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FV 222
Brassicas: Biology and Control of Brassica Flea Beetles by Integrating Trap Crops with Insecticide Use

Annual Report 2000/2001

by

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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.

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DISCLAIMER

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

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PRACTICAL SECTION FOR GROWERS

Commercial benefits of the project

The brassica flea beetle complex, (a range of *Phyllotreta* species) is becoming an increasing problem for vegetable brassica growers during the spring and summer. Attacks occur on both speciality salad vegetables and on drilled brassicas such as swedes. Severe attacks can necessitate re-drilling, and even moderate attacks on speciality salads can severely reduce leaf quality. This project aims to benefit brassica growers by:

- Identifying the potential of trap cropping as a non-chemical tool for helping to manage the flea beetle complex. If successful, this will reduce the insecticide burden on the brassica crop, thus reducing the risks of pesticide residues in produce and helping to maintain natural enemy populations. This will help fulfill the requirements of Assured Produce protocols to adopt Integrated Pest Management (IPM) techniques.
- Identifying the efficacy of existing and new potential insecticides to replace those likely to be lost in current UK and EC based reviews.
- Assessing the extent to which organic growers could adopt trap cropping as an alternative to the use of fleece crop covers for flea beetle management.

Project objectives

The overall aim of this three year project is to reduce the number of insecticide applications made to some crops for flea beetle control, and to identify additional non-chemical means of flea beetle management consistent with the principles of Integrated Crop Management (ICM). The main objectives of the project are:

1. To identify the main flea beetle species involved in causing damage at different sites, and the main periods of activity.
2. To develop techniques for managing flea beetles based on the use of novel trap crops and insecticides used either singly or in combination.

The objectives of the second year's work were:

1. To confirm the duration of *Phyllotreta* spp. flea beetle activity and identity of the flea beetle species complex species at a range of geographical locations around the country.

2. To confirm the 'attractiveness' of the potential trap crops identified in year 1, and to investigate the potential distance over which they may exert an effect of flea beetle population distribution in the field.

3. To investigate alternatives to current insecticides.

Key results and conclusions

- *Phyllotreta* flea beetles were found in varying numbers at each of the four monitoring sites (East Lothian, Herefordshire, Warwickshire and Devon). The timing of the peak beetle activity varied from May/June at some sites to June/July at others, but were caught at all sites throughout the monitoring periods (May/June to July at two sites, May to August at a third site and April to August at a fourth).

- The abundance of different *Phyllotreta* species composition varied between sites. *Phyllotreta undulata* predominated at the Herefordshire and East Lothian sites, while *P. diadamata* was the most abundant species in Devon. Preliminary investigation from the Warwickshire site suggested that *P. atra* was the commonest species there. Large numbers of non-crucifer feeding flea beetle species were caught in water traps at the Herefordshire and Devon sites, but were rarely found on trap crops or field crops.

- Of the two trap crops tested this year at two field sites (Herefordshire & Devon), summer turnip (*Brassica napus)* cv. White Lady consistently attracted more flea beetles than the control field crop (broccoli or swede) at both sites. Chinese cabbage (*Brassica rapa* ssp. *Pekinensis,* cv. Kasumi) was only found to be more attractive than the control field crop (broccoli) at the Herefordshire site, possibly reflecting the different *Phyllotreta* species composition at the two sites (see above).

- The 'attractiveness' of trap crops was again shown to increase with age, suggesting that trap crops should be sown up to two weeks in advance of the drilling/planting of the field crop.

- The ‘distance of attractiveness’ is still not fully verified, but the results from the Devon site in particular suggest that this may be in the order of 10 m rather a greater distance.
- The use of insecticidal seed treatments on turnips sown on three separate drilling dates had little effect on the percentage of seedlings damaged, with the exception of Furadan 440 (carbofuran) and Gaucho (imidacloprid) on the first drilling and Furadan 440 only on the third drilling. However, all insecticides tended to increase seedling survival, from *c.* 75-80% in untreated plots to 90-100% on treated plots. This suggests that the severity of damage on treated seedlings was lower, and hence allowed a greater proportion of plants to establish.
- The effect of a two-spray programme of Hallmark (lambda-cyhalothrin), Decis (deltamethrin), Ashlade Cypermethirn (cypermethirn) or SpinTor (spinosad) was broadly similar. A single spray treatment suppressed the flea beetle population for at least one to days, although by seven days after the first treatment damage on treated and untreated plots was similar. However, seedling survival was substantially increased by a single spray of all the products, and was maintained by a second spray applied nine days after the first.

Action points for growers:

- Growers with persistent flea beetle problems could consider growing strips of trap crops either alongside or interspersed with their field crops of brassicas. The most effective trap crop is likely to be summer turnip, cv. White Lady. Summer turnip, although is Chinese cabbage (Lo Bok, cv. Kasumi) may also be effective. Seed can be obtained from Stokes Seeds, St Catherines, Ontario, Canada (http://www.stokeseeds.com).
- Based on this year’s tentative results, trap crop strips would probably need to be be sown at 20 m intervals within the field crop. This assumes a maximum distance of attractiveness of 10 m, but this has not been fully verified, and will be investigated in the final year of the project.

- Of the currently available insecticide treatments, a two spray programme of Hallmark, Decis or Ashlade Cypermethrin can allow a proportion of seedlings to survive flea beetle attack, although a high proportion of seedlings will be damaged. Of the seed treatments, only Gaucho currently has a Specific Off-lable Approval (SOLA) for use on brassicas for the control of peach-potato aphid (*Myzus persicae*). This may also decrease plant losses due to flea beetle attack. None of the other seed treatments used are currently Approved for use on brassicas.

Anticipated practical and financial benefits

- Treating flea beetle populations on trap crops rather than on crops grown for harvest will potentially lessen the risk of pesticide residues in harvested produce, as well as reducing the overall use of insecticide on vegetables.
- Trap cropping has potential as a pest management tool for organic growers in particular, and the principle could be extended to other pests such as diamond-back moth and cabbage root fly.
- Several studies done elsewhere in the world suggest that the use of trap cropping can bring financial benefits. On average, a 10-30% overall increase in net profits, mainly resulting from reduced insecticide use and/or reduced pest attack, has been reported. It is not clear at this stage if this level of financial benefit will accrue from this project. A clearer view of this should be possible once the project has been completed.
- SpinTor (spinosad) has potential as an alternative insecticide treatment to pyrethroids for flea beetle management. However, there is no immediate prospect of this treatment being Approved for use in the UK.

EXPERIMENTAL SECTION

General Introduction

The brassica flea beetle complex, (a range of *Phyllotreta* species) is becoming an increasing problem for vegetable brassica growers during the spring and summer. Attacks occur on both speciality salad vegetables and on drilled brassicas such as swedes. Severe attacks can necessitate re-drilling, and even moderate attacks on speciality salads can severely reduce leaf quality. Although effective insecticides are available for flea beetle control (principally pyrethroids such as alpha-cypermethrin and deltamethrin), they are not persistent. Re-invasion of the crop after spraying can be very rapid and even repeated insecticide treatment often fails to give adequate control. The withdrawal of the organochlorine compound γ-HCH as a seed treatment in June 1999 and more recently for all agricultural use has further compounded flea beetle control problems.

Other insecticides Approved on brassicas can give incidental control of flea beetles. These include the carbamates aldicarb, carbofuran and carbosulfan, which are used primarily for cabbage root fly (*Delia radicum*) control. However, because of the problems of enhanced degradation, these soil-applied insecticides can only be used once a year in any one field, and not in the same field in consecutive years. In principle, organophosphorous (OP) insecticides could also be used for flea beetle control. However, current consumer and retailer concerns over the use of such products set a practical limit on their use. On-going regulatory reviews are also substantially reducing product availability - both carbofuran and carbosulfan are likely to cease to be available for use on vegetable brassicas as a result of EC reviews of Maximum Residue Limits (MRLs)).

There is therefore an urgent need to identify new effective insecticides for flea beetle management specifically on brassicas. Although some recent work has been done on flea beetle control with insecticides on brassicas (Finch & Edmonds, 1999) and other crops (Oakley *et al*., 1996; Cullis *et al*., 1999), further work is still required.

The increasing emphasis on Integrated Crop Management (ICM) in vegetable production means that growers are under pressure from their major customers to reduce insecticide use, and to integrate insecticidal control with non-chemical methods of pest management. One of the most promising techniques for flea beetle management on brassicas without insecticides is trap cropping (Vargas & Kershaw, 1979; McKeown, pers. comm.). Trap cropping is based on the principle that virtually all pests show a distinct preference for certain plant species, cultivars or crops of a certain age. Therefore, offering pests an attractive 'alternative' to the target crop at critical times during the pest's and/or the crop's development results in the concentration of the pest on the 'alternative' host - the trap crop. Protection is achieved either by preventing the pest from reaching the crop or by concentrating the pest into an area which can be economically treated with an insecticide (Hokkanen, 1991).

To be successful, trap crops must be more attractive to the pest than the main crop. Differences in attractiveness can be achieved in one of two ways. Firstly, by using a preferred plant or cultivar planted alongside the crop. Alternatively, the same crop plant as the main crop can be used, but at a different, more attractive, growth stage than the actual crop. Knowledge of the target pest, including information on overwintering, hibernation sites and the direction of infestation is also important when using trap crops (Hokkanen, 1991).

Work done at the University of Guelph, Ontario, Canada in 1996 identified that certain exotic mustard species were highly attractive to flea beetles. These reduced or in some circumstances eliminated the need for insecticide treatment in brassicas planted alongside strips of trap crops (McKeown, pers.comm.).

In the first year of this project, the attractiveness of four of these exotic crucifers (Chinese cabbage (*Brassica rapa* ssp. *pekinensis) cv.* Kasumi, summer turnip (*Brassica napus*) *cv.* White Lady, Chinese radish (Lo Bok, *Raphanus sativus*) and Indian mustard (*Brassica juncea* var. c*rispifolia*)), sown on four different dates was investigated relative to a ‘typical’ vegetable crop (broccoli or swede). Chinese cabbage and summer turnip were the most attractive to flea beetles, although all trap crops attracted more flea beetles than swede. Older trap crops (four weeks older than the field crop) were also shown to be more attractive. This provided a sound basis on which to base the second year’s work.

The scientific objectives of the work done during this second year of the project were therefore:

1. To confirm the species of flea beetle identified in year one, as being responsible for the main damage to vegetable brassicas, and the principal periods of activity.
2. To investigate the possible ‘distance of attractiveness’ of Chinese cabbage and summer turnip to flea beetles.
3. To investigate alternatives to current insecticides.

Flea beetle species and activity

Materials and methods

Site Locations

Monitoring was done at four widely separated commercial locations throughout the UK. These were:

1. Birnieknowes Farm, Cockburnspath, East Lothian.
2. Flights Farm, Ledbury, Herefordshire.
3. ADAS, Staplake Mount, Starcross, Devon.
4. HRI, Wellesbourne, Warwickshire

At each site, monitoring was done in a field growing either swedes (Devon, East Lothian and Warwickshire (1st site)), broccoli (Herefordshire) or cabbage (Warwickshire, 2nd site). All sites had a previous history of flea beetle damage, ensuring a high chance of a significant infestation developing.

Trapping procedure

Between nine and 12 water traps (17 cm diameter) were set out at each site. The traps were spaced at equal distances around the field border, between the edge of the crop and the field margin. Each water trap was three-quarter filled with water containing ‘Teepol’ surfactant to reduce surface tension. A fibre ‘wick’ clipped over the edge of the trap with a paper clip to prevent the water trap over flowing.

Beetle monitoring assessments

At Sites 1 to 3 (one and two being commercial field sites; three was an ADAS site), beetle activity was monitored at weekly intervals from just prior to the emergence of the field crop until the field crop plants had 12 true leaves (approximately May to August). At the Warwickshire site (HRI Wellesbourne), flea beetles were monitored by placing three fluorescent yellow water-traps in each of several different brassica crops. The two crops included in this report were a crop of insecticide-free overwintering swedes that had been used to produce "roots" for the Wellesbourne cabbage root fly culture, and a new crop of cabbages transplanted on 10 May 2000. On each sampling occasion, the contents of the traps were sieved into labeled pots and returned to the laboratory for counting and identification of beetles. Samples not identified immediately were stored in lactic alcohol in labeled pots.

Results

Traps were set out on 5, 9 May and 5 June 2000 at the, Herefordshire, East Lothian and Devon sites respectively. The overall trapping periods were 15, 11 and 10 weeks respectively. Flea beetles were found throughout these trapping periods at all sites.

East Lothian

Data from this year confirmed the pattern of flea beetle abundance recorded at this site in 1999, although greater numbers of flea beetle were trapped this year. With the exception of the third sampling date, total flea beetle numbers trapped increased during the first six monitoring weeks, peaking at a mean of 5.63 per trap per week on 20 June 2000, five weeks after the field crop was sown (Fig. 1). Thereafter, numbers declined sharply with less than one beetle being caught per trap per week during the last four weeks of monitoring.

As in 1999, the principal flea beetle species found was *Phyllotreta undulata*, the small striped flea beetle, which accounted for 67% of all flea beetles, recorded (Fig. 2).

Other, non-*Phyllotreta* flea beetle species accounted for the remaining population (33%).

Herefordshire

Total flea beetle numbers increased during the first three monitoring weeks, peaking at a mean of 4.18 beetles per trap per week by 26 May 2000, approximately one week after the field crop was transplanted (Fig. 3). Flea beetle numbers then declined to 0.46 per trap per week by 23 June, after which numbers remained relatively constant between 0.2 and 0.79 per trap per week for the remaining eight weeks of monitoring. The exception was in the last week of June, when numbers increased to a second, smaller peak of 2.7 beetles per trap per week.

Unlike 1999, the majority of flea beetles trapped were non-crucifer feeding flea beetles. *Aphthona* spp. were the principal flea beetle species trapped, accounting for more than 50%, with *Longitarsus* spp., *Chaetocnema* spp. and *Batophila* spp. comprising 22%, 8% and 3% of the population respectively. Of the crucifer feeding species, *Phyllotreta undulata* was the most numerous, accounting for 13%, while small numbers of *P. atra* (2%), *P. nigripes* (<1%) and other spp. (<1%) made up the rest of the population (Fig. 4).

Devon

Total flea beetle numbers were greatest at the onset of monitoring in the second week of June, with a mean of *c*. seven flea beetles per trap per week (Fig. 5). A week later, numbers had more than halved to a mean of 2.7 beetles/trap/week. Thereafter, no flea beetles were recorded other than the small numbers found in the first two weeks of July.

The principal flea beetle species found in the water traps at the Devon site were non-*Phyllotreta* (i.e. non-crucifer feeding) species; predominantly *Chaetocnema* spp. (65%) and to a lesser extent, *Haltica* spp. (10%), *Longitarsus* spp. (2%) and *Aphthona* spp. (1%) (Fig 6). Of the *Phyllotreta* species of flea beetle found, *P. diadamata* was the dominant species trapped, accounting for 10% of the total population, followed by *P. undulata, P. nemorum* and *P. nigripes,* which each comprised 1%. Other species accounted for the final 9% of the population.

Warwickshire

The number of flea beetles caught/trap/day in overwintered swedes at HRI Wellesbourne showed an extremely large peak in the 3.5-day sample collected on 16 May (Fig. 7). This appeared to indicate when the overwintering population became highly active. This peak of activity was reflected in the numbers of flea beetles caught at this time in the cabbage field (Fig. 8). However, during the 3.5-day trapping period when the high (714 beetles in total) numbers of beetles were caught in the swede crop, a total of 3675 beetles were caught in the three traps in the newly-transplanted cabbage crop. Presumably this high initial peak reflected the early dispersal of the overwintering beetles, as numbers were much lower in the following trapping period and gradually built up to the second peak (23 beetles/trap/day) that was recorded from the samples collected on 9 June. As in 1999, a late peak of beetle activity was recorded in August when, during different 3.5-day trapping periods, up to 500 beetles were caught/trap/day.

Several species were active during the main period of beetle activity. For example, in one sample of 54 beetles caught in a trap on 2 June, 24% were *Phyllotreta undulata*, 9% were *P. nigripes* and 67% were *P. atra*. The sample also contained two species of flea beetle that do not feed on cruciferous plants. All of the beetles will be identified during February 2001

Figure 1. Trap catches of all flea beetle species at the East Lothian monitoring site.

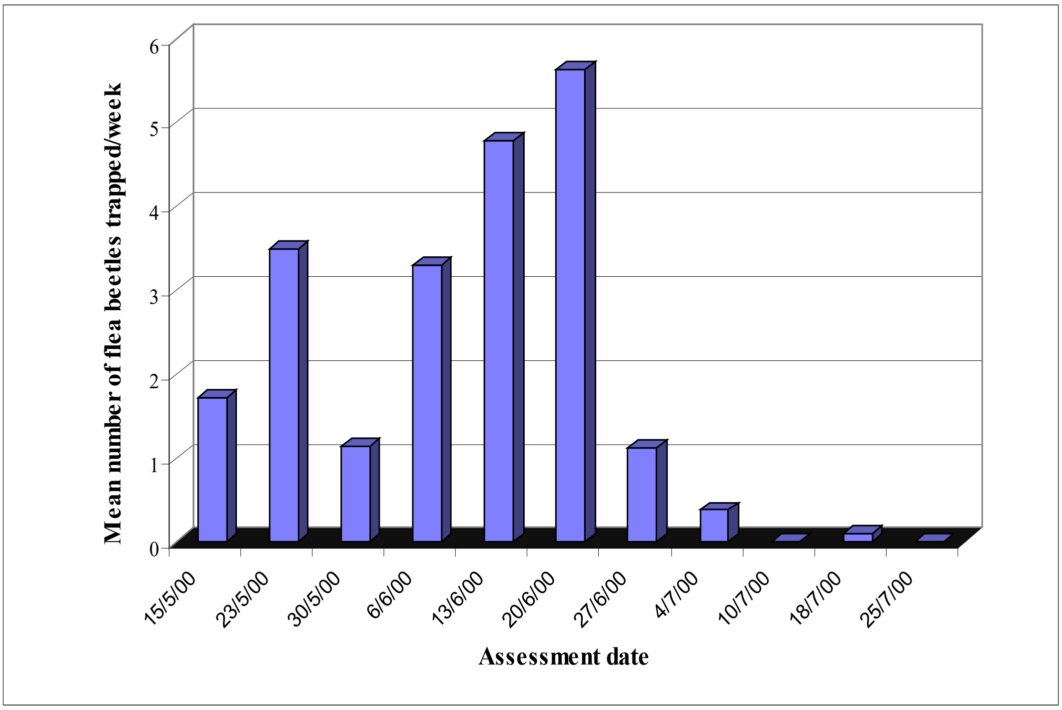


Figure 2. Overall flea beetle species composition at the East Lothian monitoring site.

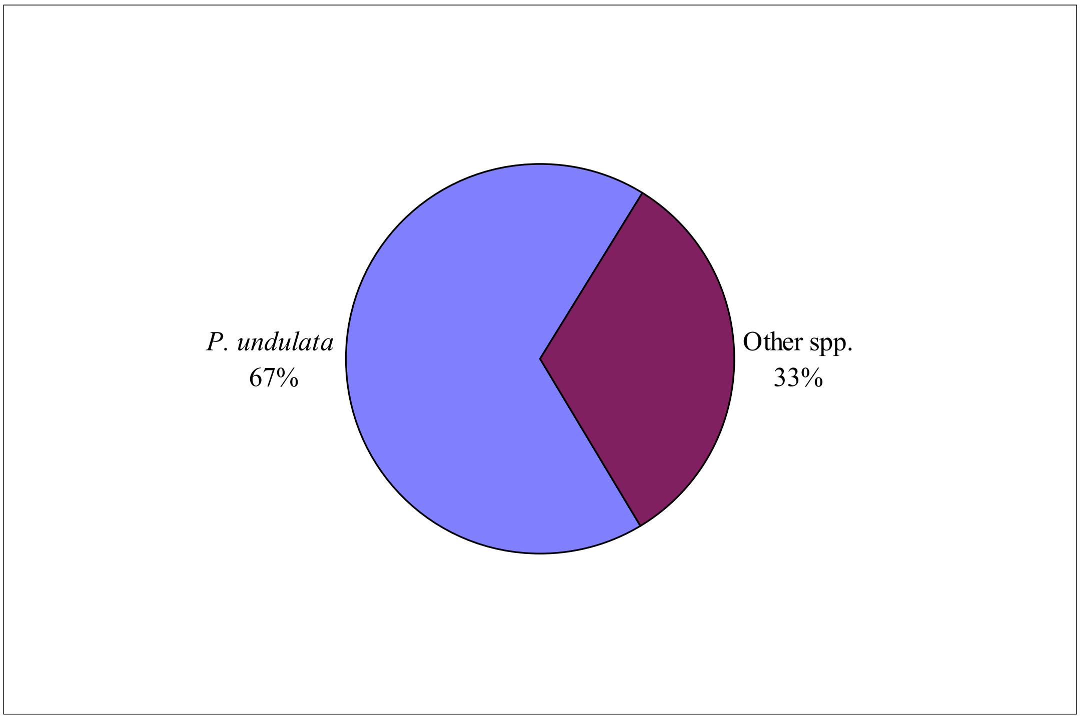


Figure 3. Trap catches of all flea beetle species at the Herefordshire monitoring site.

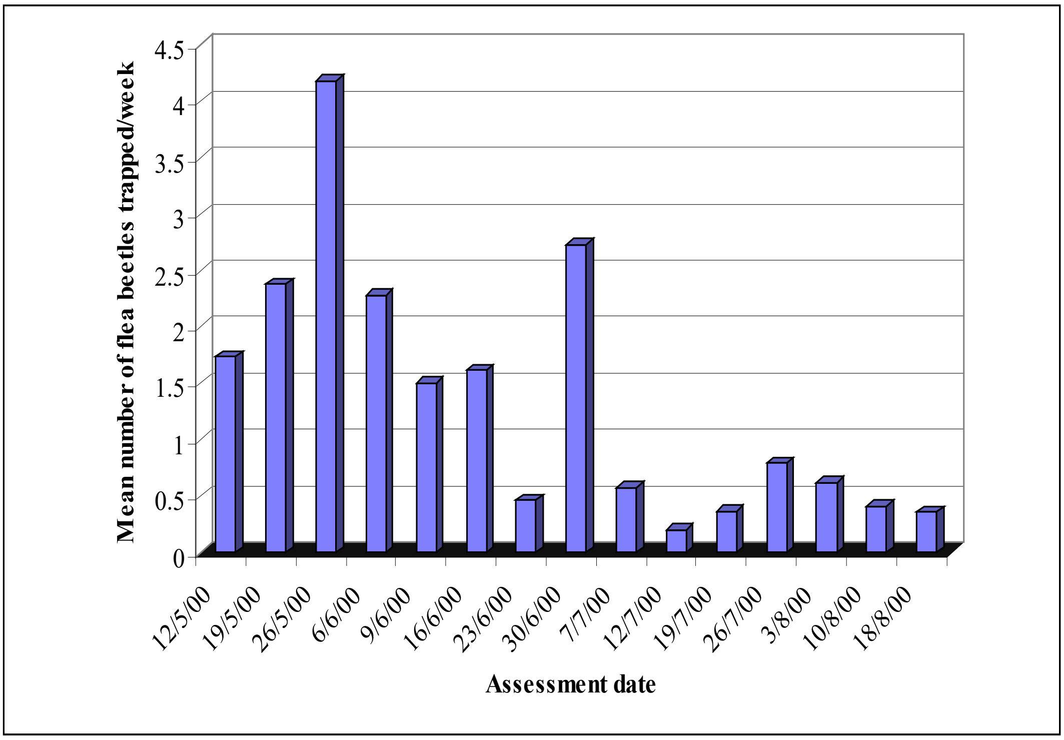


Figure 4. Overall flea beetle species composition at the Herefordshire monitoring site.

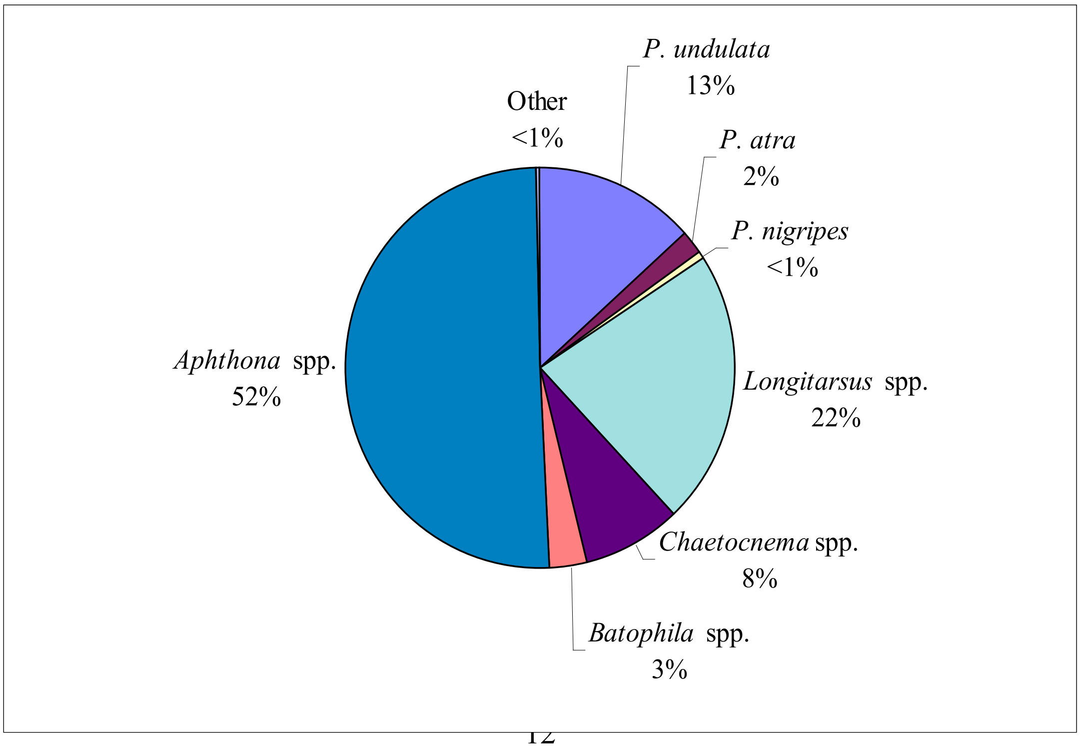


Figure 5. Trap catches of all flea beetle species at the Devon monitoring site.

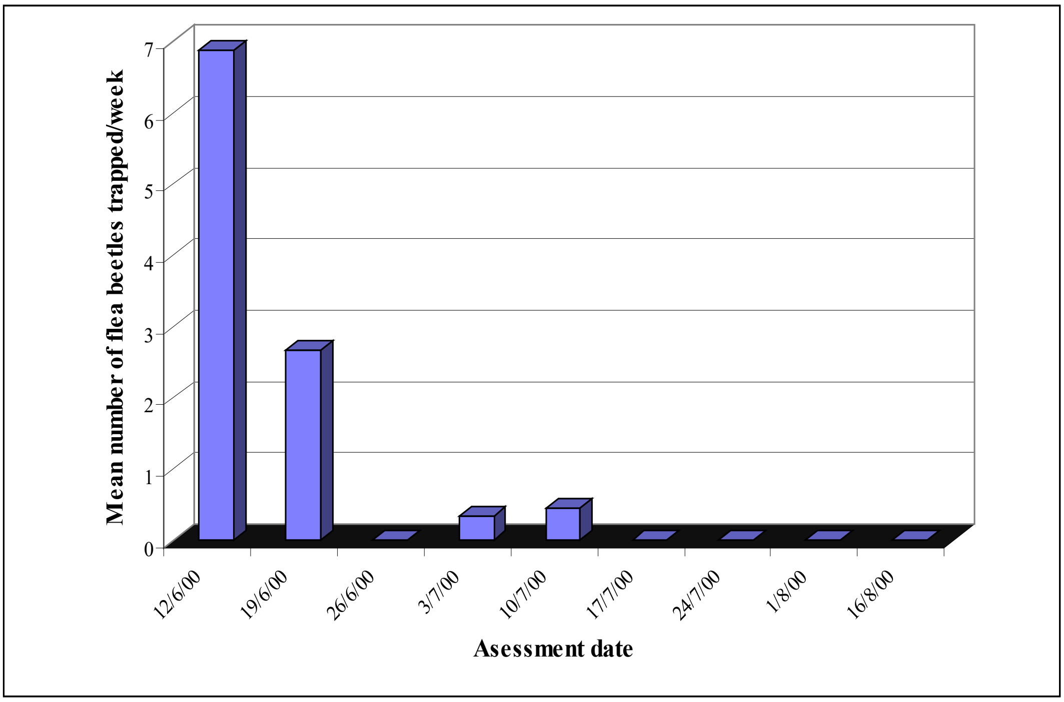


Figure 6. Overall flea beetle species composition at the Devon monitoring site.

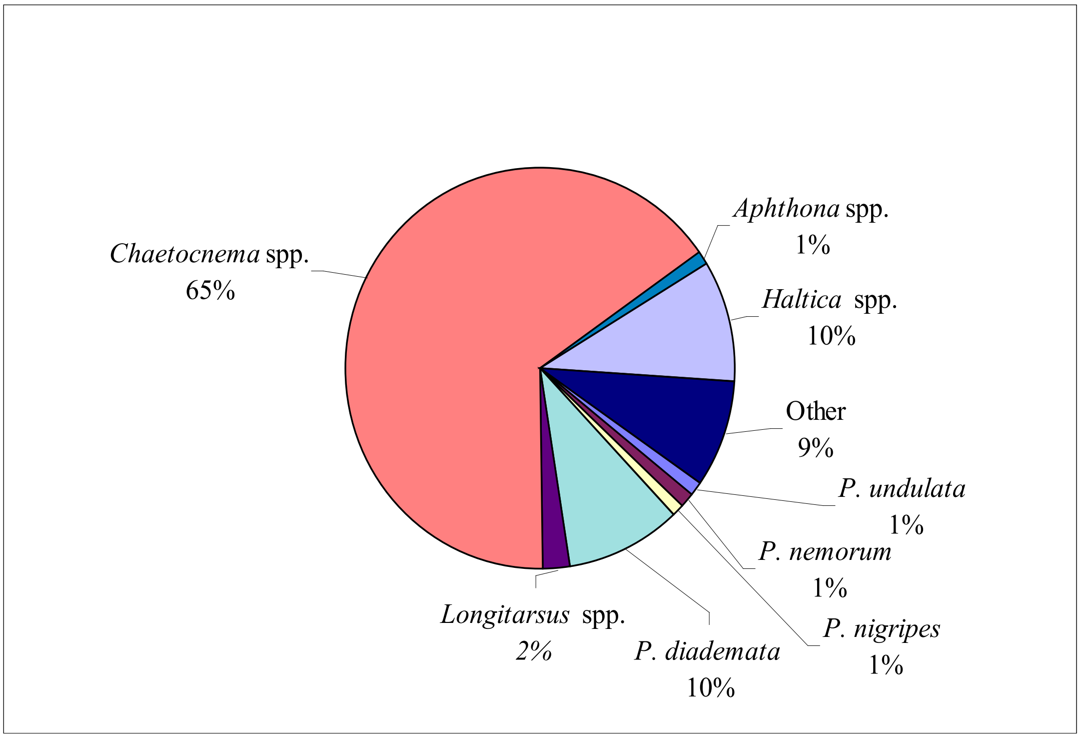


Figure 7. The numbers of flea beetles caught/trap/day in an overwintered swede crop

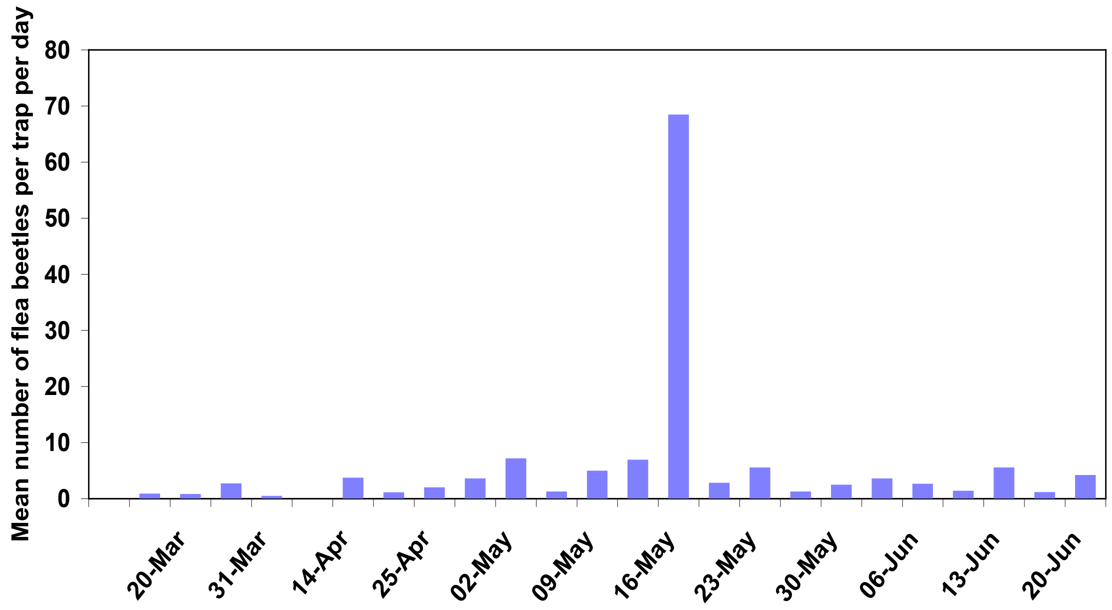
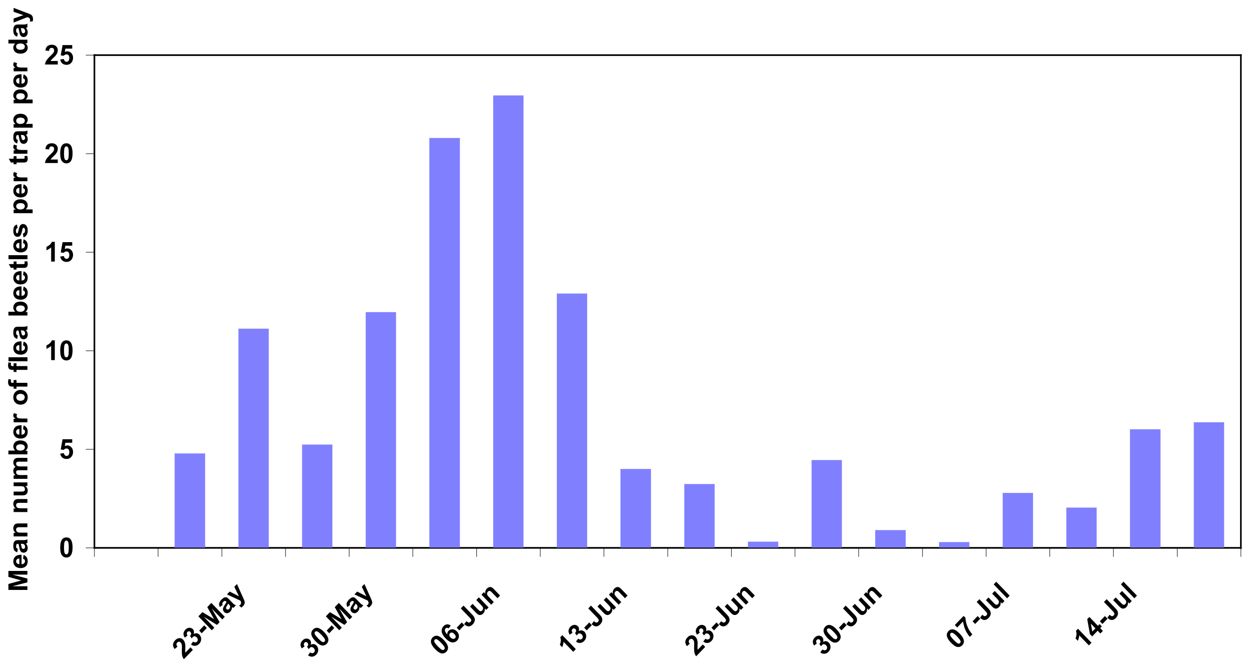


Figure 8. The numbers of flea beetles caught/trap/day in a newly-transplanted cabbage crop.



Assessment of distance of trap crop attractiveness

Materials and methods

Site location

This experiment was done at two sites, one a commercial (organic) field site, and the second on experimental land controlled by ADAS in Devon. These were:

1. Flights Farm, Ledbury, Herefordshire.
2. ADAS, Staplake Mount, Starcross, Devon.

Trap crop types

The selection of trap crops for more detailed studies was based on the results from the previous year's experiments. In 1999, four trap crops (Chinese cabbage, summer turnip, Chinese radish and Indian mustard) attracted more flea beetles than a typical field crop (swede). The Chinese cabbage (cv. Kasumi) and summer turnip (cv. White lady) at four weeks old were the most attractive and therefore chosen for further studies in 2000. The main field crop at each site (Broccoli and Swede at Hereford and Devon respectively) was adopted as the control.

Trap crop seed was obtained from a commercial seed supplier in Canada (Stokes Seeds, St Catherines, Ontario, Canada).

Experimental design

The experiment was designed to investigate the possible 'range of attractiveness' of the two trap crops relative to each other and the control under field conditions. At each site, the experiment was a randomised design of three 'treatments' (crop type) and a 'control' (transplanted broccoli at the Herefordshire site, drilled swede at the Devon site). Each treatment was replicated five times. The experimental plots were drilled in two strips running along opposite edges of the experimental field. Plot size was 16 metres long (running along the length of the rows) and two beds (*c*. 3.6 m) wide (Appendix 1).

Experimental procedure

Trap crop sowing date: due to bad weather at the Herefordshire site, sowing dates for the trap crops were staggered between 16 and 24 June 2000. Strip one was drilled on 24 June while strip two was drilled on 16 and 20 June. At the Devon site, the trap crops and the field crop controls were all sown on the 17 June 2000.

Drilling & establishment: all plots were drilled using a tractor-mounted seed drill. Three rows 53 cm apart were drilled on each bed, with a 2.5 cm within-row spacing. Immediately after emergence of the trap crops, the plots were covered with Hortifleece to protect the emerging plants from flea beetle damage prior to assessments. Covering dates were 23rd and 28th June 2000 at the Herefordshire site, and 22 June 2000 at the Devon site. At the Herefordshire site, the control crop (broccoli) was transplanted into the bare plots left along the strips, at the same time as the rest of the field was planted, approximately four weeks after the trap crops had been sown.

Assessments

Two types of assessment of beetle numbers within each plot were made approximately two and 10 days after the field crop had been transplanted and/or the Hortifleece covers removed. Both assessments were made at the following distances into the main crop:

1) Within the trap crop or control strip.
2) 1 m into the main field crop (from the edge of the trap crop/control strip)
3) 5 m into the main field crop
4) 10 m into the main field crop
5) 16 m into the main field crop
6) 26 m into the main field crop

The first assessment was a 'static' assessment. A labelled, yellow, double-sided sticky trap was attached vertically to a ringot peg and positioned at each of the six, set distances listed above, for each of the 15 plots. Traps were set out approximately 48 h prior to each assessment date (i.e. day 0 and day 8). At each assessment, all sticky traps were removed and stored in a box, using small, polystyrene sections to separate the individual traps. The traps were returned to the laboratory, where all flea beetles were carefully removed and cleaned in white spirit. Once clean, the number and identity of the flea beetles was recorded for each trap. If samples were not identified immediately, they were stored in lactic alcohol in the labelled pots.

The second assessment involved gently 'swiping' sticky targets across the crop and was done concurrently with the removal of the static traps. At each assessment, a labelled, yellow, single-sided, sticky trap was carried for a 1 m distance along the bed, at a 45° angle, immediately above the crop. The intention was that flea beetles disturbed from the crop should become stuck to the trap. Each trap was then stored in a box, separated from other traps using polystyrene separators, returned to the laboratory and assessed as before.

Data analysis

Raw data from both sites were $\log_{10}(n+1)$ transformed prior to analysis to stabilise variances. Analysis of variance was then performed on these data, in which trap crop type, distance, flea beetle species, assessment date and site were treated as factors. The significance of main effects and interactions were assessed using F (variance ratio) tests. Back-transformed means are presented throughout the text.

Results

The staggered planting of the experimental plots and the field crop at the Herefordshire site resulted in considerable variation in growth stages, effectively confounding any effect of trap crop and field crop age the relative number of beetles present on the crop types. However, the effect of trap crop age had been established in year one of the project and was not a critical part of the experiment design in 2000. Of more concern was severe pigeon damage, which resulted in total plant loss in parts of the field and in the control plots, necessitating re-planting and covering of the field crop and control plots (they were exposed again two days prior to assessments being made). The results of this experiment therefore require cautious interpretation.

The second, 'swiping' assessment method proved to be ineffective in collecting beetles. Only data from static sticky traps has been presented in the analysis.

Overall, significantly more flea beetles were trapped at the Herefordshire site compared to the Devon site (F=3.6, d.f.=1, 1793, *P*=0.05). The species range also varied between the sites. *P. undulata* was clearly the dominant species present at the Herefordshire site (Figure 8a), followed by *P. atra*, *P. nigripes*, and *P. nemorum*. *P. diadamata* was not found. Conversely, *P. diadamata,* a species not detected at the Herefordshire site, was one of the most dominant species at the Devon site, second only to *P. undulata*. *P. nigripes*, and *P. nemorum* were also present at low levels. Despite the high numbers of non-*Phyllotreta* species found in the water traps at both sites, these species were generally only found in low numbers on the trap crops (particularly in Herefordshire).

Herefordshire site

Initial analysis showed a significant difference in the number of each species found on all crop types combined (F=581.95, d.f.=4, 714, *P*<0.001, Fig. 8a). *Phyllotreta undulata* was clearly the predominant species attracted, followed by small numbers of *P. atra*, non-*Phyllotreta* flea beetles, *P. nigripes* and a few other *Phyllotreta* species (principally *P. nemorum)*. This generally reflected the relative abundance of *Phyllotreta* species found in the water traps (Fig. 8). Further analysis demonstrated significant interactions between flea beetle species and trap crop type (F=3.8, d.f.=8, 714, *P*<0.001) and species attracted and distance (F=581.95, d.f.=4, 714, *P*<0.001). However, examination of these interactions clearly showed that these results were due to changes in the abundance of *P. undulata* (Figs. 9 & 10). As a result, subsequent results and discussion will refer to only *P. undulata*.

Effect of trap crop type: trap crop type had a significant effect on the number of *P. undulata* beetles attracted (averaged over both assessment dates, F=12.23, d.f.=2, 143, *P*<0.001, Fig. 11). A mean of 10.71, 9.36 and 2.56 beetles were trapped within the summer turnip, Chinese cabbage and broccoli respectively.

A significant interaction was found between crop type and assessment date (F=29.35, d.f.=2, 143, *P*<0.001, Fig. 12). Both the Chinese cabbage and summer turnip had attracted significantly more *P. undulata* by the second assessment date, 17 days after exposing the trap crops. The numbers of *P. undulata* attracted to the broccoli (control) remained consistently low throughout the experiment.

Effect of distance from trap crop: distance (in metres from the trap crop strips) had a significant effect on the number of *P. undulata* found in the field crop (F=18.36, d.f.= 5, 143, *P*<0.001). As expected, the greatest numbers of beetles were trapped within the trap crop strips themselves. Thereafter, numbers declined rapidly with increasing distance away from the strips (Fig. 13). Within 1 m, beetle numbers had more than halved from a mean of 90.7 beetles/trap within the trap crop to a mean of 42.5 beetles/trap. At 5 m into the maincrop, numbers had dropped to 21.6 beetles/trap, less than a quarter of those recorded within the trap crops. Despite the increased number of beetles found within each of the two trap crops compared to the control, there was no significant interaction between crop type and distance into the field crop on the number of *P. undulata* found at increasing distances into the field crop (F=0.74, d.f.=10, 143, *P*=0.684, Fig.14).

Devon site

As with the Hereford site, initial analysis showed a significant difference in the number of each species found on all crop types combined (F=581.95, d.f.=4, 714, *P*<0.001, Fig. 8b). *Phyllotreta undulata* and *P. diadamata* were the predominant species found, followed by non-*Phyllotreta* flea beetles and small numbers of *P. nigripes* and *P. nemorum*. Again, this generally reflected the relative abundance of *Phyllotreta* species found in the water traps (Fig. 6). Further analysis demonstrated significant interactions between flea beetle species and trap crop type (F=4.06, d.f.=8, 716, *P*<0.001) and species attracted and distance (F=3.25, d.f.=4, 716, *P*<0.001). However, examination of these interactions clearly showed that these results were primarily due to changes in the abundance of *P. undulata* and *P. diadamata,* and to a lesser extent by the non-*Phyllotreta* flea beetles (Figs. 15 & 16). Since the other non-*Phyllotreta* flea beetles do not feed on or damage brassicas, subsequent results and discussion will refer to these two principle *Phyllotreta* species only.

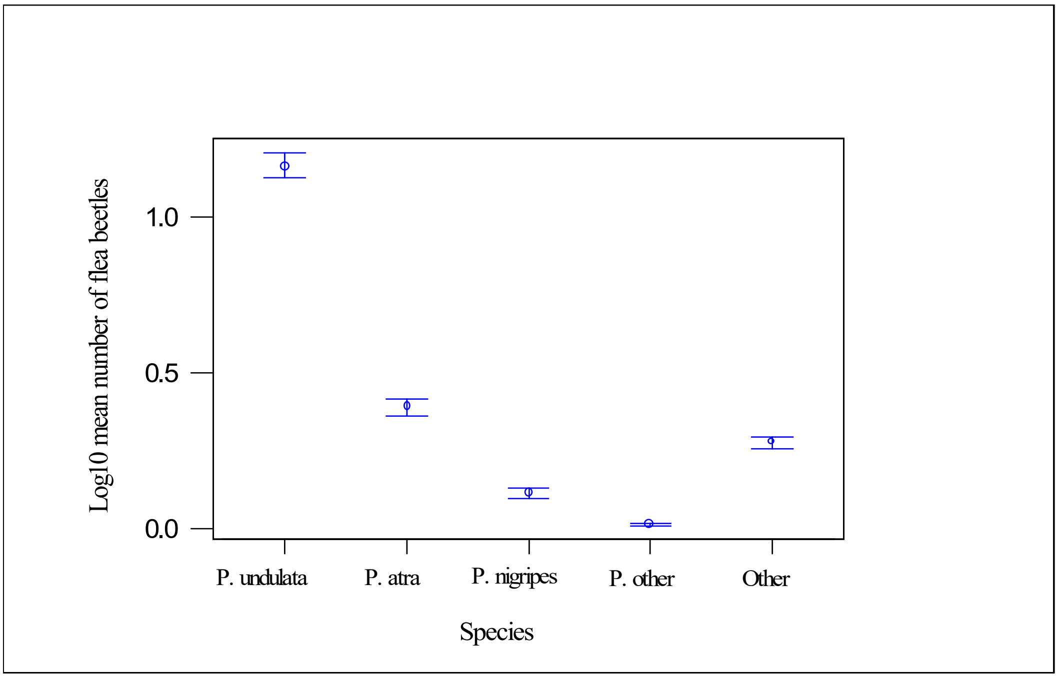
Effect of trap crop type: trap crop type had a significant effect on the number of beetles attracted (averaged over both assessment dates) (F=13.52, d.f.=2, 284, *P*<0.001, Fig. 17). Summer turnip attracted significantly more beetles than both the Chinese cabbage and the swede control. There was no significant difference between the Chinese cabbage and the control. A mean of 9.13, 6.04 and 4.11 beetles/trap were found in the summer turnip, Chinese cabbage and swede respectively.

Effect of distance from trap crop: distance (in metres from the trap crop strips) also had a significant effect on the combined number of *P. undulata* and *P. diadamata* found in the field crop (F=9.31, d.f.= 5, 284, *P*<0.001). In contrast to the Herefordshire site, increasing numbers of beetles were trapped at increasing distances into the field crop (Fig. 18). The greatest numbers of beetles were trapped at 26 m, the furthest distance from the trap crop. The lowest number of beetles was trapped 1m from the trap crop. Flea beetle numbers within the trap crop strips themselves were similar to those recorded at 10m into the maincrop. A significant interaction effect was found between assessment date and distance into the crop (F=13.53, d.f.=5, 284, P<0.001). The trend for higher numbers of beetles further away from the trap crop was clearly shown at the first assessment, two days after removing the covers over the trap crops (Fig. 19). However, this pattern was completely reversed by the second assessment, 12 days later, with the greatest number of beetles being caught within the trap crop itself. Immediately outside the trap crop, numbers dropped sharply and remained low at the increasing distances into the maincrop.

A significant interaction was also found between crop type and distance into the field crop on the number of *P. undulata* and *P. diadamata* attracted (F=3.97, d.f.=10, 284, *P*<0.001, Fig. 20). This was primarily due to the increased number of beetles found within the summer turnip compared to the Chinese cabbage and the control.

Figure 8. Mean number of different flea beetle species (± standard error) found on all the trap crops and the control at experimental sites.

a) Herefordshire



b) Devon

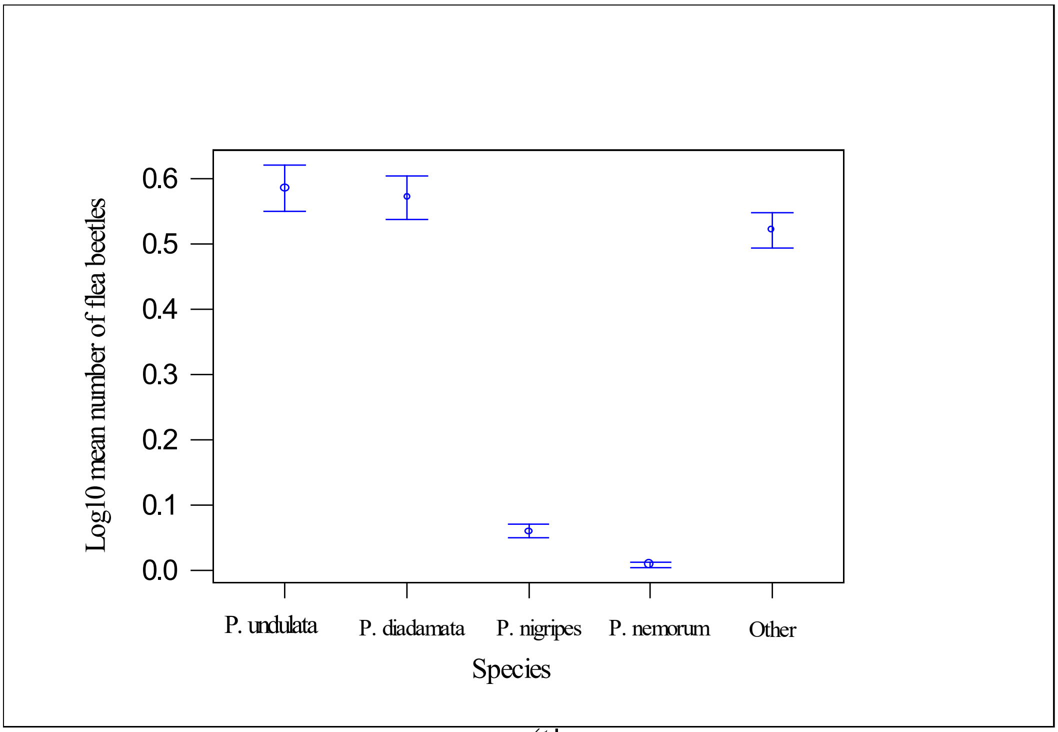


Figure 9. The interaction between the numbers of each flea beetles species trapped and trap crop type at the Herefordshire site.

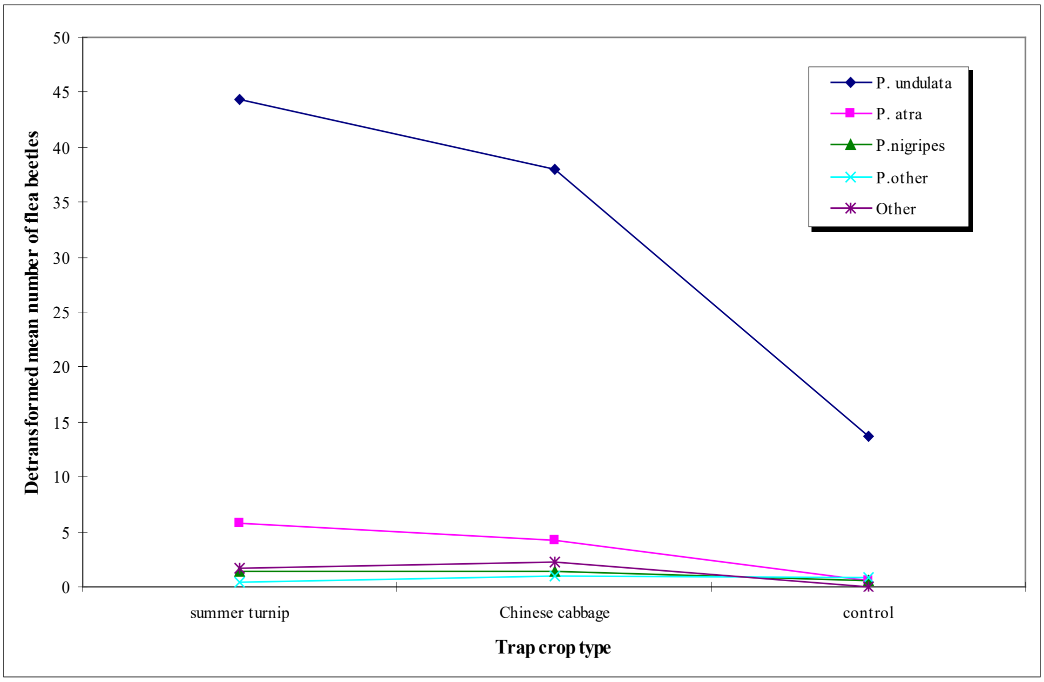


Fig.10. The interaction between number of individual flea beetle species trapped and distance into the field crop (broccoli) at the Herefordshire site.

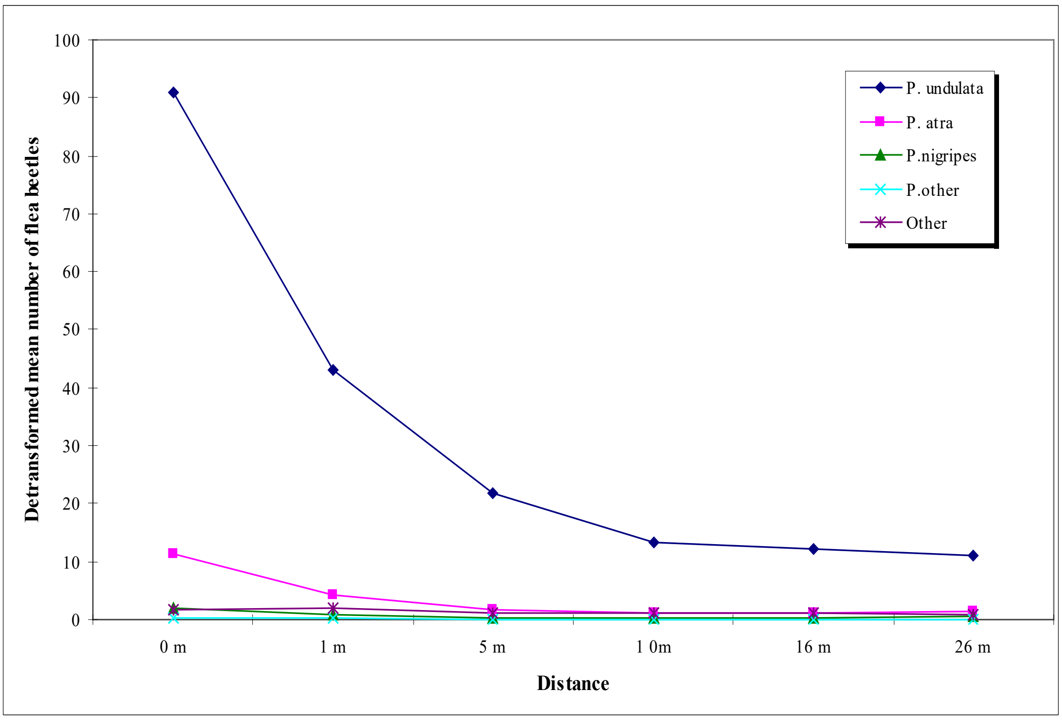


Figure 11. Mean number of *P. undulata* (± standard error) trapped in individual trap crops and broccoli (control) at the Herefordshire site.

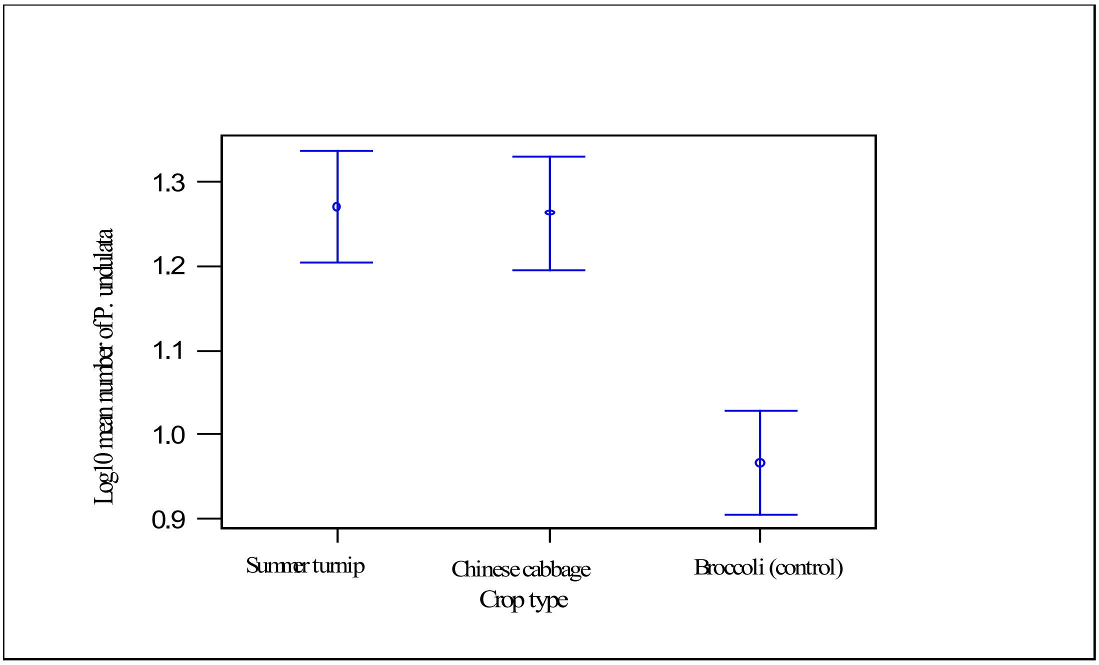


Figure 12. The interaction between the mean numbers of flea beetles (all species) trapped in different crop types and assessment date at the Herefordshire site.

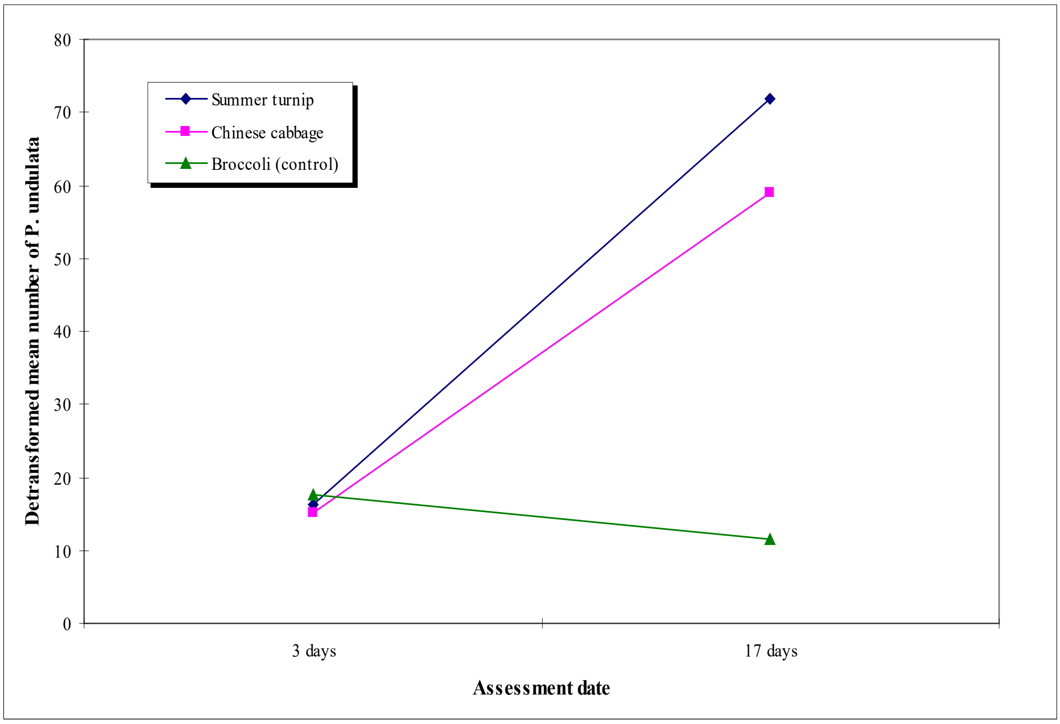


Figure 13. Mean number of *P. undulata* (± standard error) trapped at increasing distances into the field crop (broccoli) at the Herefordshire site.

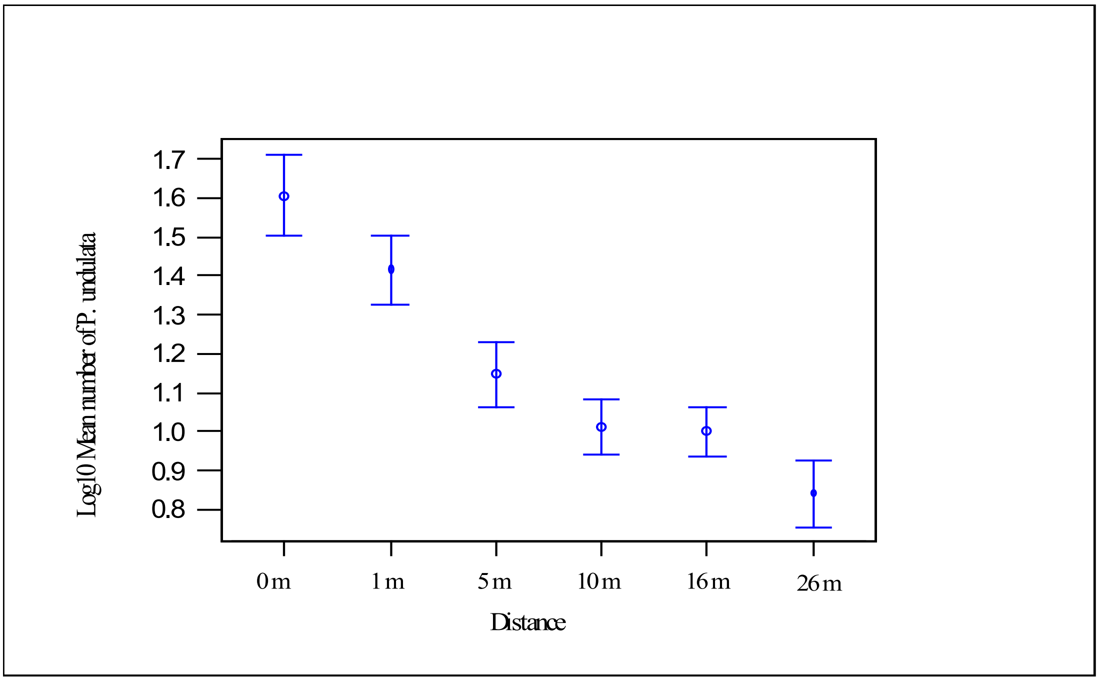


Figure 14. The interaction between the mean numbers of flea beetles (all species) trapped in different crop types and distance into the field crop (broccoli) at the Herefordshire site.

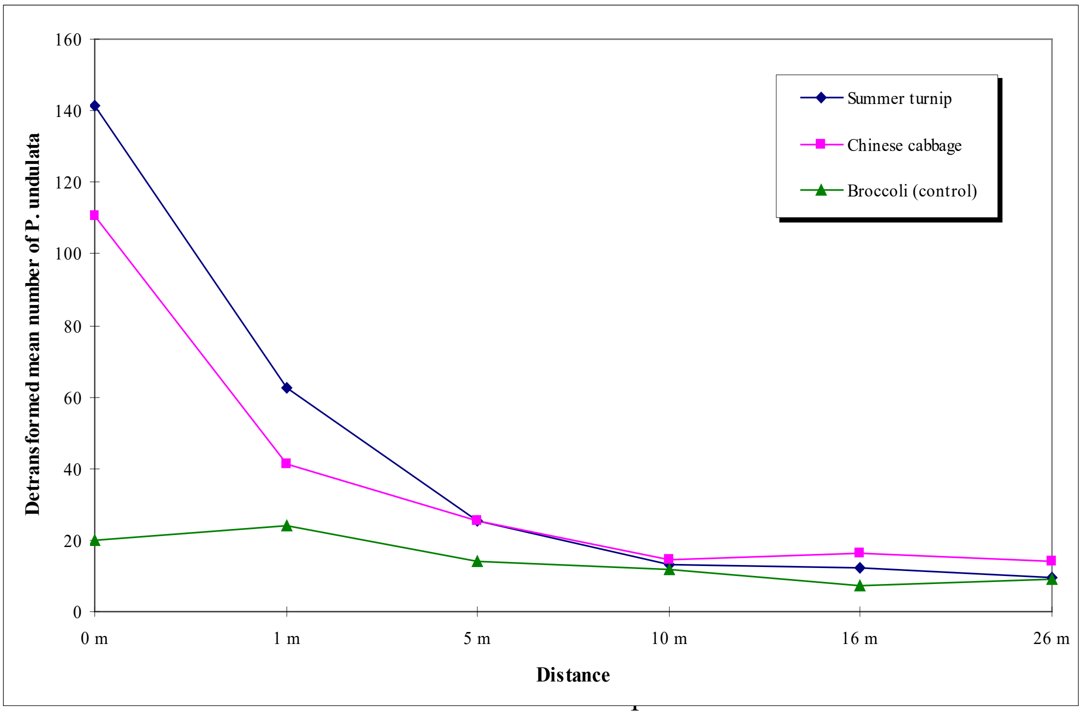


Figure 15. The interaction between the numbers of each flea beetle species trapped and trap crop type at the Devon site.

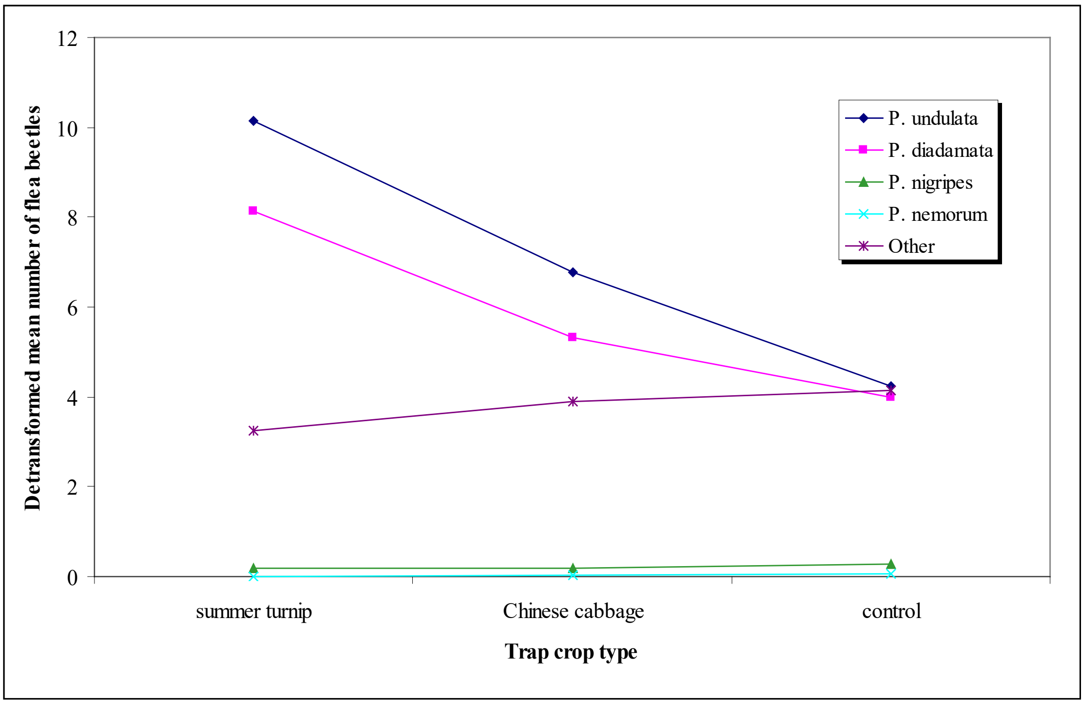


Figure 16. The interaction between the mean numbers of individual flea beetle species trapped and distance into the field crop (swede) at the Devon site.

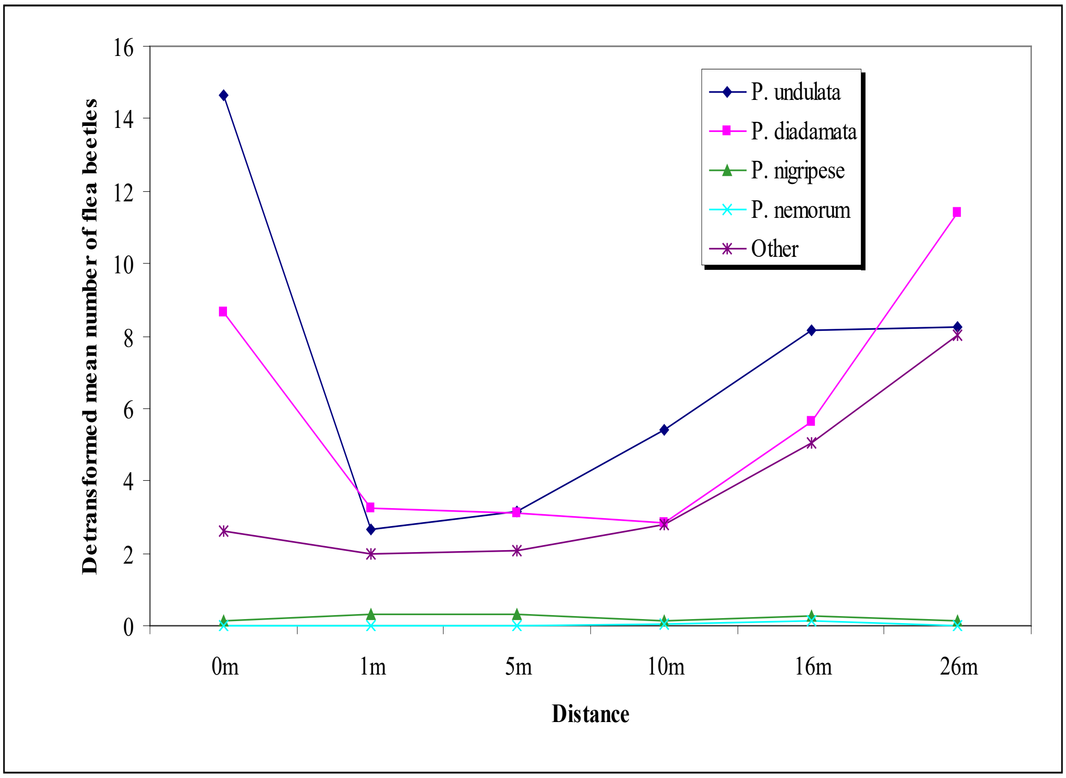


Figure 17. Mean number of flea beetles (± standard error) trapped in individual trap crops and swede (control) at the Devon site.

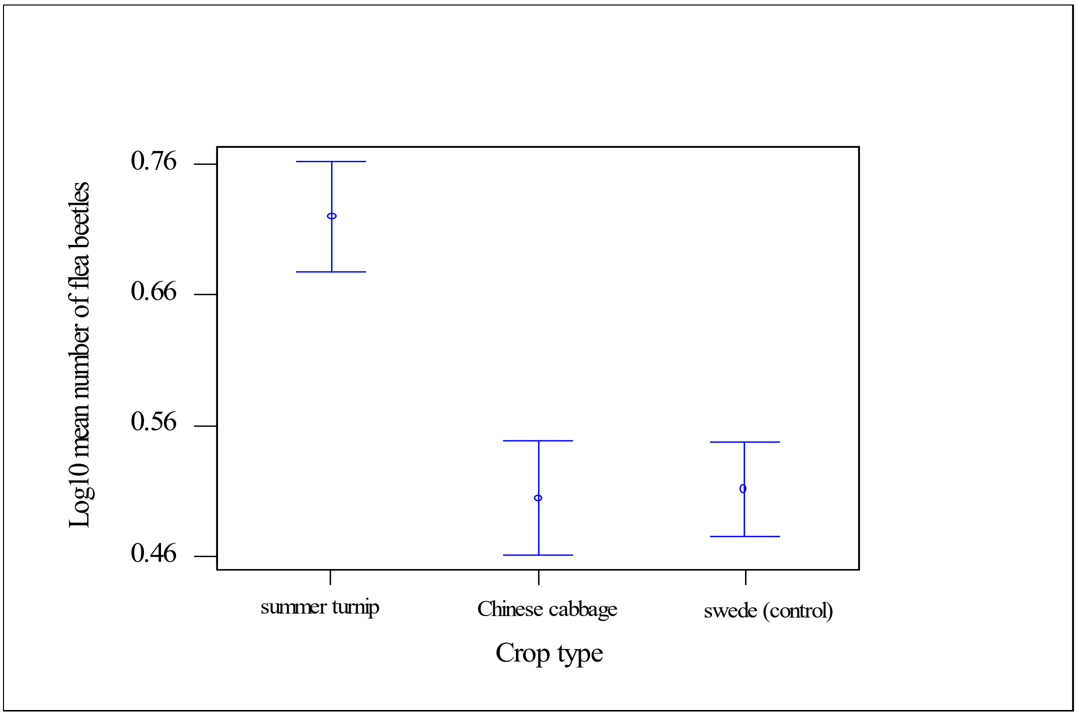


Figure 18. Mean number of flea beetles (± standard error) trapped at increasing distances into the field crop (swede) at the Devon experimental site.

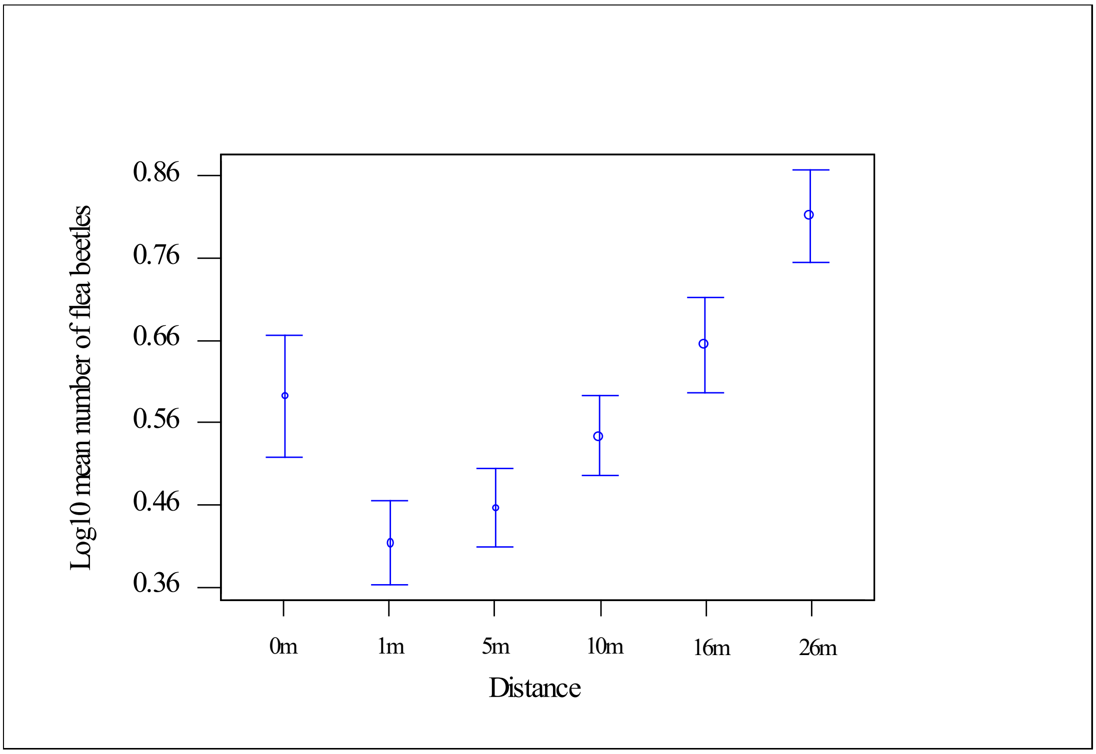


Figure 19. The interaction between assessment date and mean flea beetle numbers trapped at increasing distance into the field crop at the Devon site.

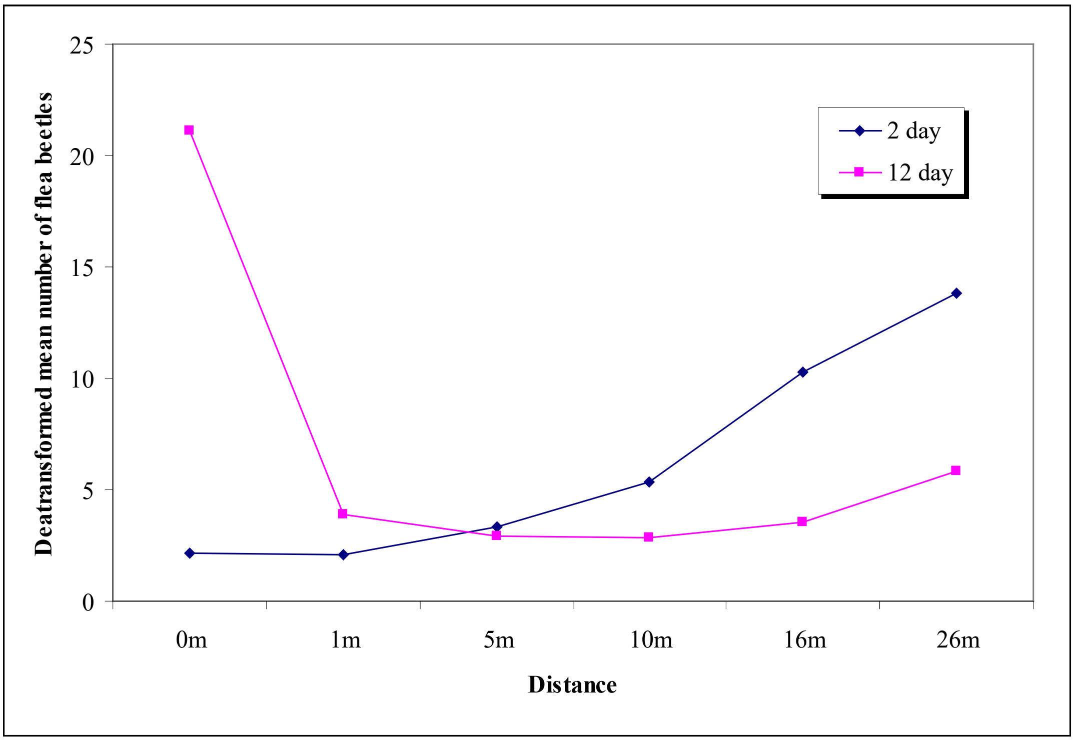
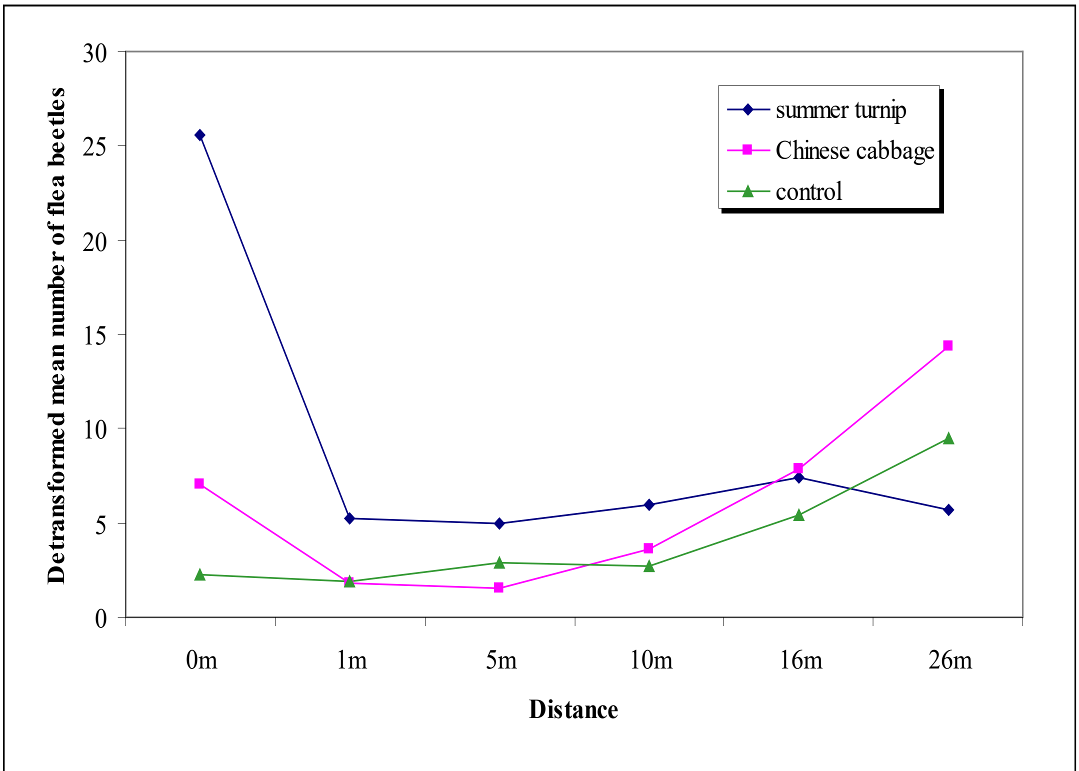


Figure 20. The interaction between the number of flea beetles trapped in different crop types and distance into the field crop (swede) at the Devon site.



Insecticide work

Effectiveness of non-OP insecticides applied as seed treatments for the control of flea beetles on brassica seedlings

Materials and methods

Elsoms Seeds supplied all of the seeds used in the part of the work involved with insecticides. Turnip seeds (cv Manchester Market), were film-coated at HRI, Wellesbourne with Gaucho (imidacloprid), UK894 (imidacloprid + beta cyfluthrin) and Furadan 440 (carbofuran). The insecticides were applied at target loadings equivalent to 25g (carbofuran) and 50g (imidacloprid) active ingredient (a.i.)/unit (1 unit =100,000 seeds) respectively, using a PVA sticker applied at a rate equivalent to 5 % of the product weight. The actual loadings achieved (Table 1) were assessed by high performance liquid chromatography (hplc) analysis of samples of the treated seed. For technical reasons, the amount of beta cyfluthriun in the UK894 treatment was not measured, but the imidacloprid was present in the seed coated treatment at a rate equivalent to 3g a.i./unit. A further batch of seed included in this test had been treated commercially with gamma-HCH, by Elsoms Seeds, and the last batch, the "control" treatment was left insecticide-free.

Table 1. Doses of insecticide applied to turnip seed, cv. Manchester Market.

Insecticide	Target dose (g a.i./unit)	Actual dose (g a.i./unit)
Carbofuran	25	24
Imidacloprid	50	42
UK894 (imidacloprid only)	3	3

On three separate occasions (8, 15 & 30 May), batches of the treated and untreated seed were drilled in 2 rows in each 3 m long bed (1.83 m wide) using a precision drill to produce a within row spacing of 7.5 cm. Each block was replicated five times and the whole experiment was laid out as a 5 x 5 Latin square. Damage due to flea beetle feeding was assessed by counting the numbers of damaged and undamaged seedlings on 15 May (7 days after 1st drilling), 25 May (10 days after 2nd drilling) and 7 June (8 days after 3rd drilling). The numbers of seedlings that survived in the various plots were recorded on 25 May (17 days after 1st drilling), 7 June (23 days after 2nd drilling) and 14 June (15 days after 3rd drilling).

Results

The effects on seedling damage and seedling survival for all three drilling dates are shown in Figures 3 and 4 respectively.

First drilling: By 7 days after drilling, all of the seedlings in the insecticide-free plots were damaged (Fig. 21 - 1st drilling). In the other plots, although the Gaucho and Furadan 440 seed treatments reduced (P = 0.05) crop damage, the UK894 and gamma-HCH did not. More (P = 0.05) seedlings survived in the plots of all four of the insecticide treatments than in the insecticide-free "control" plots (Fig. 22 - 1st drilling).

Second drilling: Ten days after drilling, all seedlings, irrespective of treatment, had been damaged (Fig. 21 - 2nd drilling). However, the numbers of seedlings that survived were reduced only in the insecticide-free plots (Fig. 22 - 2nd drilling).

Third drilling: Eight days after drilling, all of the seedlings in the insecticide-free plots were damaged (Fig. 21 - 3rd drilling). The numbers of damaged seedlings in each of the four test insecticide treatments were lower (P = 0.05) only on the plots in which carbofuran was used as the seed treatment. However, as with the 1st and 2nd drillings, seedling survival was reduced only in the insecticide-free plots (Fig. 22 - 3rd drilling).

Effectiveness of foliar insecticide sprays for the control of flea beetles on swede seedlings

Materials and methods

On 12 June, swede (cv Magres) seed was drilled at 4 rows/bed (1.83 m wide) using a precision drill to produce a within-row spacing of 7.5 cm. The first seedlings began to emerge on Friday 16 June. To minimise flea beetle damage during the weekend period, the plots were covered with Envirofleece. On Monday 19 June, the fleece was removed and Hallmark (lambda-cyhalothrin), Decis (deltamethrin) Ashlade Cypermethrin (cypermethrin), SpinTor (spinosad) and water only spray treatments were applied at 300 l water/ha and at the doses shown in Table 2. The treatments were arranged so that the 4 insecticide-treated and the untreated plots formed a 5 x 5 Latin square of 4 m long plots. The treatments were re-applied at the same rates on 28 June.

Table 2. Doses of insecticide applied

Insecticide	Product/ha (ml)	Active ingredient/ha (g)
Lambda-cyhalothrin	300	15
Deltamethrin	600	15
Cypermethrin	250	25
Spinosad	500	120

The numbers of seedlings that had emerged from the soil were counted on 19 June (7 days after drilling). The numbers of swede seedlings that survived and the damage that resulted from the beetles feeding was assessed by counting the numbers of damaged and undamaged seedlings in each plot on 19, 20 21, 27 June and 11 July.

Results

Flea beetle attack was heavy and occurred extremely rapidly on the untreated plots.

More than 90% of the untreated seedlings were damaged within 1 day of the fleece being removed.

When compared to the control plots, all four insecticide sprays reduced (*P* = 0.05) the levels of seedling damage (Fig. 23). All three sprays involving the pyrethroid insecticides (Decis, Hallmark and Ashlade Cypermethrin) were similarly effective. SpinTor was as effective as the pyrethroids, but only when applied at a 5-8 times higher dose. The counts of the percentage of seedlings damaged showed that all four insecticide treatments remained relatively effective for three days (19-21 June). They may have remained effective for longer than this but this was not ascertained as the next assessment of damage was made only on 27 June. By this date, virtually all of the seedlings had flea beetle damage (Fig. 23), and so a second spray of the relevant treatment was applied to each plot.

On 19 June, seven days after the plots were drilled, approximately 90–95% of the seedlings had emerged from the soil (Fig. 24). When a spray was applied on this date, the seedling stand remained more or less similar on all plots until the next spray was applied on 28 June. In contrast, by the time of the assessment made on 21 June, only 58% of the seedlings survived the flea beetle attack in the unsprayed (control) plots. The final assessment was made on 11 July, when the seedling stand in the sprayed plots remained relatively unchanged whereas the stand in the unsprayed plots had declined slightly to about 50%. By 11 July, the seedlings were sufficiently well developed to withstand flea beetle attack and so no further sprays were applied. Hence, even with the high levels of flea beetle attack that occur at various times of year at Wellesbourne, two sprays of an appropriate insecticide, one at the time of seedling emergence and the other about a week later, seem sufficient to prevent seedling loss.

Figure 21. Flea beetle damage on turnip seedlings after seed treatment

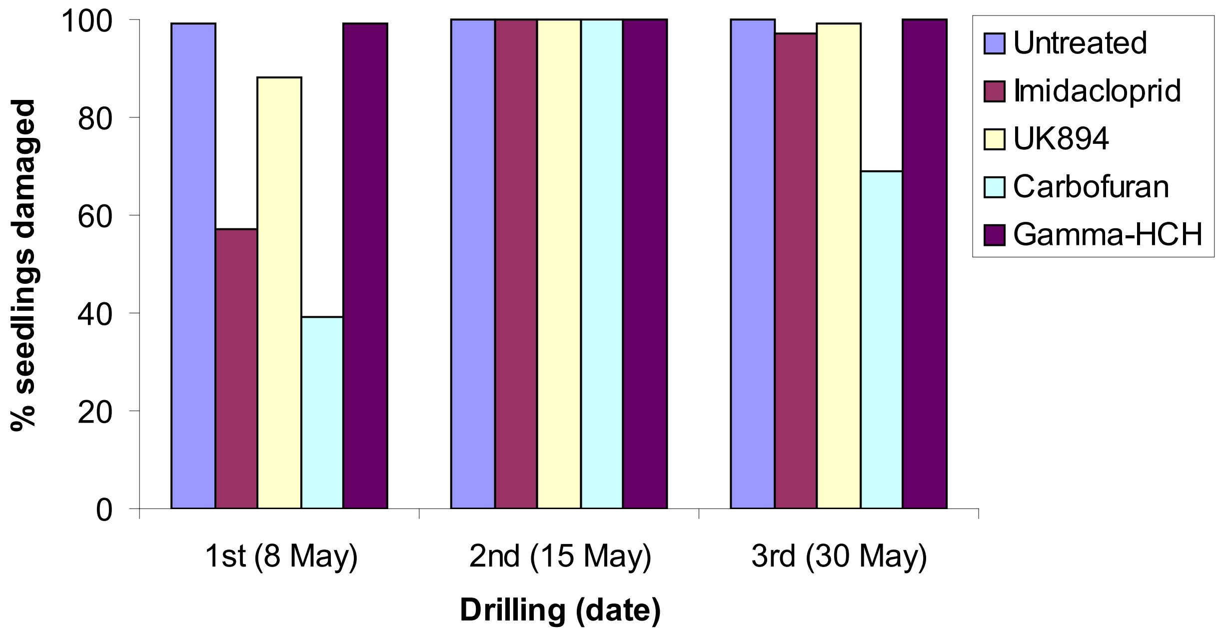


Figure 22. Turnip seedling survival after flea beetle attack

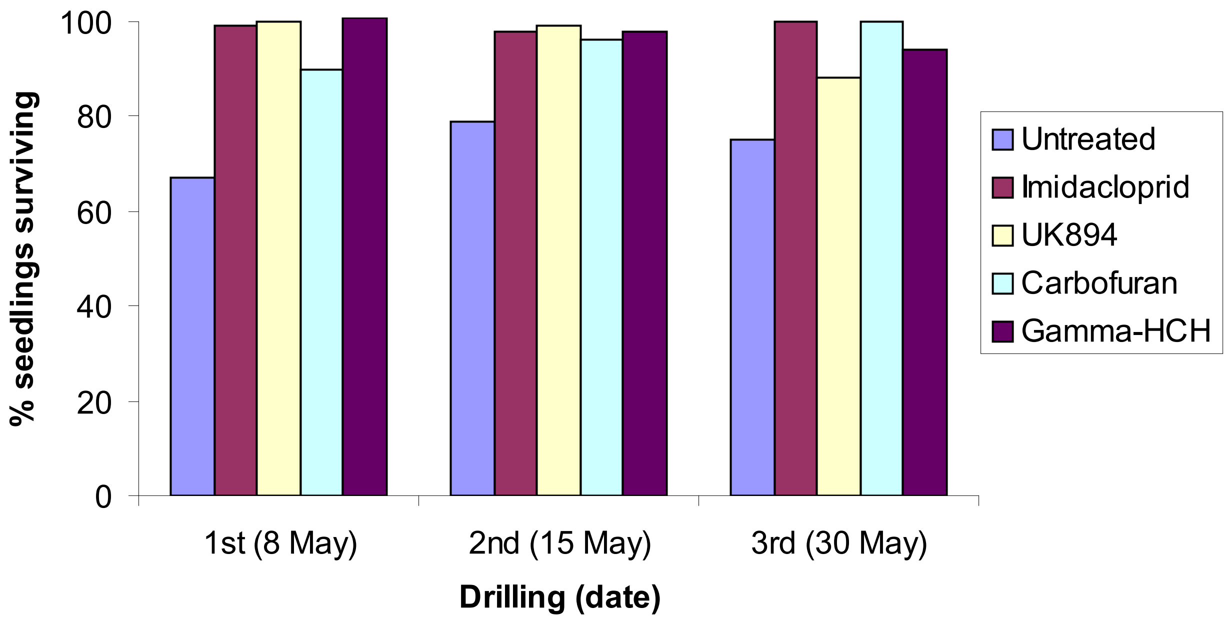


Figure 23. Flea beetle damage on swede seedlings after spray treatment

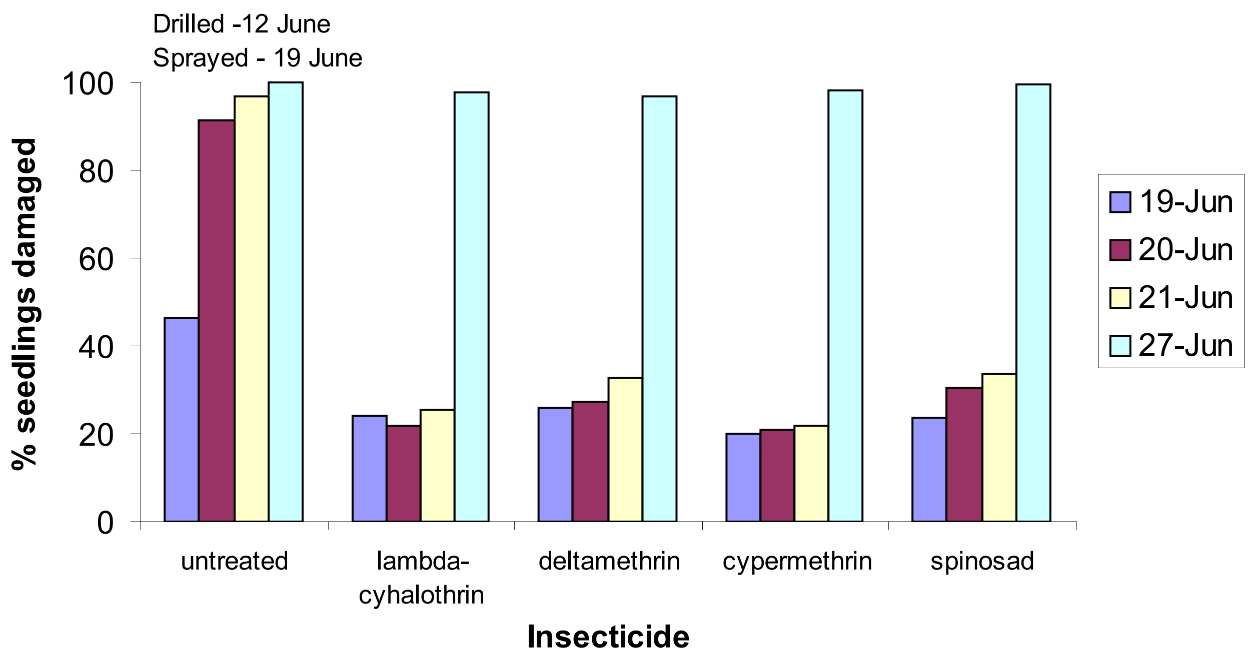
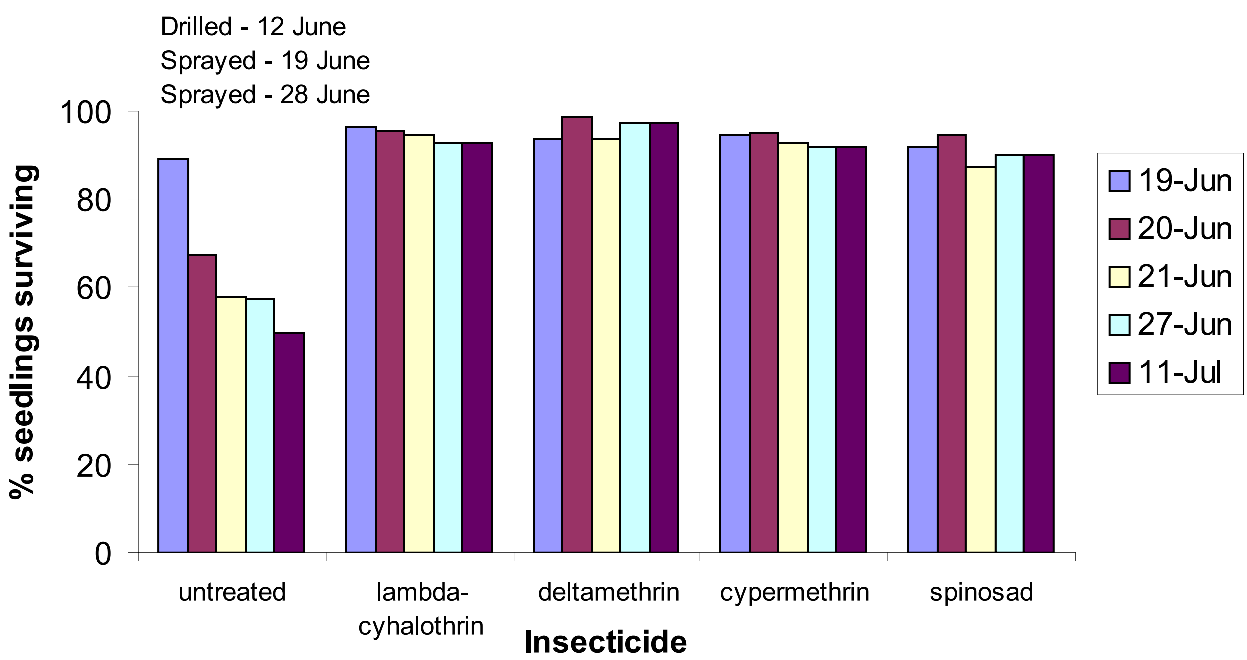


Figure 24. Swede seedling survival after flea beetle attack



General Discussion

Flea beetle monitoring

The monitoring work clearly demonstrated that *Phyllotreta* flea beetles could potentially be active for the whole of the May to July period. The extended monitoring at HRI Wellesbourne also showed that flea beetles continued to be active into the late summer. However, there were clear peaks of activity lasting four to six weeks at all sites, ranging from mid- to late May to the end of June. There were also clear differences in the *Phyllotreta* species complex between sites. *P. undulata* was the dominant species in East Lothian and Herefordshire, while *P. diadamata* was the key species in Devon. Non-crucifer feeding species were commonly found in water traps in Herefordshire and Devon, but were rarely found in significant numbers in the brassica field crops. As there is some evidence from both this year and the previous year that that flea beetle species may be attracted to varying degrees to different trap crops, determining the dominant *Phyllotreta* species in specific localities may prove to be important in selecting appropriate trap crops.

Trap cropping

Clear differences in the attractiveness of the different trap crop species tested relative to the broccoli and swede controls were demonstrated at both the Herefordshire and Devon sites respectively (Figures . At both sites, summer turnip was the most attractive species. Chinese cabbage was equally as attractive as summer turnip at the Herefordshire site but was no more attractive than the control (swede) at the Devon site. This concurs with published work, which has shown that amongst others, turnip was attractive to, and readily fed upon, by *Phyllotreta* spp. flea beetles (Vargas & Kershaw, 1979). However, evidence from both this project (this year's data and 1999 data) strongly suggests that different potential trap crops may vary in their attractiveness to different *Phyllotreta* species. Determining the dominant *Phyllotreta* species in specific localities may therefore be important in selecting effective trap crops.

Only tentative conclusions can be drawn about possible relationships between the population levels of flea beetles in the field crop and distance away from the trap crop strips. The data from the Herefordshire site suggested that the number of beetles trapped declined rapidly with increasing distance from the trap crop. The greatest number of beetles was found within the trap crop strips. At 1 m into the field crop, the flea beetle population level had more than halved in areas adjacent to trap crop strips, and at greater distances away from the field margins the relative numbers of beetles were similar regardless of the crop type on the field margin (Fig. 14) The higher beetle numbers in and adjacent to the trap crop strips may simply reflect the relative attractiveness of the trap crops in comparison to a field crop that in parts had suffered severe plant loss as a result of bird damage. It cannot be concluded that beetles are genuinely moving out of the field crop into the trap crop.

Data from the Devon site suggested that the age of the trap crop strips did have an influence on the distribution of beetles in the field crop. At the first assessment, there was a clear trend for higher numbers of beetles to be found at increasing distances into the field crop. However, by the second assessment 12 days later, this pattern had been reversed (Fig. 19), with more beetles being found in the field margin strips than further into the field. Closer inspection of the data showed that this change was largely due to the high numbers of flea beetles found in the summer turnip trap crop on the field margin (Fig. 20), whereas beetle numbers in the field crop adjacent to Chinese cabbage and swede field margin strips still tended to increase with increasing distance into the field. This may provide evidence that the maturing summer turnip crop was influencing flea populations up to at least 10 m away (Fig. 20), but this result would need frther verification.

The fact that higher numbers of beetles were generally found further into the field at the Devon site implies that *Phyllotreta* flea beetles were distributed widely across the field before the crops were sown (casual observations at the Herefordshire site suggest a similar situation there). If this is the case, then a perceived drawback of trap cropping – that planting trap crop strips through a field crop may bring more beetles into the field crop – may in fact not be serious issue.

This year's work has confirmed that potential trap crops such as summer turnip and Chinese cabbage do attract more flea beetles than conventional cruciferous crops such as swede and broccoli, although the exact choice of trap crop may be influenced by the composition of the *Phyllotreta* species complex at a particular location. The relative age of the trap crop is also a key factor. For trap crops to be most effective, they should ideally be sown at least two weeks before the field crop is due to be sown or planted. The distance over which trap crop exert an effect is still open to question, but the limited evidence from this year's work suggests that this is likely to be in the range 1 – 10 m rather than the 60 m claimed by work done in Ontario.

Trap crops may also have the added benefit of affecting other pests. For example studies done in Finland showed that Chinese cabbage (and other *Brassica* species) provided cauliflower almost complete protection against pollen beetle, *Meligethes aeneus* (Hokkanen *et al*., 1986) while results from Ontario suggested that cabbage root fly maggots also had host preferences with oilseed radish cv. Pigletta being particularly attractive.

Insecticides

The use of seed treatments had little effect on the percentage of seedlings damaged, with the exception of carbofuran and imidacloprid at the first drilling (8 May, Fig. 21) and carbofuran only on the third drilling. However, all insecticides tended to increase seedling survival, from *c.* 75-80% in untreated plots to 90-100% on treated plots. This suggests that the severity of damage on treated seedlings was lower, and hence allowed a greater proportion of plants to establish. The effect of pyrethroids insecticides and SpinTor was broadly similar. A single spray treatment suppressed the flea beetle population for at least one to days (Fig. 23), although by seven days after the first treatment damage on treated and untreated plots was similar. However, seedling survival was substantially increased by a single spray (pyrethroids or SpinTor), and was maintained by a second spray applied nine days after the first (Fig.

24).

Overall conclusions

It is clear that trap crops have the potential to influence the level of flea beetle activity on field-sown brassica crops, and the insecticide work has clearly demonstrated that reducing the intensity of flea beetle attack can allow a drilled crop to establish satisfactorily. Further work needs to be done to investigate the practical use of trap crops, particularly in terms of their spatial arrangement in relation to the field crop, and how they can best be integrated with insecticide use. In particular, the possibility of using insecticides only on the trap crop offers a potentially novel approach to flea beetle management. This will be investigated in the final year of the project.

Technology transfer

- HDC News article published in autumn 2000 reporting on the first year's work.
- Poster on "Evaluation of trap crops for the management of *Phyllotreta* flea beetles on brassicas" presented at the British Crop Protection Council conference by Julia Howard and Bill Parker, Brighton, November 2000. This generated several press reports and consequently enquiries from some growers on the status of the work and the prospects for the wider use of trap cropping.
- Results from insecticide work reported at HRIA meetings at Wellesbourne (autumn 2000) and Kirton (January 2001).

Acknowledgements

We are grateful for the cooperation of the host farmers at the East Lothian, Herefordshire and Devon field sites.

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