Project title:	**Raspberry: novel approach for integrated crop management in fresh and processed crops**
Project number:	**CP 14**
Project leader:	**Dr Stuart Gordon / Dr Nick Birch, SCRI**
Report:	**Year 1 Annual Report, November 2003**
Previous reports:	**None**
Key workers:	**PhD Student: Carolyn Mitchell** **Supervisors: Dr Stuart Gordon** **Dr Nick Birch** **Dr Steve Hubbard**
Location:	**SCRI, Invergowrie, Dundee, DD2 5DA**
Date project commenced:	**1 October 2002**
Date project completed:	**30 September 2005**
Keywords:	**raspberry, integrated crop management**

Carolyn Mitchell

Scottish Crop Research Institute
Invergowrie
Dundee
DD2 5DA
Telephone :- 01382 562731 ext. 2147
Email :- c.mitchell@scri.sari.ac.uk

Supervisors

Dr Nick Birch

Scottish Crop Research Institute
Invergowrie
Dundee
DD2 5DA
Telephone :- 01382 562731 ext. 2401
Email :- n.birch@scri.sari.ac.uk

Mr Stuart Gordon

Scottish Crop Research Institute
Invergowrie
Dundee
DD2 5DA
Telephone :- 01382 562731 ext. 2100
Email :- sc.gordon@scri.sari.ac.uk

Dr Steve Hubbard

Faculty of Life Sciences
University of Dundee
Dundee
DD1 HN
Telephone :- 01382 344291
Email :- s.f.hubbard@dundee.ac.uk

CONTENTS

Abstract

Raspberry sawfly fed on either (a) water, (b) sugar and water, or (c) sugar, water and protein showed that the number of days lived increased from an average of 2.1 days when given only water, to 4.8 days when given a sugar and water source. The average number of days lived decreases again to 3.3 days with the inclusion of a protein source.

The number of raspberry beetles caught on non-UV reflective, white sticky traps and these traps in combination with a flower volatile attractant showed that there was an 10-30 fold increase in the number of beetles caught with the addition of the attractant in the raspberry plantation at Blairgowrie and a 10 fold increase on the traps with attractant used in combination with the lures in the raspberry plantation at Norwich. The traps positioned in the blackberry plantation in Norwich showed a 10-65 fold increase in the number of beetles caught on the traps in combination with the lures.

There was no raspberry beetle migration to the hawthorn sources near the raspberry plantation at Blairgowrie and to the hedges containing hawthorn surrounding the raspberry or blackberry plantations at Norwich. At SCRI, there was migration to the hawthorn sources and there was evidence of a trend showing an increase in the numbers of beetles migrating to the hawthorn source when it was in flower and then a decrease in numbers when the raspberry plantation started to flower.

An experiment to observe over what distance the lure is active suggests that beetle migration is very dependent on the weather conditions. There were 7 individual beetles caught on traps positioned 90 metres from the plantation.

Trials of a new release system developed in collaboration with AgriSense-BCS Ltd, showed that the chemicals evaporated at a much slower rate (90 % left after 12 days for chemicals A and B) than the original glass vials (33% left after 6 days for chemical A and 0% left after 6 days for chemical B). There was always a greater number of beetles caught using the original glass dispenser in combination with the white sticky traps than the new dispenser types.

The greatest number of large raspberry aphids were found on the susceptible cultivar, Glen Ample, fewer were found on Glen Clova which has minor gene resistance and no aphids found on Glen Rosa which has the A_{10} resistance gene. There was a greater percentage of parasitized individuals found on Glen Clova than on Glen Ample.

Summary

Work in the commercial plantations this year at Blairgowrie and Norwich suggest that the identified raspberry flower volatiles can increase the attraction of the plain non-UV reflective, white sticky trap. The level of increase observed, varied between the sites and between the blackberry and raspberry plantations. The lowest was a 10-fold increase found in the raspberry plantation in Norwich and the highest was a 65-fold increase in the blackberry plantation in Norwich. The husk damage assessment around the plain traps and the traps used in combination with the lures is not complete but will hopefully show that there is a relationship between the numbers of beetles caught on the traps and the amount of damage to the husks in the area surrounding the trap. These results suggest that this system could be used as a monitoring method for growers to predict the amount of damage their plantation would suffer and allow them to apply pesticides accordingly.

Experiments were set up to observe any migration of the beetles from the plantation to nearby sources containing hawthorn when the hawthorn is in flower and then returning to the plantation when it starts to flower. This migration would be an important factor in setting up an integrated pest management strategy for the raspberry beetle. If the migration occurred when a grower was planning to use an insecticide spray against the beetle, then the spray would not be as effective at controlling numbers as expected. At the two commercial sites, the results indicate that there was very little migration to the surrounding hawthorn. This could have occurred for the following reasons: the traps were not positioned in the direction of the prevailing wind and therefore the beetles did not have an opportunity to migrate towards the source, or the hedge was severely trimmed and there may not have been

many flowers to attract the beetles. However, at SCRI, there was migration towards the hawthorn source. This indicates that the migration may be dependent on a number of factors which would have to be investigated at each individual site.

The number of large raspberry aphids observed on three different cultivars, Glen Ample, Glen Clova and Glen Rosa were as expected. The largest number of individuals were found on the susceptible variety, Glen Ample and there were a smaller number of individuals found on Glen Clova which has minor gene resistance. There were no individuals found on the Glen Rosa which has A_{10} resistance, although there are indications that this resistance has been overcome in areas in England. An interesting observation this summer, was the proportion of parasitized individuals on Glen Clova and Glen Ample. There was a greater proportion of parasitized individuals on Glen Glova suggesting that there is a mechanism of resistance that slows down development in the aphid and this allows a greater number of successful parasitisms. In laboratory experiments over the winter, I will be looking at development rates of different biotypes of the large raspberry on various cultivars of raspberry with varying levels of resistance. This relationship of development time in comparison with levels of parasitism may help to develop new control strategies.

Although the small raspberry sawfly is not thought of as an important pest at present, the increase in poly-tunnel production may favour the development of the pest. A very limited number of experiments which observed the biology of the small raspberry sawfly were undertaken during the winter. The experiments were limited due to a number of problems culturing the insects. The results indicate that the average number of days that an adult lives is increased with the addition of a sugar source in their diet. This winter I will be continuing to observe the biology of the insect.

- The use of the flower volatiles lures increased the efficiency of the sticky traps but this varied depending on the commercial site used.
- There was no beetle migration to the hawthorn sources at either of the commercial sites but there was evidence of migration at the experimental site suggesting that when developing an integrated pest management strategy other flower sources must be taken into consideration.
- The new design of volatile release system is much safer for workers to handle but the number of beetles caught using this system was lower than for the old system.
- The susceptible cultivar, Glen Ample, had a greater number of aphid present than Glen Clova and Glen Rosa had no aphids present.
- There was a greater proportion of parasitized aphids on Glen Clova than Glen Ample.

Background

This report is the findings of the first of three years work looking at ways of developing integrated pest management in raspberry production. Three insect pests of raspberry are being investigated: the small raspberry sawfly, *Priophorus morio*, the large raspberry aphid, *Amphorophora idaei,* and the raspberry beetle, *Byturus tomentosus*.

Between the months of October 2002 and February 2003, the work focussed on the small raspberry sawfly. The literature on this insect is very limited, so baseline studies on general biology are required. The following particular questions needed to be addressed –

- What is the optimum temperature for development?
- What is the survival rate at different stages of development i.e. number of successful ovipositions and the survival rate at each instar
- What are the factors influencing the number of eggs laid i.e. food source and temperature

Although many growers believe that the small raspberry sawfly is only a minor pest, the expansion in poly-tunnel production may lead to an increase in the amount of sawfly damage observed. The conditions in poly-tunnels may favour their development and allow numbers to increase. Interestingly, indications after the warm summer (2003) suggest that, even in unprotected cultivation, these warmer conditions have increased the amount of sawfly damage in all parts of England (Janet Allen (ADAS), personal communication).

This report contains some findings of the sawfly study, but due to problems with plant supply, the numbers of individuals in the population decreased to a level where experiments were not possible. Eventually, the culture died out. Fortunately, this summer a sample of larvae was collected from a site in Abingdon and this culture is becoming well established, allowing the experiments to continue through the winter.

For the past five months, I have been concentrating on work involving the raspberry beetle, *Byturus tomentosus,* and during July and August my work also included some aspects of the biology of the large raspberry aphid, *Amphorophora idaei*.

This part of the project looks at a method of monitoring the population size of the raspberry beetle and preventing the females from laying eggs. This technology, which has been developed over the past few years at SCRI and in Switzerland, involves using non–UV reflective white sticky traps which mimic the raspberry flowers and so attract the adult beetles. These traps, when placed in the plantations, can give the grower an indication of the numbers of beetles present, and when the number of beetles increases over a certain level, the use of insecticides is permitted.

The effectiveness of these traps was enhanced by the identification of two compounds found in the flower. These compounds, called semiochemicals, act as lures, attracting the beetles to the flowers. When these lures are used in combination with the sticky traps, the numbers of beetles caught increase dramatically.

This summers work entailed using non-UV reflective white sticky traps (AgriSense-BCS Ltd) in combination with the two previously identified flower volatiles, chemicals A and B. Experiments 2-5 describe the design of the experiments to observe the numbers of beetles caught using the plain white sticky traps and the sticky traps with lures and also discusses the results obtained. There was also a study to observe any migration by the beetles to any other flower source during its lifecycle and also a study that tried to indicate the distance over which volatile B is active. Finally, the numbers of beetles caught on sticky traps using a new kind of volatile dispenser were compared with the numbers of beetles caught using the original dispenser. Hopefully this will lead to modifications to the current beetle trapping design.

It was important to take this system out of the artificial environment at SCRI, which had had no pesticide application for a number of years, and into commercial plantations where the numbers of raspberry beetles have been controlled by pesticides to a level which prevents any beetle damage to the fruit. Two commercial sites were chosen.

1. R&JM Place Ltd, Church Farm, Tunstead, Norwich, Norfolk (O.S. TG 289 198). This is a large business dealing in soft fruit destined for both the fresh and processed market.

2. Mr Euan McIntyre, Cruachan, Wester Essendy, Blairgowrie (OS. NO 135 435). This is a small holding producing high quality fruit for the fresh market.

An experimental site was also used in the raspberry beetle study; this was located at the Scottish Crop Research Institute, Invergowrie, Dundee (O.S. NO 333 342). This is split into two adjacent plots; one which was planted in 1996 (plot F6), and a younger plot which was planted in 2001 (plot F4). These plots have a mixture of raspberry cultivars that are planted in blocks within the two plots.

The large raspberry aphid is also a major pest of raspberry plantations. Although large populations found on susceptible cultivars can cause direct feeding damage, the main problem is caused by the transmission of four raspberry viruses (raspberry leaf spot virus, raspberry leaf mottle virus, black raspberry vegetative necrosis virus and rubus yellow net virus), while the aphids feed on the plant tissue. In this case, resistance genes to *A. idaei* are being used as a strategy to reduce the amount of pesticide used. Cultivars containing resistance genes to the large raspberry aphid have been in use for over 40 years.

The large raspberry aphid study was carried out in the two experimental plots at SCRI. This involved sampling the aphid population on three different cultivars, Glen Ample, Glen Clova and Glen Rosa, which have varying levels of resistance to the large raspberry aphid, to observe differences in aphid numbers between the three cultivars. Other aphids species were also identified together with the predators and parasitoids present on the cultivars.

<u>Experiment 1</u> Effect of food source on the body size, lifespan and fecundity of the adult sawflies

Null Hypothesis. The addition of a food source will not increase the lifespan, fecundity or body size of the individuals.

Methods

Twenty newly emerged adult was placed in a rearing cage with a Glen Moy seedling along with either a water source, a 10% sugar solution or a 10% sugar solution and a mixture of yeast extract, yeast powder and soya flower (protein source). This rearing cage was positioned in a growth cabinet. This growth cabinet was set at 20 ºC with high intensity light and red light. These cages were checked once every 24 hours until the death of the sawfly. The length of the hind leg tibia was measured and the sawfly was dissected to obtain the number of remaining eggs. The number of oviposition sites on the seedlings was counted and added to the number of remaining eggs to obtain overall egg load.

Results

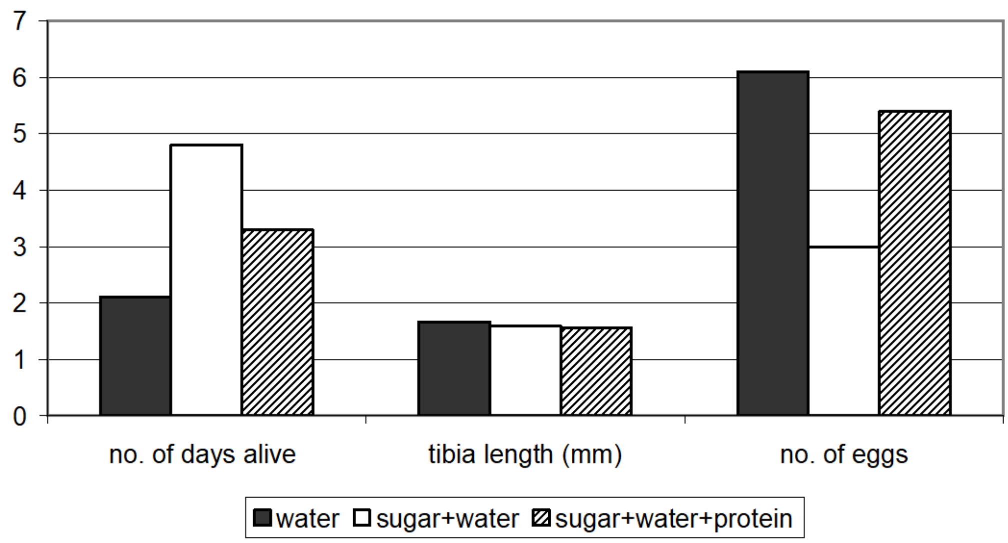


Figure 1.The average number of days alive, tibia length (mm) and number of eggs for raspberry sawfly fed on water only, sugar and water or sugar, water and protein source.

The addition of a sugar source (Figure 1) doubled the number of days lived, but the increase was reduced when a protein source was added. The tibia length was similar in sawfly fed on the three different food sources. The number of eggs produced is greatest in the sawfly which were given water only and least when the sawfly were given sugar and water.

Discussion

The sample size was small and led to a great amount of variation in the number of days lived and the number of eggs. The sample size means that the results obtained do not show any indication that the addition of a food source increases the lifespan, body size or fecundity of the sawfly. With a bigger sample size the amount of variation would be reduced and the data would be a truer picture of what was happening.

<u>Experiment 2</u> **Comparison of the number of beetles caught and the level of fruit damage using the non-UV reflective white sticky traps with and without the lures.**

Null Hypothesis. The plain white sticky traps will trap the same number of beetles as the sticky traps with the lures.

Null Hypothesis. The amount of beetle damage to the fruit surrounding the plain white sticky traps will be the same as the damage observed in areas containing sticky traps with lures.

Experiment 2.1

Methods

This was carried out at the site located in Blairgowrie. The cultivar used in the experiment was Glen Ample and the plot was planted in 2001 and therefore is still quite young. Older plots were situated to the south and east of this plot (see Figure 2).

Beetle counts

Four areas were identified in the plot (see Figure 2) and each area contained two sticky traps with lures and two sticky traps without lures. The traps were positioned on the 3rd row in from the edge approximately 50-100 cm above the ground and 5 metres into the row. There was at least 15 metres between the traps of the same design and 40 metres between the two design types (see Figure 3), although, the actual distance was dependent on the length of the rows which showed a great deal of variation. This distance between traps was chosen to avoid the odour plumes overlapping.

The sticky traps were put into position at beetle emergence (1st May 2003) and the experiment ran until first green fruit (19th June 2003). All four areas (1-4) were used in this experiment. Throughout the experiment the sticky traps and lures were replaced every seven days. The traps were wrapped in cling film and stored at 4 °C until the numbers of beetles were counted.

Damage assessment

After discussion with the grower it was decided that one area (area 2) would be protected from insecticide spraying against raspberry beetle. This allowed the assessment of the fruit damage in an area in which the beetle numbers had only been controlled by the plain sticky traps or the sticky traps with lures. The chosen area was covered in a large sheet of plastic thrown over the row to protect it from spray drift. Fruit husks were collected not more than 24 hours after the fruit had been picked. 100

husks were picked around each of the four traps in the area and these husks were frozen until damage assessment could take place.

Comparison with conventional methods

To compare the amount of damage in an area that had been farmed conventionally (application of insecticide against raspberry beetle), husks were collected from an area of the plantation that had not been protected from pesticide application. Again, these husks were frozen until damage assessment could take place.

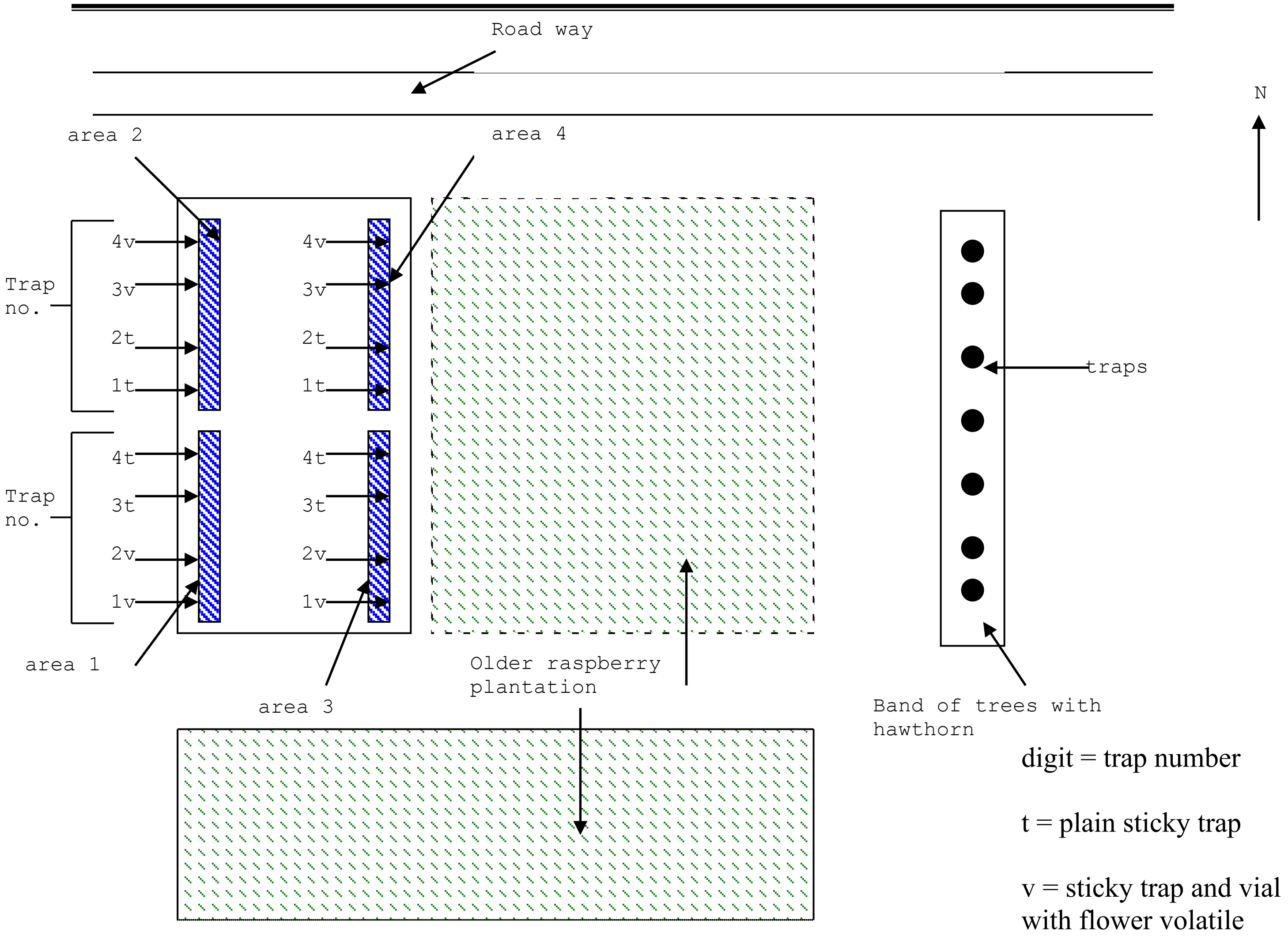


Figure 2 – ***Representation of the trap placement at Blairgowrie***

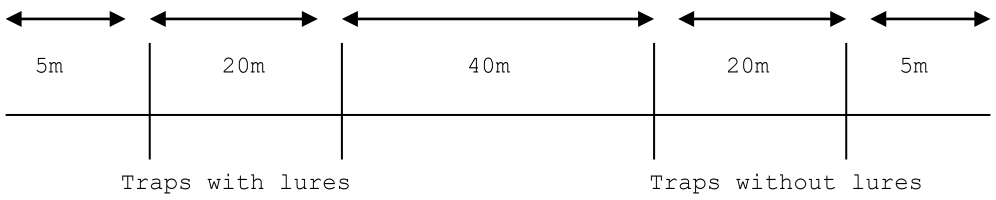


Figure 3 – ***Position of traps along one row.***

Results

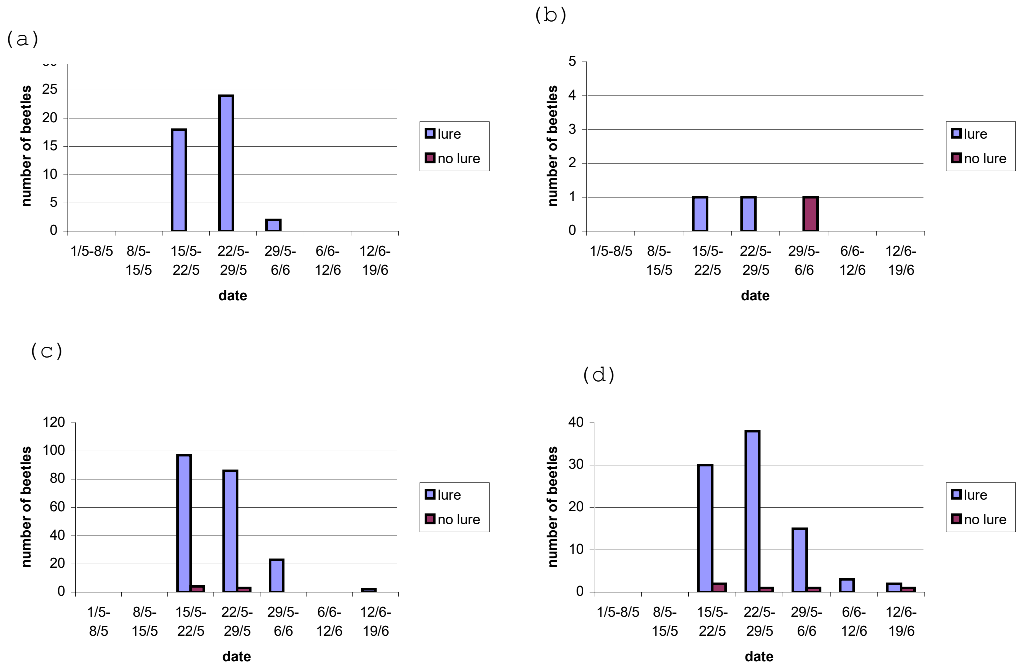


Figure 4a-d. The total number of beetles caught weekly at Blairgowrie using the plain sticky traps and the sticky traps with lures (a) area 1, (b) area 2, (c) area 3 and (d) area 4.

There is a great amount of variation in the number of beetles caught in the different areas. Areas 3 and 4 have higher populations than the other two areas. There were no beetles caught in the first two weeks (1/5-8/5), followed by an increase in the number of beetles in weeks three (15/5-22/5) and four (22/5-29/5) and then the numbers of beetles caught decreases again in the last three weeks (29/5-19/6). The highest number of beetles caught, 97 individuals, occurred in week three (15/5-22/5) in area 3. There is an obvious increase in the number of beetles caught using the traps with the lure compared to the plain traps.

Discussion

Areas 3 and 4, which are positioned next to the older plantation have higher number of beetles than the other two areas suggesting that there is migration by the beetles from the older plantation into the newer plantation. The increase in numbers caught in weeks three and four coincide with the beetle population increasing after emergence. This is followed by the decrease observed in week five that coincides with the start of flowering. The effect of the lure once flowering has started is thought to decline because the volatiles released from the flowers themselves are stronger and more attractive to the beetles. During weeks 3 and 4 the addition of the lure increased the number of beetles caught by between 10 and 30 times.

The husks were collected from area 2, which unfortunately was the area with the lowest number of beetles caught, and as expected there is a very limited amount of damage observed. Of the 200 husks collected around the traps with no lure, there was no damage observed. This was also the case in the 100 husks collected in the area conventionally farmed. Two husks collected around the area with traps and lures showed evidence of damage by raspberry beetle larvae. The numbers obtained are not great enough to come to any meaningful conclusions.

Experiment 2.2

This experiment took place in the plantation situated in Norwich. This is a 25 acre plantation of Malling Leo which was planted in 1995.

Methods

The method is very similar to Experiment 2.1. However, due to the shape of the plantation the position of the traps is different (see Figure 5). Figure 5 shows that there were two areas positioned along one row and another two areas positioned along individual rows. The traps were put in position at beetle emergence (23rd April 2003) and the experiment continued until flowering had just started (28th May 2003).

As in Experiment 2.1, an area was protected from insecticide spraying against raspberry beetle. In this experiment, row 3, which included areas 1 and 2, was protected from insecticide spraying.

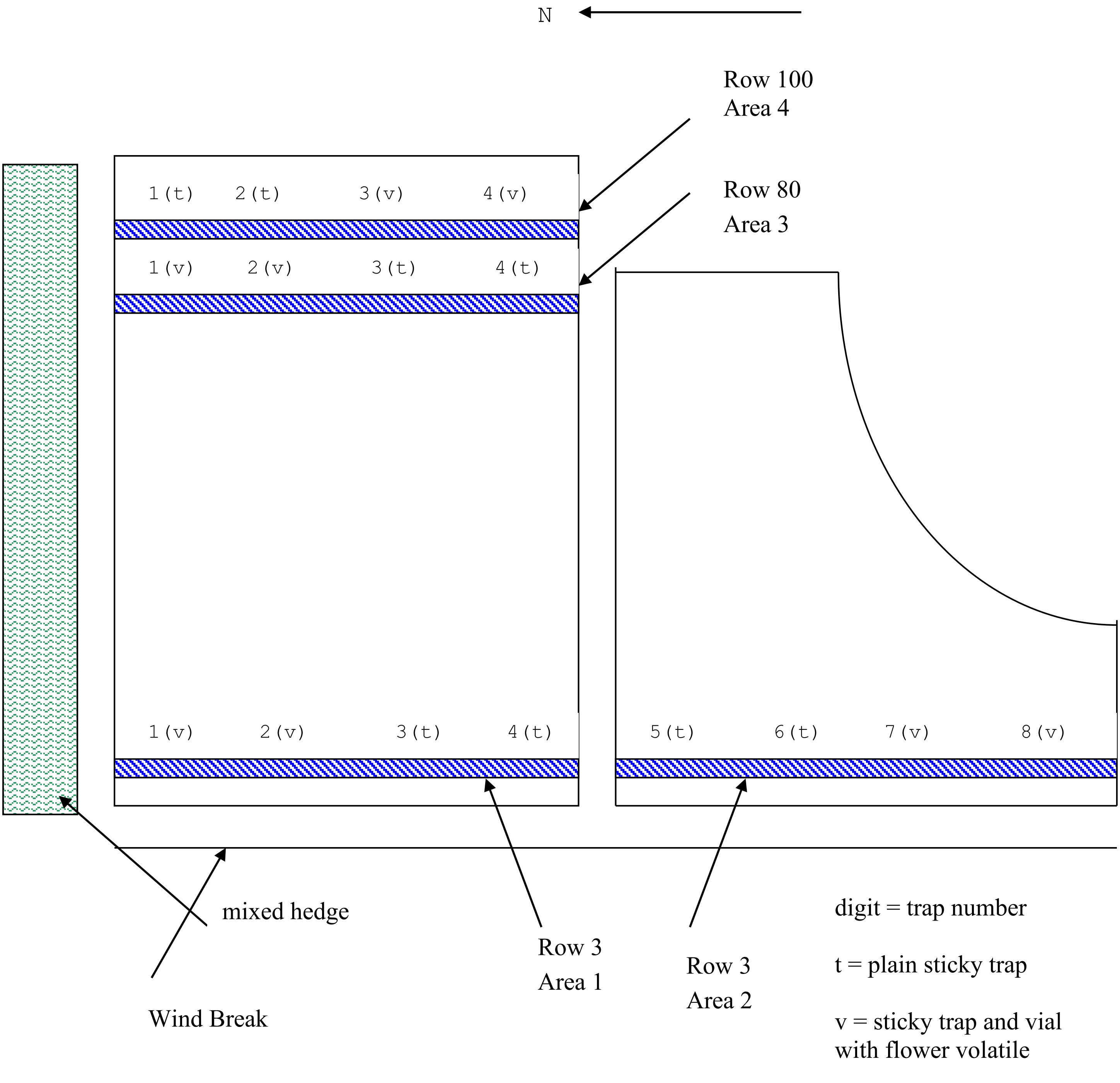


Figure 5. Representation of the shape of the raspberry plantation in Norwich and the trap placement.

Results

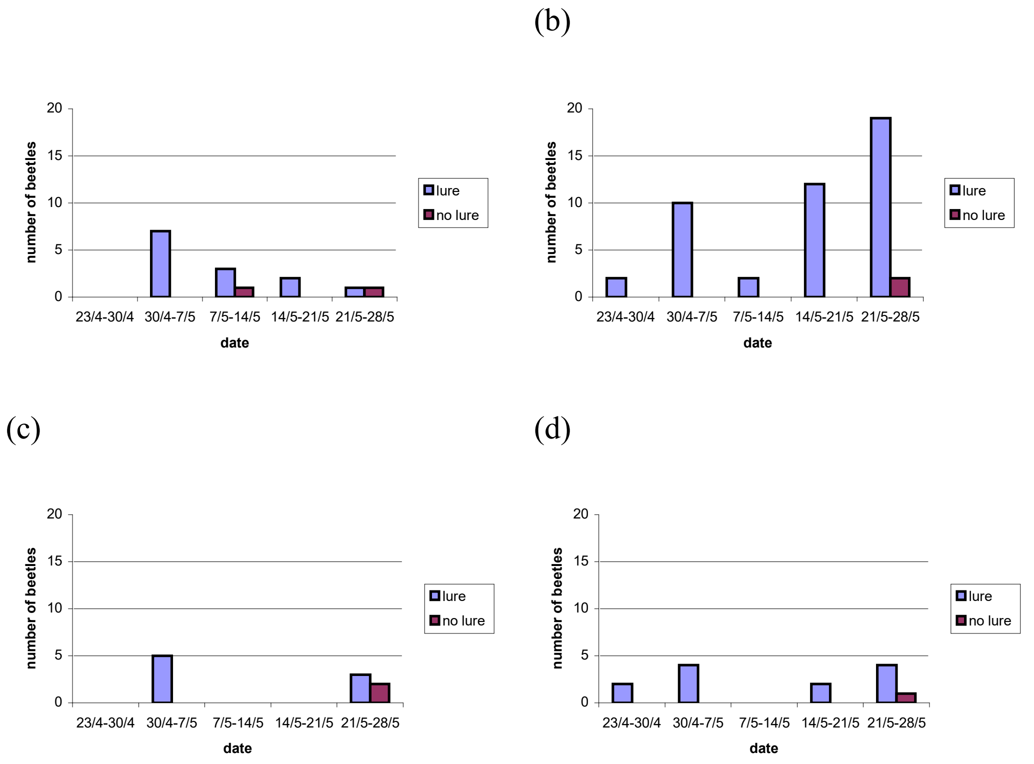


Figure 6. Total number of beetles caught weekly in the raspberry plantation in Norwich on the plain white sticky traps and the sticky traps with the lure. (a) area 1, (b) area 2, (c) area 3 and (d) area 4.

There was a small amount of variation in the number of beetles caught between different areas and the number of beetles caught in all the areas was very low. The largest number of beetles caught occurred in week 5 (21/5-28/5) in area 2, when 19 individuals were caught. This contrasts with the same week in area 3, when there were no beetles caught. The addition of the lure increased the numbers caught by 10 fold.

Discussion

There is no obvious trend in the numbers of beetles caught that relates to the increase in population size as the beetles emerge, and a decrease when the raspberries start to flower (19/5), as was observed in the results from Blairgowrie. The high numbers in area 2 may be due to beetles migrating from the blackberry plantation situated adjacent, but this would require further investigation.

The husk samples are still to be collected from Norwich.

Experiment 2.3

This experimental setup was repeated in a blackberry plantation. The grower in Norwich had noted the presence of raspberry beetle in the blackberry plantation.

Methods

The protocol was the similar to experiment 2.1, although the position of the traps was dictated by the shape of the plantation. The traps were positioned in two areas (see Figure 6) at beetle emergence (23rd April 2003) until just before first flowering (28th May 2003).

Area 1 and 2 were protected from pesticide spray against raspberry beetle and berries and husks were collected when the fruit was ready for harvest.

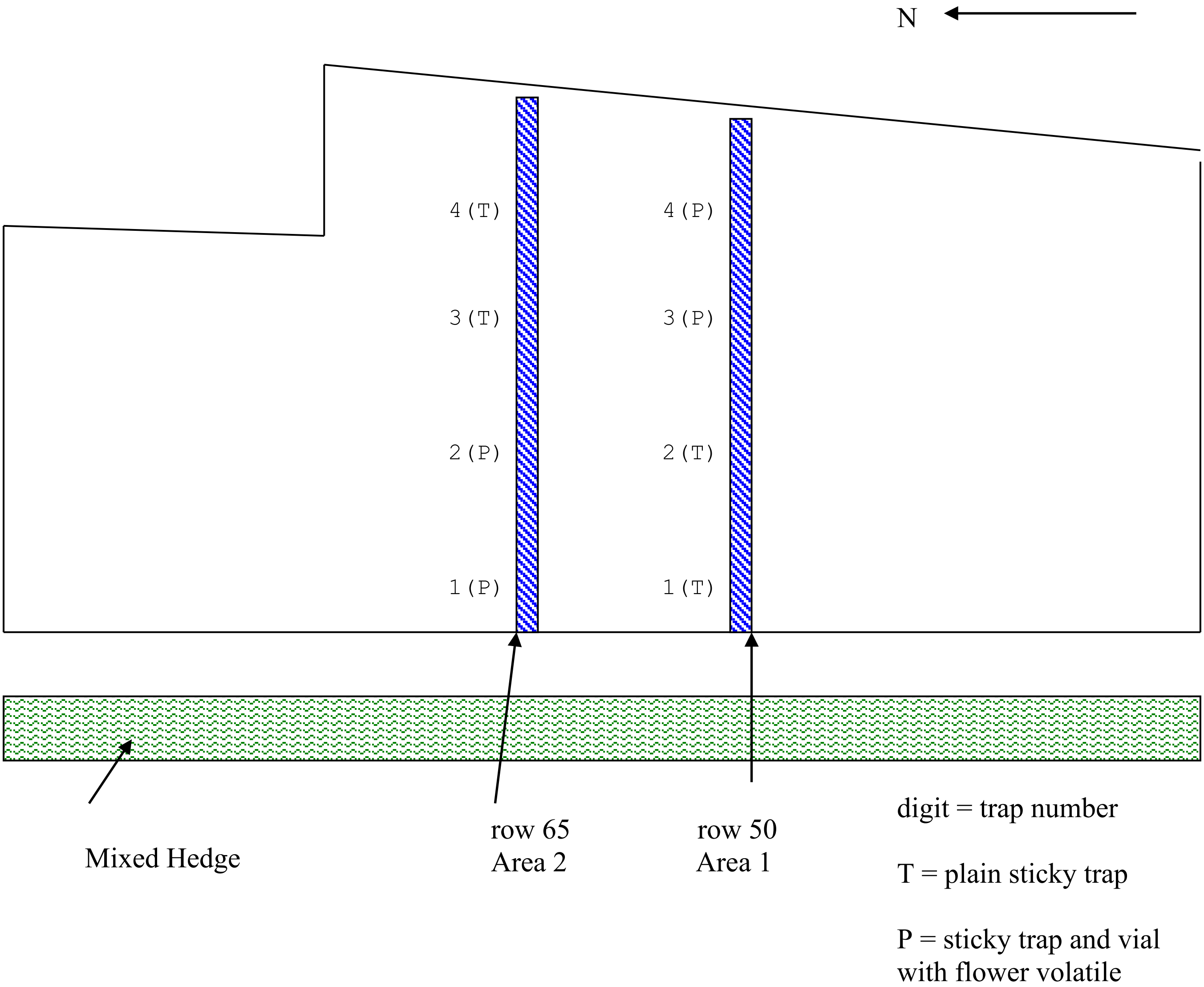


Figure 7. A diagram showing the shape of the blackberry plantation in Norwich and the trap placement.

Results

(a) (b)

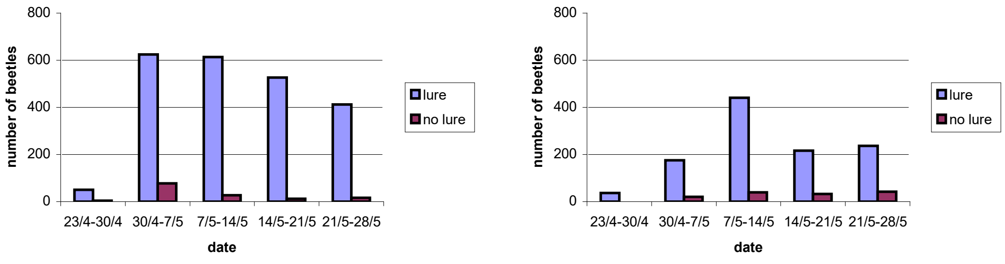


Figure 8. Total number of beetles caught weekly in the blackberry plantation in Norwich using the plain white sticky traps and the sticky traps with lures . (a) area 1 (b) area 2.

There were a small number of beetles caught in week 1, but the numbers caught increased to a very large number of beetles trapped in the remaining weeks. Overall, the traps in area 1 caught a greater amount of beetles than in area 2. The addition of the lure increased the numbers of beetles caught by between 10 and 65 fold.

Discussion

The increase in the number of beetles caught in week 2 coincided with the start of beetle emergence. It is not clear why there was a large difference between the numbers of beetles caught in area 1 and area 2.

There has been not been any previous work involving raspberry beetle in blackberry plantations and some questions still need to be addressed. Blackberries flower later than raspberries and this may effect the development time of the beetles. It is important to detect whether the populations in the raspberry plantation and the blackberry plantation are separate or if there is migration between the plantations.

3 Beetle migration to hawthorn sources surrounding the plantation

Previous observations (L Yla-Sulkava, unpublished) suggest that raspberry beetle migrate from the raspberry plantation to nearby hawthorn sources when the hawthorn is in flower and then return to the raspberry plantation when it starts to flower. This may be important in developing an IPM strategy, because if this migration involves a large proportion of the beetle population then the monitoring and control strategy must take this into account.

Null Hypothesis – The number of beetles caught on the hawthorn traps is the same throughout the season and shows no pattern linked to flowering.

Experiment 3.1

The Blairgowrie site included a band of trees containing hawthorn which was approximately 100 metres from the raspberry plantation used in experiment 2.1. From figure 2 it can be seen that there is an older adjacent plantation that separates the experimental plot from the band of trees. (Plates 1 and 2)

Method

Eight traps were positioned in the band of trees (see Figure 2) at the beginning of beetle emergence (1st May 2003) and the experiment continued until the beginning of raspberry flowering (6th June 2003).

These traps were replaced once a week and wrapped in clingfilm and stored at 4 °C until the number of beetles could be counted.

Results

	date				
trap no.	**1/5-8/5**	**8/5-15/5**	**15/5-22/5**	**22/5-29/5**	**29/5-6/6**
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	1	3	0
4	0	0	0	0	0
5	0	0	0	0	1
6	0	0	0	0	0
7	0	0	1	0	1
8	0	0	0	5	10

Table 1. Number of beetles caught weekly on the eight sticky traps positioned in the band of trees at Blairgowrie.

The numbers of beetles caught on a single sticky trap ranges from one per trap per week up to ten per trap per week. Beetles were only found on the traps during the last three weeks of the experiment (15/5-6/6). The captures frequently occurred at the same trap position during the last three weeks.

Discussion

The results show that there is very little migration to the surrounding hawthorn source and the small amount of movement that did take place was not linked to the flowering of the hawthorn (19/5). This suggests that this migration would not be important when predicting the best time to spray and developing IPM strategies.

Experiment 3.2

A similar experiment took place in the raspberry plantation in Norwich, where 6 traps were positioned 10 metres apart along the north edge of the raspberry plantation (Plate 3) and corresponding traps were positioned 15 metres into the plantation (see Figure 9). These traps were changed once a week and the experiment ran from beetle emergence (23rd April 2003) and continued until flowering had just started (28th May 2003).

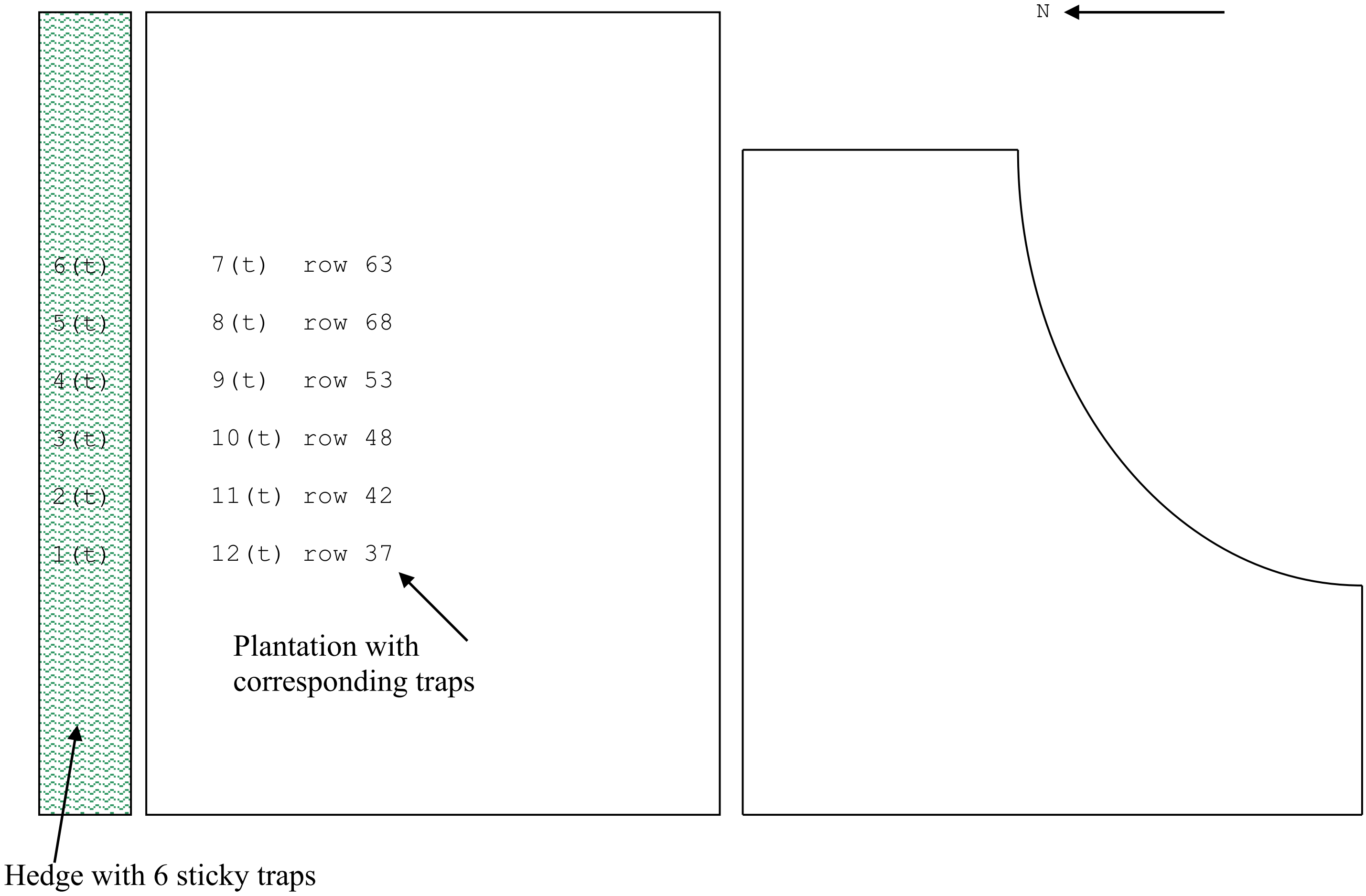


Figure 9. Placement of traps in the hedge and corresponding traps in the raspberry plantation at the Norwich site.

Results

trap position	23/4-30/4	30/4-7/5	7/5-14/5	14/5-21/5	21/5-28/5
Hedge	0	0	0	0	1
Plantation	0	0	0	0	9

Table 2. The total number of beetles caught in the raspberry plantation corresponding hedge at the site in Norwich

There were no beetles caught on the traps in the hedge or plantation until the last week (21/5-28/5). The results from the last week show that there was only one beetle caught on the traps in the hedge.

Discussion

There was no beetle migration occurring between the plantation and the hedge used in the experiments. There are a few possible explanations for this. The hedge had been severely trimmed and there may have not been many flowers on the hawthorn to attract the beetles. This may be due to the prevailing wind blowing in another direction and therefore not providing a chance for the beetles to migrate to the source. Another possible explanation is that not all hawthorn sources attract beetles and this may be the cause of the very low numbers seen on the traps in the hedge.

Experiment 3.3

Hawthorn migration was also studied in the blackberry plantation at the Norwich site. Five traps were positioned along the west side of the plantation (Plate 4) and corresponding traps were positioned 15 metres into the plantation (see Figure 10).

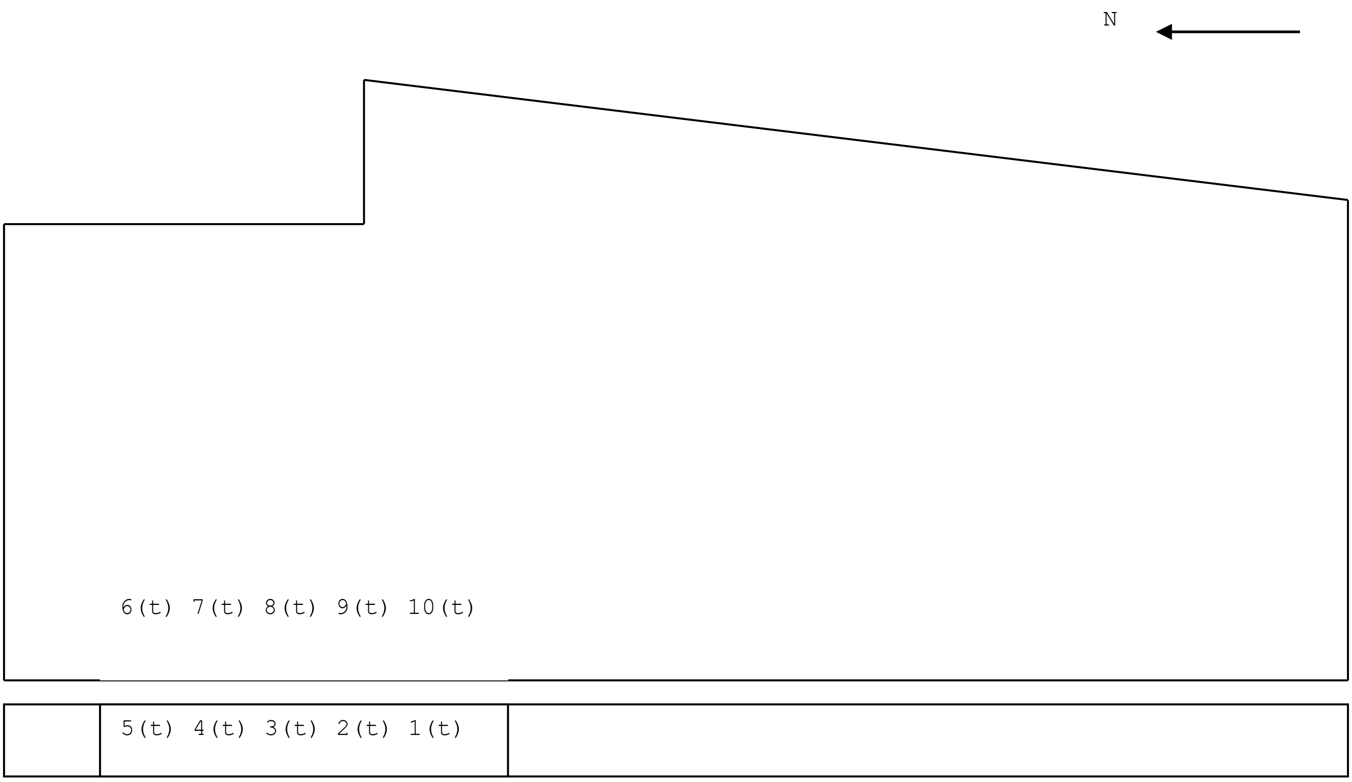


Figure 10. Trap placement in the hedge and the blackberry plantation at the site in Norwich

Results

trap position	23/4-30/4	30/4-7/5	7/5-14/5	14/5-21/5	21/5-28/5
Hedge	0	8	0	2	4
Plantation	2	99	33	30	38

Table 3. The total number of beetles caught in the hedge and corresponding traps in the blackberry plantation at the Norwich site.

A very large number of beetles were caught in the traps in the plantation but very few in the corresponding traps in the hedge. The largest number of beetles recorded in the hedge, 8 individuals, occurred in week 2.

Discussion

Although very few beetles migrated to the hedge, the 8 individuals recorded in the hedge in week 2 did coincide with the hawthorn flowering (29/4). The low numbers may be due to the prevailing wind blowing in another direction and therefore not providing a chance for the beetles to migrate to the source. Another possible explanation is that not all hawthorn sources attract beetles and this may be the cause of the very low numbers seen on the traps in the hedge.

Experiment 3.4

At the experimental site situated at SCRI, a band of trees that runs along the south side of the plantation, at a distance of approximately 28 metres, contains hawthorn bushes. Six traps were positioned in a semi-circle around the south west corner of the plantation. These traps were positioned at beetle emergence (5/5) and the experiment finished at the beginning of raspberry flowering. Again the traps were changed weekly and they were wrapped in clingfilm and stored at 4 °C until the number of beetles could be counted.

Results

	date				
trial no	5/5-12/5	12/5-19/5	19/5-26/5	26/5-2/6	2/6-9/6
1	0	0	2	0	0
2	0	2	14	1	0
3	0	3	33	8	2
4	0	7	112	4	0
5	0	1	16	4	0
6	0	0	6	0	0

Table 4. The total number of beetles caught each week on each individual traps at SCRI

The numbers of beetles caught are very low in weeks 1 and 2 and then there is a sudden increase in week 3. The numbers fall dramatically again in week 4. Trap 4 has a much larger number of beetles than the other five traps, with the numbers of beetles caught peaking in week 3 with 112 individuals.

Discussion

Migration from the plantation to the hawthorn source occurs in quite large numbers and the increase in the number of beetles on the traps coincides with the hawthorn flowering (16/5). The placement of the trap is also very important because even although there was hawthorn present along the length of the experimental area, trap 4 was located in front of a single hawthorn bush and has a greater number of beetles caught than the other five traps. This observed movement suggests that in some instances migration can occur between sources, but it must be noted that the site at SCRI has a very large population of raspberry beetles and these large numbers would not be observed in a commercial plantation.

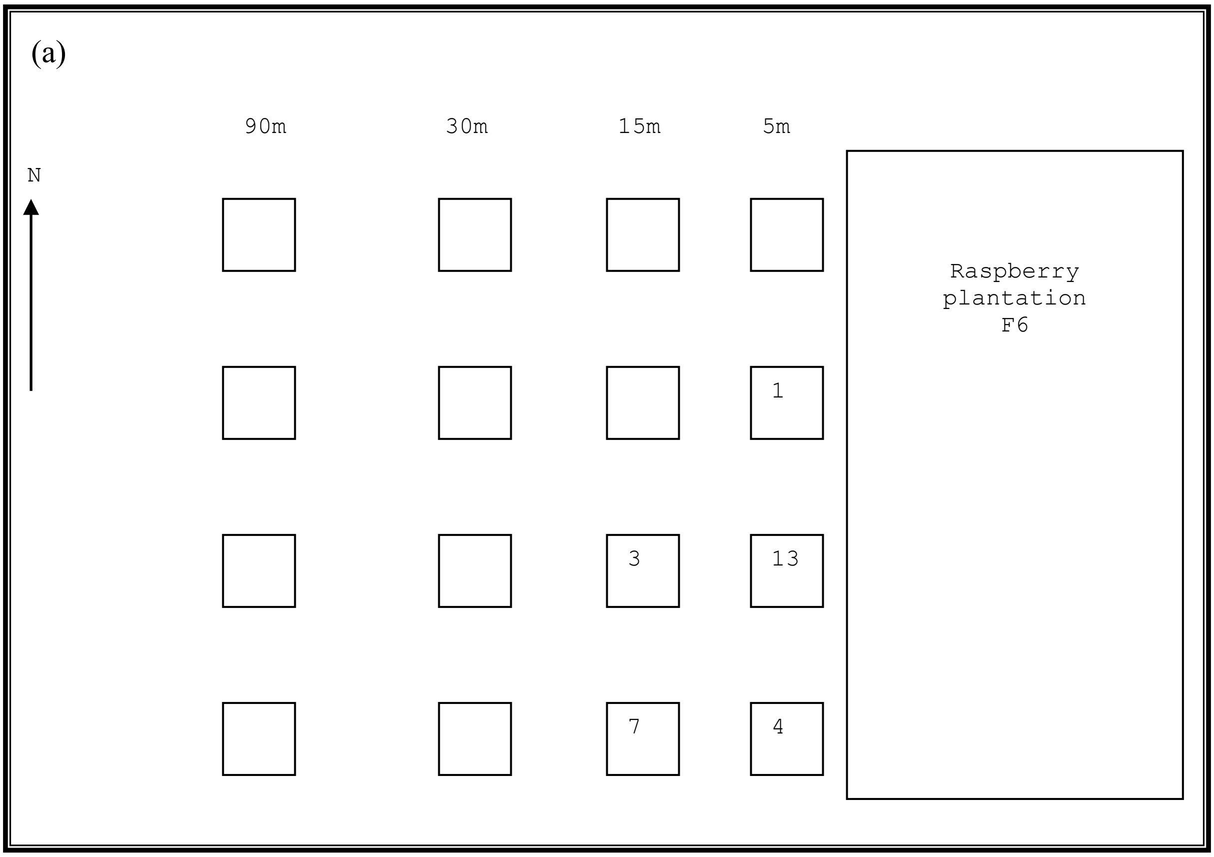
4 Over what distance is the lure active?

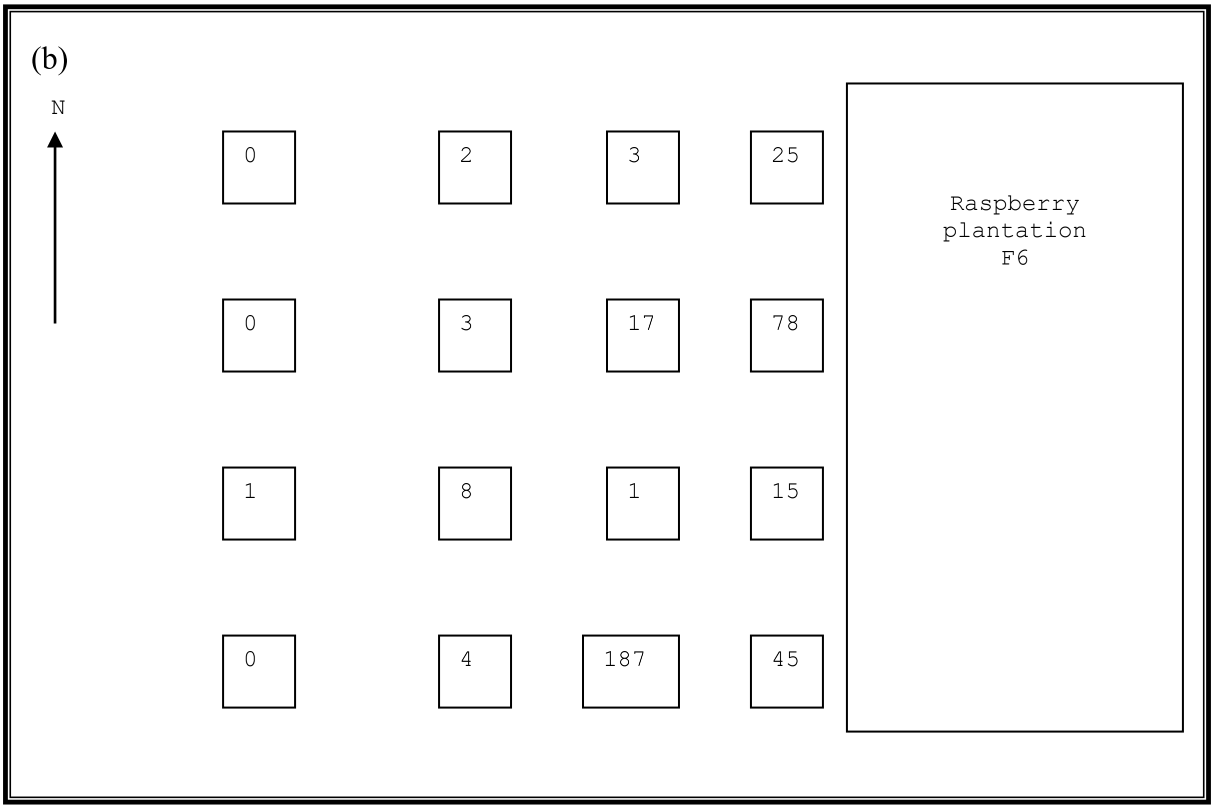
It is important to know over what distance the lure is active as this will affect the optimal distance that the traps would be set out in the plantation.

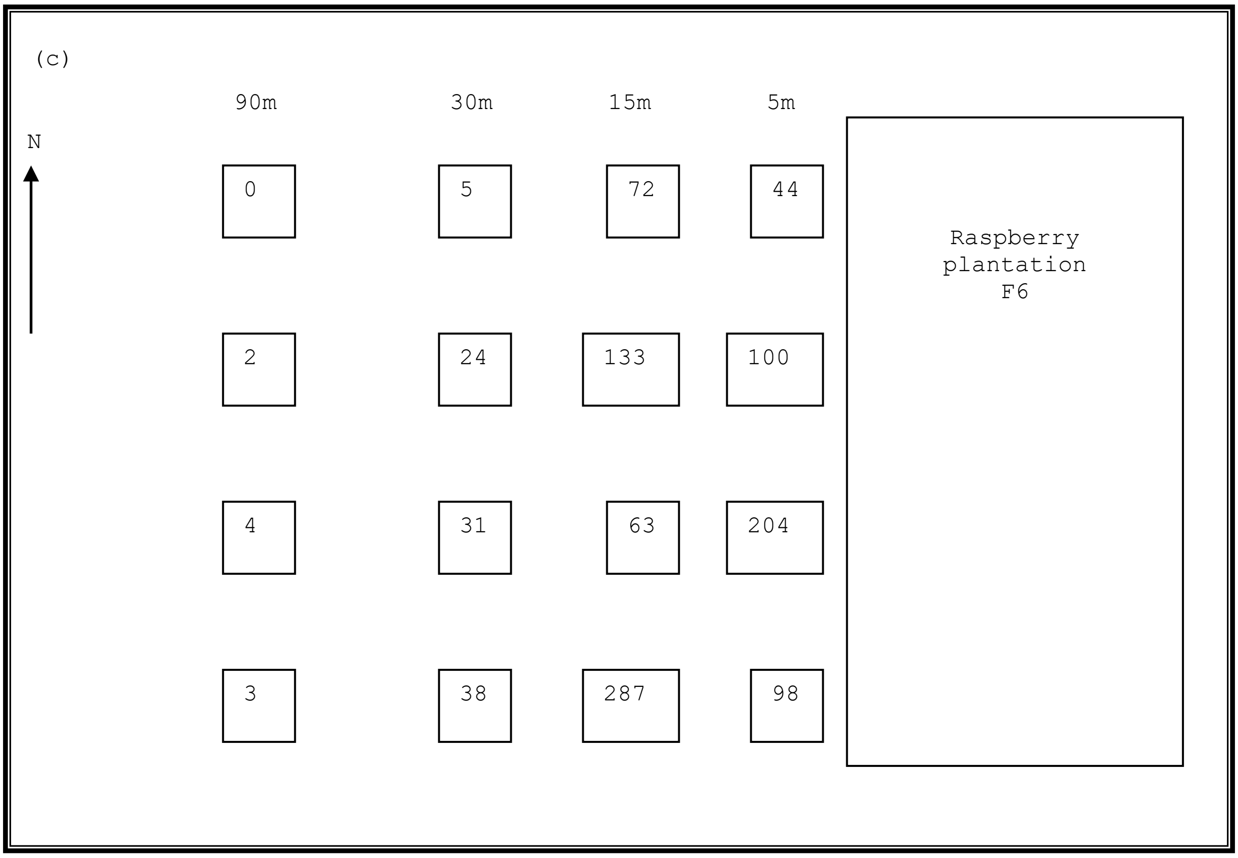
Method

Traps with lures were attached to stakes 90 cm tall and positioned 5, 15, 30 and 90 metres to the west of the plantation (Plate 5). This was repeated four times along the length of the plantation. These traps were changed once a week and the lures were changed every three days. As the lures were more exposed than they would usually be in a plantation the evaporation rate was much higher. The traps were wrapped in clingfilm and stored at 4 °C until the beetles could be counted.

Results


(a)
90m
30m
15m
5m
N
Raspberry plantation F6
1
3
13
7
4


(b)
N
0
2
3
25
Raspberry plantation F6
0
3
17
78
1
8
1
15
0
4
187
45



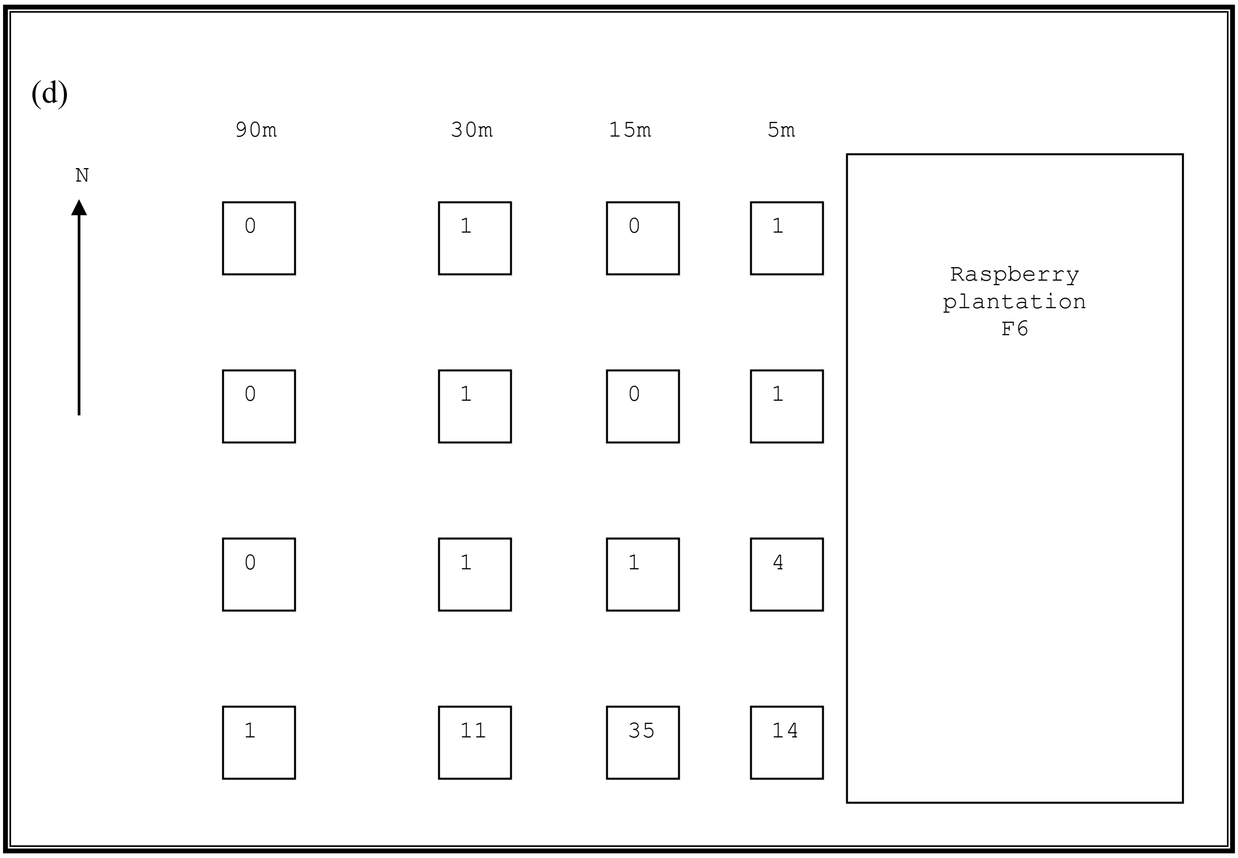


Figure 11. The placement of the sticky traps with lures and the number of beetles caught weekly on the individual traps at SCRI (a) 5/5-12/5, (b) 12/5-19/5, (c) 19/5-26/5 and (d) 26/5-5/6.

There was a great amount of variation between the numbers of beetles caught at the same distance between repetitions and between weeks. However, beetles were caught at every available distance. Week 3 (12/5-19/5) had the greatest amount of beetles caught.

Discussion

The great variation in the numbers of beetles caught between traps at the same distance and between weeks suggests that movement is very dependent on the temperature and wind direction. The addition of wind data for the four weeks may give a clearer indication of what is happening. The numbers of beetles caught suggest that the beetles can detect a lure up to and possibly beyond 90 metres. This result is different from previous years where it was thought that the beetles could only detect a lure up to 30 metres. Interestingly, there was always a large number of beetles trapped on the most southerly trap situated at 10 metres. These high numbers may have been caused by the close proximity to the hawthorn source.

These results may be artificial however, as there may be an accumulative effect of odour plumes if they were overlapping. The design of this experiment was not optimised because of space constraints but it must be repeated with the lures situated in areas where they will not be influenced by other lures.

5 Trial of a new release system

In collaboration with AgriSense-BCS Limited, a new lure release system was tested. It was thought that the present release system used was very labour intensive because the vials had to be refilled once a week. The chemicals used are also very volatile and the present system requires that the chemicals need to be handled once a week. This new lure release system was developed to reduce the amount of handling of the chemical and therefore make it safer. (Plate 6)

Experiment 5.1

Null hypothesis. There will be the same rate of evaporation from the original vials (1700 µl) and the AgriSense vials (2500 µl).

The evaporation rate of chemicals A and B from this slightly porous plastic vial was compared with the evaporation rate of the chemicals from the original glass vials. The original glass vials had a small hole in the plastic stopper to allow the release of the chemical. In vials containing chemical B, a wick was inserted to increase the evaporation rate.

Method

The two vial types containing either chemical A or chemical B were positioned in the plantation on the bottom wire (approx 90 cm above ground). This position is similar to the usual placement of the white sticky traps and therefore is exposed to similar environmental conditions, eg. wind flow. There were four repetitions of the combinations of vials and chemicals and the experiment ran for 12 days. The vials were weighed on various days throughout the duration of the experiment.

Results

Vial type	Chemical	% left on date weighed			
		28-May	29-May	03-Jun	09-Jun
AgriSense	B	100	98.11	94.98	90.46
AgriSense	A	100	95.81	94.43	91.89
Traditional	B	100	80.50	0.00	0.00
Traditional	A	100	84.73	33.64	0.00

Table5 . The mean percentage of the two chemicals left in the two vial types on three dates though out the duration of the experiment

Both chemicals A and B in the AgriSense vials show very slow evaporation over the 12 days of the experiment. There was still approximately 90 % of both types of chemical left in the AgriSense vials at the end of the 12 days. Chemicals A and B in the traditional vials showed much faster evaporation. Chemical B had completely evaporated after 6 days and Chemical A had only one third of the original volume left after 6 days.

Discussion

These evaporation rates suggest that the AgriSense vials will last approximately 17 weeks. The sticky traps and chemical are in position for 7 weeks, which means that there is an adequate volume in the vials to last the whole season. The traditional vials must be changed every 5-7 days so the new vials are labour saving.

Experiment 5.2

Null Hypothesis. The traps with the new plastic vials will catch the same number of beetles as the traps with the original glass vials.

Methods

The two areas used in this experiment are the experimental plots situated at SCRI. Each of these plots were split into blocks and each block contained a different cultivar. The two cultivars used in this experiment are Glen Ample and Glen Clova. These were chosen as they flower reasonably close together and therefore the timing of the raspberry beetle lifecycle should be similar. Unfortunately, the two plots are of different ages and this may result in differences in the number of beetles in these two plots.

There were 5 treatments:-

Chemical A AgriSense plastic vial and trap	**PA**
Chemical B AgriSense plastic vial and trap	**PB**
Chemical A Original glass vial and trap	**GA**
Chemical B Original glass vial and trap	**GB**
Plain Trap	**C**

There were 4 replicates of the 5 treatments with 2 replicates taking place in Glen Ample and 2 replicates taking place in Glen Clova. Due to a limitation in space there are PA treatments in Plot F6. Each treatment was positioned in the middle of the section. The experiment was run over a two week period.

The traps were changed once a week and wrapped in clingfilm and stored at 4 °C. The numbers of beetles were counted on each of the traps to indicate if there are differences in the numbers of beetles caught using the two vial types.

Results

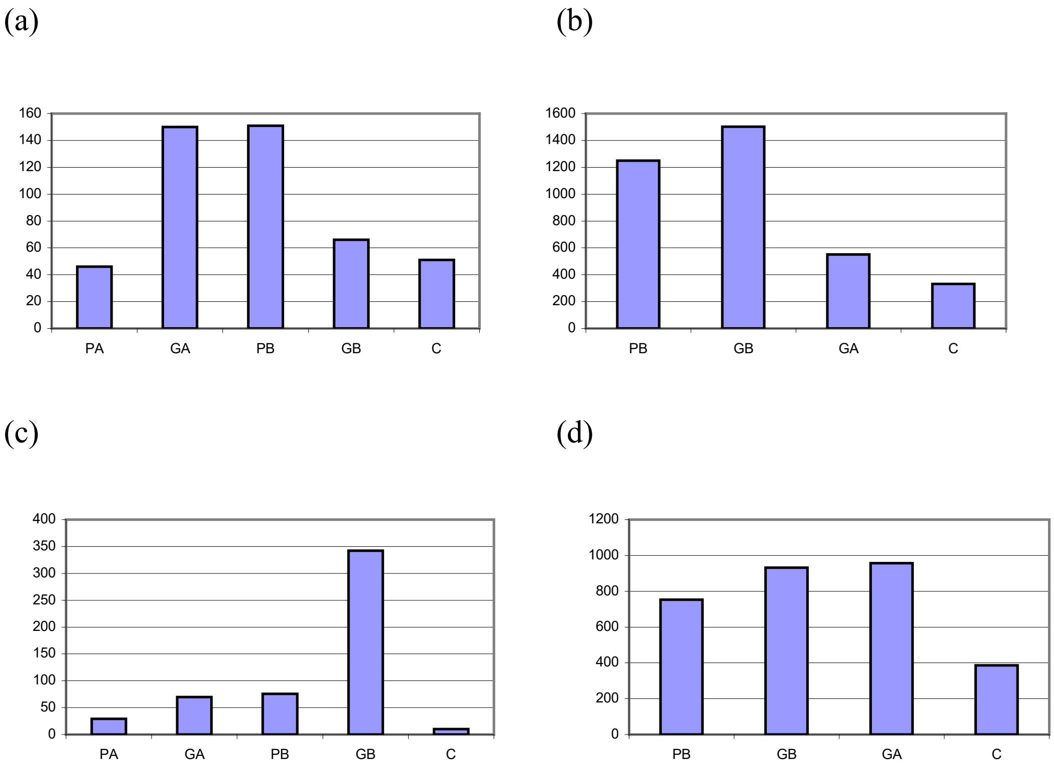


Figure 12. Total number of beetles caught on the sticky traps using the different vial types. PA – plastic vial with Chemical A, GA – glass vial with chemical A, PA – plastic vial with chemical A, PB – glass vial with chemical B and C – plain sticky trap (control). (a) Plot F4 Ample, (b) Plot F6 Ample, (c) Plot F4 Clova and (d) Plot F6 Clova.

With only one exception, the traps with the glass vials caught more beetles than the corresponding plastic vials. The one exception is in F4 Ample, where the trap with the plastic vial containing chemical B caught more beetles than the trap with the glass vial containing chemical B. In all cases the plain sticky traps used as a control caught less beetles. The traps in Plot F6 caught a greater number of beetles than the corresponding traps in Plot F4.

Discussion

These results indicate that there is still work required to optimise the release rate from the AgriSense vials. It is possible with a slightly faster evaporation rate from the plastic vials that they would catch the same number of beetles as the traditional vials. As expected, the traps in Plot F6 trapped far more beetles than in Plot F4. This is expected as plot F6 is an older plantation and therefore the population size has had more time to increase.

6 Aphid population study

Each raspberry cultivar has a different level of resistance to the large raspberry aphid. It is thought that the fitness of the aphid is affected by the cultivar on which it feeds. It has been observed that there are a greater proportion of parasitized aphids on cultivars with a higher level of resistance. This suggests that the aphids feeding on the more resistant cultivar are less fit resulting in a longer development time and therefore allowing the wasps to parasitise. This experiment will show the numbers of aphids on each cultivar and the numbers of predators and parasitoids present.

Methods

Three cultivars in F6 were used; Glen Rosa, Glen Ample and Glen Clova, giving a range of levels of resistance.

The F6 plot was split into four blocks. Each block contained the three cultivars used in the experiment. Four plants of each cultivar were sampled in one of the 4 blocks. One primocane and one floricane were sampled on each plant. Two leaves from the top of the plant, two leaves from the middle of the plant and two leaves from the bottom of the plant were sampled from each cane. (total number of leaves sampled from one plant = 12, total number of leaves sampled per cultivar = 48). This sampling was repeated in the other three blocks. Leaves from different positions on the plant were placed in separate bags. These labelled bags were stored at 4 ºC until the insects were identified. Each block was sampled once a week and on the same day of every week giving a 7 day interval between samples.

Insect identification

Amphorophora idaei and *Macrosiphum euphorbiae* were identified to instar. The other insects were identified to family. The numbers of each type of aphid and other insects present was recorded for each leaf. The number of parasitized aphids and empty mummies was also noted and an attempt to rear the parasitoids from the mummies was made.

Results

The tables below show the number of each instar of *Amphorophora idaei* and the numbers of parsitized aphids and empty mummies.

(a)

week no.	1st	2nd	3rd	3rd (al)	4th	4th (al)	adult (al)	adult	mummy	emerged
1	39	10	7	0	1	0	1	0	4	0
2	37	25	16	0	6	0	0	5	2	0
3	74	14	16	0	4	0	0	9	8	0
4	65	31	37	0	12	0	2	7	4	8
5	9	7	11	1	3	0	0	2	0	3
6	2	0	0	0	1	0	0	1	3	8

(b)

week no.	1st	2nd	3rd	3rd (al)	4th	4th (al)	adult (al)	adult	mummy	emerged
1	33	23	10	3	1	4	5	2	3	0
2	24	27	19	0	2	0	0	5	3	1
3	18	7	9	0	3	0	0	3	4	1
4	5	6	5	0	3	0	1	0	2	1
5	0	3	1	0	0	0	0	0	0	2
6	0	0	1	0	0	0	0	0	0	3

(c)

week no.	1st	2nd	3rd	3rd (al)	4th	4th (al)	adult (al)	adult	mummy	emerged
1	23	11	8	2	0	0	0	5	0	0
2	51	12	12	0	5	0	0	9	4	2
3	89	25	16	0	6	0	0	10	5	2
4	24	19	14	0	2	0	0	2	2	8
5	3	1	4	0	0	0	0	1	0	4
6	0	0	0	0	0	0	0	0	0	3

(d)

week no.	1st	2nd	3rd	3rd (al)	4th	4th (al)	adult (al)	adult	mummy	emerged
1	7	4	4	0	0	0	0	2	4	2
2	40	8	2	0	3	0	0	5	1	0
3	1	3	2	0	1	0	0	0	6	1
4	0	0	0	0	0	0	0	0	2	0
5	0	0	0	0	0	0	0	0	0	1
6	0	0	0	0	0	0	0	0	1	3

(e)

week no.	1st	2nd	3rd	3rd (al)	4th	4th (al)	adult (al)	adult	mummy	emerged
1	4	4	1	1	1	0	1	0	0	0
2	12	0	1	0	0	0	1	1	3	0
3	1	2	1	0	0	0	0	0	2	1
4	0	0	1	0	2	0	0	0	2	1
5	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	1	2

(f)

week no.	1st	2nd	3rd	3rd (al)	4th	4th (al)	adult (al)	adult	mummy	emerged
1	20	8	5	0	1	0	1	1	3	0
2	16	2	3	0	0	0	0	2	1	0
3	2	0	0	0	4	0	0	1	2	0
4	2	1	0	0	0	0	0	1	0	3
5	0	0	0	0	0	0	0	0	1	0
6	0	0	0	0	0	0	0	0	0	2

(g)

week no.	1st	2nd	3rd	3rd (al)	4th	4th (al)	adult (al)	adult	mummy	emerged
1	2	6	2	0	0	0	0	0	0	0
2	5	3	0	0	2	0	0	0	1	0
3	7	0	0	0	2	0	0	0	3	0
4	0	0	0	0	0	0	0	0	1	1
5	0	0	0	0	0	0	0	0	0	1
6	0	0	0	0	0	0	0	0	0	0

(h)

week no.	1st	2nd	3rd	3rd (al)	4th	4th (al)	adult (al)	adult	mummy	emerged
1	3	2	0	1	0	0	0	0	2	0
2	24	3	2	0	1	0	0	3	0	0
3	0	0	1	0	1	0	0	0	1	0
4	0	0	1	0	0	0	0	0	0	0
5	2	0	0	0	0	0	0	0	1	0
6	0	0	0	0	0	0	0	0	0	1

Table6 a-h. Total number of individual instars of A. idaei, numbers of mummies and number of empty mummies present weekly in every plot. (a)Ample plot 1, (b) Ample plot 2, (c) Ample plot 3, (d) Ample plot 4, (e) Clova plot 1, (f) Clova plot 2, (g) Clova plot 3 and (h) Clova plot 4. (al)= alate.

Results

The tables do not include any data on Glen Rosa. This is because there were no aphids found on the sampled leaves from any of the plots and only one mummy was found. This occurred in week 1. The numbers of *Amphorophora idaei* showed an increase over the first 3 weeks of sampling and then start to decrease for the last three weeks. There were a very low number of alate 3rd and 4th instar and adults and the majority of them were found in the first 3 weeks of sampling. There were a greater numbers of *A. idaei* found on Glen Ample than Glen Clova.

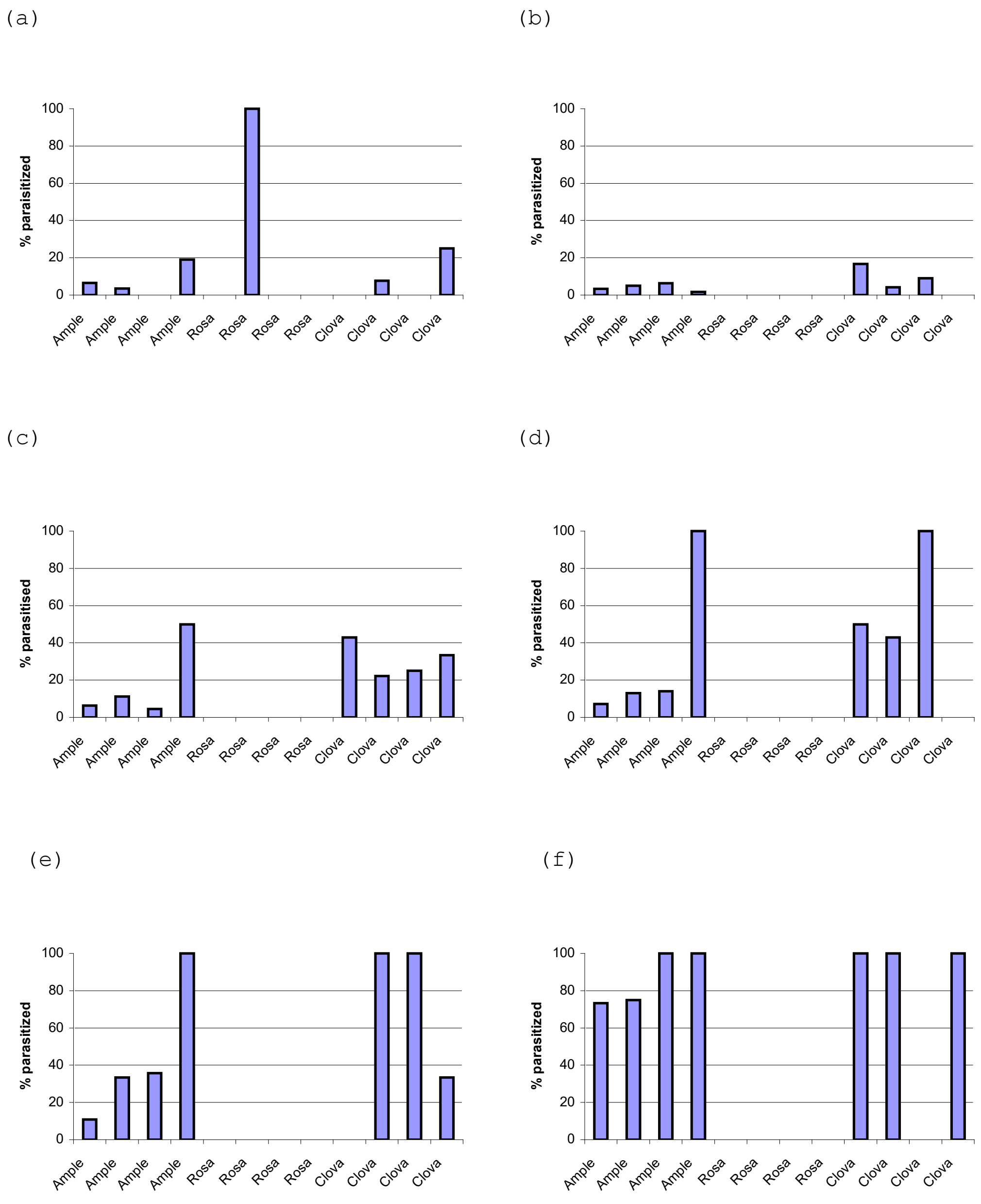


Figure 13. Percentage of parasitized aphids found weekly in each individual cultivar. (a) week 1, (b) week 2, (c) week 3, (d) week 4, (e) week 5 and (f) week 6.

In all weeks, the percentage parasitism is greater in Glen Clova than Glen Ample and the overall percentage parasitism increased through out the weeks. There was only one mummy found in Glen Rosa which results in 100 % parasitism seen in week 1.

Discussion

The numbers of aphids found suggests that the population peaked around the 14/7. This is early than in previous years and is probably a result of the unusually warm summer. As expected, there was a large number of *A. idaei* found on Glen Ample and a smaller amount found on Glen Clova. This is because Glen Ample is susceptible to all biotypes of aphids and Glen Clova has minor gene resistance and so will show some resistance to certain biotypes.

Only a very few *Macrosiphum euphorbiae* were sampled and they were found at the beginning of the season. They have more than one host plant and the majority of individuals would have moved onto potato before the sampling had started.

There were a small number of predators found. These consisted of 2-spotted and 7-spotted ladybird larvae and lacewing eggs. The rearing of wasps from the mummies indicates that there appear to be at least two species of parasitic wasp but these will be identified at a later stage.

There was only one mummy found on Glen Rosa and no other indication of aphids, which suggests that the A_{10} resistance breaking biotype of *A. idaei* is not present. This is different from previous years where a small number had been found colonising Glen Rosa. As expected there were a large number of aphids found on Glen Ample and a large proportion of parasitized individuals. However, there were a greater proportion of parasitized individuals on Glen Clova. This suggests that Glen Clova still retains partial resistance to *A. idaei* and that the individuals feeding on this cultivar are less fit and this somehow increases the parasitism rate.

Summary

This summers work has provided an insight into beetle populations in commercial plantations. The two sites chosen had a small amount of beetle activity in the raspberry plantations but a very large number of beetles were found in the blackberry plantation at the Norwich site. The use of the lure increased the numbers of beetles by 10-65 fold. The assessment of the damaged husks in Blairgowrie have indicated that there was very little beetle damage to the fruit picked around the plain traps, the traps with lures and the area conventionally farmed.

There appeared to be very little migration from the plantation to the surrounding hedgerow at either Blairgowrie or Norwich. Although these hedgerows did contain hawthorn, the hawthorn was either not attractive or the prevailing wind was not blowing in the direction suitable for migration to the traps. At SCRI however, there was migration to the hawthorn and the movement coincided with the flowering of the hawthorn and the flowering of the raspberry plantation.

The aphid study indicates that as expected, the number of aphids found on the various cultivars depends on the resistance of the cultivar. An interesting observation was that the percentage parasitism appears to be greater in the cultivar, Glen Clova, which has minor gene resistance to the large raspberry aphid. This suggests that there is some aspect of the resistance mechanism that makes the aphid more susceptible to parasitism.

Future work

This summer has provided some interesting results concerning the use of the sticky traps and the lures. The two commercial sites used this summer were very different in location and the two plantations used were very different in age, size and the cultivar present. This means that it will not be easy to make comparisons of the data produced from the two sites. Next summer, it would be advantageous to use these sites again and increase the number of sites so increase the information obtained. It would also be advantageous to find a grower that uses poly-tunnel production to observe any differences in beetle behaviour grown under different conditions.

At the site in Norwich more work will have to be done involving the raspberry beetle population in the blackberry plantation. The timing of the lifecycle must be observed to show if there are any differences in behaviour between the beetles in the blackberry plantation and the beetles in the raspberry plantation. It must be shown if there is any migration between the blackberry plantation and the adjacent raspberry plantation.

Modifications to the trap design will also be done in collaboration with AgriSense-BCS Ltd. This will increase the efficiency of the chemical release and modifications to the design to make it more user friendly.

Significance to end users

The summers work using the two identified flower volatiles was very successful and has received great interest from industry. There is hope that this could be released in the near future as a monitoring method for growers to predict the amount of damage their plantation would suffer and apply insecticides accordingly. The collaboration with AgriSense-BCS LtD has led to the development of a new release system which is both safer for workers to handle as it is sealed and requires less handling time out in the field as the volume of chemical in the vial lasts the length of the season.

The sawfly studies may become significant to growers in the next few years as more of them turn to using poly-tunnel production methods that may effect sawfly and other insect development and the damage that has been observed this summer indicates that sawfly have the potential to be a problem in unprotected cultivation.

Minor and major gene resistance to the large raspberry aphid has proved successful in controlling this pest for the last 30 years. However, the aphids ability to reproduce sexually, means that any ability to break the resistance is easily transmitted to new populations by the alates in the autumn and their ability to reproduce asexually during the summer means the numbers of the resistant-breaking biotypes can increase fairly rapidly. Over 75 % of the large raspberry aphid population has already over come A_1 resistance gene and there is evidence to suggest that there is a biotype found in England that had overcome A_{10} resistance, the strongest resistance gene. Studies into the development times and other fitness factors of this A_{10} resistance-breaking biotype and other resistance breaking biotypes and the relationship to parasitism may help in developing new control strategies.

Plate 1 Band of trees containing hawthorn at the Blairgowrie site

Plate 2 Sticky trap positioned in the band of trees near to a hawthorn source at the Blairgowrie site

Plate 3 Hedge containing hawthorn and position of the traps in the raspberry plantation at the Norwich site

Plate 4 Hedge containing hawthorn in the blackberry plantation at the Norwich site

Plate 5 Sticky traps positioned at different distances from the raspberry plantation at SCRI

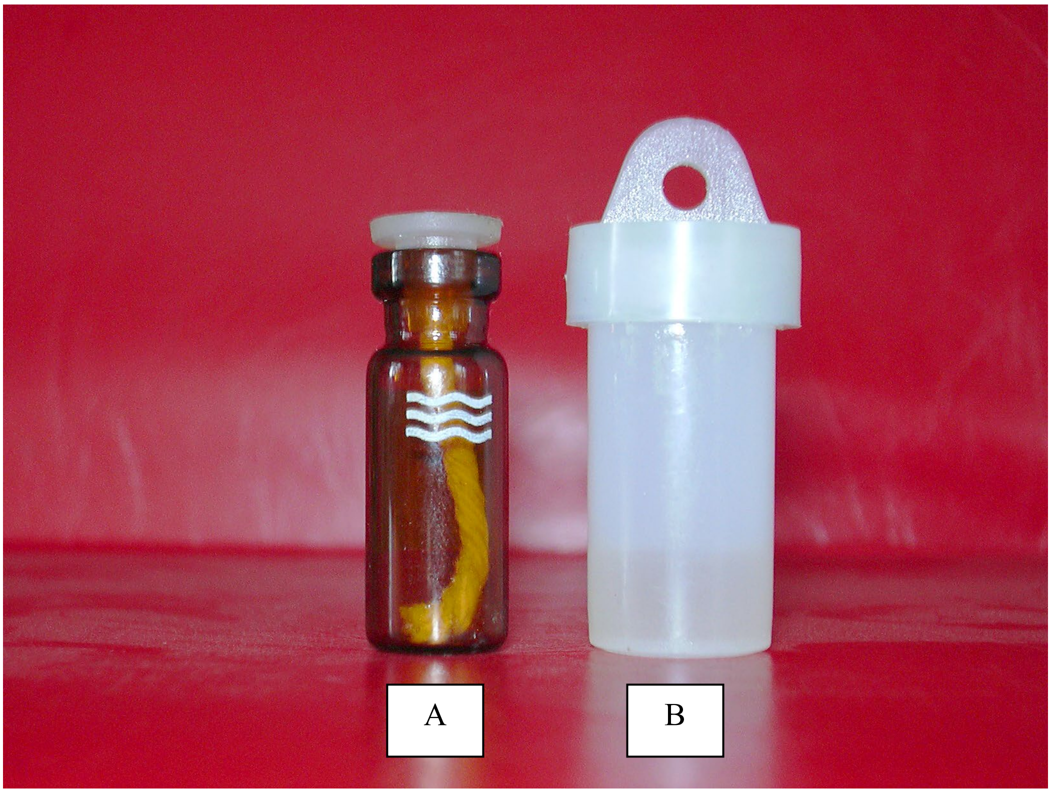


Plate 6 Old (A) and new (B) vials