Project title:	**Brassica crops: Evaluation of non-organophosphorus insecticides for controlling the cabbage root fly**
Project number:	FV 242
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Final report:	2002/2003
Previous reports:	2001/2002
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Date project commenced:	1 April 2002
Date project completed:	31 March 2003
Key words:	Swedes, cabbage root fly, Tracer (spinosad), Oncol (benfuracarb), Hallmark (lambda-cyhalothrin), ECOguard, garlic extract, film-coated seed, deterrents, insecticide baits, foliar spray.

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Brassica crops: Evaluation of non-organophosphorus insecticides for controlling the cabbage root fly

Headline

- When applied as a seed treatment to swede, spinosad provided effective control of first generation cabbage root fly larvae and partial control of the second generation. By inference, the results suggest that the seed treatment alone would provide adequate protection to module raised leafy brassicas, where lower levels of control are required.
- When applied as a spray treatment, either once, weekly or fortnightly during the second fly generation, spinosad did not control second generation cabbage root flies or larvae on an established crop of swede. However, there was some evidence that spinosad was partially effective at controlling cabbage root flies when applied as a spray in a bait solution containing sugar and yeast extract.
- Foliar sprays of lambda-cyhalothrin applied in a bait solution containing sugar and yeast extract did not control cabbage root fly.
- Foliar sprays of garlic applied once, weekly or fortnightly during the second fly generation had no effect on cabbage root fly numbers or damage in plots of swede that were exposed to the field population of flies.
- A greenhouse experiment showed that garlic granules were toxic to cabbage root fly eggs/larvae and that there was a clear dose/response effect.

Background and expected deliverables

Brassica crops are grown currently on approximately 32,000 ha in the UK and the marketed value of these crops is about £150M/annum [*Basic Horticultural Statistics for the United Kingdom. Calendar and Crop Years 1991/92 – 2001/02. Department for Environment, Food and Rural Affairs, National Statistics*]. The cabbage root fly (*Delia radicum*) is the most serious pest of brassica crops in the United Kingdom. Since 1963, the larvae of this pest have been controlled by seed-treatments, drenches, sprays and granular formulations of mainly organophosphorus (OP) insecticides. However, as a result of the UK/EU pesticide reviews, some products have been withdrawn already and others may be withdrawn in the future. There are now only two approved chemicals; chlorfenvinphos (Birlane) (approval until 31 December 2003) and chlorpyrifos (Dursban), for cabbage root fly control on root and leafy brassica crops respectively in the UK. At the end of 2003, no product will be available to control the cabbage root fly in swedes and turnips, since chlorpyrifos is not approved on these crops. Hence, the need to find alternatives, particularly for swede and turnip production, has never been greater. As a consequence, the current work has been targeted to look at alternative insecticides, alternative uses for currently approved insecticides, and non-insecticidal alternatives. Owing to the concern being expressed by swede growers, the experiments in this project concentrated on swede crops. However, the results of the project apply equally to leafy brassica crops, as levels of control do not have to be as stringent when the pest damages the part of the plant that is not used for human consumption. With leafy brassica crops, once the plants are established, the crop can tolerate some damage to the roots without any measurable loss in yield. In contrast, in swede and turnip crops where the fly larvae damage the part of the plant that is used for human consumption, the crop has to be kept pest-free throughout most of its growth period if the roots are to be acceptable at harvest.

The purpose of this project is to find ways of controlling the cabbage root fly with non-OP insecticides and to find alternative methods of using those compounds which are still available. The expected deliverables from this work include:

- An evaluation of the performance of spinosad applied as a seed treatment and as a foliar spray treatment for control of first and second generation cabbage root fly.
- An indication of whether the addition of sugar and yeast extract baits to foliar sprays of insecticide increase their effectiveness against cabbage root fly adults.
- An evaluation of whether foliar sprays of garlic reduce damage by cabbage root fly larvae in established crops of swede.
- An indication of whether garlic granules have insecticidal activity against cabbage root fly eggs and larvae.
- An evaluation of the performance of benfuracarb granules applied at drilling to control cabbage root fly on swedes.

Summary of the project and main conclusions

Five experiments were done in 2002-3 using three insecticides (lambda-cyhalothrin, spinosad, benfuracarb). In addition, a potential insect deterrent/natural insecticide (ECOguard) was assessed.

Experiments were done to answer the following questions:

- Can spinosad seed treatment be used to protect swedes against first generation cabbage root fly larvae and how frequently does spinosad have to be sprayed over swedes to control second generation larvae?
- As laboratory experiments showed that insecticide-baits increase the uptake of insecticides, do insecticides + baits sprayed onto established crops keep swede crops relatively damage free?
- How frequently do garlic spray treatments have to be applied to be capable of deterring the cabbage root fly from laying eggs on brassica plants?
- What dose of ECOguard (garlic) granules is required to kill cabbage root fly eggs/larvae when applied to swedes grown in the glasshouse?
- Will benfuracarb granules applied at drilling control cabbage root fly larvae on swedes?

Main conclusions

- When applied as a seed treatment to swede, spinosad provided effective control of first generation cabbage root fly larvae and provided partial control of the second generation.
- When applied as a spray treatment, spinosad did not control second generation flies or larvae on an established crop of swede, even when applied once a week throughout the second generation egg laying period.
- When applied in a bait solution containing sugar and yeast extract, spinosad was partially effective at controlling cabbage root flies released into cages placed over field plots of swede. However, the flies were released on one occasion only. This effect did not remain after the baits were aged for 2 weeks.
- A single application of insecticide-treated bait (containing either spinosad or lambda-cyhalothrin) did not reduce damage to exposed plots of swede by the field population of flies.

- In a field trial, garlic sprays failed to deter adult cabbage root flies from laying even when applied once a week throughout the second generation egg laying period.
- In a greenhouse experiment, mortality of cabbage root fly eggs/larvae showed a positive dose response when newly-laid eggs were added to swede plants immediately after garlic granules had been applied to the plants.
- Benfuracarb granules applied to swede plots at drilling had no effect on cabbage root fly control over the period of the first and second fly generations.

Financial benefits

- Without adequate insecticidal control, it is estimated that about 24% of the plants in field brassica crops would be rendered unmarketable by the cabbage root fly.
- In crops such as swedes and turnips (marketed value about £17M/annum), in which the pest attacks directly the part of the crop used for human consumption, the losses would be considerably higher. This sector of the industry may not be sustainable if the cabbage root fly cannot be controlled effectively.
- Even if cultural methods could be relied on to lower overall damage to 15-20%, the Industry could still be facing losses of about £25M per annum from the area of crop that needs protecting currently against attacks by the cabbage root fly.

Action points for growers

Spinosad soil treatments (field experiment -swede)

- **Seed treatment** Highly effective at controlling the first generation of cabbage root fly larvae and persistent enough provide partial control of second generation larvae.
- **Spray (drench)** Treatments failed to control second generation cabbage root fly adults/larvae even when applied weekly for 6 weeks, throughout the second generation.

Insecticide-treated baits (field experiment -swede)

- **Spinosad** Reduced cabbage root fly egg laying, probably by killing adult flies. The effects did not persist when baits were aged for 2 weeks.

- **Lambda-cyhalothrin** Had little effect on cabbage root fly control.

Insect deterrents (field experiment - swede)

- **ECOguard liquid** This was applied as a spray treatment to test the performance of the active ingredient (garlic extract) as a soil insecticide, as well as a deterrent to egg laying. There was no evidence of cabbage root fly control even when applied weekly for 6 weeks during the second fly generation.

Natural insecticides (glasshouse experiment - swede)

- **ECOguard granules** Mortality of cabbage root fly eggs/larvae showed a positive dose response when eggs were added to swede plants immediately after garlic granules had been applied. At the proposed field rate, 60-80% control was observed.

Insecticide granules (field experiment – swede)

- **Benfuracarb** Failed to control second generation cabbage root fly larvae when applied to plots of swede at drilling.

SCIENCE SECTION

Introduction

Since about 1997, the HDC has funded projects on insecticidal control of cabbage root fly on brassica crops. During 1997-2000 ADAS researchers looked for insecticidal treatments that would give better control of the cabbage root fly in swede crops (FV 66a). Unfortunately, none of the insecticides tested during 1997 and 1998 appeared to give adequate control and from the experiments done with chlorfenvinphos during 1999, the researchers concluded that it was only possible to draw tentative conclusions. At about the same time, an HDC project entitled "Radish: evaluation of non-OP insecticides for controlling cabbage root fly" (FV 159a) was done at HRI Wellesbourne. While the results from the radish trials helped to identify the insecticides that could be used to control the cabbage root fly in field brassica crops, the radish data were limited. This is because some radish crops are in the field for only 21 days and so to avoid problems from crop residues, the amount of insecticide used has to be kept to the minimum.

As the need for alternative control methods became more urgent, research during 1999-2000 focused on finding non-OP compounds as possible control agents for the cabbage root fly on swedes, turnips and leafy brassicas (FV 223). Of the seven insecticides tested in 1999, three proved suitable for further trials. Fipronil (Fipronil) was the most highly potent and effective compound tested, cyromazine (Neporex) also showed considerable promise and, as expected, carbofuran (Yaltox) the "positive" control was also effective (Jukes *et al.,* 2000). The results showed that imidacloprid (Gaucho) should not be used for root fly control, and confirmed an earlier finding that this insecticide extends the period that the fly larvae feed and so increases crop damage. Similarly, all three pyrethroid compounds tested, the soil-active tefluthrin (Force) and the two foliar-active compounds lambda-cyhalothrin (Hallmark) and deltamethrin (Decis) should not be applied, as they kill few cabbage root fly larvae but appear to kill beneficial organisms. As a result, crop damage following such treatments is greater than doing nothing at all. Hence, applying pyrethroid insecticides by conventional methods to control the cabbage root fly should be avoided at all costs (Jukes *et al.,* 2000).

The experiments done during 2000-2001 (FV 223; Jukes *et al.,* 2001) confirmed the results from the 1999-2000 trials. They indicated also that the bacterial fermentation product "spinosad" was effective at controlling the cabbage root fly when applied as 1) a seed treatment, 2) a module drench prior to planting, or 3) as a field drench after planting. However, it was not evaluated as a mid-season foliar spray for control of second and third generation cabbage root fly larvae on swedes or turnips.

In 2001-2002 (FV 222), the work was continued with 1) a seed treatment trial focusing on spinosad, 2) laboratory and field trials to determine whether physical/chemical barriers could deter flies from laying their eggs on crop plants and 3) a laboratory experiment to determine whether the addition of sugar/yeast extract baits to insecticides increased their efficacy as foliar sprays (Jukes *et al.,* 2002). Spinosad seed-treatment of turnips was not phytotoxic at doses up to 160 g a.i./100,000 seeds (unit). Chlorfenvinphos was the most phytotoxic treatment (<40 g a.i./unit) and Gigant (chlorpyrifos) was safe up to 40 g a.i./unit when applied with talcum powder. However, in field trials only spinosad and chlorfenvinphos reduced root damage and larval survival compared to control plants. None of the barrier deterrents tested (Antistress, ECOguard, Majestic or Seagrow) reduced damage to swede roots or reduced the numbers of cabbage root fly larvae surviving. In fact some treatments (particularly Seagrow) appeared to increase feeding damage on the roots. ECOguard (garlic granules) and Seagrow (composted seaweed) showed some deterrent effects on egg-laying in the laboratory, but these effects were not transferred to the field. When applied in bait solutions containing sugar and yeast extract, lambda-cyhalothrin, chlorpyrifos, spinosad and fipronil all killed adult cabbage root fly. Fipronil was consistently the most effective insecticide and lambda-cyhalothrin the least effective. Pirimicarb was shown to kill onion fly, but not cabbage root fly.

Following on from the studies in 2001-2002, the experiments in the present project have focused on the use of spinosad, baits and garlic treatments. The project involved field and glasshouse trials. The advantages of glasshouse trials are that they allow all insecticides to be tested at the same insect pressure and a range of insecticide doses can be tested in a limited space prior to extensive, and hence more expensive, field trials. In addition, variations in the results caused by changing weather conditions and/or beneficial insects can also be avoided. The work during this one-year project was “short-term”, and was concerned solely with finding possible replacements for the OP-based treatments applied currently.

Experiments were done to answer the following five questions:

1. Film-coated seed and mid season sprays

Can spinosad seed treatment be used to protect swedes against first generation cabbage root fly larvae and how frequently does spinosad have to be sprayed over swedes to control second generation larvae?

2. Insecticide-treated baits

As laboratory experiments showed that insecticide-baits increase the uptake of insecticides, do insecticides + baits sprayed onto established crops keep swede crops relatively damage free?

3. Cabbage root fly deterrents/natural insecticides

How frequently do garlic spray treatments have to be applied to be capable of deterring the cabbage root fly from laying eggs on brassica plants?

4. Natural insecticides

What dose of ECOguard (garlic) granules is required to kill cabbage root fly eggs/larvae when applied to swedes grown in the glasshouse?

5. Carbamate granules

Will benfuracarb granules applied at drilling control cabbage root fly larvae on swedes?

The five experiments

For scientific reasons the test chemicals are shown as the active ingredients (with one product name in parenthesis) in the Materials and Methods sections, as certain chemicals are available under a range of different product names.

The actual active ingredients tested, together with the representative product (shown in parenthesis), were: lambda-cyhalothrin (Hallmark), spinosad (Tracer), benfuracarb (Oncol) and garlic extract (ECOguard).

Experiment 1. Can spinosad seed treatment be used to protect swedes against first generation cabbage root fly larvae and how frequently does spinosad have to be sprayed over swedes to control second generation larvae?

Materials and methods

a) Seed treatment

Swede seeds were film-coated at HRI Wellesbourne with spinosad (Tracer 480SC) at a target loading of 150 g a.i./unit (1 unit = 100,000 seeds). This dose was chosen because it appeared to be the maximum seed coat capacity for this seed coat/formulation combination. A PVA sticker at the rate of 2% of product weight was applied with all treatments. A further batch of seed was left insecticide-free.

b) Field experiment

Nine (1.83 m wide x 15 m long) seedbeds were prepared in the experimental area at HRI Wellesbourne. On 23 April, the seedbeds were drilled alternately with insecticide-free and insecticide-treated seed. Each bed was drilled with swede seed at 13 seeds/m row, using a tractor mounted Stanhay Singulaire seed drill. Four rows were drilled into each bed to give a row spacing of 46 cm. On 25 April (prior to seedling emergence) the outer four insecticide-free-seed beds were covered with Envirofleece to exclude first generation cabbage root fly. All of the treated-seed beds and the central insecticide-free seed bed were left uncovered.

On 25 June, approximately 4 weeks after the end of first cabbage root fly generation (indicated by monitoring cabbage root fly egg laying in a nearby plot), five plants were sampled from each of the central two treated-seed beds and 10 plants from the central, uncovered, insecticide-free seedbed. A 15 cm diameter x 15 cm deep soil core was taken from around the roots of each plant. Cabbage root fly pupae were extracted from the soil samples by flotation in water and the numbers of pupae recovered were counted. The roots were washed, weighed and scored for cabbage root fly damage.

On 10 July, the fleece was removed. The beds were split into four, 3 m plots with 1m of bed between each plot. Swedes were removed from the inter-plot spaces. The subsequent spray treatments were applied such that the treated plots were arranged in a randomised Latin Square design, split for treated and insecticide-free seed. The spray treatments were all spinosad (Tracer 480SC) at a rate of 500 ml product/ha in 730 l water/ha, and were applied using a knapsack sprayer. The plots were sprayed: once, every week, every 2 weeks or left unsprayed. The first application was applied on the day the fleece was removed and the spraying continued throughout the period of egg laying by second generation cabbage root fly. Subsequent spray dates are shown in Table 1. A total of 7 applications were made to the plots treated weekly and 4 to the plots treated fortnightly. On 4 September, all of the plots were covered with Envirofleece to exclude third generation cabbage root fly, whilst the eggs that had been laid already were allowed to develop to pupation.

From 31 September to 9 October, the plots were uncovered and 15 cm diameter x 15 cm deep soil cores were taken from around the roots of 6 plants in each plot. In addition, approximately 50 roots/plot were harvested. Cabbage root fly pupae were extracted from the soil samples by flotation in water and the numbers recovered were counted. The roots were washed, weighed and scored for cabbage root fly damage. The root damage index was calculated based on scoring damage to each root on a scale from 0 (no damage) to 4 (>50% damage). The mean numbers of cabbage root flies recovered from the soil samples and the mean root damage index were subjected to Analysis of Variance. The insect counts were square root transformed prior to analysis.

Table 1. Application dates for spinosad spray treatments

Treatment name	Treatment details	Spray dates
A	No sprays	
B	Spray once	10 July
C	Spray weekly	10, 17, 24 July, 1, 7, 14, 21 August
D	Spray fortnightly	10, 24 July, 7, 21 August

Results

Egg laying by the second generation of cabbage root flies started to increase from mid-July onwards and peak numbers of eggs were laid at the end of July (egg samples taken from a nearby monitoring plot).

The seed treatment provided excellent control (84% reduction in numbers of pupae) of first generation cabbage root fly larvae (Figure 1) and, irrespective of subsequent spray treatments, also reduced the numbers of second generation cabbage root fly pupae recovered (63-71% reduction) compared with the insecticide-free control ($P<0.05$) (Figure 2). Similarly, the root damage index at harvest was also reduced by the seed treatment ($P<0.05$) (Figure 3). In contrast, the spray treatments, even when applied weekly (7 sprays), had no effect on the numbers of pupae recovered, or on the levels of root damage observed, when compared with the insecticide-free control (Figure 2).

Figure 1. The mean numbers of pupae recovered at the end of the first generation of cabbage root fly from swede roots grown from seed film-coated with spinosad (back-transformed values following analysis).

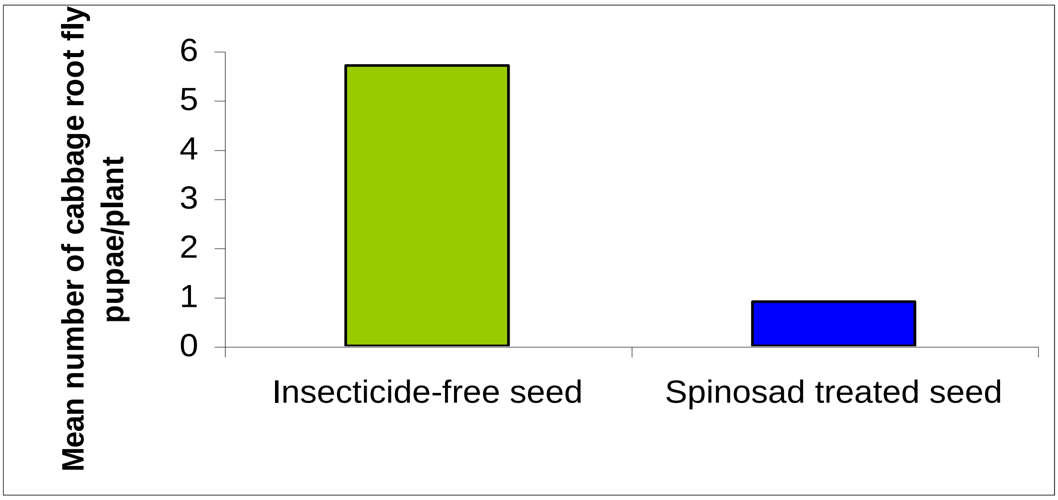


Figure 2. The mean numbers of cabbage root fly pupae recovered at the end of the first generation of cabbage root fly from swede roots grown from seed film-coated with spinosad (back-transformed values following analysis).

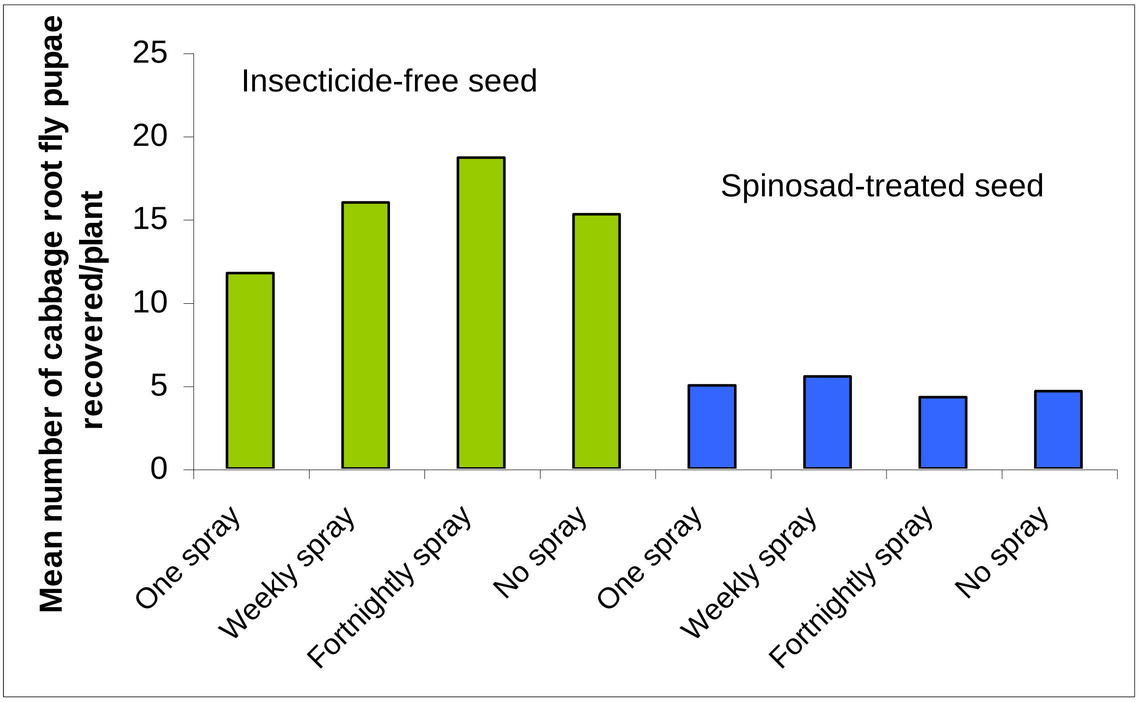
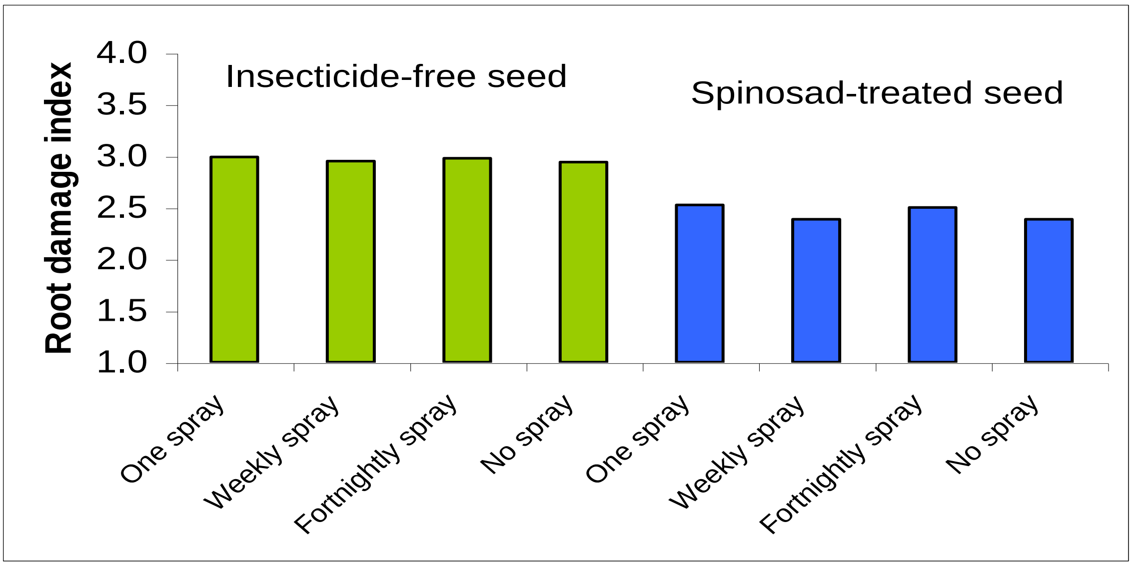


Figure 3. The mean root damage index at the end of the first generation of cabbage root fly of swede roots grown from seed film-coated with spinosad.



Experiment 2. As laboratory experiments showed that insecticide-baits increase the uptake of insecticides, do insecticides + baits sprayed onto established crops keep swede crops relatively damage free?

Materials and methods

Nine (1.83 m wide x 17 m long) seedbeds were prepared in the experimental area at HRI Wellesbourne. On 28 May, each bed was drilled with swede seed, at 13 seeds/m row, using a tractor mounted Stanhay Singulaire seed drill. Four rows were drilled into each bed to give a row spacing of 46 cm. On 30 May (prior to seedling emergence) all of the beds were covered with Envirofleece to exclude the first generation of cabbage root fly.

On 17 July, the fleece was removed and the beds were split into three, 5 m plots with 1 m of bed between each plot. Swedes were removed from the inter-plot spaces. The subsequent spray treatments were allocated to plots, such that the experiment consisted 9 randomised blocks, with one plot in each block receiving one of three treatments. The treatments were: a) bait only, b) bait + spinosad (Tracer 480SC, 500 mg a.i./l) and c) lambda-cyhalothrin (Hallmark with Zeon technology, 500 mg a.i./l). The bait consisted of 20% sucrose, 5% Marmite, 10% propylene glycol (to maintain the bait in liquid form) and 0.5% Codacide (to aid adhesion to the swede leaves).

In blocks 1-3 and 7-9 the first 2.5 m of each plot was sprayed at 200 l/ha with a knapsack sprayer and the whole 5 m plot was covered with a net cage suspended on polypropylene hoops made from water pipe. Half of each plot was left insecticide-free to provide the flies with a refuge, so they would not be forced to contact the Insecticide-treated leaves. In blocks 4-6 the whole 5m plot was sprayed, as with the caged plots, but the plots were left uncovered. At the spray rate used, and if all plants were sprayed, the dose applied would be 100 g a.i./ha for both active ingredients.

On 18 July, 40 male and 40 female, 6-day old cabbage root flies were released into each cage in blocks 1-3. After 2 weeks, on 5 August, 40 male and 40 female, 6-day old cabbage root flies were released into the cages in blocks 7-9.

On 4 September, blocks 4-6 were covered with Envirofleece to exclude the third generation of cabbage root fly, whilst the eggs that had been laid already were allowed to develop to pupation.

From 25-30 September, the plots were uncovered and 15 cm diameter x 15 cm deep soil cores were taken from around the roots of 6 plants in each plot. In addition, approximately 50 roots were harvested from each plot. Cabbage root fly pupae were extracted from the soil samples by flotation in water and the numbers of pupae recovered were counted. The roots were washed, weighed and scored for cabbage root fly damage. The root damage index was calculated based on scoring damage to each root on a scale from 0 (no damage) to 4 (>50% damage). The mean numbers of cabbage root flies recovered from the soil samples and the mean root damage index were subjected to Analysis of Variance. The insect counts were square root transformed prior to analysis.

Results

When flies were introduced into the cages with freshly applied insecticide/bait treatments there was a reduction ($P<0.05$) in both the numbers of pupae recovered (Figure 4) and the root damage index (Figure 5) in the spinosad treated plots compared with the insecticide-free plots (Blocks 1-3). However, after 2 weeks of ageing (Blocks 7-9), spinosad showed no signs of retaining its efficacy ($P=0.05$). Lambda-cyhalothrin was ineffective when applied with bait, both when freshly applied and aged for 2 weeks ($P=0.05$). A single treatment of insecticide with bait (either spinosad or lambda-cyhalothrin) applied to plots exposed to the natural population of cabbage root fly reduced neither cabbage root fly numbers nor damage ($P=0.05$).

Figure 4. The mean numbers of cabbage root fly pupae recovered from around swede plants sprayed with Insecticide-treated baits (back-transformed values following analysis). U = insecticide-free, L = lambda-cyhalothrin, S = spinosad, Caged = single introduction of cabbage root flies into cages, Natural = exposed to natural cabbage root fly infestation.

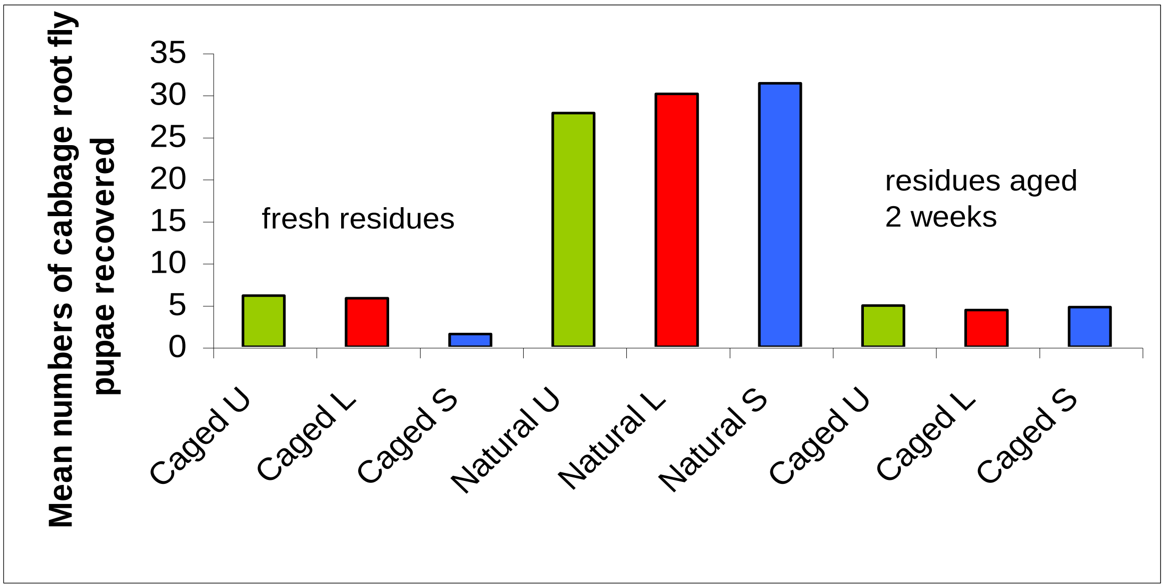
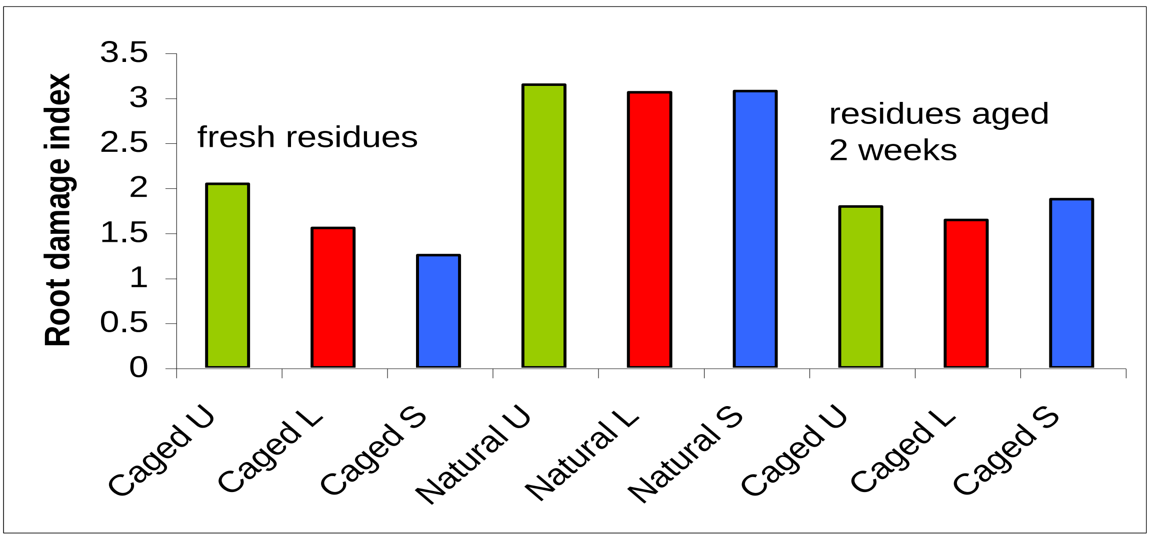


Figure 5. The mean root damage index of swedes sprayed with Insecticide-treated baits. U = insecticide-free, L = lambda-cyhalothrin, S = spinosad, Caged = single introduction of cabbage root flies into cages, Natural = exposed to natural cabbage root fly infestation.



Experiment 3. How frequently do garlic spray treatments have to be applied to be capable of deterring the cabbage root fly from laying eggs on brassica plants?

Materials and methods

Five (1.83 m wide x 15 m long) seedbeds were prepared in the experimental area at HRI Wellesbourne. On 28 May, each bed was drilled with swede seed, at 13 seeds/m row, using a tractor mounted Stanhay Singulaire seed drill. Four rows were drilled into each bed to give a row spacing of 46 cm. On 30 May (prior to seedling emergence) all of the beds were covered with Envirofleece to exclude the first generation of cabbage root fly.

On 17 July, the fleece was removed. The beds were split into four, 3 m plots with 1m of bed between each plot. Swedes were removed from the inter-plot spaces. The subsequent spray treatments were allocated to plots, such that the experiment consisted of 5 randomised blocks. Each block contained a plot that was 1) sprayed once, 2) sprayed every week, 3) sprayed every 2 weeks or 4) left unsprayed**.** The spray treatments all consisted of garlic extract (ECOguard liquid) at a rate of 4 l product/ha + 4 l adjuvant/ha in 730 l water/ha and were applied using a knapsack sprayer. The first application was applied on the day that the fleece was removed and the spraying continued throughout the second generation of cabbage root fly. Spray dates are shown in Table 2. A total of 7 applications was made to plots treated weekly and 4 to the plots treated fortnightly. On 4 September, all of the plots were covered with Envirofleece to exclude the third generation of cabbage root fly, whilst the eggs that had been laid already were allowed to develop to pupation.

From 17-18 September, the plots were uncovered and 15 cm diameter x 15 cm deep soil cores were taken from around the roots of 6 plants in each plot. In addition, approximately 50 roots were harvested from each plot. Cabbage root fly pupae were extracted from the soil samples by flotation in water and the numbers of pupae recovered were counted. The roots were washed, weighed and scored for cabbage root fly damage. The root damage index was calculated based on scoring damage to each root on a scale from 0 (no damage) to 4 (>50% damage). The mean numbers of cabbage root flies recovered from the soil samples and the mean root damage index were subjected to Analysis of Variance. The insect counts were square root transformed prior to analysis.

Table 2. Application dates for garlic spray treatments

Treatment name	Treatment details	Spray dates
A	No sprays	
B	Spray once	10 July
C	Spray weekly	10, 17, 24 July, 1, 7, 14, 21 August
D	Spray fortnightly	10, 24 July, 7, 21 August

Results

There was no evidence of a reduction in numbers of pupae recovered (Figure 6) or in the root damage index (Figure 7) as a result of any of the garlic spray treatments (P=0.05).

Figure 6. The mean numbers of cabbage root fly pupae recovered from around swede roots after treatment with garlic (ECOguard liquid) spray (back-transformed values following analysis).

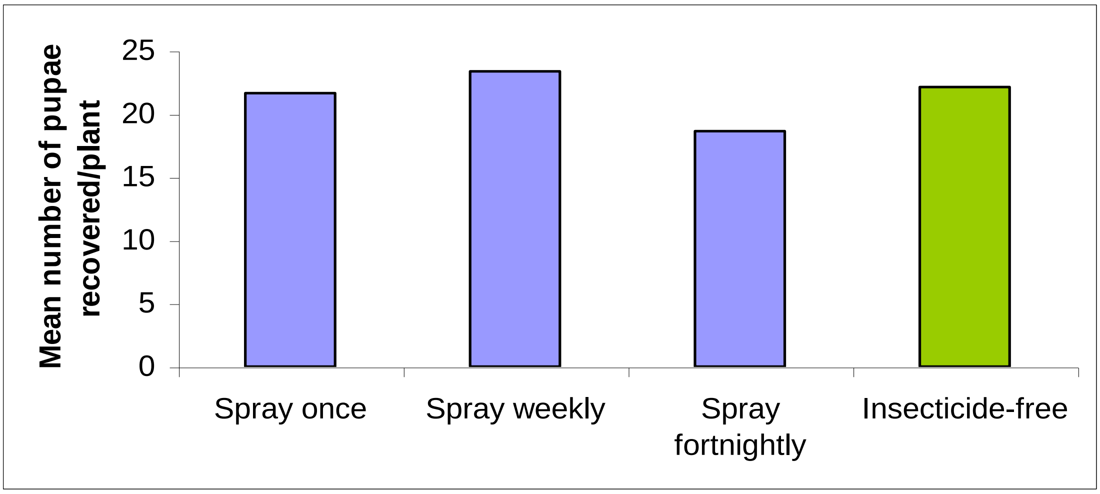
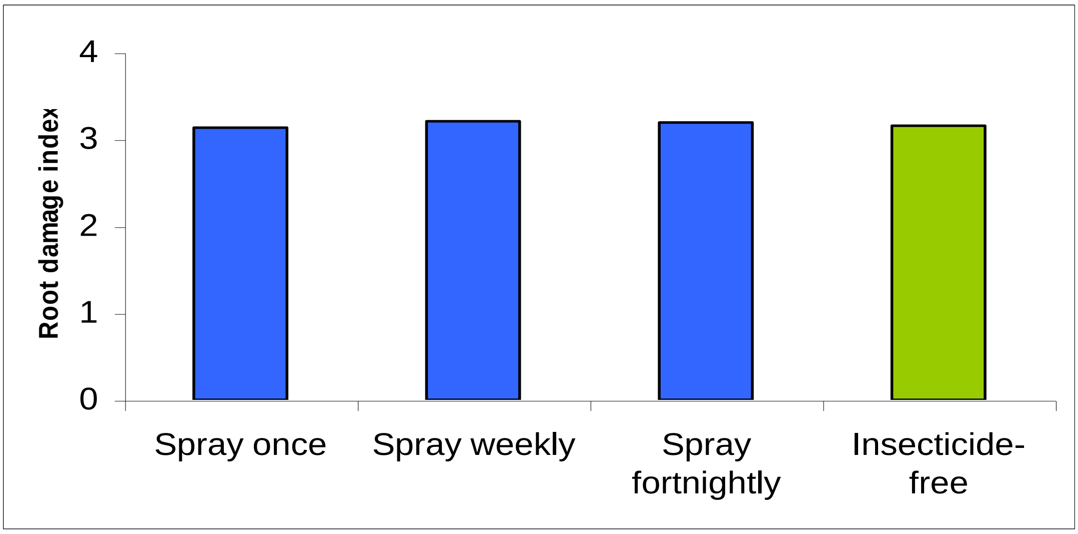


Figure 7. The mean root damage index of swede roots after treatment with garlic spray (ECOguard liquid)



Experiment 4. What dose of ECOguard (garlic) granules is required to kill cabbage root fly eggs/larvae when applied to swedes grown in the glasshouse?

Materials and methods

The standard field-sowing rate for swede was assumed to be 100,000 seeds/ha and the standard ECOguard granule application rate was taken to be 12 kg/ha. Assuming that each seed received an equal share of the applied granules, then the "standard" dose is 0.12 g/plant. The test doses chosen for evaluation were based on this figure (Table 3).

Table 3. Doses of Ecoguard (garlic) granules used in glasshouse trial

Treatment	Dose (proportion of "standard")	Dose (g product/plant)
1	insecticide-free	0
2	0.5	0.06
3	1	0.12
4	2	0.25
5	4	0.5
6	8	1.0

Swede seeds were sown into 308 Hassy trays and grown in a heated glasshouse under lights. At the 4-leaf stage, 90 plants were transplanted into Optipot 9M square pots and allowed to establish under the same glasshouse conditions (20 ± 2 ^{o}C) for a further 4 weeks.

On 17 January, pre-weighed samples of garlic granules were applied to the base of swede plants (15 plants treated at each dose). The granules were covered with loam soil, which was moistened with water (1-2 ml). Immediately after treatment, 20 cabbage root fly eggs, obtained from the laboratory culture maintained at HRI (Finch & Coaker, 1969), were washed onto the soil at the base of each plant. The experimental plants were arranged in 15 blocks, each containing 1 plant from each of the 6 treatments. The positions of the plants within each block were randomised fully.

On 17-18 February, by which time the root fly larvae should have completed their development, the cabbage root fly larvae and pupae were extracted from the potting compost by flotation in water and the numbers of larvae and pupae recovered from each plant were recorded. The roots were washed and weighed. The mean numbers of cabbage root flies recovered from the soil samples and the mean root weight were subjected to Analysis of Variance. The insect counts were expressed as a percentage of the number of eggs applied and the data were arcsine transformed prior to analysis.

Results

All doses of garlic granules reduced the recovery of cabbage root fly larvae and pupae compared to the insecticide-free control ($P<0.05$) and there was a statistically-significant dose response (Figure 8). Almost complete control was achieved at the highest dose tested, and at the dose equivalent to the recommended field application rate (0.12 g product/plant) insect numbers were reduced by almost 60%. There was also evidence that the treatments had increased larval development time. It was expected that all of the larvae would have pupated by the time the insects were washed out from the soil around the plants. However, relatively large numbers of larvae were recovered and the ratio of larvae to pupae increased with increasing dose (Figure 9). As insect survival increased, root damage also increased and as a result of this, root weight decreased ($P<0.05$) with decreasing dose (Figure 10).

Figure 8. The percentage survival of cabbage root fly larvae and pupae applied as eggs to swede plants treated with ECOguard (garlic) granules (back-transformed values following analysis).

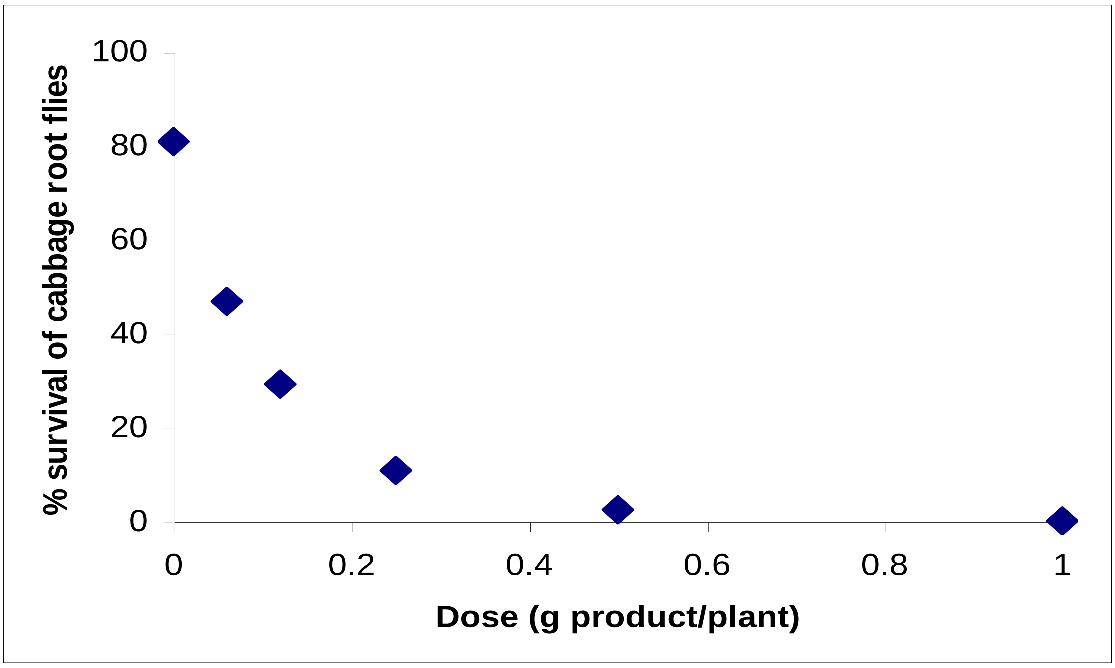


Figure 9. The ratio of cabbage root fly larvae to pupae recovered from swede plants treated with different doses of ECOguard (garlic) granules.

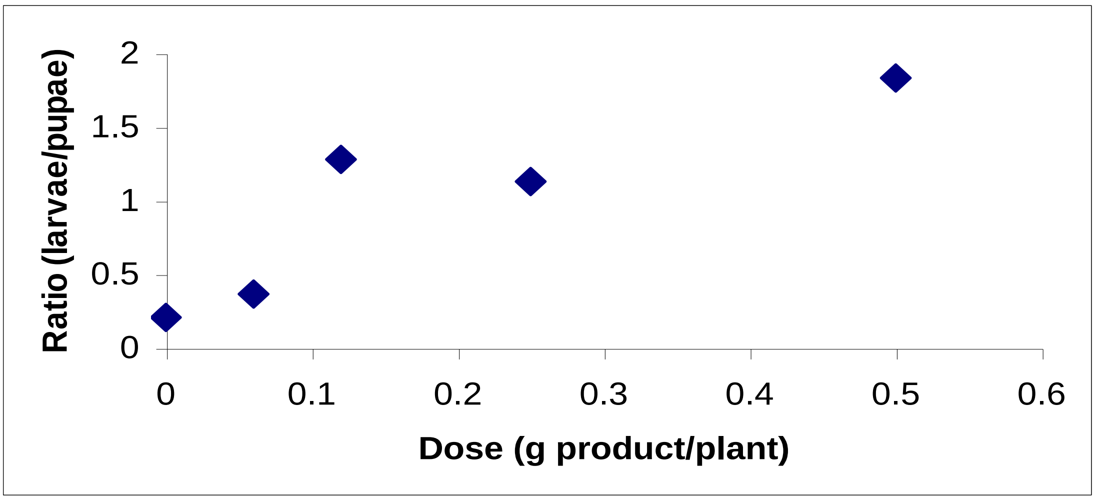
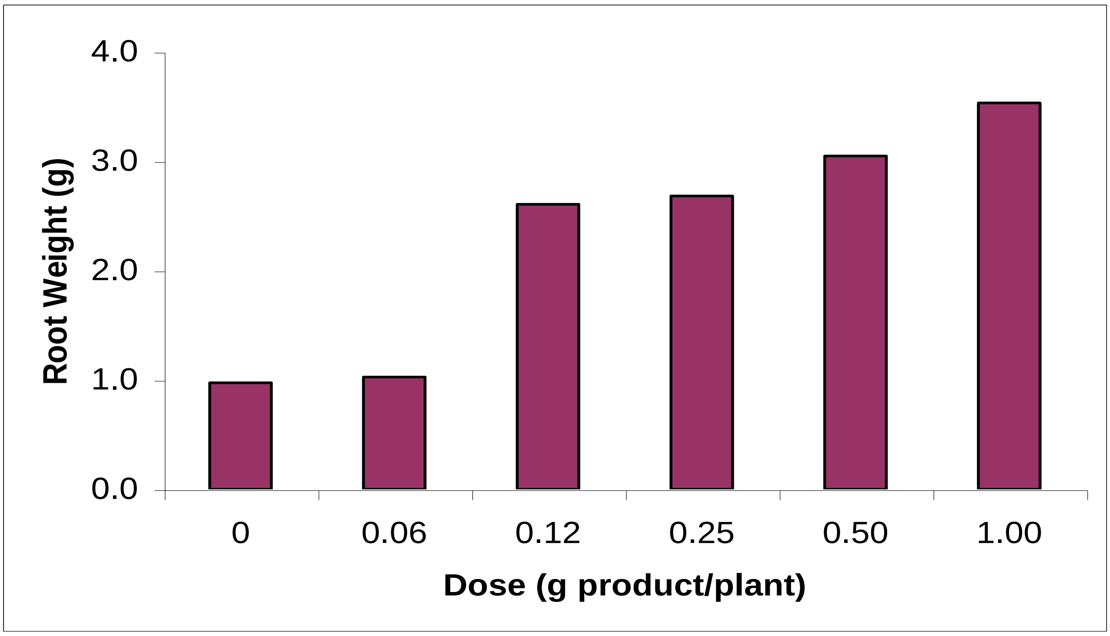


Figure 10. The combined effect of the ECOguard (garlic) granule treatments and cabbage root fly damage on the harvested weight of the swede roots in the glasshouse trial.



Experiment 5. Will benfuracarb granules applied at drilling control cabbage root fly larvae on swedes?

Materials and methods

Four (1.83 m wide x 10 m long) seedbeds were prepared in the experimental area at HRI, Wellesbourne. On 19 June, the beds were drilled with swede seed, at 13 seeds/m row, using a tractor mounted Stanhay Singulaire seed drill. Four rows were drilled into each bed to give a row spacing of 46 cm. Benfuracarb granules (Oncol 10G, 3.5 g product/10 m row) were added to two of the four rows in each bed at drilling using a Horstine Farmery granule applicator. The granules were placed onto the soil surface and incorporated to a depth of about 5 cm by the following seed drill. The dose rate chosen was based on the recommended rate for sugar beet (3.0 g/10 m row). The plots were left uncovered, so that they were exposed to egg laying by the second generation of cabbage root fly. On 4 September, all of the plots were covered with Envirofleece to exclude the third generation of cabbage root fly, whilst the eggs that had been laid already were allowed to develop to pupation.

On 12 September, the plots were uncovered and 15 cm diameter x 15 cm deep soil cores were taken from around the roots of 6 plants in each row in the central two beds and in addition, approximately 50 roots were harvested from each row. Hence, four treated and four insecticide-free rows were sampled. Cabbage root fly pupae were extracted from the soil samples by flotation in water and the numbers of insects recovered were counted. The roots were washed, weighed and scored for cabbage root fly damage. The root damage index was calculated based on scoring damage to individual roots on a scale from 0 (no damage) to 4 (>50% damage). The mean numbers of cabbage root flies recovered from the soil samples and the mean root damage index were subjected to Analysis of Variance. The insect counts were square root transformed prior to analysis.

Results

Root damage due to feeding by cabbage root fly larvae was heavy on all plots. Compared with the insecticide-free control, the benfuracarb treatment reduced the numbers of insects by 24%, but almost 20 pupae were recovered/plant and the difference was not statistically significant (p=0.05) (Figure 11). There was no reduction due to the benfuracarb treatment in the levels of root damage caused (P=0.05) (Figure 12).

Figure 11. The mean numbers of cabbage root fly pupae recovered from around swede roots after treatment with benfuracarb granules at drilling (back-transformed values following analysis).

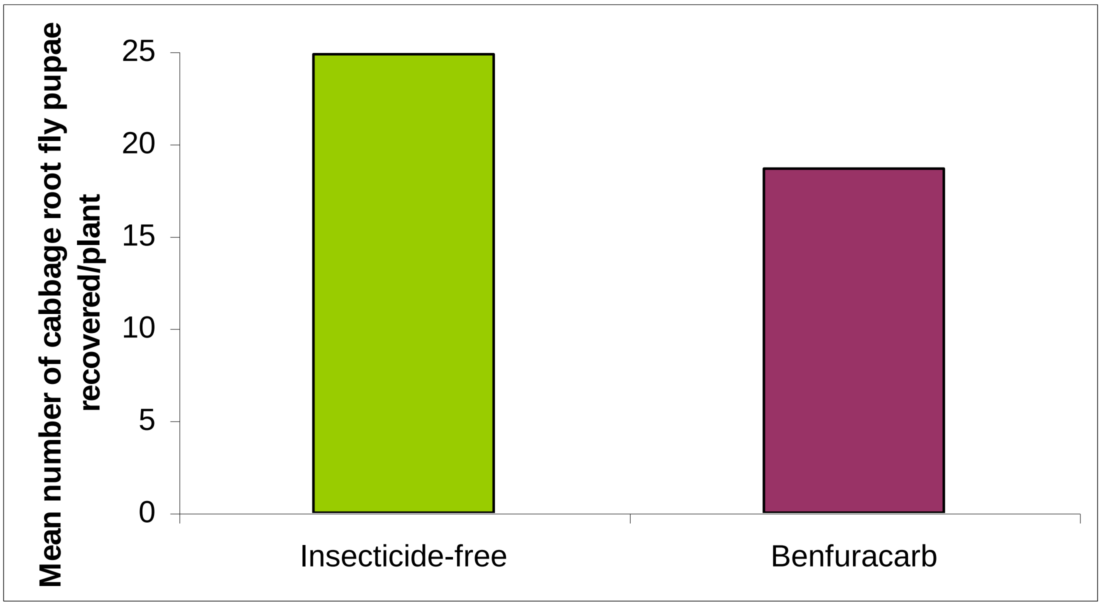
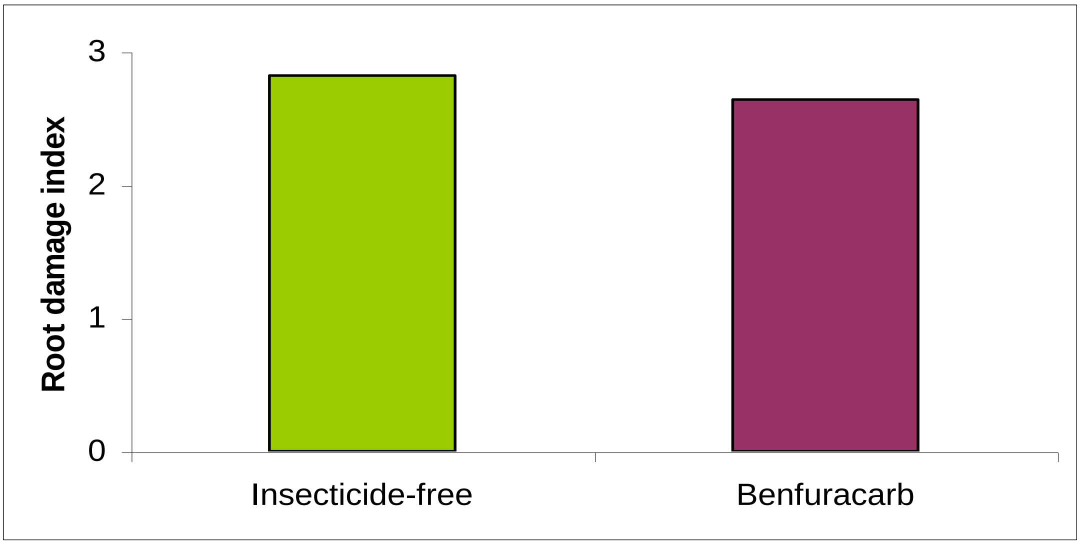


Figure 12. The mean root damage index of swede roots after treatment with benfuracarb granules.



CONCLUSIONS

Film-coated seed

Spinosad seed treatment at 150 g a.i./unit provided excellent control of first generation cabbage root fly larvae and was still partially effective against second generation larvae (12-16 weeks after drilling). These results support the findings of the 2001 field trials (Jukes *et al*, 2002). It is likely that this level of first generation control would be repeated, even at lower doses, and, if used in conjunction with an effective mid-season spray, spinosad seed treatment would be a useful addition to crop protection strategies in swede. By inference, the results suggest that the seed treatment alone would provide adequate protection to module raised leafy brassicas, where lower levels of control are required.

Mid-season sprays

Results from the plot trials on mid-season sprays of spinosad were disappointing. Little or no reduction in insect survival was observed, even when 7 (weekly) sprays were applied at a dose of 500 ml product (48% a.i.)/ha. There are a number of possible explanations for this:

1) The insecticide is ineffective against the target insect stage, which could be either the adult flies or newly-hatched larvae. Previous experiments using spinosad applied as a soil drench

have indicated that it is very effective against cabbage root fly larvae. In contrast, previous experiments have shown that spinosad alone is relatively ineffective against adult flies.

2) The spray treatments failed to reach the target. In the case of cabbage root fly larvae (the more susceptible target) it is vital that sufficient insecticide reaches the soil surface close to the base of the plant. Previous studies have highlighted this as a potential problem with the application of other active ingredients (Jukes *et al*, 2000).
3) Spinosad spray treatments are broken down rapidly by sunlight.
4) Spinosad in this form is bound rapidly and irreversibly to the soil surface and is therefore effectively deactivated.
5) The chosen dose was insufficient to control the cabbage root fly, particularly if any of the above points is a factor.

<u>Insecticide-treated baits</u>

Glasshouse trials with insecticide-treated baits (Jukes *et al,* 2001) showed that it is possible to increase the amount of insecticide acquired by adult onion flies and cabbage root flies using this method of application, thereby killing them. The present challenge is how to translate these effects to achieve effective cabbage root fly control in the field. The results of Experiment 2 have confirmed that a degree of cabbage root fly control can be achieved using sprays of bait treated with spinosad and a single cohort of flies was killed in sufficient numbers to reduce damage. However, these effects are obviously short-lived since the bait was no longer effective 2 weeks after treatment. With this in mind, it is not surprising that a single application of spinosad + bait to plots exposed to the natural population, and therefore continually re-invaded by flies, had no effect. Further research is needed to address the following issues:

1) Will sufficient female flies ingest the insecticide + bait and die before laying their eggs to reduce the overall numbers of eggs laid?
2) Is the crop foliage the most appropriate carrier for baits or can the cabbage root fly be killed at its normal feeding sites?
3) Is there the potential to improve the composition of baits (there could be a compromise between ensuring baits are attractive, but not making them so nutritious that only small amounts are imbibed)?
4) Are there more effective insecticides that are available currently and which are more toxic and therefore reduce the time between ingestion and dying?

In addition, the combination of chlorpyrifos + bait applied as a foliar spray may be worth considering for evaluation in field plots. It was shown to be similar in performance to spinosad in cage experiments in a glasshouse in 2001-2002, and aged residues were almost as effective as fresh ones (Jukes *et al.*, 2002).

At the total spray rate used in this trial (200l/ha), 100g a.i./ha of both active ingredients would be applied if all plants were sprayed. This dose could be reduced, as the critical consideration is the concentration of the liquid, not the overall dose. Hence reducing the spray volume or spraying intermittently would reduce the overall dose, which may be an important consideration if multiple applications need to be made.

<u>Insect deterrents/natural insecticides</u>

When considered as fly deterrents, the garlic products tested have performed poorly, both in the present trials and in previous trials (Jukes *et al*, 2002). However, there is a strong indication that a targeted soil application of the granular product is effective against cabbage root fly eggs and larvae. Insect numbers were reduced by almost 60% at the dose equivalent to the recommended field application rate (0.12g product/plant). However, it is important to remember that this experiment was done under glasshouse conditions, and that the garlic granules were fresh when the single cohort of cabbage root fly eggs was applied. In the field, plants would be exposed to egg laying over a period of several weeks and the efficacy of the garlic granules would be expected to decline with age. In addition, the garlic granules were applied and maintained under 'ideal' conditions, so that they were spread evenly around the plant and were neither too wet nor too dry. The insecticidal effects of garlic on cabbage root fly eggs/larvae were not translated to the field when the liquid formulation of ECOguard was used (Experiment 3), but it is reasonable to assume that similar application/control problems to those described above for spinosad sprays could have occurred. Also, there may well be some leaching of the product away from the critical zone in the soil surface, during wet weather conditions or irrigation.

<u>Carbamate granules</u>

Benfuracarb, like carbosulfan (Marshall 10G), does not have the same killing power against cabbage root fly larvae as carbofuran (Yaltox). In the single dose trial conducted here (3.5 g product/10 m) there was some evidence of a reduction in the numbers of cabbage root fly larvae present, but this was insufficient to reduce levels of root damage.

TECHNOLOGY TRANSFER

16 Oct 2002	HDC/HRI brassica event at HRI Kirton - talk by Rosemary Collier on cabbage root fly control.
April 2003	Article commissioned for June 2003 edition of HDC News

GLOSSARY

a.i.	active ingredient
mg	milligram or one-thousandth of a gram (g)
OP	organophosphorus
PVA	polyvinyl acetate – sticks the insecticide onto the seed coat
Unit	100,000 seeds

ACKNOWLEDGEMENTS

We thank the HDC for funding this work and the two project co-ordinators, Mr Ian Morrison of Kettle Produce Ltd, Fife and Mr Fred Tyler of Alphagrow Ltd, Lancashire, for the information they supplied and for the considerable enthusiasm and encouragement they provided throughout the project. We are also grateful to Dow Agrosciences who supplied us with samples of Tracer 480SC (spinosad) and ECOspray Limited, Swaffham, Norfolk, for the supply of ECOguard liquid and granular products.

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