencing of the traces. As a result of these various problems no molecular analysis results have been generated for the 2004 and 2005 leaf washings.

Using ARISA profiling offers a powerful tool for analysing microbial biodiversity on plant surfaces which is rapid and accurate to within a few base pairs. More development is obviously needed to overcome the various problems encountered in this molecular method but this was outside the resources in this project.

Conclusions

- Bacteria and yeasts were the most numerous microorganisms recorded on plates, but generally restricted to three or four commonly occurring types
- There were differences in types of bacteria, yeasts and other fungi at different times of the season but these were not consistent between years or related to rain all
- Filamentous fungi generally occurred at much lower incidence compared to yeasts and bacteria but were more diverse in types with up to 33 different types recorded on plates during the course of the study
- There was no consistent effect of pesticide programme on the incidence of bacteria, yeasts or other fungi that were recorded on plates
- The molecular method developed for characterising the plant surface microflora requires more development

APPENDIX A

Table 1. Summary of treatments in Zero residue system (ZRMS)

Timing	Pest/Disease target	Treatment
Pre bud burst	Scab/nectria canker	copper oxychloride
Bud burst – petal fall (conventional pesticides)	scab	dithianon captan myclobutanil
	mildew	myclobutanil
	nectria/storage rots	carbendazim
	Tortrix/winter moth	methoxyfenozide
	tortrix	fenoxycarb
	aphids/weevils/sawfly/capsids	thiacloprid
Petal fall – harvest (sulphur, biocontrol or cultural control only)	mildew	sulphur
	codling moth	Granulosis virus
	tortrix	*Bacillus thuringiensis*
	storage rots	Rot risk assessment (Cross & Berrie, 2000) Inoculum removal Selective picking
Post harvest (conventional pesticides)		
September / October	scab/mildew	myclobutanil + captan
October	nectria canker	tebuconazole
October	aphids	pirimicarb
Pre leaf fall	scab	urea
Leaf fall	nectria canker	copper oxychloride tebuconazole

Table 2. Rainfall and rain days recorded at East Malling Research in 2004-2006

Month	2004		2005		2006	
	Rainfall mm	Rain days	Rainfall mm	Rain days	Rainfall mm	Rain days
March	33.0	22	48.0	15	40.4	16
April	52.0	21	49.2	13	70.8	15
May	43.6	13	33.0	18	77.0	20
June	34.8	12	6.2	9	8.4	10
July	44.2	16	39.0	12	11.0	11
August	88.2	19	51.2	10	40.8	22
September	22.4	15	32.6	21	42.0	15

Table 3. Scab incidence as % infected leaf litter, shoots or fruit in 2004 at four commercial trial sites in Kent

Mildew assessment	1 Broadwater Gala		2 Northcourt Cox		3 Mount Ephraim Gala		4 Norham Cox	
	ZRMS	Grower	ZRMS	Grower	ZRMS	Grower	ZRMS	Grower
Leaf litter* 13 April	24.7	30.0	0	1.2	61.7	49.2	28.3	24.7
Whole tree 27 April	0	0	0	0	0	0	0	0
Whole tree 18 May	50	-	0	-	0	-	1 tree	-
Shoots 8 June	-	-	0	-	0	-	0	-
Shoots 17 June	-	-	0	0	0	-	0	0
Shoots 24 June	-	-	0	-	0	-	0	-
Shoots 1 July	-	-	0	-	0	0	0	-
Shoots 8 July	12.5	13.5	0	-	0 (1 apple)	-	0	-
Shoots 20 July	-	-	0	-	0	-	-	-
Shoots 6 August	2.5	1.5	-	-	-	-	-	-
Shoots 23 August	-	-	0	0	1.5	2.5	0	0
Fruit harvest September	9.6	4.6	0.1	0	0.4	0.1	0	0.1

* % of sample points where leaves present

Table 4. Powdery mildew incidence as % infected blossoms or shoots 2004 at four commercial trial sites in Kent

Mildew assessment	1 Broadwater Gala		2 Northcourt Cox		3 Mount Ephraim Gala		4 Norham Cox	
	ZRMS	Grower	ZRMS	Grower	ZRMS	Grower	ZRMS	Grower
Primary blossom April	0	0	2.4	1.6	0.5	0.5	0.6	0.7
Primary veg May	Very low	Very low	High	High	High	High	Moderate	Moderate
18 May	0		0		14.0		8.0	
8 June	6.0		75.0		70.0		22.0	
15 June							22.0	
17 June	10.0		74.5	44.5	66.0		27.5	38.5
24 June	12.0		40.0		32.0		14.0	
1 July			36.0		71.0	38.5	22.0	
8 July	30.5	31.5	42.0		66.0		28.0	
20 July					86.0		20.0	
6 August	20.5	23.5	58.0					
23 August			64.5	33.0	68.0	40.5	7.5	12.0

Table 5. **Incidence as % infected fruit of post-harvest rots in Gala stored until December 2004 or February 2005 from two commercial sites in Kent**

Storage rot	1 Broadwater Gala December 2004		3 Mount Ephraim Gala February 2005	
	ZRMS	Grower	ZRMS	Grower
Brown rot	0.08	0.08	2.2	2.7
Nectria	0.06	0.08	1.4	0.8
Botrytis	0.04	0.03	0.1	0.09
Penicillium	0.01	0.02	0.05	0.09
Gloeosporium	0	0	0.01	0
Other	0	0	0.01	0.03
Total losses due to rots	**0.19**	**0.21**	**3.8**	**3.7**

Table 6. **Pest damage to fruit recorded as % damaged fruit at harvest 2004 at four commercial trial sites**

Pest	1 Broadwater Gala		2 Northcourt Cox		3 Mount Ephraim Gala		4 Norham Cox	
	ZRMS	Grower	ZRMS	Grower	ZRMS	Grower	ZRMS	Grower
Rosy apple aphid	0	0.2	0	0	0	0.3	1.8	1.6
Sawfly	0	0	0	0	0.1	0	0	0.2
Tortrix	2.8	9.4	0.1	0.1	0.5	0.3	0.3	0.7
Early caterpillar	0.3	0.3	0.1	0.4	0.1	0.6	2.6	2.9
Codling moth	0.2	0	0.2	0.1	0.5 (0.2)	2.2 (0.3)*	0.2	0.4
Earwig	0.3	0.1	0.4	0.2	0.5	1.0	0.8	0.3
Rhynchites	0	0	0.2	0.1	0.2	1.6	0	0.1
Capsid	0	0	0	0	0	0	0	0
Blastobasis	0	0	0	0	0	0	0	0
Mussel scale	0	0	0	0	0	0	0	0
Total pest damage	**3.6**	**10.0**	**1.0**	**0.9**	**2.0 (2.2)**	**6.0 (6.3)**	**5.7**	**6.2**

* Codling stings

Table 7. Scab incidence as % infected leaf litter, shoots or fruit 2005 at four commercial trial sites in Kent

Scab assessment	1		2		3		4	
	Broadwater Gala		Northcourt Cox		Mount Ephraim Gala		Norham Cox	
	ZRMS	Grower	ZRMS	Grower	ZRMS	Grower	ZRMS	Grower
Leaf litter* April	27.5	31.7	3.3	8.9	13.3	31.4	42.0	70.0
Whole tree May	0	0	0	0	8.0	0	0	2.0
Shoots 31 May	-	-	-	-	0	-	-	-
Shoots 7 June	-	-	-	-	-	-	0	-
Shoots 8 June	-	-	-	-	0	-	-	-
Shoots 13 June	-	-	0	-	-	-	-	-
Shoots 16 June	-	-	-	-	0	-	-	-
Shoots 20 June	-	-	-	-	-	-	0	0
Shoots 23 June	0	-	-	-	-	-	-	-
Shoots 28 June	-	-	-	-	0	-	-	-
Shoots 1 July	-	-	0	-	-	-	-	-
Shoots 6 July	-	-	-	-	0	0	-	-
Shoots 8 July	-	-	-	-	-	-	0	-
Shoots 12 July	-	-	0	0	-	-	-	-
Shoots 11 August	-	-	0	0	-	-	-	-
Shoots 17 August	-	-	-	-	0	0	-	-
Shoots 19 August	-	-	-	-	-	-	0	1.0
Fruit Harvest September	0.3	0.3	0.1	0.1	0.3	0	0	0

* % of sample points where leaves present

Table 8. **Powdery mildew incidence as % infected blossoms or shoots 2005 at four commercial trial sites in Kent**

Mildew assessment	1		2		3		4	
	Broadwater Gala		Northcourt Cox		Mount Ephraim Gala		Norham Cox	
	ZRMS	Grower	ZRMS	Grower	ZRMS	Grower	ZRMS	Grower
Primary blossom April	0	0	0.6	1.2	0.25	0	1.1	2.0
Primary veg May	0	0.09	3.3	2.7	1.8	0.1	1.1	2.3
31 May	-	-	-	-	34.0	-	42.0	-
8 June	-	-	-	-	28.0	-	42.0	-
13 June	-	-	58.0	-	-	-	-	-
16 June	-	-	-	-	36.0	-	-	-
17 June	-	-	-	-	-	-	16.0	-
20 June	-	-	-	-	-	-	22.5	52.0
23 June	40.0	-	-	-	-	-	-	-
28 June	-	-	-	-	50.0	-	-	-
6 July	-	-	30.0	-	44.5	34.0	-	-
8 July	-	-	-	-	-	-	10.0	-
12 July	-	-	25.0	8.0	-	-	-	-
11 August	-	-	88.5	85.0	-	-	-	-
17 August	-	-	-	-	79.5	35.0	-	-
19 August	-	-	-	-	-	-	18.0	12.5

Table 9. **Incidence as % infected fruit of post-harvest rots in cv. Gala stored until December 2005 or February 2006 from two commercial sites in Kent**

Storage rot	1		3	
	Broadwater Gala December 2005		Mount Ephraim Gala February 2006	
	ZRMS	Grower	ZRMS	Grower
Brown rot	0.05	0.05	0.3	0.35
Phytophthora	0	0	0.02	0.20
Nectria	0	0	0.15	0.09
Botrytis	0	0	0.1	0.08
Penicillium	0	0	0.05	0.04
Gloeosporium	0	0	0	0
Other	0	0	0.03	0
Total losses due to rots	**0.05**	**0.05**	**0.66**	**0.76**
% Class 1	**92.0**	**88.0**		

Table 10. Incidence as % infected fruit of post-harvest rots in cv. Cox stored until February 2006 from a commercial site in Kent

Storage rot	2 Northcourt Cox February 2006	
	ZRMS	Grower
Brown rot	0.25	0.11
Phytophthora	0	0.05
Nectria	0.17	0.17
Botrytis	0.08	0.06
Penicillium	0	0.01
Gloeosporium	0.07	0.09
Other	0.04	0.01
Total losses due to rots	0.6	0.5

Table 11. Pest damage to fruit recorded as % damaged fruit at harvest 2005 at four commercial trial sites in Kent

Pest	1		2		3		4	
	Broadwater Gala		Northcourt Cox		Mount Ephraim Gala		Norham Cox	
	ZRMS	Grower	ZRMS	Grower	ZRMS	Grower	ZRMS	Grower
Rosy apple aphid	0	0	0	0.4	0.1	0.1	0	0
Sawfly	0	0	0	0	0	0	0	0.1
Tortrix	0.4	0.1	0	0.1	1.0	2.0	0.5	0.5
Early caterpillar	0.5	0	0.6	0.1	1.1	0.5	1.9	3.0
Codling moth	0.1	0.1	0.1	0	0.5 (0.8)*	1.2 (3.5)*	0.1	1.4
Earwig	0.7	0.5	0.2	0.2	0.9	1.4	4.3	4.5
Rhynchites	0	0.2	0	0.1	0	0	0.3	0
Capsid	0	0	0.2	0.4	0	0	0.2	0.1
Blastobasis	0	0	0	0	0	0	0	0
Mussel scale	0	0	0	0	0	0	0	0
Total pest damage	**1.7**	**0.9**	**1.1**	**1.3**	**3.6 (4.4)**	**5.2 (8.7)**	**7.3**	**9.6**

* Codling stings

Table 12. Scab incidence as % infected leaft litter, shoots or fruit 2006 at four commercial trial sites in Kent

Scab assessment	1		2		3		4	
	Broadwater Gala		Northcourt Cox		Mount Ephraim Gala		Norham Cox	
	ZRMS	Grower	ZRMS	Grower	ZRMS	Grower	ZRMS	Grower
Leaf litter* April * % of sample points where leaves present	26.3	42.5	2.5	0.6	67.0	81.3	16.9	32.5
Whole tree May	0	0	0	0	0	0	0	0
Shoots 6 June					2.0	-		
Shoots 23 June	0	-						
Shoots 4 July							0 1.0	0 0.9
Shoots trusses 7 July	1.25 0.5	1.25 0.6						
Shoots trusses 11 July			25.0 58.5	3.8 8.8	0.6 0.6	1.9 1.8		
Shoots 10 August			5.0	0				
Shoots 21 August							2.0	3.5
Shoots 29 August					0.5	0		
Shoots 30 August	1.25	0						
Fruit harvest September	0.6	0.4	52.5	6.0	0	0.2	1.6	1.1
% leaves October with late scab	13.0	8.0	60.0	20.0	34.0	37.0	34.0	29.0

Table 13. Powdery mildew incidence as % infected blossoms or shoots 2006 at four commercial trial sites in Kent

Mildew assessment	1		2		3		4	
	Broadwater Gala		Northcourt Cox		Mount Ephraim Gala		Norham Cox	
	ZRMS	Grower	ZRMS	Grower	ZRMS	Grower	ZRMS	Grower
Primary blossom April	0	0	0.9	0.4	0.3	0.05	1.1	2.4
Primary veg May	0.05	0.05			0.9	0.04		
6 June					18.0	-		
23 June	28.0	-						
4 July							70.0	11.3
7 July	48.8	23.1						
11 July			100	95.0	38.1	33.1		
10 August			98.5	55.0				
21 August							43.0	13.5
29 August					23.0	22.0		
30 August	28.1	11.3						

Table 14. Incidence as % infected fruit of post-harvest rots in cv. Gala stored until November 2006

Storage rot	1 Broadwater Gala November 2006	
	ZRMS	Grower
Brown rot	0.1	0.05
Phytophthora	0.01	0.01
Nectria	0.03	001
Botrytis	0.03	0.04
Penicillium	0.02	0.03
Gloeosporium	0	0
Other	0	0
Total losses due to rots	**0.19**	**0.14**

Table 15. Pest damage to fruit recorded as % damaged fruit at harvest 2006 at four commercial trial sites

Pest	1		2		3		4	
	Broadwater Gala		Northcourt Cox		Mount Ephraim Gala		Norham Cox	
	ZRMS	Grower	ZRMS	Grower	ZRMS	Grower	ZRMS	Grower
Rosy apple aphid	0.7	0.7	0	3.5	0	0.1	0	0
Sawfly	0.1	0.3	0.1	0	0	0.6	0.2	0.3
Tortrix	0.5	0	0.3	0	0.7	3.1	2.2	0.7
Early caterpillar	0.7	0.2	2.6	0	0.4	1.0	1.0	0.7
Codling moth	0.6	0.1	0	0.1	0.5 (0.1)*	2.4 (0)*	3.3	1.2
Earwig	0.8	0.2	1.0	0.7	0.9	1.0	3.9	1.1
Rhynchites	0	0	0	0	0	1.7	0.1	0.4
Capsid	0	0	0	0	0	0	0.2	0.3
Blastobasis	0	0	0	0	0	0	0	0
Mussel scale	0	0	0	0	0	0	0	0
Total Pest damage	**3.4**	**1.5**	**4.0**	**4.3**	**2.5 (2.6)**	**9.9 (9.9)**	**10.9**	**4.7**

* Codling stings

Table 16. Results of pesticide residue analysis carried out on apples cvs. Cox or Gala sampled at harvest from various plots in 2004-2006. Figures in bold indicate a detected residue. Other figures indicate the pesticide residue was absent or below the level of detection

Year	Pesticide	Residue detected mg/kg -Sample origin									
		Broad Water Farm		North Court Farm		Mount Ephraim		Norham Farm		East Malling Research Wiseman's orchard	
		ZRMS	Grower	ZRMS	Grower	ZRMS	Grower	ZRMS	Grower	ZRMS (MS)	Conventional (CS)
2004	chlorpyrifos	<0.01	**0.3**	<0.01	<0.01	<0.01	**0.1**	**0.01**	**0.05**	<0.01	<0.01
	myclobutanil	<0.01	**0.03**	<0.01	<0.01	<0.01	**0.03**	**0.04**	**0.02**	<0.01	<0.01
	bupirimate	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	**0.07**	**0.02**	<0.01	<0.01
	tolylfluanid	**0.04**	**0.1**	<0.01	<0.01	<0.01	<0.01	**0.04**	**0.2**	<0.01	**0.06**
	penconazole	<0.01	**0.03**	<0.01	<0.01	<0.01	**0.01**	<0.01	<0.01	<0.01	**0.06**
	pirimicarb	<0.01	**0.05**	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	methoxyfenozide	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	thiacloprid	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	fenoxycarb	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	dithianon	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	carbendazim	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
2005	penconazole	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	**0.01**	**0.01**	<0.01	<0.01
	cypermethrin	<0.01	<0.01	<0.01	**0.04**	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	methoxyfenozide	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	thiacloprid	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	fenoxycarb	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	dithianon	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	carbendazim	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	**0.059**	**0.05**	<0.05	<0.05
2006	chlorpyrifos	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	myclobutanil	<0.01	**0.01**	<0.01	**0.01**	<0.01	**0.01**	<0.01	**0.01**	<0.01	<0.01
	bupirimate	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	tolylfluanid	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	penconazole	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	pirimicarb	<0.01	**0.01**	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	methoxyfenozide	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	thiacloprid	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	fenoxycarb	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	dithianon	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	carbendazim	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	flonicamid	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Notes: Limit of detection (LOD) for chlorpyrifos, myclobutanil, bupirimate, tolylfluanid, penconazole and pirimicarb is 0.01mg/kg; Limit of detection for methoxyfenozide, thiacloprid, fenoxycarb, dithianon, carbendazim and flonicamid is 0.05 mg/kg

Table 17. Occurrence of pesticide residues above reporting limits in 2003 government surveillance of UK produced apples in 2003 (82 samples analysed)

Pesticide	Target	MRL (mg/kg)	Reporting Limit (mg/kg)	% samples > Reporting Limit
bupirimate	mildew	no MRL	0.05	1
captan	scab	3	0.05	12
carbendazim	post harvest rots/canker†	2	0.05	15
chlorpyrifos	caterpillar, aphid etc	0.5	0.02	48
diphenylamine	scald post harvest	5	0.05	6
dithiocarbamates	post harvest rots†/canker	3	0.1	1
metalaxyl	post harvest rots	1	0.05	5
myclobutanil	mildew, scab	0.5	0.05	1
penconazole	mildew, scab	0.2	0.05	1
pirimicarb	aphids	1	0.02	4
tolylfluanid	scab/post harvest rots†	5	0.05	1

† as pre-harvest sprays

Table 18. Occurrence of pesticide residues above reporting limits in government surveillance of UK produced apples in 2005.= (30 samples analysed)

Pesticide	Target	MRL (mg/kg)	Reporting Limit (mg/kg)	% samples > Reporting Limit
captan	scab	3	0.02	20
carbendazim	post harvest rots/canker†	2	0.05	23
chlorpyrifos	caterpillar, aphid etc	0.5	0.02	40
dithianon	scab	5	0.05	3
dithiocarbamates	post harvest rots†/canker	3	0.05	3
iprodione	not approved	10	0.02	3
myclobutanil	mildew, scab	0.5	0.05	3
pirimicarb	aphids	1	0.02	3
tolylfluanid	scab/post harvest rots†	5	0.05	3

† as pre-harvest sprays

Table 19. Advice received from agrochemical companies on extending harvest intervals to reduce the risk of reportable residues

Active ingredient	Product name	Parent company	Suggested Advice
deltamethrin	Decis	Bayer	In most historic residue trials, multiple applications were made at a dose greater than the UK recommended rate and no residues above the reporting limit (0.05 mg/kg) were found in most cases. Despite being looked for, deltamethrin isn't detected by PRC monitoring
methoxyfenozide	Runner	Bayer	A 28 day harvest interval could result in non-detectable residue
pirimicarb	Aphox	Syngenta	It would be difficult to eliminate residues entirely without extending the PHI considerably. This would reduce the flexibility of the user to utilise the product against later season aphid attacks
penconazole	Topas	Syngenta	The currently approved GAP allows 10 applications at 50 g/ha with a 14-day PHI. Extending the PHI to 28 days does not result in consistently low residues. However, recent studies have indicated that if only 3 applications are made, and with a 14 day PHI, residues are usually below the reporting limit of 0.05 mg/kg
thiacloprid	Calypso	Bayer	21-day harvest interval would reduce the chances of a positive residue

Table 20. Advice received from producer cooperatives on extending harvest intervals to reduce the risk of reportable residues

Active ingredient	Example product name (s)	Statutory PHI	Recommended PHI to avoid reportable residues
bupirimate	Nimrod	1 day	Reportable residues rarely appear to arise from commercial use
captan	Captan 80	14 days	Even early season (April) sprays can result in reportable residues in a small number of instances and the frequency of such residues increased when the reporting limit was reduced from 0.05 to 0.02 mg/kg
carbendazim	Delsene, Defensor	-	No longer approved for use on apple
chlorpyrifos	Dursban	14 days	A 60 day PHI eliminates reportable residues
dithiocarbamates (e.g. mancozeb)	Karamate	4 weeks	Even early season (April) sprays can result in reportable residues in a small number of instances.
myclobutanil	Systhane	14 days	Reportable residues rarely appear to arise from commercial use

Table 21. Treatments, pesticide programmes and varieties in Wiseman's plots at EMR 2004-2007

Treatment	Pesticide use	Varieties	IPDM programme for control of pests, diseases and storage rots
U-S	Untreated	Susceptible Cox, Gala, Fiesta, Discovery	None
C-S	Conventional	Susceptible Cox, Gala, Fiesta, Discovery	Routine pesticides bud burst to harvest Captan (28 & 14 days preharvest) for control of storage rots
M-S	Managed	Susceptible Cox, Gala, Discovery	Managed pesticides early and after harvest. Biocontrol during fruit development Rot risk assessment, inoculum removal (cankered shoots and brown rot), selective picking for control of storage rots
U-R	Untreated	Scab-resistant Saturn, Ahra, Discovery	None
C-R	Conventional	Scab-resistant Saturn, Ahra, Discovery	Routine insecticides and mildewicides. Reduced scab fungicide programme Captan (28 and 14 days pre-harvest) for control of storage rots
M-R	Managed	Scab-resistant Saturn, Ahra, Discovery	Managed pesticides early and after harvest. Biocontrol during fruit development Rot risk assessment, inoculum removal (cankered shoots and brown rot), selective picking for control of storage rots

Table 22. Apple scab incidence in Wiseman's Orchard, East Malling Research 2004

Item	Cultivar	Scab susceptible			Scab resistant		
		CS	MS	US	CR	MR	UR
% infected trees May	Cox	0	0	100			
	Gala	5.0	0	100			
	Fiesta	15.0	0	100			
	Discovery	0	0	10	0	0	0
	Saturn				0	0	0
	Ahra				0	0	5.0
% infected shoots September	Cox	3.8	0	100			
	Gala	5.0	0	100			
	Fiesta	1.25	0	100			
	Discovery	0	0	3.8	0	0	1.25
	Saturn				0	0	0
	Ahra				0	0	0
% infected fruit at harvest	Cox	0.4	0.05	48.1			
	Gala	2.4	0.1	89.3			
	Fiesta	1.0	0	56.3			
	Discovery	0	0	0.4	0	0.45	0.25
	Saturn				0	0	0
	Ahra				0	0	0
Mean % leaves with late scab in October	Cox	22	4	88			
	Gala	27	9	97			
	Fiesta	14	8	100			
	Discovery	0	0	26	0	0	3
	Saturn				0	0	0
	Ahra				0	0	0

Leaf litter assessment in mid-April 2004 recorded two leaves in one plot. No leaves remained in any other plots

Table 23. Apple scab incidence in Wiseman's Orchard, East Malling Research, 2005

Item	Cultivar	Scab susceptible			Scab resistant		
		CS	MS	US	CR	MR	UR
Leaf litter left in plots April 2005	Whole plots % sample points where leaves	19.2	20	32.5	19.9	38.4	32.5
% infected rosettes May	Cox	0	0	58.8			
	Gala	0.8	0.3	65.2			
	Fiesta	0.2	0	44.5			
	Discovery	0	0	0.1	0	0	0.3
	Saturn				0	0	0
	Ahra				0	0	0
% infected shoots June	Cox	0	0	95			
	Gala	7.5	0	100			
	Fiesta	0	0	80			
	Discovery	0	0	2.5	0	0	0
	Saturn				0	0	0
	Ahra				0	0	0
% infected shoots August	Cox	0	0	100			
	Gala	12.5	0	100			
	Fiesta	0	0	95			
	Discovery	0	0	25	0	0	15
	Saturn				0	0	0
	Ahra				0	0	0
% infected fruit at harvest	Cox	0.3	0.1	37.0			
	Gala	1.2	0	70.0			
	Fiesta	0.7	0	23.2			
	Discovery	0	0	0.4	0	0.1	0.1
	Saturn				0	0	0
	Ahra				0	0.1	0.4
% fruit with storage scab ***	Cox	0	0	0			
	Gala	1.2	0.2	69.5			
	Fiesta	0	0	0			
	Discovery	-	-	-	-	-	-
	Saturn				0	0	0
	Ahra				-	-	-
Mean % leaves with late scab in October	Cox	0	0	44			
	Gala	9	0	67			
	Fiesta	0	0	55			
	Discovery	0	0	1	0	0	0
	Saturn				0	0	0
	Ahra				0	0	0

*** NB: Storage scab only includes new scab lesions that have developed in store. It does not include scab that was present on the fruit at harvest. Cox and Fiesta fruit were assessed in February 2006. Gala and Saturn fruit were assessed in March 2006

Table 24. Apple scab incidence in Wiseman's Orchard, East Malling Research, 2006

Item	Cultivar	Scab susceptible			Scab resistant		
		CS	MS	US	CR	MR	UR
Leaf litter left in plots April 2006	Whole plots % sample points where leaves	30	35	45	33.4	54.2	18.4
% infected rosettes June	Cox	0.8	1.3	78.5			
	Gala	8.3	4.0	99.0			
	Fiesta	2.8	1.8	73.8			
	Discovery	0.3	0.3	24.5	1.5	8.3	11.3
	Saturn				0	0	0
	Ahra				0	0	0
% infected shoots June	Cox	0	0	77.5			
	Gala	30.0	10.0	100			
	Fiesta	7.5	0	90			
	Discovery	0	2.5	0	0	0	0
	Saturn				0	0	0
	Ahra				0	0	0
% infected shoots August	Cox	5.0	0	92.5			
	Gala	25.0	22.5	100			
	Fiesta	7.5	5.0	82.5			
	Discovery	0	0	0	0	0	0
	Saturn				0	0	0
	Ahra				0	0	0
% infected fruit at harvest	Cox	3.5	1.3	42.3			
	Gala	6.2	5.8	92.4			
	Fiesta	3.9	1.8	63.5			
	Discovery	0.7	0.2	24.0	1.8	4.5	4.7
	Saturn				0	0	0
	Ahra				0	0	0
% fruit with storage scab *** March 2007	Cox	0.06	0.2	0.04			
	Gala	6.1	4.0	67.6			
	Fiesta	1.6	1.5	35.4			
	Discovery	-	-	-	-	-	-
	Saturn				-	-	0.04
	Ahra				-	-	-
% leaves late scab October 2006	Cox	22.0	40.0	81.0			
	Gala	39.0	57.0	100			
	Fiesta	22.0	41.0	96.0			
	Discovery	22.0	0	35.0	0	15.0	4.0
	Saturn				0	0	0
	Ahra				0	3?	9?

*** NB: Storage scab only includes new scab lesions that have developed in store. It does not include scab that was present on the fruit at harvest

Table 25. Percentage of cv. Gala fruit infected with scab at harvest in experimental plots at East Malling Research 2001-2006

Treatment	2001	2002	2003	2004	2005	2006
US	72	98	51	89	70	93
CS	0.5	5.6	0.3	2.4	1.2	6.2
MS	1.0	2.7	0.3	0.1	0	5.8

Table 26. Apple powdery mildew incidence in Wiseman's Orchard, East Malling Research 2004

Item	Cultivar	Scab susceptible			Scab resistant		
		CS	MS	US	CR	MR	UR
Primary mildew % infected blossoms May	Cox	0	0	1.75			
	Gala	0	0	0.5			
	Fiesta	0.13	0	0.63			
	Discovery	0	0	0	0	0	0.13
	Saturn				0	0	0.4
	Ahra				0	0	26.9
Primary mildew % infected shoots May	Cox	0	0	2.6			
	Gala	0	0.1	1.1			
	Fiesta	0	0	0.4			
	Discovery	0	0	0	0	0	0
	Saturn				0.1	0	1.8
	Ahra				0.05	0	20.2
Secondary mildew % infected shoots June	Cox	10	12.5	87.5			
	Gala	15	10	100			
	Fiesta	7.5	5	90			
	Discovery	7.5	2.5	17.5	0	5.0	42.5
	Saturn				5	7.5	100
	Ahra				0	10	100

Table 27. Apple powdery mildew incidence in Wiseman's Orchard, East Malling Research 2005

Item	Cultivar	Scab susceptible			Scab resistant		
		CS	MS	US	CR	MR	UR
Primary mildew Mean infected shoots/tree May	Cox	0	0	2.7			
	Gala	0	0	1.4			
	Fiesta	0	0	0.9			
	Discovery	0	0	0.2	0	0	0
	Saturn				0	0	2.7
	Ahra				0	0	16.1
Secondary mildew % infected shoots June	Cox	7.5	7.5	80			
	Gala	10	7.5	80			
	Fiesta	5	2.5	57.5			
	Discovery	0	0	37.5	0	0	80
	Saturn				2.5	30	100
	Ahra				0	5	97.5

Table 28. Apple powdery mildew incidence in Wiseman's Orchard, East Malling Research, 2006

Item	Cultivar	Scab susceptible			Scab resistant		
		CS	MS	US	CR	MR	UR
Primary mildew Mean % infected shoots May	Cox	0	0	1.9			
	Gala	0.2	0	1.6			
	Fiesta	0	0	0.1			
	Discovery	0	0	0	0	0	0.1
	Saturn				0	0	8.4
	Ahra				0	0	20.6
Secondary mildew % infected shoots June	Cox	7.5	5.0	82.5			
	Gala	5.0	0	82.5			
	Fiesta	0	0	60.0			
	Discovery	0	0	25.0	0	0	72.5
	Saturn				0	0	95.0
	Ahra				0	0	100
Secondary mildew % infected shoots August	Cox	25.0	5.0	100			
	Gala	42.5	22.5	97.5			
	Fiesta	25.0	5.0	87.5			
	Discovery	0	0	62.5	2.5	0	95.0
	Saturn				0	17.5	95.0
	Ahra				0	7.5	100

Table 29. % shoots of cvs. Cox and Gala with secondary mildew in June/July in Wiseman's Orchard at East Malling Research

Site/Treatment	Cultivar	2002	2003	2004	2005	2006
US	Cox	78	75	88	80	82.5
US	Gala	100	92.5	100	80	82.5
CS	Cox	5	10	10	7.5	7.5
CS	Gala	2.5	15	15	10.0	5.0
MS	Cox	5	15	13	7.5	5.0
MS	Gala	7.5	20	10	7.5	0

Table 30. Risk of occurrence of various fungal rots in store based on rot risk assessment system 2004-2006

Fungal Rot	Variety	2004	2005	2006
Brown rot	Cox / Fiesta	**High**	**High**	**High**
	Gala / Saturn	**High**	**High**	**High**
Phytophthora	Cox / Fiesta	Low	Low	Moderate
	Gala / Saturn	Low	Moderate	Moderate
Nectria	Cox / Fiesta	Moderate	Moderate	**High**
	Gala / Saturn	High	High	**High**
Gloeosporium	Cox / Fiesta	Low	Low	Low
	Gala / Saturn	Low	Low	Low

Table 31. Mean % losses due to rots in apples cvs Cox, Gala, Fiesta and Saturn following various treatments or management systems, harvested September 2004 and stored in CA until midMarch 2005

Fungal Rot	Cox			Gala			Fiesta			Saturn		
	US	CS	MS	US	CS	MS	US	CS	MS	UR	CR	MR
Brown rot	8.2	1.6	1.5	1.5	0.2	0.2	1.6	0.7	1.0	0.7	0.3	0.6
Botrytis	0.8	1.8	0.4	0	0.2	0.3	0.7	0.1	0.1	0	0	0
Phytophthora	0.6	0	0	0	0.2	0	0.1	0	0	0.1	0	0
Penicillium	1.0	0.4	0.4	0.6	0.1	0.2	0.5	0.3	0.1	0.4	0.5	0
Nectria	6.8	3.1	1.1	10.3	0.8	0.6	20.4	4.5	1.9	1.5	2.2	0.2
Gloeosporium	0.9	0.5	0	0.1	0.2	0.1	0.3	0.2	0.1	0.2	0.4	0.3
Diaporthe	0.4	0.3	0.1	0	0	0	0.6	0.3	0.5	0.1	0.1	0
Botryosphaeria	0.6	0.2	0.2	0	0	0	0.2	0.1	0.1	0	0	0
Other	0.8	0.3	0.2	0	0	0.1	0.4	0.2	0.1	0.5	1.6	1.0
Mean % loss	**16.3**	**7.8**	**3.6**	**12.4**	**1.4**	**1.3**	**24.4**	**6.0**	**3.6**	**3.4**	**4.8**	**2.0**

Table 32. Mean % losses due to rots in apples cvs Cox, Gala, Fiesta and Saturn following various treatments or management systems, harvested September 2005 and stored in CA until mid March 2006

Fungal Rot	Cox			Gala			Fiesta			Saturn		
	US	CS	MS	US	CS	MS	US	CS	MS	UR	CR	MR
Brown rot	17.2	1.03	0.6	12.6	0.82	0.28	6.0	0.64	1.13	1.15	0.4	0.9
Botrytis	0.2	0.04	0.1	0.04	0.1	0.12	0.05	0.02	0	0.2	0.15	0.2
Phytophthora	0	0	0	0.12	0.05	0	0	0	0	0.01	0	0
Penicillium	0.2	0.1	0	0.25	0.07	0.07	0.2	0.1	0.04	0.04	0.05	0.08
Nectria	1.0	0.14	0.05	58.1	2.67	0.22	6.8	0.63	0	2.25	1.85	0.73
Gloeosporium	0.03	0.02	0	0.1	0.06	0.08	0	0	0	0.25	0.2	0.08
Diaporthe	0.1	0.03	0	0	0	0	0	0.02	0	0	0	0.03
Botryosphaeria	0.1	0.04	0.1	0	0	0	0	0	0	0	0	0
Other	0.05	0.1	0	0	0.05	0.08	0.3	0	0	0.51	0.18	0.15
Mean % loss	**18.7**	**1.44**	**0.72**	**71.1**	**3.81**	**0.82**	**13.4**	**1.39**	**1.18**	**4.39**	**2.83**	**2.05**
Storage scab				**69.5**	**1.2**	**0.22**				**-**	**-**	**-**

Table 33. Mean % losses due to rots in apples cvs Cox, Gala, Fiesta and Saturn following various treatments or management systems, harvested September 2006 and stored in CA until mid March 2007

Fungal Rot	Cox			Gala			Fiesta			Saturn		
	US	CS	MS	US	CS	MS	US	CS	MS	UR	CR	MR
Brown rot	10.03	0.49	0.55	8.2	0.34	0.15	5.5	0.12	0.55	1.66	0.26	0.43
Botrytis	0.2	0.12	0.43	0	0	0.04	0	0	0.07	0	0	0
Phytophthora	0.05	0.02	0	0	0	0	0.15	0	0	0	0	0
Penicillium	0.14	0.14	0.19	0	0.06	0.02	0.16	0.16	0	0	0.05	0.01
Nectria	1.4	0.3	0.16	28.7	0.71	0.19	6.7	0.63	0.14	0.52	0.58	0.08
Gloeosporium	0.37	0.25	0.08	0	0.04	0.05	0.15	0	0	0.08	0.06	0.08
Diaporthe	0.21	0.21	0.03	0	0	0	0.01	0.12	0.03	0	0	0
Botryosphaeria	0.06	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0.07	0	0	0	0	0	0.03	0.11	0	0.02
Mean % loss	**12.75**	**1.44**	**0.89**	**7.91**	**1.37**	**0.45**	**8.8**	**0.98**	**0.77**	**2.33**	**0.93**	**0.66**
Storage scab	**0.03**	**0.06**	**0.18**	**82.5**	**8.77**	**3.1**	**35.6**	**1.63**	**1.54**	**-**	**-**	**-**

Table 34. Pest damage to fruit as % fruit damaged recorded at harvest 2004 in zero residues trial, Wiseman's Orchard, East Malling Research

Pest	Managed	Conventional	Untreated
Rosy apple aphid			
Susceptible variety*	0.1	1.1	38.1
Resistant variety*	0.02	0.2	26.5
Sawfly			
Susceptible variety	0.3	1.0	1.3
Resistant variety	0.8	0.8	2.2
Tortrix			
Susceptible variety	1.1	1.5	5.1
Resistant varierty	2.0	1.1	3.8
Early caterpillar			
Susceptible variety	0.2	0.1	2.1
Resistant variety	0.5	0.2	1.1
Codling moth			
Susceptible variety	0.5	1.2	3.4
Resistant variety	0.5	0.6	2.6
Earwig			
Susceptible variety	1.2	1.9	4.2
Resistant variety	1.1	1.9	4.5
Rhynchites			
Susceptible variety	0.6	1.1	24.5
Resistant variety	0.6	0.4	14.9
Capsid			
Susceptible variety	0.01	0	0.2
Resistant variety	0	0	0.1
Blastobasis			
Susceptible variety	0.1	0.1	0.1
Resistant variety	0.1	0	0.1
Mussel scale			
Susceptible variety	0	0	0
Resistant variety	0	0	0.1
Total pest damage			
Susceptible variety	**4.1**	**8.0**	**79.0**
Resistant variety	**5.6**	**5.2**	**55.9**

Table 35. Pest damage to fruit as % fruit damaged recorded at harvest 2005 in zero residues trial, Wiseman's Orchard, East Malling Research

Pest	Managed	Conventional	Untreated
Rosy apple aphid			
Susceptible variety*	0.02	0	1.0
Resistant variety*	0.05	0	1.5
Sawfly			
Susceptible variety	0.02	0.05	0.3
Resistant variety	0.1	0.1	1.4
Tortrix			
Susceptible variety	0.9	1.5	10.3
Resistant variety	1.0	1.3	6.5
Early caterpillar			
Susceptible variety	0.1	0.5	1.3
Resistant variety	0.3	0.3	3.3
Codling moth			
Susceptible variety	1.0	0.9	5.3
Resistant variety	1.0	0.6	6.9
Earwig			
Susceptible variety	0.8	1.3	3.2
Resistant variety	0.8	1.1	4.9
Rhynchites			
Susceptible variety	0.4	0.7	38.1
Resistant variety	0.5	0.2	20.7
Capsid			
Susceptible variety	0	0	0.05
Resistant variety	0	0	0
Blastobasis			
Susceptible variety	0	0	0.05
Resistant variety	0	0.02	0.1
Mussel scale			
Susceptible variety	0	0	0.02
Resistant variety	0	0	0.05
Total pest damage			
Susceptible variety	**3.3**	**5.2**	**60.3**
Resistant variety	**4.7**	**4.4**	**47.8**

Table 36. Pest damage to fruit as % fruit damaged recorded at harvest 2006 in zero residues trial, Wiseman's Orchard, East Malling Research

Pest	Managed	Conventional	Untreated
Rosy apple aphid			
Susceptible variety*	1.0	1.6	29.5
Resistant variety*	1.4	0.7	11.7
Sawfly			
Susceptible variety	0.5	1.8	2.8
Resistant variety	1.2	1.4	4.3
Tortrix			
Susceptible variety	0.7	0.7	10.1
Resistant variety	1.3	0.5	7.8
Early caterpillar			
Susceptible variety	0.4	0.8	3.2
Resistant variety	1.1	0.5	4.2
Codling moth			
Susceptible variety	0.1 (0.08)*	0.3	8.0 (0.2)
Resistant variety	0.6	0.1	4.5
Earwig			
Susceptible variety	0.4	0.5	7.5
Resistant variety	0.7	0.3	4.2
Rhynchites			
Susceptible variety	1.9	2.2	35.5
Resistant variety	4.3	1.7	37.5
Capsid			
Susceptible variety	0	0	0
Resistant variety	0	0	0
Blastobasis			
Susceptible variety	0.1	0	1.5
Resistant variety	0.1	0	1.1
Mussel scale			
Susceptible variety	0	0	0.2
Resistant variety	0	0	0.3
Total pest damage			
Susceptible variety	**8.1**	**10.5**	**87.7**
Resistant variety	**14.9**	**10.3**	**81.3**

* Codling sting

Table 37. Fungicides applied to managed (MS, MR) and conventional (CS, CR) plots in Wiseman's Orchard in 2004. Treatments were applied at the recommended dose unless stated

Fungicide / Timing		Treatment / number of sprays (% dose)			
		CS	CR	MS	MR
Pre bud burst	copper	0	0	1	1
Bud burst – Petal fall	dithianon	2	1	2	1
	myclobutanil +captan	5	1	6	1
	myclobutanil	0	0	0	0
	captan	0	0	0	0
	bupirimate	0	4	0	4
	carbendazim	0	0	1	1
Petal fall – harvest	myclobutanil + captan	3	1	0	0
	myclobutanil	0	0	0	0
	bupirimate	4	7	0	0
	tolylfluanid	2	2	0	0
	sulphur	0	0	8 (30-50)	8(30-50)
Post-harvest	myclobutanil + captan	0	0	1	1
	urea	0	0	1	1
	copper	2	2	2	2
Cost	**£/ha**	**411**	**360**	**384**	**283**

Table 38. Fungicides applied to managed (MS, MR) and conventional (CS, CR) plot in Wiseman's Orchard in 2005. Treatments were applied at the recommended dose unless stated

Fungicide / Timing		Treatment / number of sprays (% dose)			
		CS	CR	MS	MR
Pre bud burst	copper	0	0	1	1
Bud burst – petal fall	dithianon	2	1	2	1
	myclobutanil +captan	6	2	5	1
	myclobutanil	0	0	1	1
	captan	0	0	0	0
	bupirimate	0	4	0	4
	carbendazim	0	0	1	1
Petal fall – harvest	myclobutanil + captan	2	0	0	0
	myclobutanil	0	0	0	0
	bupirimate	5	6	0	0
	captan	1	1	0	0
	tolylfluanid	1	1	0	0
	sulphur	0	0	7 (30-50)	7(30-50)
Post-harvest	myclobutanil + captan	0	0	1	1
	urea	0	0	1	1
	copper	2	2	2	2
Cost	**£/ha**	**411**	**345**	**323**	**271**

Table 39 . **Fungicides applied to managed (MS, MR) and conventional (CS, CR) plots in Wiseman's Orchard 2006. Treatments were applied at the recommended dose unless stated**

Fungicide / Timing		Treatment / number of sprays (% dose)			
		CS	CR	MS	MR
Pre bud burst	copper	0	0	1	1
Bud burst – petal fall	dithianon	2	1	2	1
	myclobutanil +captan	4	1	4	1
	pyrimethanil	3	1	2	1
	captan	0	0	0	0
	bupirimate	0	3	0	3
	carbendazim	0	0	3	3
Petal fall – harvest	myclobutanil + captan	3	0	0	0
	myclobutanil	0	0	0	0
	bupirimate	3	6	0	0
	captan	0	0	0	0
	tolylfluanid	2	2	0	0
	sulphur	0	0	7 (30-50)	7(30-50)
Post-harvest	myclobutanil + captan	0	0	1	1
	tebuconazole	0	0	1	1
	urea	0	0	1	1
	copper	2	2	2	2
Cost	**£/ha**	**475**	**341**	**390**	**304**

Table 40. **Insecticides applied to plots in Wiseman's Orchard in 2004. Treatments were applied at recommended dose**

Date	Growth stage	CS	CR	MS	MR
4 April	Green cluster	Dursban	Dursban	Runner	Runner
9 April	Pink bud	Calypso Runner	Calypso Runner	Calypso	Calypso
15 May	Petal fall	Calypso	Calypso	Calypso Insegar	Calypso Insegar
18 June	Fruitlet	-	-	-	-
4 July	Fruitlet	-	-	-	-
20 August	Pre-harvest	Bt	Bt	Bt	Bt
Cost £/ha		**167**	**167**	**199**	**199**

Table 41. Insecticides applied to plots in Wiseman's Orchard in 2005. Treatments were applied at recommended dose

Date	Growth stage	CS	CR	MS	MR
9 April	Green cluster	Dursban	Dursban	Runner	Insegar
15 April				Insegar	Runner
27 April	Pink bud	Calypso Dursban	Calypso	Calypso	Calypso
20 May	Petal fall	Calypso Insegar	Calypso Insegar	Calypso Insegar	Calypso Insegar
18 June	Fruitlet	-	-	-	-
4 July	Fruitlet	-	-	-	-
20 August	Pre-harvest	-	-	-	-
5 October	Post-harvest	-	-	Aphox	Aphox
Cost £/ha		**146**	**140**	**236**	**233**

Table 42. Insecticides applied to plots in Wiseman's Orchard in 2006. Treatments were applied at recommended dose

Date	Growth stage	CS	CR	MS	MR
20 April	Green cluster	Dursban	Dursban	Runner	Runner
27 April				Insegar	Insegar
15 May	Pink bud	Calypso	Calypso	Calypso	Calypso
2 June	Petal fall	Calypso Insegar	Calypso Insegar	Calypso Insegar	Calypso Insegar
5 July	Fruitlet	Runner	Runner		
5 August	Fruitlet	Runner	Runner	CGV	CGV
16 August	Fruitlet	-	-	CGV	CGV
25 August	Fruitlet	-	-	CGV	CGV
12 October	Post-harvest	-	-	Aphox	Aphox
Cost £/ha		**231**	**231**	**231 + Cost CGV**	**231 + cost CGV**

Table 43. **Russet recorded on fruit at harvest in Wiseman's Orchard, East Malling Research in 2004. Figures are percentage of fruit with russet in categories 0-2, i.e. acceptable in Class 1**

Item	Variety	Scab susceptible			Scab resistant		
		CS	MS	US	CR	MR	UR
% fruit with russet acceptable in Class 1	Cox	100	98.5	-			
	Gala	100	99.5	100			
	Fiesta	100	100	100			
	Discovery	98.1	99	95.5	96.7	98.3	97.9
	Saturn				100	100	100
	Ahra				100	99.4	82.3

Table 44. **Russet recorded on fruit at harvest in Wiseman's Orchard, East Malling Research in 2005. Figures are percentage of fruit with russet in categories 0-2, i.e. acceptable in Class 1**

Item	Variety	Scab susceptible			Scab resistant		
		CS	MS	US	CR	MR	UR
% fruit with russet acceptable in Class 1	Cox	100	100	98.5			
	Gala	100	100	100			
	Fiesta	99	99.5	100			
	Discovery	75.2	83.4	49.1	88.7	77.4	76
	Saturn				100	100	100
	Ahra				94.9	89.7	80.5

Table 45. **Russet recorded on fruit at harvest in Wiseman's Orchard, East Malling Research in 2006. Figures are percentage of fruit with russet in categories 0-2, i.e. acceptable in Class 1**

Item	Variety	Scab susceptible			Scab resistant		
		CS	MS	US	CR	MR	UR
% fruit with russet acceptable in Class 1	Cox	100	100	93.1			
	Gala	100	92.5	100			
	Fiesta	100	100	100			
	Discovery	78.8	80.9	77	84.4	93.3	71.9
	Saturn				98.5	100	95.2
	Ahra				94.9	89.4	65.7

Table 46. % mildewed leaves recorded in apple shoots cv Cox in 2004 following various treatments applied for mildew control

Product	Active ingredient	Rate / ha	Mean % mildewed leaves recorded		
			16 June	2 July	13 July
Untreated	-	-	85.0	98.0	99.0
Sulphur	Sulphur	5 L (50% rate)	78.5	71.5	85.0
Potassium bicarbonate + Agral	Potassium bicarbonate + wetter	5 kg	86.5	93.5	98.0
Farmfos + Agral	Potassium phosphite + wetter	5 L	80.0	79.0	93.5
Farmfos+ potassium bicarbonate + Agral	Potassium bicarbonate + Potassium phosphate + wetter	5 kg + 5 L	83.0	89.5	97.0
Crop Life + calcium carbonate	Citrus and coconut extract	300ml + 250g	83	93.5	97.0
Sulphur + potassium bicarbonate	Sulphur + potassium bicarbonate	5 L + 5kg	80.5	82.5	93.5

Table 47. % mildewed leaves recorded in apple shoots cv Cox in 2005 following various treatments applied for mildew control

Product	Active ingredient	Rate/ha	Mean % mildewed leaves recorded on 28 June
Untreated	-	-	96.5
Sulphur	Sulphur	5 L (50% rate)	76.7
Potassium bicarbonate + Silwet	Potassium bicarbonate + wetter	5 kg	91.5
Farmfos	Potassium phosphite	5 L	88.0

Table 48. % mildewed leaves recorded in apple shoots cv Cox in 2006 following various treatments applied for mildew control

Product	Active ingredient	Rate / ha	Mean % mildewed leaves recorded		
			6 July	14 July	1 August
Untreated	-	-	47.7	73.3	81.3
Farmfos	Potassium phosphite	5 L	48.0	45.8	53.8
Potassium bicarbonate + Silwet	Potassium bicarbonate + wetter	5 kg	42.0	47.1	51.1
Potassium bicarbonate + Wetcit	Potassium bicarbonate + citrus extract	5 kg + 2ml/L	51.0	48.9	56.4

Figure 1. **Mean number of RAA and green apple aphid colonies per plot recorded in spring 2007 following autumn treatment in 2006**

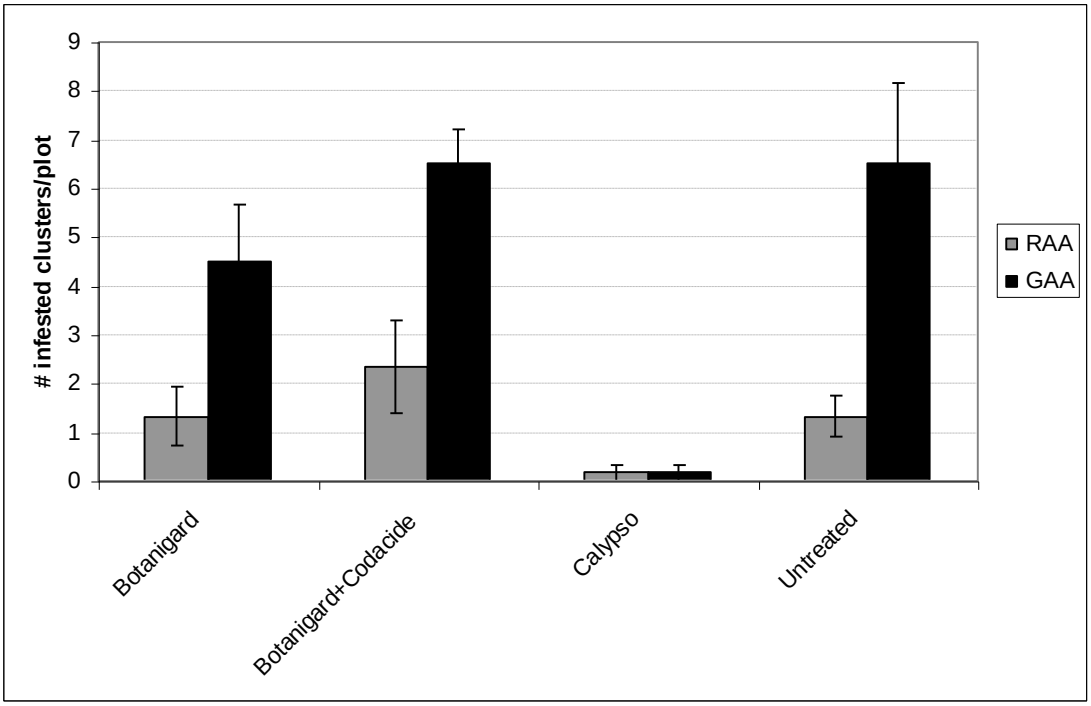

Table 49. **Mean number of ascospores extracted from overwintered leaf samples of apple cv. Bramley treated the previous December with various chemicals in 2004 or 2005**

Product	Active ingredient	Product rate per litre	Mean number of ascospores / ml	
			2004	2005
Untreated	-	-	694	27,000
Urea	urea	50g	278	500
Systhane	myclobutanil	0.9ml	556	0
Indar	fenbuconazole	2.8ml	139	56
Scala	pyrimethanil	2.25ml	0	222
Folicur	tebuconazole	2ml	278	0
Potassium bicarbonate + Agral	Potassium bicarbonate + wetter	20g + 1ml	-	889

Table 50. Mean number of ascospores extracted from overwintered leaf samples of apple cv. Bramley treated the previous December with various chemicals either as dip treatments to detached leaves or foliar spray treatments to orchard plots

Product	Active ingredient	Product rate per litre	Mean number of ascospores / ml	
			Dip	Foliar spray
Untreated	-	-	1,250	278
Urea	urea	50g	0	139
Systhane	myclobutanil	0.9ml	139	350
Indar	fenbuconazole	2.8ml	1,333	1,889
Scala	pyrimethanil	2.25ml	83	222
Folicur	tebuconazole	1.2ml	139	222
Potassium bicarbonate + Silwet	Potassium bicarbonate + wetter	20g + 1ml	222	0

Table 51. PCR primers used for the apple microbial diversity analyses

PCR Primer	Primer sequence (5'-3')
Prokaryotic	
Pk16F	AGAGTTTGATCATGGCTCAG
Pk16R	CTTGTTACGACTTCACCCCA
Pk23R	CACGGTACTAGTTCACTATCGGTC
PkITSF	GTCGTAACAAGGTAGCCGTA
PkITSR (6-FAM)	TGACTGCCAAGGCATCCACC
Eukaryotic	
Ek18F	AGAGGAAGTAAAAGTCGTAACAAG
EkITS1F	CTTGGTCATTTAGAGGAAGTAA
Ek28R (VIC)	ATATGCTTAAGTTCAGCGGG

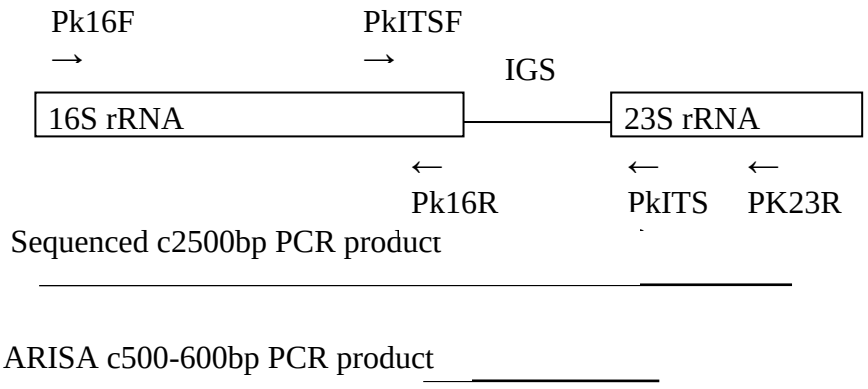

Figure 2. **The prokaryotic 16S-23S rRNA intergenic spacer (IGS) region showing the positions of the PCR primers used in this study**

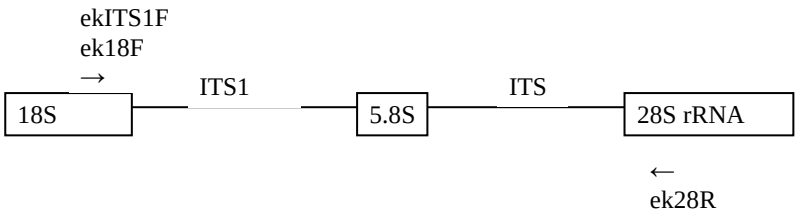

Figure 3. **The eukaryotic rRNA ITS region showing the position of PCR primers used in this study**

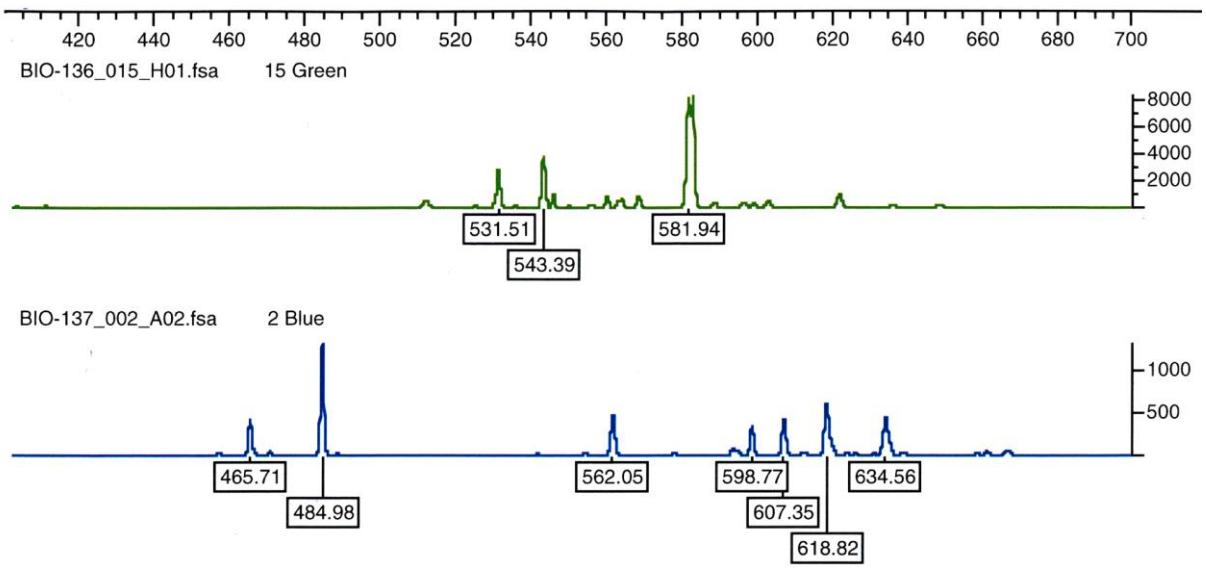

Figure 4. **Microbial diversity profiles run on an automated DNA sequencer from PCRs amplifying across the intergenic spacer regions between the rRNA genes**
The example electropherograms show sized peaks marking discrete laser detected PCR products. Blue peaks are from prokaryotes (6-FAM fluorescent label) and green peaks are from eukaryotes (VIC fluorescent label). These two are scored in Tables 52 and 53 as examples

Table 52. **Example of prokaryotic scores from above blue ARISA electropherogram**

Species peak	465	485	562	581	589	598	605	620	635	other
Sample 137	x	x	x			x	x	x	x	

Table 53. **Example of eukaryotic scores from above green ARISA electropherogram**

Species peak	531	543	552	561	564	668	582	608	624	648	other
Sample 136	x	x					x				

Table 54. Dates in 2004 when leaves or fruits were sampled from Wiseman's orchard at East Malling Research and rain in 7 or 14 days prior to sampling and most recent fungicides applied

Sample date	Rain mm in 7 days before sampling	Rain mm in 14 days before sampling	Treatment	Fungicides applied in 2-3 weeks before sampling
25 May	1.4	1.4	US	None
			CS	21 May myclobutanil + captan 12 May myclobutanil + captan 1 May myclobutanil + captan
			MS	21 May myclobutanil + captan + carbendazim 12 May myclobutanil + captan 1 May myclobutanil + captan
			UR	None
			CR	21 May myclobutanil + captan 12 May bupirimate 2 May bupirimate
			MR	21 May myclobutanil + captan + carbendazim 12 May bupirimate 2 May bupirimate
30 June	3.2	31.2	US	None
			CS	29 June myclobutanil + captan 9 June myclobutanil + captan 2 June myclobutanil + captan
			MS	29 June sulphur 18 June sulphur 9 June sulphur
			UR	None
			CR	29 June bupirimate 18 June bupirimate 9 June bupirimate
			MR	29 June sulphur 18 June sulphur 9 June sulphur
21 October	26.4	48.2	US	None
			CS	(16 August bupirimate + tolylfluanid)
			MS	4 October myclobutanil + captan
			UR	None
			CR	(16 August bupirimate + tolylfluanid)
			MR	4 October myclobutanil + captan

Table 55. **Numbers of bacteria cfu recorded on Tryptic soy agar plates from washings from rosette leaves or fruit of apple cv. Discovery sampled from plots in Wiseman's orchard East Malling Research receiving five different pesticide programmes in 2004**

Sample date	Treatment	No of cfu of bacteria per ml x10^3					
		By	Bc	Bw	Bp	Total cfu	Total types
25 May Petal fall Rosette leaves	**US**	89	669.1	0	0	758.1	2
	CS	92.3	299.5	0	0	391.8	2
	MS	0	320.2	0	0	320.2	1
	UR	12.9	708.3	100.8	0	822.0	3
	CR	0.38	862.5	1.6	0	864.5	3
	MR	89.0	1337.8	0	0	1426.8	2
30 June Fruitlet Rosette leaves	**US**	63.4	409.4	6.25	0	478.8	3
	CS	303.8	39101.9	0	0	39405.7	2
	MS	190.7	4475	240.8	0	4906.5	3
	UR	3.13	990.7	550	0	1543.8	3
	CR	51.5	3485.7	204	0	3741.2	3
	MR	137.5	3587.5	1.13	0	3726.1	3
21 Oct Rosette leaves	**US**	151692.5	152363.5	0	0	304056	2
	CS	75806.8	303000	0	0	378806.8	2
	MS	195.5	303000	0	0	303195.5	2
	UR	1278.9	303000	0	0	304278.9	2
	CR	3512.5	303000	0	0	306512.5	2
	MR	7625.5	228000	75	0	235700.5	3

Table 56. **Numbers of yeast cfu recorded on MYGP agar plates from washings from rosette leaves or fruit of apple cv Discovery sampled from plots in Wiseman's orchard East Malling Research receiving five different pesticide programmes in 2004**

Sample date	Treatment	No of cfu of yeasts per ml x10^2							
		Ypc	Yr	Ypfs	Yc	Yw	Yob	Total cfu	Total types
25 May Petal fall Rosette leaves	US	2.3	0.5	0	0	0	0	2.8	2
	CS	0.3	0.4	12.5	0	0	0	13.2	3
	MS	1.5	0	0	0	0	0	1.5	1
	UR	3.1	0.9	37.7	0.3	0	0	79.7	4
	CR	75.5	12.5	0	0	0	0	88	2
	MR	25.8	0	0	37.5	0	0	63.3	2
30 June Fruitlet Rosette leaves	US	64.5	4.25	0.5	0.15	0	0	69.4	4
	CS	41.65	3.9	12.5	0	0	0	58.0	3
	MS	149.05	4.65	0.25	0	0	0	153.95	3
	UR	187.65	2.13	25.38	0	0	0	215.16	3
	CR	103.4	100.5	0	0	0	0	203.9	2
	MR	87.78	78.5	0.38	0.13	0	0	166.79	4
21 Oct Rosette leaves	US	252.03	53.9	0.63	0	0	0	306.8	3
	CS	388.9	101.9	12.75	0	0	12.6	516.2	4
	MS	373.1	276.3	25	0	1.75	0	676.2	4
	UR	565.7	50.6	12.6	0	0	12.5	641.4	4
	CR	144.9	4.4	0.75	0	0	12.5	162.5	4
	MR	82.3	50.4	12.9	0	0	12.5	158.1	4

Table 57. Numbers of yeast cfu recorded on PDA/ Rifamycin plates from washings from rosette leaves or fruit of apple cv. Discovery sampled from plots in Wiseman's orchard East Malling Research receiving five different pesticide programmes in 2004

Sample date	Treat-ment	No of cfu of fungi per ml x10^2																		
		F 50	**F 51**	**F 23**	**F 31**	**F 47**	**F 49**	**F 48**	**F 43**	**F 21**	**F 60**	**F 56**	**F 3**	**F 46**	**F cfs**	**F 17**	**F 27**	**F 12**	**F 16**	**Total cfus**	**Total types**
25 May Petal fall Rosette leaves	**US**	0	0	0	0	0	0	0	0	0	0	0	0	662.1	0	0	0	0	0	662.1	1
	CS	0	0	0	0	100.3	0	0	0	0	0	0	0	1942.7	0	0	25.4	0	0	2068.4	3
	MS	0	0	0	0	87.5	0	0	0	0	0	0	0	209.3	0	0	0	38.2	0	335.0	3
	UR	0	0	0	0	112.5	0	0	0	0	0	0	0	175	1.03	0	0	0	0	288.5	3
	CR	0	0	0	0	37.6	0	0	0.13	0	0	0	0	226.9	0	0	0	0.4	0	265.03	4
	MR	0	0	0	0	0	0	0	0	0	0	0	0	840.7	0	0	25.3	0.13	0	866.1	3
30 June Fruitlet Rosette leaves	**US**	0	0	0	0	0	0	0	0	0	0	0	0.25	26.65	0	0	0	62.5	0	89.4	3
	CS	0	0	0	0.38	75	0	0	0	0	0	0	0	100	0	0	0.38	37.5	0	213.25	5
	MS	0	0	0	0	0	0	0	0.13	0	0	0	0	15.63	0	12.5	0.13	62.5	0	90.89	5
	UR	0	0	0	0	0.13	0	0	0.13	0	0	0	0	15.28	12.5	0	0	25.28	0	53.32	5
	CR	0	0	0	0	25	0	12.5	0	0	0	0	0	25.4	0	0	0	12.5	0	75.4	4
	MR	0	0	0	25.15	12.5	0	0	0.13	0	0	0	0	12.63	12.5	0	0	0.13	0	63.04	6
		F 50	**F 51**	**F 23**	**F 70**	**F 47**	**F 49**	**F 82**	**F 43**	**F 21**	**F 60**	**F 56**	**F 3**	**F 46**	**F cfs**	**F 15**	**F 58**	**F 12**	**F 16**	**Total cfus**	**Total types**
21 Oct Rosette leaves	**US**	0	38.3	0.2	13.4	0.2	0	0	0.2	0	0	0.2	0	2.5	0.2	0	0	0	0	55.2	8
	CS	0.4	14.8	0	88.5	25.2	12.5	12.5	0.3	0	0	12.5	0	0	0	0	0.2	0	0	166.9	9
	MS	0	3.4	0	13	0	0	0	0.2	0	0	0	0	29	175.2	0.3	0.3	0	0	221.4	7
	UR	0	52.2	0	0.2	0	0	0	0.6	0	50.7	0.3	0.7	12.5	0	0.2	0	0	0	229.9	8
	CR	0	0.7	0	0.2	37.7	0	0	0.2	0	0	0	0	0.7	0.4	0.2	0	0	0	40.1	7
	MR	0	39.9	0	0.3	0.3	0	0	13.5	0.2	0.5	0	0	0.5	0	0	0	0	0	55.2	7

Table 58. Dates in 2005 when leaves or fruits were sampled from Wiseman's orchard at East Malling Research and rain in 7 or 14 days prior to sampling and most recent fungicides applied

Sample date	Rain mm in 7 days before sampling	Rain mm in 14 days before sampling	Treatment	Fungicides applied in 2-3 weeks before sampling
3 June	9.6	11.4	US	None
			CS	20 May myclobutanil + captan 10 May myclobutanil + captan 27 April myclobutanil + captan
			MS	20 May myclobutanil + captan 10 May myclobutanil + captan + carbendazim 27 April myclobutanil + captan
			UR	None
			CR	20 May myclobutanil + captan 9 May bupirimate 27 Aprilbupirimate
			MR	20 May myclobutanil + captan + carbendazim 10 May bupirimate +carbendazim 27 April bupirimate
10 August	5.0	11.8	US	None
			CS	26 July bupirimate + captan 15 July bupirimate 4 July bupirimate
			MS	26 July sulphur 15 July sulphur 5 July sulphur
			UR	None
			CR	26 July bupirimate + captan 15 July bupirimate 4 July bupirimate
			MR	26 July sulphur 15 July sulphur 5 July sulphur
5 October	6.6	16.2	US	None
			CS	(23 August bupirimate + tolylfluanid)
			MS	(23 August sulphur)
			US	None
			CR	(23 August bupirimate + tolylfluanid)
			MR	(23 August sulphur)

Table 59. **Numbers of bacteria cfu recorded on Tryptic soy agar plates in washings from rosette leaves or fruit of apple cv Discovery sampled from plots in Wiseman's orchard East Malling Research receiving five different pesticide programmes in 2005**

Sample date	Treatment	No of cfu of bacteria per ml x10^2					
		By	Bc	Bw	Bp	Total cfu	Total types
3 June Petal fall Rosette leaves	US	127.25	4008.75	125	0	4261	3
	CS	189.4	2407	0	0	2596.4	2
	MS	54.4	2156.25	0.38	0	2211.03	3
	UR	127.65	152142.5	0	0	152270.15	2
	CR	39.15	315.4	0	0	354.55	2
	MR	92.25	406.25	4	0	502.5	3
10 Aug Fruitlet Rosette leaves	US	100.9	76386.25	4.13	12.5	76503.78	4
	CS	44	150139.05	65	0	150248.05	3
	MS	119	76675.65	15	0	76809.65	3
	UR	594.05	152157.9	0	12.5	152764.45	3
	CR	78.15	150126.75	215.4	250.25	150670.55	4
	MR	178.15	151954.75	117.4	5687.5	157937.8	4
5 Oct Rosette leaves	US	1315.9	501.9	0	0	1817.8	2
	CS	228	2875	0.75	0	3103.75	3
	MS	244.4	961.65	1.25	0	1207.3	3
	UR	1104.8	1982.5	90.13	0	3177.43	3
	CR	381.75	2033.75	50	0	2465.5	3
	MR	955.4	385	25.5	0	1365.9	3

Table 60. **Numbers of yeast cfu recorded on MYGP agar plates from washings from rosette leaves or fruit of apple cv Discovery sampled from plots in Wiseman's orchard East Malling Research receiving five different pesticide programmes in 2005**

Sample date	Treatment	No of cfu of yeasts per ml x10^2							
		Ypc	Yr	Ypfs	Yc	Yw	Yob	Total cfu	Total types
3 June Petal fall Rosette leaves	US	55.65	25	0.25	0	0	0	80.9	3
	CS	5.25	1.88	0	0	0	0	7.13	2
	MS	1	0	0	0	0	0	1	1
	UR	84.44	15.25	0	0	0	0	99.69	2
	CR	13.15	12.75	0.13	0	0	0	26.03	3
	MR	27.63	0.13	0	0	0	0	27.76	2
10 Aug Fruitlet Rosette leaves	US	41.75	1.13	12.75	0.75	0	0	56.38	4
	CS	12.75	0	0	0.63	0	0	13.38	2
	MS	17.25	0.88	0.13	0	0	0	18.26	3
	UR	696.4	51.4	12.75	0	0	0	760.55	3
	CR	148.28	0.5	0.38	0.25	0	0	149.41	4
	MR	45.8	4.25	0.25	0	0	0	50.3	3
5 Oct Rosette leaves	US	151.25	14.15	37.5	0.25	0	0	203.15	4
	CS	58.4	2.25	12.5	12.75	0	0	85.9	4
	MS	69.9	13.25	0	1	0	0	84.15	3
	UR	210.9	25.9	13.28	13.75	0	0	263.83	4
	CR	62.15	0.5	0	0.63	0	0	63.28	3
	MR	81.9	12.5	62.5	0	0	0	156.9	3

Table 61. Numbers of yeast cfu recorded on PDA/ Rifamycin plates from washings from rosette leaves or fruit of apple cv. Discovery sampled from plots in Wiseman's orchard East Malling Research receiving five different pesticide programmes in 2005

Sample date	Treat-ment	No of cfu of fungi per ml x10^2																		
		F 7	**F 83**	**F 19**	**F 8**	**F 47**	**F 41**	**F 82**	**F 43**	**F 55**	**F 60**	**F 58**	**F 3**	**F 46**	**F cfs**	**F 15**	**F 27**	**F 31**	**F 16**	**Total cfus**	**Total types**
3 June Petal fall Rosette leaves	**US**	0	0	0	0	0	0	0	0	0	0	0	12.63	0.75	0	0	0	0	0	13.38	2
	CS	0	0	0	0	0	0	0	0	0	0	0	0.13	25.13	0	0	0	0	0	25.26	2
	MS	0	0	0	0	0	0	0	0	0	0	0	0	0.38	0	12.5	0	0	0	12.88	2
	UR	0	0	0	0	0	0	0	0	0	0	0	0.38	1.0	0	0	0	0	0	1.38	2
	CR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	MR	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0.5	1
10 Aug Fruitlet Rosette leaves	**US**	0.13	0	0	0	175	0	0	0	0.13	0	0	12.88	27.03	0.25	0	0	0	0	215.42	6
	CS	0	0	0	0	88.5	0	0	0	0	0	0	0	0	0	0	0	0	0	88.5	1
	MS	0	0	0.13	0	0	0	0	0	0.13	0	0	0.38	90.63	0.38	0	0	0	0	91.65	5
	UR	0	0.13	0	0.25	0	0	0	0	0	0	0	12.5	151.55	0.25	0	0	0	0	164.68	5
	CR	0	12.5	25.38	0.25	0	0	0	25	0.13	0	0.25	50.15	425.75	0	0	0	0	0	539.41	8
	MR	0	0	0.25	0.25	162.5	0	0	0	0	0	0	0	27.63	0	0	0	0	0	190.63	4
		F 7	**F 51**	**F 19**	**F 70**	**F 47**	**F 41**	**F 82**	**F 43**	**F 21**	**F 60**	**F 25**	**F 3**	**F 46**	**F cfs**	**F 15**	**F 27**	**F 31**	**F 16**	**Total cfus**	**Total types**
5 Oct Rosette leaves	**US**	0	0	0	0.25	0	0	0	0.88	0	0	0	0.25	3.38	0	0	0	12.5	0	17.26	5
	CS	0	0	0	0	0	0	0	0.13	0	0	0.25	0	16.13	0	38.15	0	0	12.5	67.16	5
	MS	0	12.5	0	0	0	0	0	0	0	0.88	0	0	3.13	0	0	0	0	0	16.51	3
	UR	0	0	0.13	0	0	0.38	0	0	0	0	0	0.38	6.5	0	0	12.5	0.13	12.5	32.52	7
	CR	0	13.5	0	0	0	0	0	13.13	0	0	0	0	2.13	0	0	0	0	0	28.76	3
	MR	0	0	0	0.25	0	0	0	1	0	0	0	0	1.51	0	2.17	0	0.13	0	5.06	5

Table 62. **Dates in 2006 when leaves or fruits were sampled from Wiseman's orchard at East Malling Research and rain in 7 or 14 days prior to sampling and most recent fungicides applied**

Sample date	Rain mm in 7 days before sampling	Rain mm in 14 days before sampling	Treatment	Fungicides applied in 2-3 weeks before sampling
7 August	1.4	7.0	US	None
			CS	4 August bupirimate + tolylfluanid 12 July bupirimate 28 June myclobutanil + captan
			MS	4 August sulphur 20 July sulphur 13 July sulphur
			UR	None
			CR	4 August bupirimate + tolylfluanid 12 July bupirimate 28 June bupirimate
			MR	4 August sulphur 20 July sulphur 13 July sulphur

Table 63. **Numbers of bacteria cfu recorded on Tryptic soy agar plates in washings from rosette leaves or fruit of apple cv Discovery sampled from plots in Wiseman's orchard East Malling Research receiving five different pesticide programmes in 2006**

Sample date	Treatment	No of cfu of bacteria per ml x10^2					
		By	Bc	Bw	Bp	Total cfu	Total types
7 August Rosette leaves	**US**	694.05	5362.5	352.15	26.9	6435.6	4
	CS	30.92	151621.25	3.9	13.5	151669.57	4
	MS	9.75	10038.15	145.05	0	10192.95	3
	UR	2.65	152376.75	2528.75	1242.9	156151.05	4
	CR	232.15	3000	0	0	3232.15	2
	MR	18.8	6263.15	30.28	287.5	6599.73	4
7 August Fruit	**US**	1339	2275	6093.9	39.4	9747.3	4
	CS	37.5	229128	0	1500	230665.5	3
	MS	200	7000	430.5	919.65	8550.15	4
	UR	75.5	88875	0	263.75	89214.25	3
	CR	37.5	3130.15	4250	253.9	7671.55	4
	MR	75000	5850	3	3.25	80856.25	4

Table 64. **Numbers of yeast cfu recorded on MYGP agar plates from washings from rosette leaves or fruit of apple cv Discovery sampled from plots in Wiseman's orchard East Malling Research receiving five different pesticide programmes in 2006**

Sample date	Treat-ment	No of cfu of yeasts per ml x10^2							
		Ypc	Yr	Ypfs	Yc	Yw	Yy	Total cfu	Total types
7 August Rosette leaves	US	287.15	87.8	38.15	26.25	0	0	439.35	4
	CS	297.3	103.8	12.65	0	0	0	413.75	3
	MS	226.15	201.8	0.25	51.3	0	0	479.5	4
	UR	498.5	317.75	53.15	52.65	0	0	922.05	4
	CR	22.25	1.65	1.03	0	0	0	24.93	3
	MR	468.65	114.03	13	37.5	0	0	633.18	4
7 August Fruit	US	3390.15	1	2.13	2486.75	100	0	5980.03	5
	CS	3007.25	569.25	116.4	5923.38	0	0	9616.28	4
	MS	658.75	526.13	130.9	599.05	0	365.25	2280.08	5
	UR	5400.9	237.8	50.25	387.5	0	0	6076.45	4
	CR	3243.3	51.5	440.28	745.25	0	0	4480.33	4
	MR	1515.4	100.4	40.63	3005	0	0	4661.43	4

Table 65. Numbers of yeast cfu recorded on PDA/ Rifamycin plates from washings from rosette leaves or fruit of apple cv. Discovery sampled from plots in Wiseman's orchard East Malling Research receiving five different pesticide programmes in 2006

Sample date	Treat-ment	No of cfu of fungi per ml x10^2																		
		F 6	F 7	F 41	F 8	F 47	F 42	F 12	F 43	F 52	F 60	F 58	F 3	F 46	F cfs	F 15	F 12	F 31	F 16	Total cfus	Total types
7 August Rosette leaves	US	0	0	0	0	0	0	0	0	0	0	0	0	13.9	13.5	0	0.13	0	0	27.53	3
	CS	0	0	0	1.15	0	0.13	0	0.25	0	0	0	0	0.9	12.5	0	0	0	0	14.93	5
	MS	0	0	0	0	0	0	0	0	0	0	0	0	13.0	0.13	0	0	0	0	13.13	2
	UR	0.13	0	0	0	0	0	0	0	0	0	0	0	13.25	38.78	0	0	0	0	52.16	3
	CR	0	0	0	0.25	0	0	0	0	0	0	0	0	0	0.63	0	0	0	0	0.88	2
	MR	0	0	0	2.75	0	0.38	0	0	0	0	0	0	276	38	0	0	0.25	0	317.38	5
7 August Fruit	US	0	0	0	2.9	0	0	0	12.5	0	0	0	0	0	102.88	0	0	0	0	118.28	3
	CS	0	0	0	181	0	0	0	0	0	0	0	0	0	131.25	0	0	0	0	312.25	2
	MS	0.13	2.4	87.5	1.88	0	0.38	0	0	0.25	0	0	0	0	101.65	0	0	0	0	194.19	7
	UR	0	0	0	128	0	0	0	0	0	0	0	0	0	90.05	0	0	0	0	218.05	2
	CR	0	0	0	0	0	0	0	0	0	0	0	0	0	519.13	0	0	0	0	519.13	1
	MR	0	3	0	16.78	0	0.25	0	0	0	0	0	0	0	140	0	0	0	0	160.03	4

APPENDIX B

Objective 6a. To evaluate the longer term effects of the zero pesticide residue strategy on arthropod populations in apple trees compared to a broad-spectrum routine programme and untreated

OBJECTIVES

The objectives of the study were:

1. To assess of the biodiversity of Coleoptera, Heteroptera, Auchenorhyncha, Neuroptera, Formicidae and Araneae, including an estimation of the total Arthropoda diversity of an experimental apple orchard at East Malling Research.
2. To investigate the effects of different pest management programs (conventional treatment based on routine use of broad-spectrum insecticides, a pest and disease management program based on early spring and post harvest treatments designed to give zero pesticide residue on fruits at harvest and control untreated plots) on the biodiversity, structure and organisation of Coleoptera, Heteroptera, Auchenorhyncha, Neuroptera, Dermaptera, Formicidae and Araneae assemblages and some pest populations.

METHODS

The apple orchard at East Malling Research (Wiseman field – Lat: 51:17:08N, Lon: 0:28:13E) was surrounded by arable fields, other fruit orchards, including pear and cherry, and small areas of woodland. A replicated experiment evaluating: (1) 'zero pesticide residues' integrated pest management programme (ZERO) was in progress in this orchard, where selective pesticides were used only in the early and late parts of the growing season to avoid the occurrence of detectable levels of pesticides in fruits at harvest, (2) full pesticide (conventional CONV) and (3) untreated control (UNTR) treatments were included. As the faunal compositions of cicadas were similar in CONV and ZERO treatments the data obtained from these treatments were unified. The experimental orchard (1.14 ha) was divided into 12 plots, where the three different pest management systems were applied with four replicates. The plots were separated from each other by alder (*Alnus cordata*) windbreaks and contained rows of different apple cultivars. Every plot contained the cultivar Discovery on which the biodiversity sampling was conducted. A commercial weed-free strip was maintained by herbicide spraying in the tree rows and the grass alleys were mown regularly.

Pitfall traps were used to collect ground surface-dwelling arthropods. The traps were plastic beakers 500 cm^3 in volume, 90 mm in diameter set in the ground and half-filled with 50% solution of ethylene glycol and were covered by a rain shield. 36 pitfall traps (12 traps per treatment) were used, three traps in each plot. The traps were placed in the middle of the 4th, 6th and 8th rows of the 12 row plots. The traps were operated from early April to the end of October, and were emptied biweekly and the samples were preserved in formalin. The arthropod assemblages were collected from the herb layer (grass and forb alleyways) by sweep netting. A triangular sweep net (32 cm long on each side) was used. Two replicate sweep net samples, each of 100 sweeps was taken on every sampling occasion from each plot (8 repetitions per treatment), monthly between April to October. The canopy surface arthropods were collected by a beating method, biweekly, from early of May until end of September. Three samples were taken from each plot on each sampling occasion. Each sample consisted of the arthropods collected from four trees (3 samples/plot x 4 trees/sample=12 trees/plot). The same labelled trees of cultivar Discovery are used throughout the whole year. The collected arthropod material was placed in nylon bags, and "etherised" by Ethyl acetate and then sorted into Taxa (Coleoptera, Heteroptera, Auchenorrhyncha, Neuroptera, Dermaptera, Orthoptera, Formicidae and Araneae). The numbers in each class were recorded in a primary Excel spreadsheet database. Additionally, 20 x 20 cm double-sided yellow sticky traps were used for collecting Auchenorhyncha and Neuroptera, but also other groups. Two traps were deployed in the lower part of the canopy of each plot (two traps/plot x two sides/trap = four replicates/plot, 16 replicates/treatment). The traps were deployed in May (for a one week period before and for a one week period after blossom) and from July till end of September. They were changed biweekly.

Data were analysed after ln(x+1) transformation of the raw data. After robust Welch ANOVA test, pairwise comparison of means was used to separate means. In the case of species richness,

metric ordination, principal coordinates analysis (PCoA), based on the Horn similarity index was applied to compare the composition of arthropod assemblages of differently treated plots.

RESULTS

83,549 individual specimens were collected in the major taxa studied (Aranae, Coleoptera, Auchenorrhycha and Heteroptera) in total over the four years of sampling (2001, 2002, 2004 and 2006) (Table 1). The highest numbers were collected in the UNTR plots (37,670) with similar numbers in the CONV and ZERO plots (23,210 and 22,669 respectively). However, the pesticide management treatments had significant effects on the species richness and composition of the arthropod communities, as discussed below:

Aranae

Potential prey density:
During the four-year study, the abundance of some potential prey groups (Achenorrhyncha adults, Psylla adults, Neuroptera, Heteroptera, Coleoptera, Lepidoptera larvae, Hymenoptera parasitica adults) was assessed in the canopy of apple trees with yellow sticky traps in 2001 and 2002, and with a tree-beating method in 2004 and 2006. The abundant prey organisms in May, independently from the collecting method used, were beetles, parasitic wasps, apple suckers (*Psylla mali*) and leafhoppers. Leafhoppers and parasitic wasps (2001), apple suckers (2002), and beetles, predacious bugs and apple suckers (2004) dominated the samples in June and July. Leafhoppers and parasitic wasps (2001, 2002) and predacious bugs and beetles (2004) were common in the canopy in August. The main potential prey group was leafhoppers during the second peak of spiders in September and first week of October in all years. The aphids (mainly *Dysaphis plantaginea* and also *Aphis pomi*) were assessed visually in 2001 and 2002 and counted in the tree-beating samples in 2004 and 2006. Their abundance was significantly higher in the UNTR plots compared to CONV and ZERO plots, especially in May and June 2001 and 2006, the years with higher aphid infestation. No significant difference was found between CONV and ZERO plots during the whole season with exception of 2001, when aphids (*D. plantaginea*) were more abundant in ZERO plots in May and June. The total abundance of potential prey was higher in the UNTR plots compared to CONV and ZERO plots throughout the whole season. The abundances in CONV and ZERO plots were similar.

Canopy spider assemblages:
During the four-year study, a total of 8,305 individual spiders of 69 species were collected and identified. 5,958 individuals comprising 51 species were collected in the canopy. Both the CONV and ZERO treatments significantly reduced the total arboreal spider abundance compared to the UNTR plots in all the investigated years. Similar tendencies were found in the case of the species richness (Table 2).

The CONV and ZERO treatments lowered the abundance, compared to UNTR plots, at the guild, ‘web builders’ by 55.6% and 53.3%, ‘ambushers and runners’ by 56.8% and 63.2% and ‘active nocturnal hunters’ by 58.6% and 50.5% respectively. The effect on abundances was significant (Table 3.). Most of the spider species or genera showed a similar pattern (Table 3). The only exception was *Neottiura bimaculatum*, *Tetragnatha* sp. (juveniles) and *Xysticus* sp. (juveniles). Their abundances in CONV and UNTR plots were similar (*N. bimaculatum* and *Xysticus* spp.), or was higher in the CONV treatment (*Tetragnatha* sp.) (Table 3).
There were substantial differences in effects of pesticide regimes between the different sexes and the juveniles. Both in the CONV and ZERO treatments, the abundance of females decreased significantly more than the males. This was especially obvious in the CONV plot, where the treatments, compared to UNTR plots, lowered the abundance of females by 65.3% while the decrease of males was only 18.6% (Fig. 1). As a consequence, the proportion of males in the arboreal spider assemblages increased from 32.4% in the UNTR plots to 52.6% and 53.5% in the CONV and ZERO plots respectively. The abundance of juveniles also decreased – to the value between the females and males (Fig. 2).

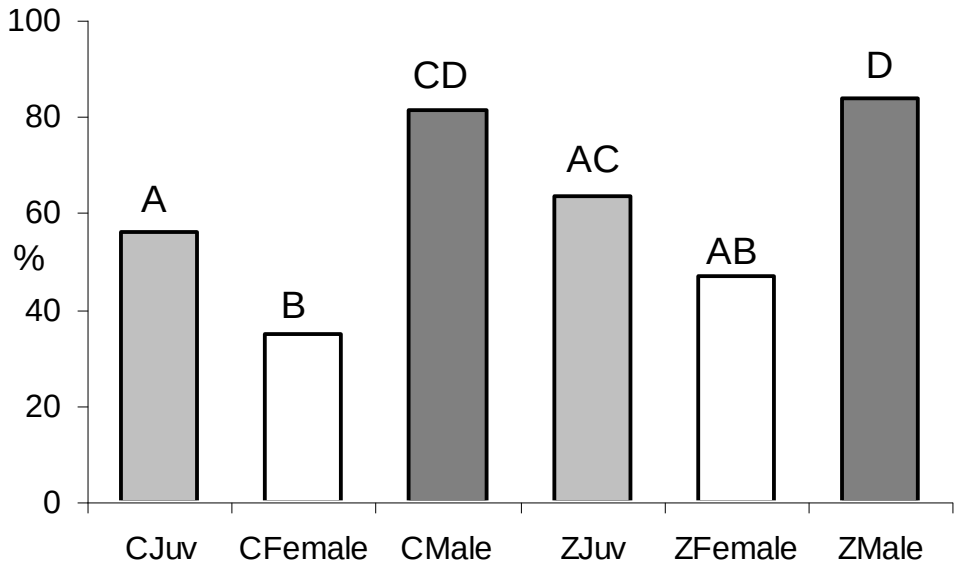

Figure 1. **Relative abundance (%) of juvenile (Juv), female and male spiders in the conventionally treated (C) and 'zero pesticide residue' (Z) plots compared to the untreated control (100%). The different letters represent significant difference ($p<0.05$)**

Metric ordination of the cumulated data of the four years revealed that the genus composition of adult and juvenile assemblages, independent from the treatments, differed significantly. The proportion of the main genera and the family Linyphiidae in the adult and juvenile assemblages were as follow: *Araniella* (25.7%, 32.6%), *Theridion* (26.5%, 21.0%), *Neottiura* (*bimaculatus*) (0.28%, 13.7%), *Philodromus* (4.62%, 13.5%), *Linyphiidae* (25.7%, 2.6%) and *Tetragnatha* (0.14%, 4.4%). Smaller differences were found between the treatments within adult and juvenile assemblages. Also, the spring and autumn spider assemblages separated from each other characteristically. The composition of spiders from different treatments showed smaller differences. In spring the greatest difference was found between the UNTR and CONV plots. The spider assemblages in the ZERO plots were intermediate, but closer in composition to the UNTR plots. However, in autumn the composition of CONV and ZERO spider assemblages became closer and showed similar distance to the UNTR plots. The spring and autumn composition of the spider assemblages in the UNTR plots were slightly separated from the other two treatments. For example the abundance of *Theridion* sp. and linyphiids (including *Entelecara acuminata*), *Enoplognatha* sp. *Gibbaranea* sp. was more than twice that in the UNTR plots than the CONV and ZERO plots, whilst other genera were less abundant.

Herb layer spider assemblages:

1,412 individuals comprising 41 species were collected from the herb layer (Table 4). The abundance of the herb layer spiders was significantly higher in the UNTR plots than in the CONV and ZERO plots. The four year's total abundance decreased by 35.8% and 33.5% of the UNTR plots in the CONV and ZERO treatments respectively. Similarly, values in the canopy were 44.4% and 45.4% suggesting that the negative effects of the treatments on the spiders were stronger in the canopy. The species richness of herb layer spider assemblages was slightly lower in the CONV plots than the other treatments, but the difference was not significant.

The most common genera in the herb layer were *Microlinyphia* (presumably *M. pusilla*), *Tetragnatha* (mainly *T. extensa* and with lower abundance *T. pinicola*), *Mangora* (*M. acalypha*), *Neottiura* (*N. bimaculatus*), *Araniella* (*A. cucurbitina* and *A. opistographa*) and *Xystichus* (*X. cristatus* or *X. kochi*). These five genera comprised 76.1% of the total catch (Table 5).

Significantly more spiders were collected in the ZERO plots than in the CONV plots in June, and the abundance was also higher in May. In contrast, no difference was found afterwards, in July, August and September. The abundance was usually higher in the UNTR plots compared to the other two treatments, but the difference was significant only in September. The composition of adult and

juvenile spiders showed marked differences. The composition of differently treated plots within the same age group was more similar. The ZERO and UNTR plots showed significant differences in adult and juvenile assemblages. The CONV plots showed less distinct character.

Auchenorrhyncha

In the first two sampling years when full identification of specimens to species level was done, a total of 15,247 individuals of 69 cicada species was recorded. The most common species, in order of relative abundance (%), collected in canopy, by yellow sticky traps and beating, were *Empoasca decipiens* (53.1%), *Edwardsiana rosae* (9.5%), *Ribautiana debilis* (7.5%), *Eupteryx atropunctata* (3.8%), *Zygina flammigera* (3.1%) and *Edwardsiana crataegi* (3.0%). In the herb layer, the dominant species was *Javesella pellucida* (69.5%) while *Euscelis incisus* (7.5%), *Arthaldeus pascuellus* (6.2%) and *Deltocephalus pulicaris* (6.1%) were found in smaller numbers (Table 6).

Cicada assemblages of the canopy*:*
In the yellow sticky trap samples in 2001, there was a significantly ($P<0.05$) higher mean species richness in the untreated plots (UNTR) than in the conventional (CONV) plots. Species richness in the ZERO plots was intermediate**.** There was no significant difference between the differently treated plots in 2002 though the species richness increased following the same trend with the decreasing insecticide pressure (Fig. 2).

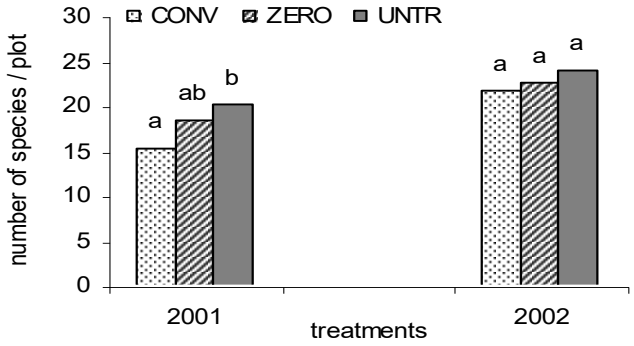

Figure 2. Effect of different treatments on average species richness of auchenorrhyncha in yellow sticky trap samples in 2001 and 2002. p<0.1)

Similarly, the average number of individuals was highest in the UNTR plots. The numbers of individuals were lower in the CONV and ZERO plots and there was no significant difference between them. A similar relationships was also apparent when males and females were analysed separately. For the females, both the CONV and ZERO treatments reduced significantly the number of cicada assemblages, compared to the UNTR plots (Figs 3 and 4). However, the number of males did not differ significantly in the CONV and UNTR plots in 2001.

The number of species and individuals collected by beat sampling was less in 2002 than in 2001 and much less than collected by yellow sticky traps (Figs 5 and 6). The number of males was insufficient for statistical analysis, but in both years, similarly to the yellow sticky trap samples, the species richness was the highest in the UNTR plots. Regarding the total abundance values and the numbers of males and females separately, in the samples collected by the beating technique, cicadas occurred in significantly higher abundance in UNTR plots, compared to CONV and ZERO plots (Fig. 5 and 6).

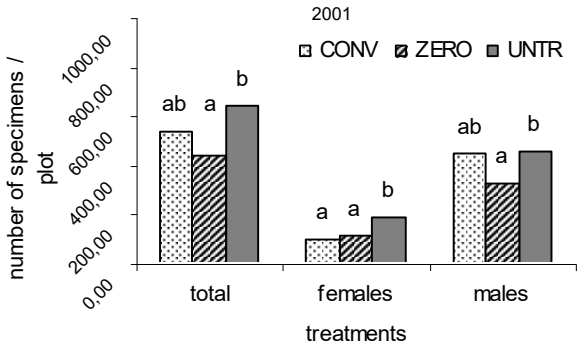

Figure 3. Effect of different treatments on average number of auchenorrhyncha specimens in yellow sticky trap samples in 2001 (p<0.1)

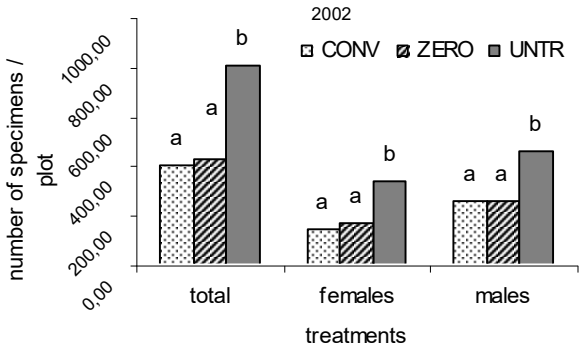

Figure 4. Effect of different treatments on average number of auchenorrhyncha specimens in yellow sticky trap samples in 2002 (p<0.01)

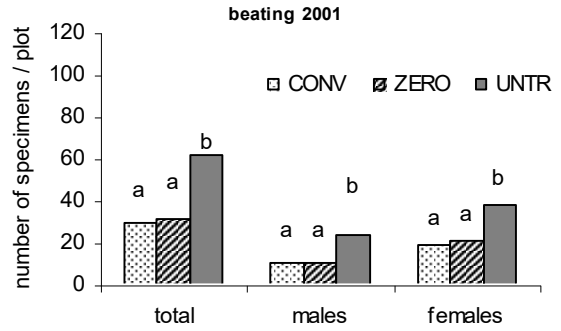

Figure 5. Effect of different treatments on mean number of auchenorrhycha specimens in beating samples in 2001 (p<0.05)

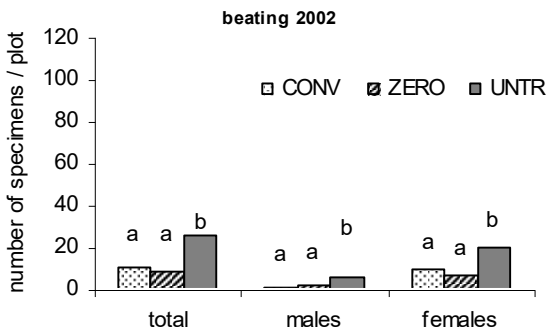

Figure 6. Effect of different treatments on mean number of auchenorrhycha specimens in beating samples in 2002(p<0.1)

The greatest number of species caught by yellow sticky traps were collected in August and September each year. The species richness in this period was three or five times higher than in spring in 2002. At most of the sampling dates, the highest species richness was observed in the UNTR plots, while species richness did not differ in the CONV and ZERO plots, except in August and September. At this time, the increase in the number of species in UNTR plots also developed in the ZERO plots, in contrast to CONV plots where the species richness showed only a slight increase (Figs 7 and 8).

The seasonal abundance graphs were more or less similar in the different years, and showed a smaller peak in May and two higher peaks in August and September. Even though there was an early termination of the insecticide treatments in the ZERO plots, the abundance of cicadas was lower during the whole season (Figs 9 and 10).

The Rényi-diversity values in the differently treated plots in the canopy layer showed that there were significantly more diverse cicada assemblages in the UNTR plots throughout the whole length of alpha scale parameter than in CONV plots, where broad spectrum insecticides were applied. The differences were notable even in the section sensitive to rare species (as for example where alpha=1), but remarkable differences were shown in the sections sensitive to moderately frequent and frequent species (Figs 11A, B). The cicada assemblages of the ZERO plots differed significantly from each other in the two years of observation. The Rényi-diversity of cicada assemblages in the ZERO treatment was identical with the diversity of UNTR plots in 2001 and with the diversity of CONV plots in 2002 (Figs 11 A, B).

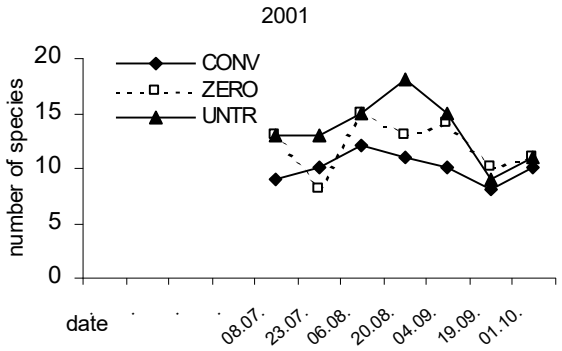

Figure 7. Effect of treatments on number of cicada species collected by yellow sticky traps in 2001

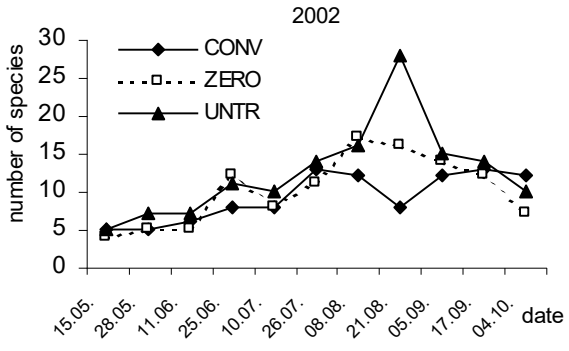

Figure 8. Effect of treatments on number of cicada species collected by yellow sticky traps in 2002

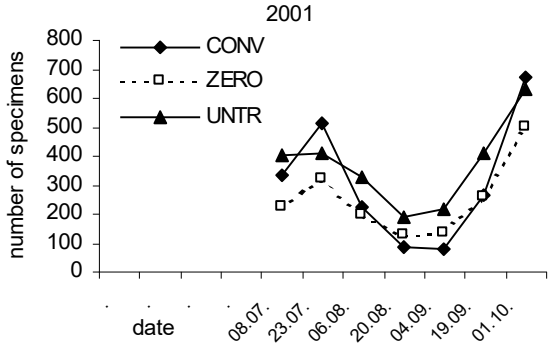

Figure 9. Effect of treatments on cicada populations collected by yellow sticky traps in 2001

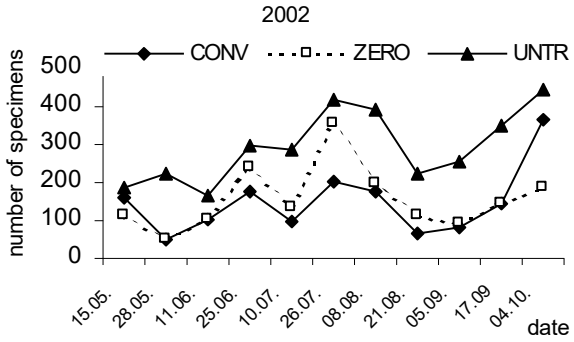

Figure 10. Effect of treatments on cicada populations collected by yellow sticky traps in 2002

Auchenorrhyncha assemblages in the herb layer:

According to the statistical analysis, the higher insecticide pressure of CONV and ZERO treatments had little effect on cicada assemblages of the herb layer. Reduction of density in the CONV plots was observed in 2001, and only for the females (Table 3). The species richness values did not differ significantly in sweep netting samples in 2001, however, unlike the tendency observed with yellow sticky trap and beating samples, numbers of species were the lowest in UNTR plots and the highest in ZERO plots. In 2002, however, the effect of the lower insecticide load was perceptible also in herb layer of UNTR plots.

In the herb layer, diversity relationships were similar to those in the canopy (Figs 11 C, D). Significantly more diverse cicada assemblages formed in UNTR control plots, compared to CONV ones. The diversity of ZERO plots was closer to the UNTR in 2001, but closer to the CONV in 2002, throughout the whole length of the scale parameter.

When the abundance of the common species and different sexes were analysed separately, the main tendencies were similar: the CONV and ZERO treatments reduced the abundance of the cicada species compared to UNTR plots and did not differ from each other (Table 2). The only exception was the most abundant species, *Empoasca decipiens*. The average number of the males of *E. decipiens* in the CONV and ZERO plots was identical to ones in UNTR plots in both years.

Only a few specimens were collected by the beating technique. The most frequent species among these was *Edwardsiana rosae*, which was collected only in 2001 in sufficient numbers for statistical analysis. In the case of the males of *E. rosae* and females belonging to Edwardsiana genus (supposedly representing mostly *E. rosae*), abundance values for the UNTR plots were significantly higher than those in the CONV and ZERO plots. In the ZERO plots, similarly to the results with yellow sticky trap samples, the values were between the CONV and UNTR plots.

Numbers of *Zygina hyperici* (Table 2), and *Eupteryx atropunctata, Javesella pellucida* and *Zyginidia scutellaris* (the latter species are not shown in Table 2) that were feeding on herbaceous plants did not differ significantly in the canopy of apple trees in the differently treated plots.

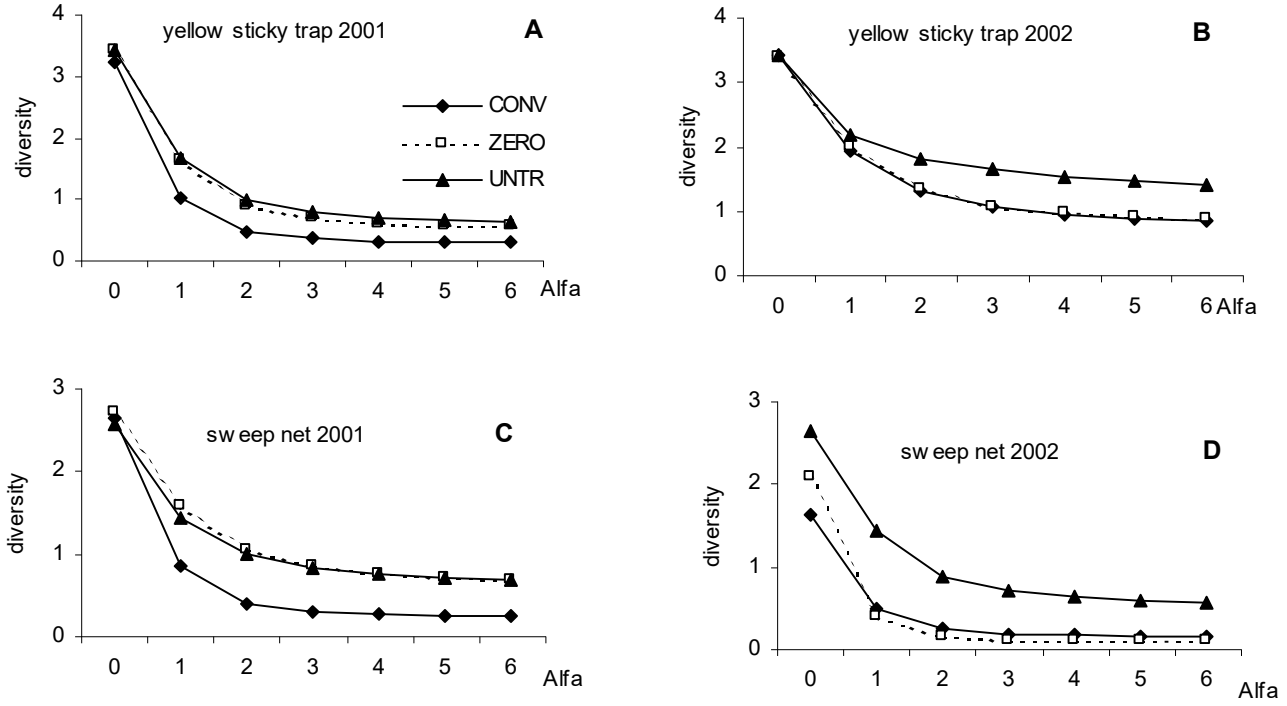

Figure 11. Effect of different treatments on Rényi diversity values of cicada assemblages collected by yellow sticky traps and sweep netting in 2001 and 2002

Parasitisation of the adults:
Some of the cicadas collected by us were infected by parasitoids, mainly by ectoparasitoids from the family Dryinidae (Hymenoptera) and Pipunculidae (Diptera). As a result of the analysis (two way ANOVA) of yellow sticky trap samples collected in 2001, it was found that in the subfamily Typhlocybinae (mainly *Edwardsiana rosae*, some *Edwardsiana crataegi* and *Alnetoidia alneti*) the parasitisation in the UNTR plots was significantly ($p<0.05$) higher for both sexes, while there was no significant difference between the parasitisation of males and females. The level of parasitism was lower in species belonging to genus *Empoasca*. There were no detectable differences in the level of parasitism, nor between the sexes nor between the pest management systems (Fig. 12 and 13).

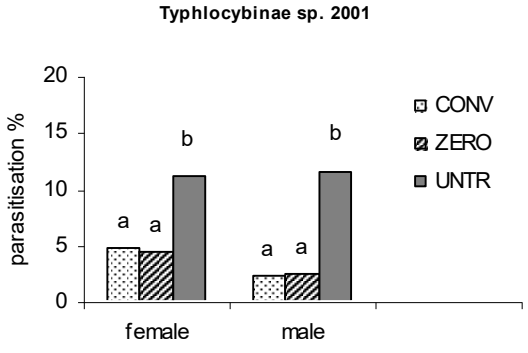

Figure 12. Parasitisation level of males and females belonging to *Typhlocybinae* (mainly *Edwardsiana rosae,* some *E. crataegi* and *Alnetoidia alneti*) in 2001 ($p<0.01$)

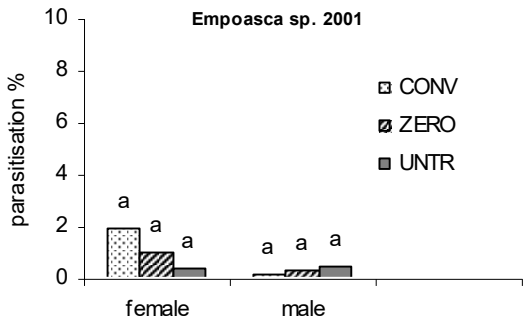

Figure 13. Parasitisation level of males and females belonging to *Empoasca* genus in 2001. ($p<0.01$)

When observing the parasitism rate of the genus *Edwardsiana* in 2002 by two-way ANOVA, remarkable differences could be detectable between the parasitisation during the first and second half of the growing season, both for males and females. While in the first half of the season the level of parasitism remained under 1%, in the second half, especially at the end of September and in October, it increased in all of the three management systems up to 14% (UNTR plots). The parasitisation of males and females did not differ significantly in the autumn period. The parasitisation level in the UNTR plots was remarkably and significantly ($p<0.05$) higher than in the CONV and ZERO plots, which were similar. Thus the insecticide treatments reduced the activity and density of the parasitoids (Fig. 14).

When observing the parasitisation of males and females of the genus *Empoasca* combined by two-way ANOVA, the parasitisation of females in the first half of the vegetation period was significantly ($p<0.05$) higher in the CONV than the UNTR plots. The values for the ZERO plots were intermediate. There was no detectable difference in parasitisation rates of the males between the treatments in the second half of the season when the level of parasitism, in contrast to the genus *Edwardsiana*, was lower (Fig. 15).

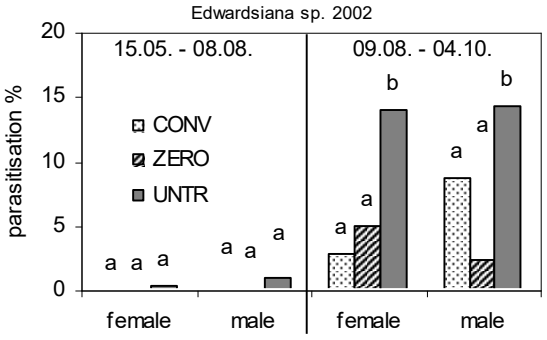

Figure 14. **Parasitisation level of males and females belonging to genus *Edwardsiana* (mainly *E. rosae*) in first and second half of the vegetation period. ($p<0.05$)**

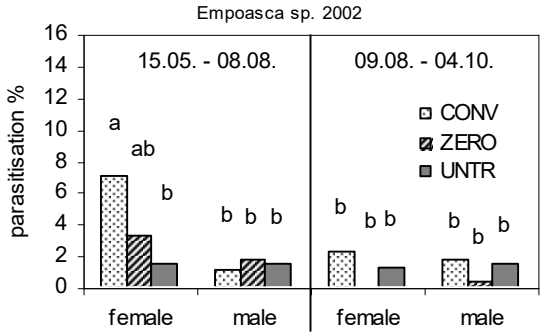

Figure 15. **Parasitisation level of males and females belonging to genus *Empoasca* (mainly *E.decipiens*) in first and second half of the vegetation period. ($p<0.05$)**

Heteroptera

During the four-year survey 5,825 specimens belonging to 85 species were collected. A full list of the species collected in each year by each sampling method is given in Table 8. 3,304 specimens were collected from the canopy with the beating funnel. The relative abundance (%) values of the most common Heteroptera species collected by beating, with the numbers of individuals and species are presented in Table 8. The dominant true bug species, in descending order were *O. vicinus*, *A. mali*, *A. nemorum*, *H. planicornis*, *Phytocoris reuteri*, *L. rugulipennis*, *Ph. longipennis*, *Palomena prasina*, *O. marginalis*, *Blepharidopterus angulatus* and *Deraeocoris ruber.* These eleven species comprised between 80% and 86% of the total catch in the canopy of each orchard. These species were variously abundant in the differently treated plots, so *A. nemorum* was the dominant species in the plots treated with insecticides, while in the UNTR plots *A. mali* and *O. vicinus* had high relative abundances (Table 9). The herb layer inhabiting *L. rugulipennis* was also frequent in the canopy, especially in the plots treated with insecticides.

The mean catch (number of individuals/10 trees) shows that the total abundance of Heteroptera was the highest in the UNTR plots and the lowest in the plots treated with insecticides (Table 10).

The Heteroptera assemblages of the herb layer (sweep-net sampling) and ground surface differed (pitfall traps) considerably from those in the canopy (Table 10). *L. rugulipennis* was the most abundant species in the herb layer. Other important species were some grass-feeding mirids belonging to the tribe Stenodemini (*Leptopterna dolabrata*, *Notostira elongata* and *Stenodema calcaratum*) and the polyphagous *Closterotomus norwegicus* and *Lygus pratensis*. Among the important species, only one (*Nabis ferus*) was zoophagous. All the species frequently collected with pitfall trapping, belonged to the mainly ground-living families Lygaeidae and Cydnidae and the partly ground-living Tingidae. These species were very sporadic with the other sampling methods. The

dominant species were the small (probably) moss-feeding lace bug *Acalypta platycheila* and lygaeid *Scolopostethus affinis*, the latter feeding mostly on *Urtica*. Besides these, only the lygaeid *Taphropeltus contractus* was common in the traps.

DISCUSSION

Araneae

The composition of spiders was very similar in the insecticide treated and untreated plots. This and other results (e.g. Bogya *et al*., 1999) suggest that the common spider species in the canopies of apple orchards are not agrobionts. The effect of insecticides was especially negative on orchard canopy spiders as the treatments concur with the peak of adults in May, early June. We also showed that the pesticide treatments affect mainly the females. The juveniles and especially males compensated better for the toxic effects of pesticides, probably by higher immigration. As a result, the sex ratio shifted to a male bias in the pesticide treated plots. The prey supply was similar in the ZERO and CONV treatments. The early season treatments of less harmful pesticides did not result in more abundant spider assemblages during the year either in the canopy or in the herb layer. The positive effects of the lower chemical disturbance on the spider abundance in the spring and early June diminished in a short time period (about one month). Post disturbance recovery was fast in the plots where the prey/spider ratio was high (CONV) and slow where this ratio was low (ZERO). Similar effects were found in the years with characteristically different spider populations. This suggests that spider assemblages of apple orchards saturate quickly to a point where they are in balance with their prey supply. However, intra-guild predation can play a part in the organisation of apple orchard spider assemblages. *Neottiura bimaculatum*, *Tetragnatha* (*extensa*) not only compensated, but over-compensated for the higher pesticide disturbance in the CONV plots which implies rapid colonisation to an enemy free space. The populations of these two spider species are probably controlled by other predators that are less common in the CONV plots. The source of colonisation can be also important. The third genus (*Xystichus*) that was able to compensate for the higher insecticide pressure was common in the herb layer and especially on the ground surface. We found substantial differences in the composition of adult and juvenile spider assemblages both in the canopy and in the herb layer. This suggests significant restructuring in spider assemblages during the season i.e. different number of offspring, different mortality rates and/or movement between the adult and juvenile habitats for different spider species. Aerial dispersal by ballooning is positively related to habitat generalists while habitat specialists, as the risk of landing in an unsuitable habitat is higher, rarely disperse in this way (Bonte *et al*., 2003).

Auchennorrhncha

Among the 15,247 specimens, belonging to 69 Auchenorrhyncha species, collected in the experimental orchard of East Malling Research, the dominant species was *Empoasca decipiens*. Its proportion in the samples collected in the canopy was more than 50%. The other frequent species, individually, did not reach 10% of the whole sample. These were *Edwardsiana rosae*, *Ribautiana debilis*, *Eupteryx atropunctata*, *Zygina flammigera, Edwardsiana crataegi, Empoasca vitis* and *Alnetoidia alneti*. All of the species were recorded as common in apple orchards in Kent, UK by Bleicher *et al*. (2007). *E. rosae, E. crataegi* and *A. alneti* can spread in high densities (Chiswell, 1964; Jay & Cross, 1999), while *Z. flammigera* and *E. vitis* occurs less frequently in orchards in southern England. *E. vitis* was very abundant in an apple orchard in the Netherlands and also in an organic apple orchard investigated by Bleicher *et al*. (2007). In the present investigations, *E. rosae* was found more frequently, while Chiswell (1964) and Jay and Cross (1999) found *E. crataegi* in higher numbers in apple orchards in Kent. Occurrence of *E. decipiens* in English apple orchards is variable. It was not found by Chiswell (1964). Massee (1954) and Alford (1992), however, recorded it in apple orchards of the UK and it was also commonly found in Malaise trap samples in Hungarian apple orchards (Bleicher *et al*., 2006). The high proportion of males *E. decipiens* in our samples also indicated that this species could be overrepresented in samples collected by methods based on migrating activity. Even though *R. debilis* was among the most frequent species during our investigations, it was not found by Chiswell (1964).

The proportion of the dominant species, *Javesella pellucida* in the herb layer was nearly 70%. The other noticeable species were *Euscelis incisus*, *Arthaldeus pascuellus* and *Deltocephalus pulicaris*, none of which reached 8% of the total number of spiders.

The highest species richness and abundance in the canopy was in the UNTR plots. The number of species was reduced significantly by the CONV treatments in 2001 (yellow sticky trap samples) and in 2002 (beating samples), compared to the UNTR plots. At other sampling occaisions there was a decline in numbers, but this was not significant.

Similarly to species richness, the abundance was the highest in the UNTR plots. The conventional treatments reduced significantly the number of females in the CONV plots, compared to the UNTR ones. However, despite the higher insecticide pressure, the number of males trapped did not differ significantly between the CONV and UNTR plots in 2001.

Observation of the species found in high abundances on yellow sticky traps showed that the CONV treatment reduced the abundance of the species feeding only on woody plants. These were the males and the females of *Edwardsiana rosae, Edwardsiana crataegi, Ribautiana debilis, Zygina flammigera, Empoasca vitis* and *Alnetoidia alneti.* These results coincide with the findings of Collyer and Geldermalsen, (1975) and Teulon and Penman (1986). The most significant decrease in abundance could be detected for *E. rosae.* However, the opposite tendency could be observed in the case of the males of the dominant species, *Empoasca decipiens* was detectable in the CONV plots in higher or equal numbers compared to the UNTR plots, whilst the females of the *Empoasca* genus (supposedly mainly *E. decipiens*) were more abundant in UNTR plots. On the whole, it can be concluded that the males of *E. decipiens* could compensate for the insecticide pressure successfully, by rapid immigration into the orchard. It could be established that the number of males decreased to a smaller degree than the number of females. This was most characteristic at *E. decipiens.* The reason for this difference is possibly a difference in migrating activity of the two sexes.

Suppression of the abundance of *E. crataegi* and probably other species overwintering in the orchard decreased the diversity in the CONV plots and the differences in composition between the CONV and UNTR plots indicate that the insecticide treatments modified not only the abundance, but also the structure of the cicada assemblages. Recolonisation after treatments played a more significant role in composition of the assemblages, where broad spectrum insecticides are applied.

The ZERO treatments reduced the species richness values, although to a lesser degree than the CONV treatments compared to UNTR plots. Although early season treatments and selective insecticides were used, the abundance of Auchennorrhncha was reduced by the ZERO treatments to a similar level to the CONV treatments. Numbers of the most abundant species, feeding only on woody plants in the ZERO plots, were only slightly higher or similar to the CONV ones. The diversity of cicada assemblages of ZERO plots was similar to the diversity of the assemblages in the UNTR plots in 2001 and to the diversity in the CONV plots in 2002. Consequently, the ZERO treatment, even though the insecticide treatments were limited to the period before fruit set, did not result in a remarkable increase in numbers of cicada species known as potential pests of apple. Additionally, it means that the second generation of the frequent species does not migrate in significant numbers into the orchard. The small degree of colonisation is particularly conspicuous when the proximity of UNTR plots and the small plot sizes is considered. Thus, the cicada assemblages of the ZERO plots were essentially determined by the treatment affects on the first generation. The assemblages of the ZERO treatments were similar to the UNTR plots in the first year, but were similar to the CONV plots in the second year, in both composition and diversity. The single additional application of Calypso (thiacloprid) in May in 2002 was sufficient to make the assemblages in the ZERO treated plots similar to the CONV plots.

The effect of the pesticide treatments on the density of cicadas was less noticeable in the sweep net samples from the herb layer. However, the diversity relations indicated that the insecticide treatments, although to a smaller degree, did influence the cicada assemblages.

The majority of parasitised cicadas collected by us were infected by ectoparasitoids. They belonged to the families Dryinidae (Hymenoptera) and Pipunculidae (Diptera), although they could not be identified to species, This agrees with the observations of Chiswell (1964) and Jay and Cross (1999). The maximum parasitisation level was about 14% in the genus *Edwardsiana* and about 7% in the genus *Empoasca*. Parasitisation of *Edwardsiana* increased significantly in the second half of the vegetation period, while the parasitisation the *Empoasca* was greater in the first half of the vegetation period. The higher insecticide load reduced, remarkably, the parasitisation level of the genus *Edwardsiana*. Thus, the insecticide treatments had a greater reducing effect on the activity and density of the parasitoids, than on the density of *Edwardsiana rosae*. This could be the possible explanation for rapid and heavy infestation caused by cicadas in apple orchards in Kent in 1994 and 1995 (Jay & Cross, 1999), when the cicadas became resistant to chlorpyriphos, while their parasitoids supposedly died. Thus, the resistance of cicadas and lack of parasitoids simultaneously caused serious plant protection problems. However, the parasitisation level observed in the UNTR control plots in our studies may not have an important role in regulating *E. rosae*. This coincides with findings of

Verestsagina (1962) in the case of the family Dryinidae. It is probable that other factors also influence the density of *E. rosae* and *E. crataegi*.

Heteroptera

In four sampling years during the six-year long study, 88 true bug species were collected, 12 species new to the East Malling list. This is 16% of the total UK Heteroptera fauna (about 560 species).

The dominant species were very different in the different strata. The abundant species in the canopy layer, in decreasing order of their relative abundance, were *O. vicinus*, *A. mali*, *A. nemorum*, *H. planicornis*, *Ph. reuteri*, *L. rugulipennis*, *Ph. longipennis*, *P. prasina*, *O. marginalis*, *B. angulatus* and *D. ruber.*

Collyer (1953) listed the anthocorids *Anthocoris confusus, A. nemoralis, A. nemorum, O. majusculus, Orius minutus* (Linnaeus, 1758), the nabids *H. apterus, Nabis (Himacerus) lativentris* Boheman, 1852 (today *H. mirmicoides*) and the mirids *A. mali, B. angulatus, Campyloneura virgula, C. verbasci, D. (Camptobrochis) lutescens, D. ruber, H. planicornis* (as *Capsus meriopterus* (Pallas, 1772)), *M. chlorizans, M.* (*P.*) *ambiguus, O. marginalis, Orthotylus nassatus* Fabricius, 1787, *Ph. reuteri, Phytocoris tiliae, Phytocoris ulmi, P. perplexus* and *Plagiognathus arbustorum* as predacious species occurring in orchards in Essex, UK. Among them *B. angulatus* was mentioned as the most abundant species and *A. nemorum*, *O. majusculus*, *O. minutus* and *C. verbasci* as species occur abundantly both on cultivated and neglected apple orchards. Among the *Orius* species, *O. majusculus* was more abundant than *O. minutus*, while *O. niger* has been found rarely on apple trees (Collyer, 1953). Alford (1992) lists four additional predacious species not mentioned by Collyer (1953): the pentatomid *Pentatoma rufipes* (Linnaeus, 1758), the nabid *H. mirmicoides*, the anthocorid *O. vicinus* and the microphysid *Loricula elegantula*. Three additional phytophagous species are also listed: the mirids *L. pabulinus* and *Plesiocoris rugicollis* (Fallén, 1807) as apple pests and *Calocoris fulvomaculatus* (Degeer, 1773) a polyphagous capsid feeding on apple. From these species in our survey *O. minutus, N. lativentris, O. nassatus, P. rufipes, P. rugicollis* and *C. fulvomaculatus* were not found in the investigated apple orchards. Furthermore, *O. majusculus, A. confusus, C. virgula, C. verbasci, D. lutescens, H. planicornis, O. marginalis, Ph. ulmi, H. mirmicoides, L. elegantula* and *L. pabulinus* occurred at less than 1% relative abundance.

There are two *Heterotoma* species in Europe (Tamanini, 1962), *H. meriopterum* and *H. planicornis,* though in many taxonomical studies they are treated as synonymous and discussed under the name of *H. meriopterum*. In the UK, only *H. planicornis* occurs, so the species mentioned by Collyer (1953) as *Capsus meriopterus* must be *H. planicornis*. The other problematic species is *O. minutus*. The occurrence of this species in Britain is dubious (Péricart, 1996) and it can be separated from its sister species *O. vicinus* only by male genitalia. We have found only *O. vicinus* (as the most abundant Heteroptera species in the canopy of apple orchards) and it is possible that the species named as *O. minutus* by Collyer (1953) belonged to this species.

In the canopies of 11 investigated apple orchards in Norway, the main Heteroptera species, in decreasing order of their total abundance, were *A. mali*, *O. marginalis, M. ambiguus*, *B. angulatus, A. nemorum* and *Orius* spp. (Austreng & Somme, 1980) while in an apple orchard in Germany the most abundant predacious species in decreasing order were *M. ambiguuus, M. chlorizans, P. perplexus, B. angulatus* and *O. minutus* (Steiner *et al*., 1970). Schaub *et al*. (1987) report *O. marginalis, Orius* spp., *A. nemorum, M. ambiguus* and *D. lutescens* as the most common species in the canopies of apple orchards in Switzerland. Kinkorová & Kocourek (2000) in Czech Republic found *Orius* spp. (*O. minutus,* followed by *O. vicinus*, and *O. laticollis* (Reuter, 1884)) as dominant on the apple trees followed by *H. planicornis***.** Their results show *Nabis pseudoferus* as more frequent than *N. ferus* (opposite to our data from Kent) and *A. mali* and *A. nemorum*, very abundant in our study, did not occur or was found only in low numbers, respectively, in the Czech republic. *L. rugulipennis* and *M. chlorizans* were listed as the most common phytophagous species (Kinkorová & Kocourek, 2000). In the south-western part of the former Soviet Union *O. horvathi*, *A. mali, P. perplexus*, *D. ruber* were listed as very abundant in orchards (Zerova *et al*., 1992). From the listed species, *O. marginalis, B. angulatus, M. ambiguus* and *M. chlorizans* were often more abundant in the canopy of apple orchards in continental Europe than in Kent, UK. However, increases of their populations in some localities is possible. *D. lutescens, O. minutus, O. laticollis* and *N. pseudoferus* occurred in apple orchards in Kent with less than a 1% relative abundance. Therefore, these species probably play only limited part in the control of pests in Kent.

Fifty-three species were collected by sweep netting at East Malling Research. Except *L. rugulipennis* and *N. ferus,* the species that were common in the herb layer were all rare in the canopy. The most frequent species in both treatments was *L. rugulipennis.* Its relative abundance with *N. ferus*

and *S. calcaratum* was higher in treated plots. In contrast, *L. dolabrata*, *C. norwegicus* and *Stictopleurus abutilon* occurred with higher relative abundance in the insecticide-free control. With pitfall trapping, we found lace bugs *A. platycheila* and *Kalama tricornis*, seed bugs *S. affinis* and *T. contractus,* and the burrower bug *Tritomegas bicolor* to be relatively common.

The occurrence of two recent immigrants was interesting from the viewpoint of faunal research. *Deraeocoris flavilinea* was recently detected in Britain (Miller, 2001). During our investigation, *D. flavilinea* was frequently found in the canopy. The first specimens were collected at East Malling Research by beating on 24 July 2002 and *D. flavilinea* became abundant at East Malling Research in 2004. Most of the individuals were collected between 17 June and 13 August,

Malumphy *et al*., (1998) reported the first occurrence of the adventive species, the andromeda lace bug (*Stephanitis takeyai*), from the UK. The close relative of this species, the pear lace bug, *Stephanitis pyri* (Fabricius, 1822) is an irregular pest in continental Europe in pear and apple orchards (Rácz & Balázs, 1996) but it is not yet reported from Britain. *S. takeyai* shows similarity to the pear lace bug but it is darker and more slender. Its host plants are *Pieris* species including *Pieris japonica* (Halstead & Malumphy, 2003).

The species composition of Heteroptera assemblages differed only slightly between the treated and untreated experimental plots. However, the differences between the insecticide treatments (treated versus untreated, control plots) were more characteristic when the species composition and the dominance orders were compared (Horn similarity).

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Table 1. Total number of species sampled in each taxa

Taxa, sampling method and year	Pesticide management			
	Conventional	Zero residues	Untreated	Total
Spiders (sweep netting)				
2001	28	36	61	125
2002	17	26	18	61
2004	192	179	270	641
2006	156	166	263	585
Total	393	407	612	1412
Spiders (pitfall trapping)				
2001	-	-	-	-
2002	62	88	110	260
2004	632	745	1198	2575
2006	271	333	357	961
SUM	965	1166	1665	3796
Ground beetles (pitfall trapping)				
2001	1994	1521	2352	5867
2002	2039	1923	2917	6879
2004	1716	2353	2565	6634
2006	1266	1583	2471	5320
SUM	7015	7380	10305	24700
Rove beetles (pitfall trapping)				
2001	130	227	139	496
2002	107	118	113	338
2004	441	454	637	1532
2006*	332	502	395	1229
SUM	1010	1301	1284	3595
Beetles (canopy beating)				
2001	556	1041	1494	3091
2002	305	342	802	1449
2004	1353	970	2277	4600
2006	384	386	1185	1955
SUM	2598	2739	5758	11095
Beetles (sweep netting)				
2001	311	251	418	980
2002	111	131	349	591
2004	284	267	475	1026
2006	210	258	623	1091
SUM	916	907	1865	3688
Plant hoppers (canopy beating)				
2001	0	42	94	136
2002	5	8	21	34
2004	215	133	1120	1468
2006	101	77	708	886
SUM	321	260	1943	2524
Plant hoppers (yellow sticky traps)				
2001	1774	1307	1835	4916

Table 1. Total number of species sampled in each taxa

Taxa, sampling method and year	Pesticide management			
	Conventional	Zero residues	Untreated	Total
2002	1020	1034	1844	3898
SUM	2794	2341	3679	8814
Plant hoppers (sweep netting)				
2001	223	254	252	729
2002	106	131	120	357
2004	2306	1677	1895	5878
2006	1395	1013	1709	4117
SUM	4030	3075	3976	11081
True bugs (beating method)				
2001	106	144	399	649
2002	91	122	242	455
2004	261	288	1447	1996
2006	53	52	99	204
SUM	511	606	2187	3304
True bugs (sweep netting)				
2001	120	142	158	420
2002	49	33	62	144
2004	566	404	547	1517
2006	59	88	293	440
SUM	794	667	1060	2521

Table 2. Abundance (total abundance / 12 trees ± S.D.) and species richness (number of species/4 trees) of spiders in the canopy of differently treated apple orchard plots: CONV: conventionally treated with broad spectrum insecticides, ZERO: 'zero pesticide residue treatments', UNTR: untreated control

	CONV	ZERO	UNTR
Abundance			
2001	76.25 (17.88) a	67.75 (14.97) a	108.25 (17.25) b
2002	41.00 (7.61) A	50.00 (8.17) A	74.750 (4.72) B
2004	200.75 (54.77) A	211.00 (48.37) A	398.50 (87.03) B
2006	145.50 (27.01) A	126.50 (12.40) A	252.50 (13.48) B
Species richness			
2001	1.60 (0.66) a	2.40 (0.84) a	1.57 (1.15) a
2002	3.17 (0.88) a	3.00 (0.73) a	3.90 (3.90) a
2004	5.07 (0.70) a	4.82 (0.76) a	6.40 (0.66) b
2006	2.07 (0.97) a	3.07 (0.59) a	3.60 (0.99) a
2002-2006*	3.44 A	3.63 A	4.63 B

Means followed by different capitals or different lowercase letters within the row represent significant difference $p<0.05$ and $0.05<p<0.10$ respectively

* Two-way ANOVA (treatments *versus* years)

Table 3. Mean abundance (four year's total abundance/12 trees ± S.D.) of the main spider guilds and the most common genera and species (including Linyphiidae juveniles) in the canopy of apple trees

	CONV	ZERO	UNTR
Hunting strategies			
Web builders	387.25 (70.08) A	371.25 (48.62) A	696.5 (99.94B
Ambushers and runners	64.00 (8.68) A	71.25 (18.73) A	112.75 (11.95) B
Active nocturnal hunters	14.5 (5.45) a	12.505.07a	24.75 (6.95) b
Genera and species			
Web builders			
Araniella spp.	139.00 (30.61) A	151.75 (22.10) A	241.50 (65.07) B
Araniella opisthographa	6.50 (3.11) a	11.50 (2.38) b	9.75 (3.86) b
Theridion spp.	74.25 (17.15) A	94.00 (20.31) A	198.75 (54.83) B
Theridion varians	5.75 (2.06) a	7.25 (1.71) a	19.25 (15.13) b
Neottiura spp.	76.75 (20.55) a	45.50 (6.56) b	89.25 (44.06) a
Fam. Linyphiidae	17.25 (5.85) A	15.25 (2.63) A	52.00 (24.89) B
Entelecara acuminata	4.25 (4.43) a	1.75 (2.06) a	17.75 (15.33) b
Tetragnatha spp.	29.50 (7.59) a	16.75 (8.38) b	20.00 (3.56) b
Anelosimus spp.	14.25 (5.44) a	15.50 (7.05) a	24.00 (0.82) b
Enoplognatha spp.	5.50 (3.11) a	6.75 (2.87) a	17.00 (5.89) b
Gibbaranea spp.	7.25 (2.75) a	7.00 (2.71) a	18.75 (12.97) b
Ambushers and runners			
Philodromus spp.	54.00 (9.49) A	60.00 (20.30) A	101.25 (13.00) B
Xysticus spp.	8.00 (1.63) a	9.00 (1.41) a	8.75 (4.92) a
Active nocturnal hunters			
Anyphaena accentuata	12.25 (5.97) a	8.75 (5.91) a	19.750 (5.68) b

Means followed by different capitals or different lowercase letters within a row represent significant difference $p<0.05$ and $0.05<p<0.10$ respectively

Table 4. Mean abundance (abundance /200 sweeps ± S.D.) and mean species richness (number of species /200 sweeps ± S.D.) of herb layer spider assemblages

	CONV	ZERO	UNTR
Abundance			
2001+2002	11.25 (3.20) a	15.50 (3.11) a	19.75 (3.77) b
2004	48.00 (15.51) a	44.75 (14.41) a	67.50 (7.42) b
2006	39.00 (4.40) a	41.50 (10.41) a	65.75 (14.64) b
SUM	98.25 (17.25) A	101.75 (21.48) A	153.00 (10.68) B
Species richness			
2001	1.00 (0.82) a	0.50 (0.577) a	0.50 (0.577) a
2002	1.75 (0.96) a	3.75 (1.50) b	2.00 (0.82) a
2004	3.25 (1.26) a	3.50 (1.29) a	4.50 (1.73) a
2006	2.25 (1.89) a	3.75 (1.26) a	4.50 (3.42) a
2002-2006*	2.42 a	3.67 b	3.67 ab

Means followed by different capitals or different lowercase letters within a row represent significant difference $p<0.05$ and $0.05<p<0.10$ respectively
* Two-way ANOVA (treatments versus years)

Table 5. Mean abundance (four year's total abundance/12 trees ± S.D.) of the main spider families and the most common genera in the herb layer of the differently treated apple orchard plots

Families	CONV	ZERO	UNTR
Fam. Liniphidae	42.75 (9.14) a	46.25 (12.42) a	61.75 (5.91) b
Microlinyphia pusilla	8.00 (4.69) a	10.50 (2.64) a	9.00 (6.05) a
Microlinyphia spp. juv.	25.75 (4.27) a	24.25 (9.21) a	41.25 (5.96) b
Fam. Tetragnathidae	23.75 (15.52) AB	13.25 (3.59) A	36.25 (4.42) B
Tetragnatha spp.	23.75 (15.52) AB	13.25 (3.60) A	34.75 (2.75) B
Fam. Araneidae	20.50 (5.45) a	22.75 (4.42) a	27.25 (4.72) a
Araniella spp.	4.25 (2.22) a	2.50 (7.25) a	3.50 (2.09) a
Mangora spp.	11.50 (2.52) a	9.50 (2.65) a	14.00 (5.16) a
Fam. Theridiidae	6.00 (2.58) a	8.50 (1.73) a	11.75 (1.50) b
Neottiura psp.	4.00 (2.45) a	4.00 (1.83) a	6.00 (2.71) a
Fam. Thomisidae	3.50 (1.00) A	6.50 (2.88) B	10.50 (3.00) C
Xystichus psp.	3.5 (1.00) a	3.75 (1.26) a	6.75 (2.99) b

Means followed by different capitals or different lowercase letters within the row represent significant difference $p<0.01$ and $0.05<p<0.10$ respectively

Table 6. Mean numbers of the most common cicada species in yellow sticky trap samples and beating samples in the plots under different pesticide management systems (p<0.1)

Year	2001			2002		
	CONV	**ZERO**	**UNTR**	**CONV**	**ZERO**	**UNTR**
Yellow sticky traps						
E. decipiens male	348.8 (80.7) a	203.8 (45.7) b	269.8 (16.5) ab	124.3 (25.8) a	124.5 (25.5) a	140.0 (26.0) a
Empoasca spp. female	49.5 (16.7) a	50.5 (5.4) ab	73.0 (8.8) b	36.8 (12.3) a	47.0 (15.6) a	95.5 (3.4) b
E. rosae male	19.8 (13.2) a	22.3 (5.2) a	34.5 (7.8) a	22.8 (6.6) a	19.5 (8.9) a	69.8 (8.3) b
E. crataegi male	5.5 (4.4) a	13.8 (9.9) a	22.3 (6.9) a	2.0 (2.3) a	0.5 (1.0) a	20.3 (8.1) b
Edwardsiana spp. female	–	–	–	29.5 (8.3) a	28.0 (11.4) a	105.3 (31.2) b
Typhlocybinae female*	15.3 (2.9) a	24.8 (8.6) a	50.3 (14.0) b	–	–	–
R. debilis male	5.5 (3.3) a	9.0 (12.0) a	42.3 (44.3) b	16.5 (5.9) a	13.0 (6.9) a	73.25 (15.4) b
Ribautiana spp. female	–	–	–	4.8 (2.2) a	3.0 (1.2) a	13.8 (6.9) b
A. alneti male	4.8 (3.3) a	8.0 (4.7) a	9.5 (1.0) a	8.3 (7.1) a	5.3 (2.2) a	18.0 (4.5) b
Alnetoidia spp. female	–	–	–	2.5 (3.1) a	3.0 (1.4) a	12.0 (2.0) b
Z. flammigera male	–	–	–	16.8 (7.3) ab	7.0 (3.7) a	34.5 (18.0) b
Z. hyperici male	–	–	–	3.0 (1.8) a	9.5 (15.0) a	8.5 (6.0) a
Zygina spp. female	3.0 (1.4) a	5.0 (1.8) a	10.0 (3.2) b	10.5 (2.9) a	8.25 (4.9) a	39.0 (11.5) b
Beating						
Tot No. of species	3.5 (1.7) a	3.5 (1.0) a	5.0 (0.8) a	2.8 (1.0) a	3.0 (1.8) a	7.3 (1.0) b
Total no. of specimens	29.8 (5.9) a	31.0 (11.4) a	61.5 (15.8) b	10.8 (5.4) a	8.5 (5.3) a	25.3 (8.6) b
E. rosae male	4.3 (0.5) a	7.3 (2.5) a	13.5 (3.7) b	–	–	–
Edwardsiana spp. female	8.3 (1.5) a	10.5 (3.1) a	14.8 (3.0) b	–	–	–

* supposedly mainly females of *Edwardsiana rosae*, partly *E. crataegi*, and in small quantity *Alnetoidia alneti*

Table 7. Mean number of the most common cicada species per plot in sweep net samples (p<0.1)

Sweep net	CONV	ZERO	UNTR
2001			
Total number of species	7.5 (1.7) a	8.8 (3.3) a	7.3 (1.7) a
Total number of specimens	77.8 (29.8) a	97.5 (32.4) a	95.0 (11.2) a
Number of males	57.0 (28.2) a	63.5 (25.5) a	63.0 (7.0) a
Number of females	20.8 (2.5) a	34.0 (9.1) b	32.0 (4.4) b
Javesella pellucida	46.0 (28.3) a	35.8 (20.0) a	35.8 (5.0) a
Arthaldeus pascuellus	3.0 (1.8) a	5.0 (3.5) a	7.5 (4.4) a
Deltocephalus pulicaris	0.8 (1.0) a	8.3 (14.6) a	5.8 (4.3) a
Euscelis incisus	0.3 (0.5) a	5.0 (6.2) a	8.8 (8.4) a
Psammotettix confinis	0.3 (0.5) a	3.5 (2.6) b	1.5 (1.3) a
2002			
Total number of species	2.8 (1.0) a	3.0 (1.8) a	7.3 (1.0) b
Total number of specimens	32.8 (6.6) a	38.5 (4.2) a	36.3 (13.8) a
Number of males	26.5 (4.8) a	32.0 (3.9) a	30.0 (10.0) a
Number of females	6.3 (2.4) a	5.8 (1.5) a	6.3 (4.1) a
Javesella pellucida	23.5 (3.3) ab	30.5 (5.7) a	18.8 (6.9) b

Table 8. List of Heteroptera species collected in the canopy, herb layer and on the ground surface of apple orchards in Kent in 2001 (01), 2002 (02), 2004 (04) and 2006 (06)

	2001, 2002, 2004, 2006		2001, 2002, 2004, 2006		2004, 2006	
	beating		sweeping		pitfall trapping	
	treated	untreated	treated	untreated	treated	untreated
Suborder Cimicomorpha						
Family Anthocoridae						
Anthocoris confusus Reuter, 1889		04				
Anthocoris nemoralis (Fabricius, 1794)	02, 04	01, 02, 04, 06				
Anthocoris nemorum (Linnaeus, 1761)	01, 02, 04, 06	01, 02, 04, 06	01, 02	01, 06	04, 06	
Cardiastethus fasciiventris Garbiglietti, 1869	01, 04	04, 06				
Orius (Heterorius) majusculus (Reuter, 1879)	01, 02, 04	01, 02, 04				
Orius (Heterorius) vicinus Ribaut, 1923	01, 02, 04, 06	01, 02, 04, 06	01, 04	04, 06	04	
Orius (s. str.) laevigatus (Fieber, 1860)	01, 04	01, 04	01, 04	01, 04, 06		
Orius (s. str.) niger Wolff, 1804			01, 04	01, 04		
Family Microphysidae						
Loricula elegantula (Bärensprung, 1858)				04		
Family Miridae						
Adelphocoris lineolatus (Goeze, 1778)			01			
Apolygus lucorum (Meyer-Dür, 1843)	04					
Apolygus spinolai (Meyer-Dür, 1841)	01					
Atractotomus mali (Meyer-Dür, 1843)	01, 02, 04	01, 02, 04		04		04
Blepharidopterus angulatus (Fallén, 1807)	01, 02, 04, 06	01, 02, 04, 06	01	02		
Campylomma verbasci (Meyer-Dür, 1843)	04	01, 04				
Campyloneura virgula (Herrich-Schäffer, 1835)	01					
Capsus ater (Linnaeus, 1758)				02, 04		
Closterotomus norwegicus (Gmelin, 1788)	02, 04	01, 04	02, 04, 06	02, 04, 06		
Compsidolon salicellum (Meyer-Dür, 1843)		01, 04				
Deraeocoris flavilinea (A. Costa, 1862)	02, 04	02, 04				
Deraeocoris lutescens (Schilling, 1836)	01	01				
Deraeocoris ruber (Linnaeus, 1758)		01, 02, 04				
Dicyphus errans (Wolff, 1804)	01			01		
Heterotoma planicornis (Pallas, 1772)	01, 02, 04	01, 02, 04		04, 06		

	2001, 2002, 2004, 2006		2001, 2002, 2004, 2006		2004, 2006	
	beating		sweeping		pitfall trapping	
	treated	untreated	treated	untreated	treated	untreated
Leptopterna dolabrata (Linnaeus, 1758)			06	02, 04, 06		
Liocoris tripustulatus (Fabricius, 1781)	01	02		01		
Lygocoris pabulinus (Linnaeus, 1761)	02	04	02	02		
Lygus pratensis (Linnaeus, 1758)	02, 04, 06	02, 04, 06	01, 02, 04, 06	04, 06	04	04
Lygus rugulipennis Poppius, 1911	01, 02, 04, 06	01, 02, 04, 06	01, 02, 04, 06	01, 02, 04, 06	04	
Malacocoris chlorizans (Panzer, 1794)	04	04, 06				
Megaloceroea recticornis (Geoffroy, 1785)			01, 06	01, 06		
Mesopsallus ambiguus (Fallén, 1807)	04					
Miridae sp. (larvae)	04			02, 04		
Notostira elongata (Geoffroy, 1785)	02, 04		01, 02, 04, 06	01, 02, 04, 06		
Orthotylus (s. str.) marginalis Reuter, 1884	04	02				
Phytocoris (Ktenocoris) varipes Boheman, 1852				06		
Phytocoris (s. str.) reuteri Saunders, 1875	01, 02, 04, 06	01, 02, 04, 06			04	04
Phytocoris (s. str.) tiliae (Fabricius, 1776)	02, 04	01, 02, 06				
Pilophorus perplexus (Douglas & Scott, 1875)	01, 04	01, 02, 04, 06		04		
Plagiognathus arbustorum (Fabricius, 1794)	01, 04	01, 04	01, 04	01		04
Plagiognathus chrysanthemi (Wolff, 1804)	02		01, 04	01, 04		
Plagiognathus fulvipennis (Kirschbaum, 1856)			04			
Psallus perrisi (Mulsant, 1852)		01, 02				
Psallus varians (Herrich-Schäffer, 1842)		02				
Stenodema calcaratum (Fallén, 1807)	02, 04	02, 04	01, 02, 04, 06	01, 02, 04, 06	04	
Stenodema laevigatum (Linnaeus, 1758)	06		04, 06	04, 06		
Trigonotylus caelestialium (Kirkaldy, 1902)			01, 04	01, 04		
Family Nabidae						
Himacerus (Aptus) mirmicoides (O. Costa, 1834)	04	04, 06				
Himacerus (s. str.) apterus (Fabricius, 1798)	02, 04, 06	02				
Nabis (s. Str.) ferus (Linnaeus, 1758)	01, 02, 04, 06	01, 04, 06	01, 02, 04, 06	01, 04, 06	04	04
Nabis (s. Str.) rugosus (Linnaeus, 1758)			04	04		
Nabis (s. Str.) pseudoferus Remane, 1949			01, 04			
Family Tingidae						
Acalypta platycheila (Fieber, 1844)			04	04, 06	04	04, 06

	2001, 2002, 2004, 2006		2001, 2002, 2004, 2006		2004, 2006	
	beating		sweeping		pitfall trapping	
	treated	untreated	treated	untreated	treated	untreated
Derephysia foliacea (Fallén, 1807)					04	
Kalama tricornis (Schrank, 1801)			01, 04	04	04	04
Physatocheila dumetorum (Herrich-Schäffer, 1838)	04, 06					
Stephanitis takeyai Drake & Maa, 1955	06					
Tingis (s. Str.) ampliata (Herrich-Schäffer, 1839)						04
Suborder Pentatomomorpha						
Family Acanthosomatidae						
Acanthosoma haemorrhoidale (Linnaeus, 1758)	04, 06	02				
Elasmucha grisea (Linnaeus, 1758)	01					
Family Berytidae						
Berytinus clavipes (Fabricius, 1775)		06	04			
*Berytinus minor (*Herrich-Schäffer, 1835)			04, 06	01, 04, 06		04
Berytinus signoreti (Fieber, 1859)			06			
Family Coreidae						
Coreus marginatus (Linnaeus, 1758)	01, 04, 06					
Family Cydnidae						
Tritomegas bicolor (Linnaeus, 1758)	04		04	04	04	04
Tritomegas sexmaculatus (Rambur, 1842)	01	01				
Family Lygaeidae						
Cymus claviculus (Fallén, 1807)				04		
Cymus melanocephalus Fieber, 1861			02	06		
Drymus sylvaticus (Fabricius, 1775)	04	02			06	
Heterogaster urticae (Fabricius, 1787)	02, 04	01, 02				
Kleidocerys resedae (Panzer, 1797)	01, 06	01				
Lasiosomus enervis (Herrich-Schäffer, 1842)			01	01	04	
Metopoplax ditomoides (Costa, 1843)	01	04				
Nysius senecionis (Schilling, 1829)	04, 06	01, 02, 04, 06	04, 06	01, 06		
Nysius thymi (Wolff, 1804)	04		04			
Peritrechus geniculatus (Hahn, 1831)	06					
Peritrechus nubilus (Fallén, 1807)	06					
Rhyparochrominae sp. (larvae)			06	06	04	

	2001, 2002, 2004, 2006		2001, 2002, 2004, 2006		2004, 2006	
	beating		sweeping		pitfall trapping	
	treated	untreated	treated	untreated	treated	untreated
Scolopostethus affinis (Schilling, 1829)	04, 06	04, 06	06	06	04, 06	
Scolopostethus thomsoni Reuter, 1874						
Stygnocoris fuligineus (Geoffroy, 1785)			04, 06	01, 04	04, 06	
Stygnocoris sabulosus (Schilling, 1829)			06			
Taphropeltus contractus (Herrich-Schäffer, 1835)	02, 04, 06		04	04	04	
Family Pentatomidae						
Aelia acuminata (Linnaeus, 1758)	06	04, 06	06	06		
Dolycoris baccarum (Linnaeus, 1758)		06	01, 04	04		
Palomena prasina (Linnaeus, 1761)	01, 02, 04, 06	01, 02, 04	01, 02, 04	01, 02, 04		
Pentatominae sp. (larvae)		02	04	04		04
Piezodorus lituratus (Fabricius, 1794)	04, 06					
Podops inuncta (Fabricius, 1775)			06			
Family Piesmatidae						
Piesma maculatum (Laporte, 1832)	01, 06	02				
Family Rhopalidae						
Brachycarenus tigrinus (Schilling, 1817)			06			
Stictopleurus abutilon (Rossi, 1790)	02, 06	06	04, 06	04, 06		
Stictopleurus punctatonervosus (Goeze, 1778)	06		01, 04	01, 04, 06		

Table 9. Relative abundance (%), the total and mean abundance and the species richness of the most frequent Heteroptera species. Relative abundance values less than 1% are marked with *

Species	treated	untreated
Orius vicinus	11.5	17.9
Atractotomus mali	3.9	29.6
Anthocoris nemorum	31.6	16.3
Heterotoma planicornis	6.7	6.6
Phytocoris reuteri	12.9	6.6
Lygus rugulipennis	9.6	2.4
Phytocoris longipennis		
Palomena prasina	1.9	*
Orthotylus marginalis	*	*
Blepharidopterus angulatus	1.5	4.5
Deraeocoris rubber		*
Plagiognathus arbustorum	*	*
Anthocoris nemoralis	2.1	1.8
Himacerus apterus	*	*
Deraeocoris flavilinea	*	3.0
Pilophorus perplexus	*	*
Mesopsallus ambiguous	*	
Phytocoris tiliae	*	*
Nabis ferus	2.6	*
Malacocoris chlorizans	*	*
Nysius senecionis	1.2	*
Psallus varians		*
Orius laevigatus	*	*
Stenodema calcaratum	1.1	*
Psallus variabilis		
Total number of individuals	**1146**	**2202**
Number of individuals per 10 trees	**3.1**	**12.1**
Number of species	**56**	**46**

Table 10. Relative abundance values (%) of the most frequent Heteroptera species collected in apple orchards in Kent by sweep-net and pitfall trap sampling. Relative abundance values less than 1% are marked with *

Species	sweep netting		pitfall trapping	
	treated	untreated	treated	untreated
Lygus rugulipennis	39.18	25.15	1.0	
Acalypta platycheila	*	*	1.0	57.89
Scolopostethus affinis	*		43.12	9.65
Taphropeltus contractus	*		29.36	*
Nabis ferus	14.46	7.12	1.83	*
Notostira elongata	10.61	10.82		
Lygus pratensis	8.38	9.36	1.0	*
Tritomegas bicolor	*	0.19	8.26	8.77
Stenodema calcaratum	10.06	4.78	1.0	
Leptopterna dolabrata	*	14.33		
Closterotomus norwegicus	2.72	7.41		
Kalama tricornis	*	*	1.83	6.14
Stictopleurus abutilon	1.0	5.36		
Total number of specimens	**1432**	**1026**	**109**	**114**
Number of species	**44**	**40**	**15**	**16**

APPENDIX C

Technology Transfer Activities

Grower talks and site visits

- Visit East Malling Executive Board to East Malling Trial to discuss Zero Residues – July 12 2004
- Visit by Growers Gala Club to Gala trial site 1 to see Zero residues Trial – September 1 2004
- Berrie A M Producing apples free of pesticide residues – Talk to BIFGA growers 9 February 2005
- April 2005 Talk given at Cider growers conference on zero residue apple production
- May 12 2005 Talk on Zero residue apple production at Tesco's Grower of the year event
- 19 July 2005 – Visit by Marks and Spencer growers to zero residue trial site at Mount Ehraim, Kent.
- July 26 and August 2 2005 HDC workshops on Rot risk assessment conducted by A Berrie to train growers as part of alternative strategy for rot control, part of zero residue production.
- British Crop Protection Conference, Glasgow 31 Oct-2 Nov 2005. Paper given on zero residue apple production.
- 8 Feb 2006. 2 hour lecture and training given by J Cross to Hutchinsons Ag Chem reps, including progress report on zero residue apple production
- M&S conference 20 May 2005, participated
- September 22 2005 Exhibit on Zero residue trial at East Malling Trade open day.
- March 14 2006 Talk given to West Sussex Fruit Group on coping with zero residues in apple production.
- 20 April 2006 – Discussion on zero residue management system with Empire World Trade growers
- 13 June 2006 – Visit of Swedish Grower group to Zer residue trial at East Malling
- 12 July 2006 – Visit of Waitrose growers to North Court Fruit Farm to discuss zero residues system
- 18 July 2006 – Visit to East Malling trial by West Sussex Fruit Growers
- 23 July 2006 – Visit to East Malling Trial by Director of pesticide distributer company
- 25 July 2006 - Visit to East Malling Trial by Certis UK Ltd
- 19 October 2006 – Talk on Zero residues system at National Fruit Show
- 19 October 2006 – Poster on Zero residues system at National Fruit Show
- 8 March 2006 – Short presentation on zero residues system by grower participating in trials.

Scientific meetings

- A M Berrie - Producing apples free of pesticide residues Talk at IOBC conference, Italy, October 2004
- September 2005 – Talk given on disease control in Zero residue apple production at IOBC orchard diseases workshop
- 20/21 November 2006 – Poster on Zero residues at COST meeting Vienna
- 18/19 January 2007 – Short presentation on zero residues system at International meeting on apple scab, Maidstone, Kent

Other meetings

- Project HH3122STF – Growers steering committee meeting – 11 March 2005
- 28 April 2005 – Discussion with grower and technologist from the Co-op Group on zero residue production in apples and pears
- Marks & Spencer plc – Post-harvest chain improvement: Back to Basics workshop, 30 September 2005. Talk given 'Insect control in zero residue IPM systems'
- Marks & Spencer plc – Post-harvest chain improvement: Back to Basics workshop, 30 September 2005. Talk given 'Post-harvest control of apple rots in zero residue systems'
- 21 February 2006 – Project HH3122STF – Growers' steering committee meeting
- 30 June 2006 – RELU workshop, London
- 10 July 2006 – Discussion on Zero residues trial with consultant from New Zealand
- 23 January 2007 – Meeting with Marks & Spencer Technologist to discuss zero residues

- 21 March 2007 - Project HH3122STF – Growers steering committee meeting

Publications

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Objective 7. – Technology transfer

Technology transfer was based on a combination of grower visits to trial sites, presentations at EMRA Members' days and other grower meetings, attending scientific meetings and technical and scientific publications. These are listed in appendix C. The zero residues approach has been widely publicised and debated with great interest in the system expressed by Marks & Spencer plc and Waitrose. The system will be included in The Defra Best Practice Guide for UK Apple Production due to be revised in 2007. An HDC Factsheet will also be finalised in 2007. World Wide Fruit growers have been encouraged to adopt the zero residue system for Gala in 2007.

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