FINAL REPORT

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

FV 242b

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Project title:	**Brassica crops: Evaluation of non-organophosphorus insecticides for controlling the cabbage root fly**
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Signed on behalf of: Warwick HRI

Signature:…………………………………………… ***Date***: …………………………….

Name: Professor Simon Bright
Director and Head of Department

GROWER SUMMARY

SCIENCE SECTION

GROWER SUMMARY

Headline

- When applied as a seed treatment to swede, spinosad and chlorpyrifos provided excellent control of cabbage root fly (2^{nd} generation) when the swedes were at the seedling stage. Spinosad continued to provide partial control of the 2^{nd} and 3^{rd} generations of the fly larvae, but chlorpyrifos was less effective as the swedes grew.
- Dual compound granules supplied by Syngenta provided no control of cabbage root fly but excellent control of flea beetles. Certis Exp 60818 A granules were tested, but the specified dose was insufficient to control cabbage root fly.
- Spinosad solutions can be applied in-furrow at sowing and some control of cabbage root fly was observed. The potential dose rates available to growers are unlikely to be high enough to provide sufficient protection, but it did prove to be more effective than applying the same dose to the growing crop (previous year's work).
- Drench treatments with spinosad were the most effective tested, and better than chlorpyrifos at the same dose. The insect growth regulators teflubenzuron and diflubenzuron were partially effective, but cyromazine failed to control the larvae at all.
- Although there are a number of potential treatments for control of cabbage root fly on leafy brassicas, no completely effective method of controlling cabbage root fly on established crops of swede has been identified. The key question is 'how can the soil-active insecticides identified be applied so that they are in the right location to protect long-season crops such as swede'?

Background and expected deliverables

Brassica crops are grown currently on approximately 30,000 ha in the UK and the marketed value of these crops is about £166M/annum [*Basic Horticultural Statistics for the United Kingdom. Calendar and Crop Years 1993-2003. 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; carbosulfan (Marshall) and chlorpyrifos (Dursban), for cabbage root fly control on leafy brassica crops in the UK. Since 31 December 2003, no product has been available to control the cabbage root fly on swede and turnip, 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 persistence of spinosad applied as a seed treatment for control of second and third generation cabbage root fly.
- An evaluation of the field performance of novel insecticide granules against the second generation of the cabbage root fly.
- An indication of the effectiveness of in-furrow application of spinosad solutions at drilling.
- An evaluation of the performance of spinosad, diflubenzuron, teflubenzuron and cyromazine when drenched onto modules pre-planting.

Summary of the project and main conclusions

Four experiments were done in 2004 using six insecticides (Tracer (spinosad), Dimilin (diflubenzuron), Dursban (chlorpyrifos), Triguard (cyromazine), Nemolt (teflubenzuron), Certis Exp 60818 A and a Syngenta granule (Syngenta)).

Experiments were done to answer the following questions:

1. What dose of spinosad is required to ensure that seed treatments persist sufficiently to control at least one generation of cabbage root fly?
2. Can novel insecticide granules be used to control cabbage root fly on swede?
3. Can in-furrow sprays of spinosad be used to control cabbage root fly on swede?
4. How effective are drench treatments (cyromazine, diflubenzuron, teflubenzuron, spinosad and chlorpyrifos) at controlling cabbage root fly on leafy brassicas in the field?

Main conclusions

- When applied as a seed treatment to swede, spinosad provided partial control of two generations of cabbage root fly larvae and reduced seedling losses. Chlorpyrifos reduced seedling losses but offered no subsequent protection.
- Dual compound granules supplied by Syngenta provided no control of cabbage root fly but excellent control of flea beetles. Certis Exp 60818 A granules were tested, but the dose specified was insufficient to control cabbage root fly.
- Spinosad solutions can be applied in-furrow at sowing and some control of cabbage root fly was observed. The potential dose rates available to growers are unlikely to be high enough to provide sufficient protection, but it did prove to be more effective than applying the same dose to the growing crop (previous year's work).
- Drench treatments with spinosad were the most effective tested and were better than chlorpyrifos at the same dose. The insect growth regulators teflubenzuron and diflubenzuron were partially effective, but cyromazine provided no long term control. At harvest, all of the treated curds were at least as big as the untreated curds.

The aim of this project is to evaluate novel insecticides and with the exception of chlorpyrifos, none of the insecticides evaluated is approved currently for cabbage root fly control.

Seed treatments (field experiment -swede)

- **Spinosad** — This naturally derived chemical can persist over two fly generations but the doses tested were insufficient to provide economic control of cabbage root fly larvae up to harvest. Excellent control was observed when the plants were at the seedling stage.
- **Chlorpyrifos** — The dose used successfully to protect transplanted leafy brassicas is insufficient for control of cabbage root fly throughout the season, but, as with spinosad, excellent control was achieved when the plants were at the seedling stage.

Granular treatments (field experiment –swede)

- **Syngenta granule** — This dual compound granule appeared to increase larval survival and therefore root damage, compared to the untreated plants. However it provided good flea beetle control, increasing plant growth rates in the early part of the season.
- **Certis Exp 60818 A** — Has been shown to be an effective compound for the control of cabbage root fly larvae, but in this trial the dose was insufficient to have an effect.

In-furrow treatments (field experiment - swede)

- **Spinosad** — The application of spinosad to the seed furrow at drilling was almost certainly a more effective method of application than mid-season sprays to the foliage but the doses tested did not provide economic control of the cabbage root fly larvae.

Module drench treatments (field experiment – cauliflower)

- **Chlorpyrifos** — The standard treatment was little better than the control
- **Diflubenzuron** — Was more effective than the standard treatment
- **Teflubenzuron** — Was more effective than the standard treatment
- **Cyromazine** — Was the least effective treatment tested and probably does not warrant further investigation
- **Spinosad** — Was the best treatment tested and more effective than the standard treatment

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.
- There are currently no financial benefits arising from this work as we are awaiting pesticide approval of the products tested.

Action points for growers

There are no action points for growers, however the relevant agro-chemical companies should be actioned to seek pesticide approvals for the most promising treatments.

SCIENCE SECTION

Introduction
The work during this one-year project was "short-term", and was concerned with finding possible replacements for the OP-based treatments applied currently and quantifying the efficacy of different methods of application. The project involved field trials only and was developed from results of the 2003 trials conducted at Warwick HRI.

Experiments were done to answer the following four questions:

1. Film-coated seed
What dose of spinosad is required to ensure that seed treatments persist sufficiently to control at least one generation of cabbage root fly?
2. Insecticide granules
Can novel insecticide granules be used to control cabbage root fly on swede?
3. In-furrow treatment
Can in-furrow sprays of spinosad be used to control cabbage root fly on swede?
4. Pre-planting drench treatments
How effective are drench treatments (cyromazine, diflubenzuron, teflubenzuron, spinosad and chlorpyrifos) at controlling cabbage root fly on leafy brassicas in the field?

The four 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: cyromazine (Triguard), spinosad (Tracer), teflubenzuron (Nemolt), chlorpyrifos (Dursban), diflubenzuron (Dimilin), Certis Exp 60818 A and a Syngenta granule (dual insecticide granule from Syngenta)

Experiment 1.

What dose of spinosad is required to ensure that seed treatments persist sufficiently to control at least one generation of cabbage root fly?

Materials and methods

a) Seed treatment
Swede (cv Helenor) seeds were film-coated with spinosad (Tracer 480SC) at target loadings of 125 and 150 g a.i./unit (1 unit = 100,000 seeds). A PVA sticker, at the rate of 2% of product weight, was applied with the treatment. The seeds were film-coated at HRI Wellesbourne and a further batch of seed was left insecticide-free. Two other treated swede seed batches were supplied by Elsoms seeds. These were spinosad at 96 g a.i./unit and chlorpyrifos at 9.6 g a.i./unit (the standard rate for leafy brassicas). All of the treatments are listed in Table 1.

b) Field experiment

Six (1.83 m wide x 34 m long) seedbeds were prepared in the experimental area (Sheep Pens field) at Warwick HRI Wellesbourne. On 1 July, the inner four seedbeds were divided into five, 6 m long, plots (with 1 m between plots) to give a total of 20 plots. Each plot was assigned a treatment using an incomplete Latin square design. The plots were drilled with the appropriate seed batch on 1 July, using a tractor mounted Stanhay Singulaire seed drill. All of the plots were drilled at 13 seeds/m row, 4 rows/bed and with 38 cm between rows. The outer two (Guard) beds were drilled with untreated seed.

The intention was to assess the efficacy of each treatment against a single generation of the cabbage root fly (either the second or third generation). Therefore, on 6 July (when the seedlings had just started to emerge, one half (3 m) of each plot was covered with Envirofleece® to exclude second generation cabbage root fly, whilst the other half of the plot was left exposed, but covered subsequently to exclude the third generation. On 9, 16, 23, 30 July and 6 August seedling survival was assessed by counting the numbers of seedlings in a marked 2 m portion of each row. Then, on 13 August, after the end of second generation (indicated by monitoring cabbage root fly egg laying in a nearby plot), the fleece was removed from the covered areas to allow third generation flies access to the swedes. This fleece was then used to cover the areas that had been exposed to the second generation.

On 16 September, six plants were sampled from each of the plots that had been exposed to second generation cabbage root fly. A 15 cm diameter x 15 cm deep soil core was taken from around the roots of each plant. In addition, approximately 50 roots were harvested from each of the plots. Cabbage root fly larvae and 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 mean root damage index was calculated based on the damage to each root, which was scored on a scale from 0 (no damage) to 4 (>50% damage).

On 4 November, when all of the cabbage root fly larvae had formed pupae, the plots that had been exposed to the third generation were sampled as described above. The mean root damage index was calculated based on the damage to each root, which was scored on a scale from 0 (no damage) to 4 (>50% damage).

Additionally, on 5 August, flea beetle damage was assessed by counting the numbers of holes in the foliage of 10 plants (five from each of the middle two rows of the uncovered areas) of each plot.

The seedling counts were subjected to Analysis of Variance. Seedling survival between July and August was analysed using GLM analysis assuming a binomial distribution and a logit link function. The mean numbers of cabbage root flies recovered from the soil samples, the mean root weight and the mean root damage index were subjected to Analysis of Variance. The insect counts were log transformed prior to analysis.

To provide background information, cabbage root fly activity was monitored in a small plot of cauliflower near to the main experimental plots. Soil samples were taken from 20 plants twice a week from April until October 2004.

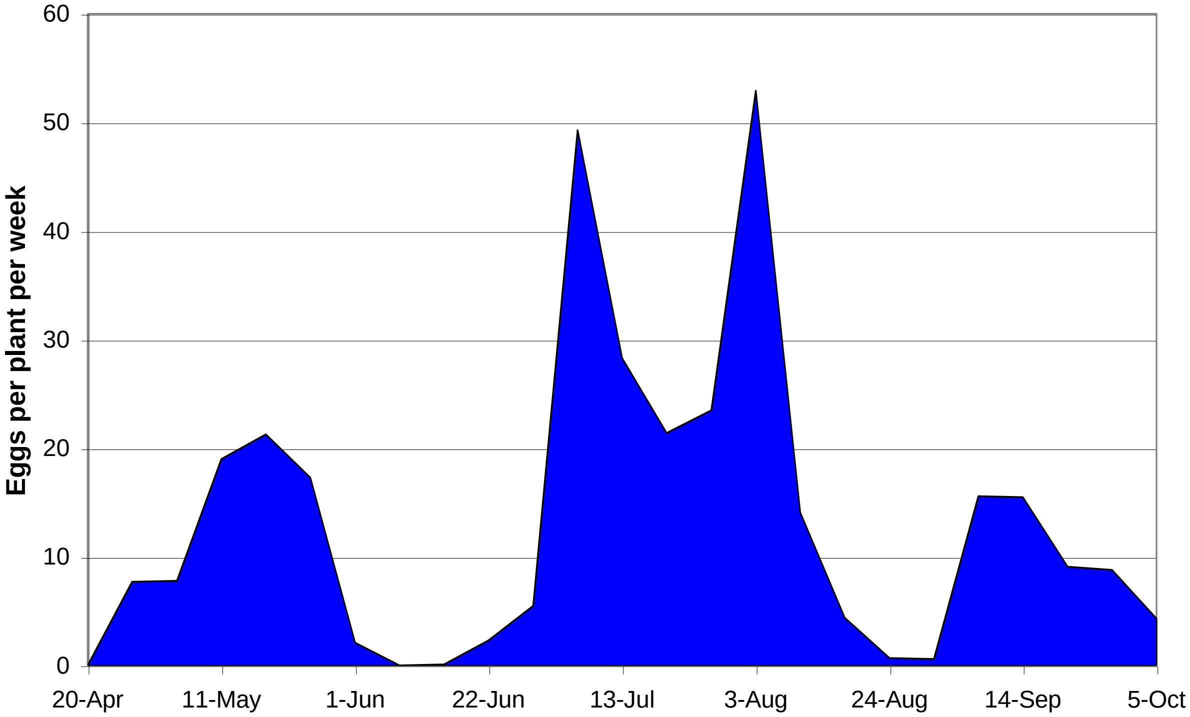
Table 1. Seed treatments: Insecticides and doses.

Treatment code	Treatment	Dose (g a.i./unit)
A	Untreated	
B	Chlorpyrifos	9.6
C	Spinosad	96
D	Spinosad	125
E	Spinosad	150

Results

Cabbage root fly activity: The numbers of eggs laid on cauliflower plants in the nearby monitoring plot, are shown in Figure 1. The second fly generation started in early July, soon after drilling, and the third generation in early September.

Figure 1. Cabbage root fly monitoring data – mean number of eggs/plant/week.



The spinosad and chlorpyrifos seed treatments increased seedling survival during the second generation of cabbage root fly (Figure 2). Statistically significant differences between the insecticide-free and insecticide-treated plots were evident for all sampling dates ($p=0.05$). The results of the analysis for the seedling counts at the last sampling date as a proportion of the maximum seedling count over all dates indicated there was a statistically significant difference between the insecticide-free plots and the insecticide treatments (Figure 3).

Figure 2. The effect of seed treatment on survival of swede seedlings after exposure to 2nd generation cabbage root fly.

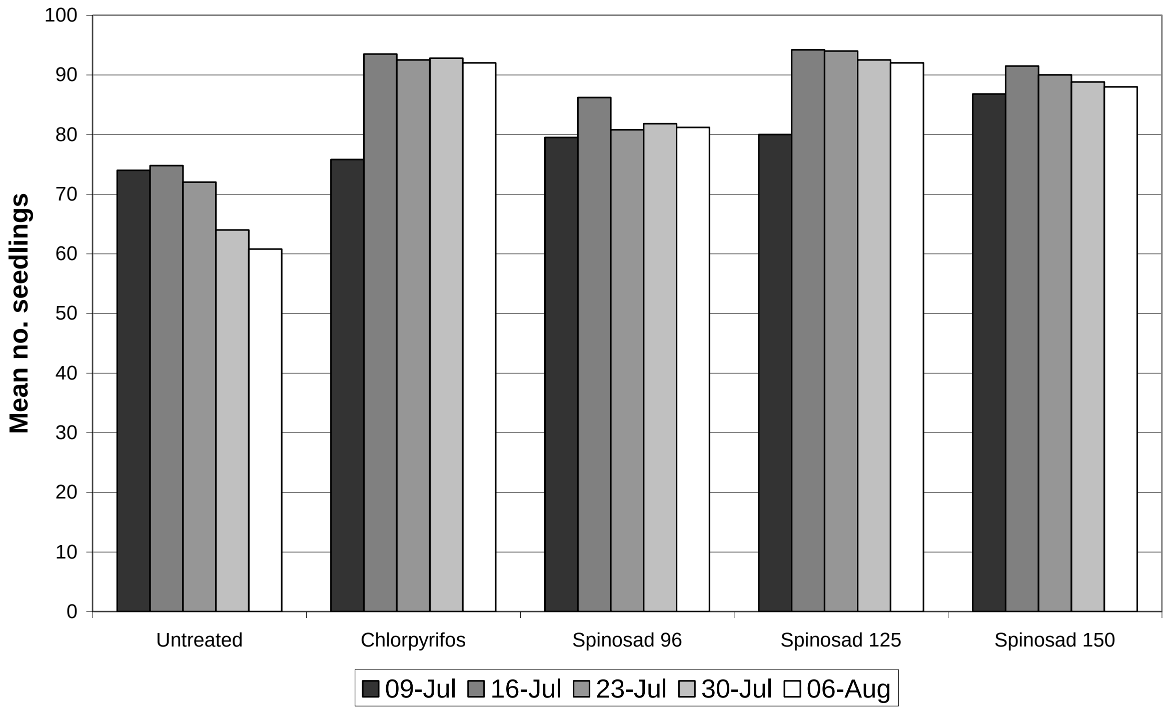
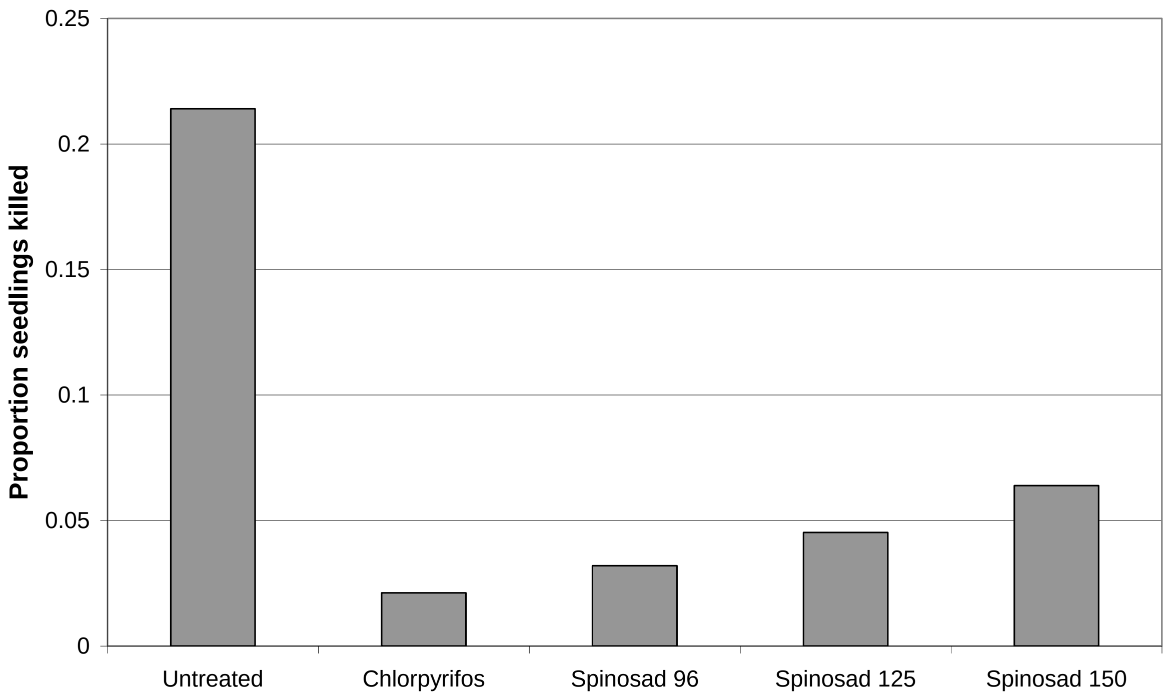
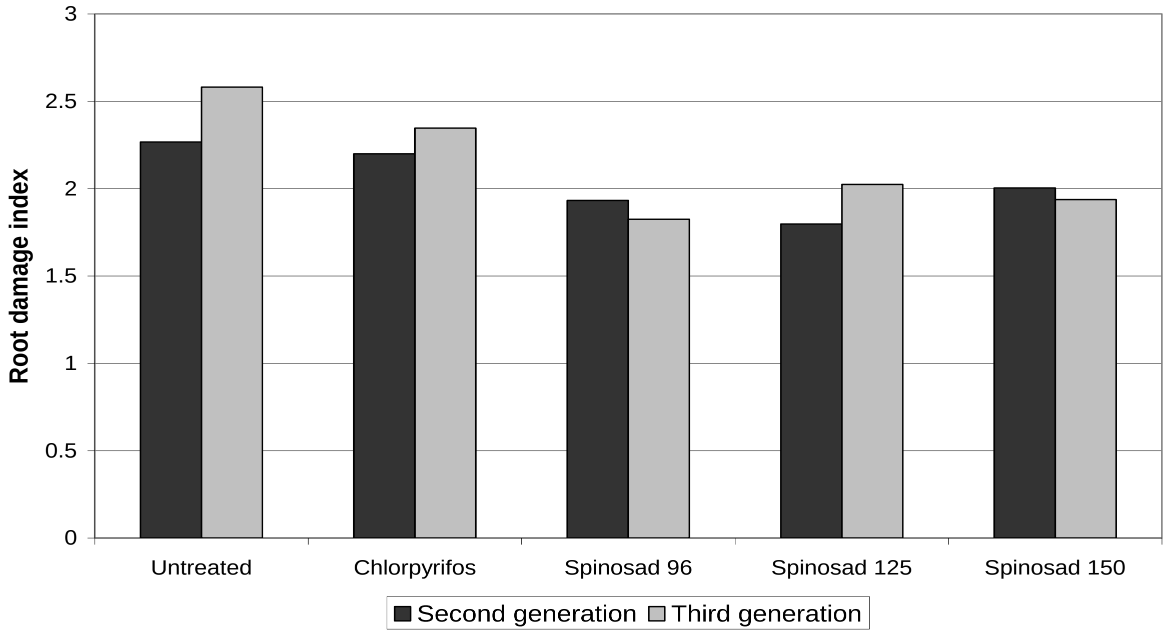


Figure 3. The effect of seed treatment on the proportion of swede seedlings killed by 6 August after exposure to 2nd generation cabbage root fly



There was a statistically significant effect of treatment on the root damage index (p= 0.002). The insecticide-free roots and the roots treated with chlorpyrifos were more damaged than those treated with spinosad (p=0.05) (Figure 4). However, no significant difference between the two generations was evident (p-value = 0.175) and there was also no evidence of an interaction between the treatments and the generations (p-value = 0.316).

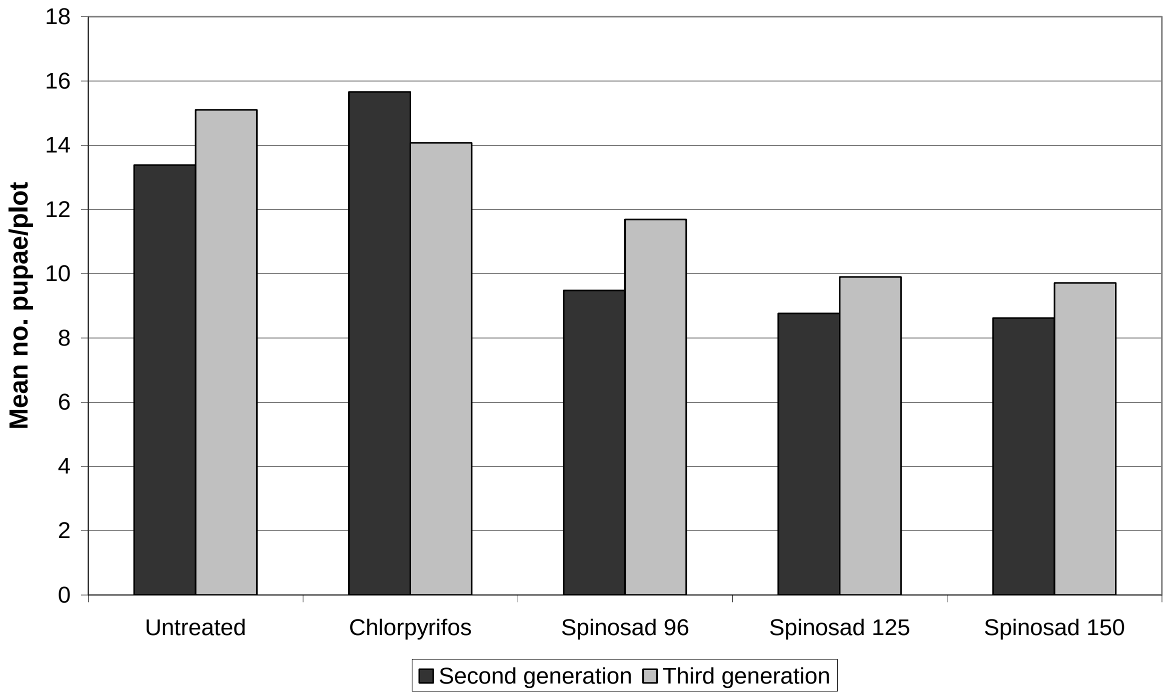
Figure 4. The effect of seed treatment on the root damage index of swede plants after exposure to 2nd or 3rd generation cabbage root fly



There were no significant differences in the total pupal counts for the five treatments (p-value = 0.564), nor between the two generations (p-value = 0.469) (Figure 5). The interaction between the main treatments and the generations was also not significant (p-value = 0.237).

There was no evidence of flea beetle control with any of the treatments.

Figure 5. The effect of seed treatment on the numbers of pupae recovered from swede plants after exposure to 2nd or 3rd generation cabbage root fly (back-transformed means).



Experiment 2.

Can novel insecticide granules be used to control cabbage root fly on swede?

Materials and methods

The linear doses required were calculated (Table 2) based on recommendations from the manufacturers and the amounts of granules required for 5 m of row were weighed out into glass tubes (16 tubes/treatment).

Table 2. Granule treatments: Insecticides and doses.

Treatment code	Treatment	Dose	
		kg product/ha	g product/m row
A	Untreated		
B	Syngenta granule	8	0.366
C	Syngenta granule	16	0.732
D	Syngenta granule	32	1.464
E	Certis Exp 60818 A	5	0.229

Six (1.83 m wide x 45 m long) seedbeds were prepared in the experimental area (Sheep Pens field) at Warwick HRI Wellesbourne. On 5 July, the inner four seedbeds were divided into five, 5 m long, plots (with 5 m between plots) to give a total of 20 plots. The granule applicator used is a custom built device with the granules being carried on a continuously rotating belt. The belt is driven by the land wheels on the seed drill unit mounted on the tractor and the granules are delivered to the soil surface just before the coulter on the seed box. The granule applicator was calibrated using dummy granules on a prepared seed bed away from the experimental area. Each plot was assigned a treatment using an incomplete Latin square design. The plots were drilled with the appropriate treatment on 5 July, using the tractor mounted Stanhay seed drill unit with attached granule applicator. All of the plots were drilled at 13 seeds/m row, 4 rows/bed and with 38 cm between rows. The outer two (Guard) beds were drilled with untreated seed.

On 13, 20, 27 July and 3, 10 August seedling survival was assessed by counting the numbers of seedlings in a marked 2 m portion of each row.

On 15 September, six plants were sampled from each of the plots that had been exposed to second generation cabbage root fly. A 15 cm diameter x 15 cm deep soil core was taken from around the roots of each plant. In addition, approximately 50 roots were harvested from each of the plots. Cabbage root fly larvae and 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 mean root damage index was calculated based on the damage to each root, which was scored on a scale from 0 (no damage) to 4 (>50% damage).

Additionally, on 30 July, flea beetle damage was assessed by counting the numbers of holes in the foliage of 10 plants (five from each of the middle two rows of the uncovered areas) of each plot.

The seedling counts were subjected to Analysis of Variance. Seedling survival between July and August was analysed using GLM analysis assuming a binomial distribution and a logit link function. The mean numbers of cabbage root flies recovered from the soil samples, the mean root weight and the mean root damage index were subjected to Analysis of Variance.

To provide background information, cabbage root fly activity was monitored in a small plot of cauliflower near to the main experimental plots. Soil samples were taken from 20 plants twice a week from April until October 2004 (see Figure 1 above).

Results

The seedling count data are summarised in Figure 6. Statistically significant differences are apparent for all sampling dates and mean seedling counts were higher in the Syngenta granule 16 and 32 treatments than in the insecticide-free control (p=0.05). The results of an analysis of the proportion of seedlings at the last sampling date (in August) compared with the maximum number of seedlings recorded at any time suggest there was a significant difference between the untreated control plots and the Syngenta granule treatment at rate 32 (p-value = 0.005) (Figure 7). No other significant differences were evident.

Figure 6. The effect of granule treatment on survival of swede seedlings after exposure to 2nd generation cabbage root fly

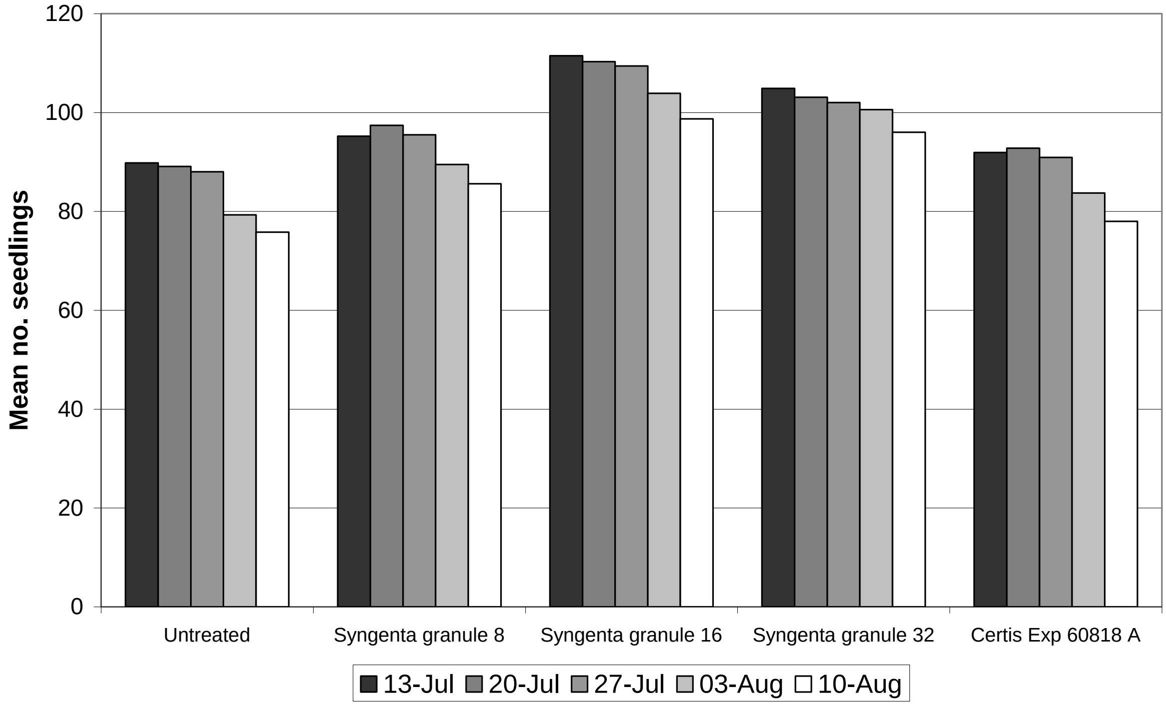
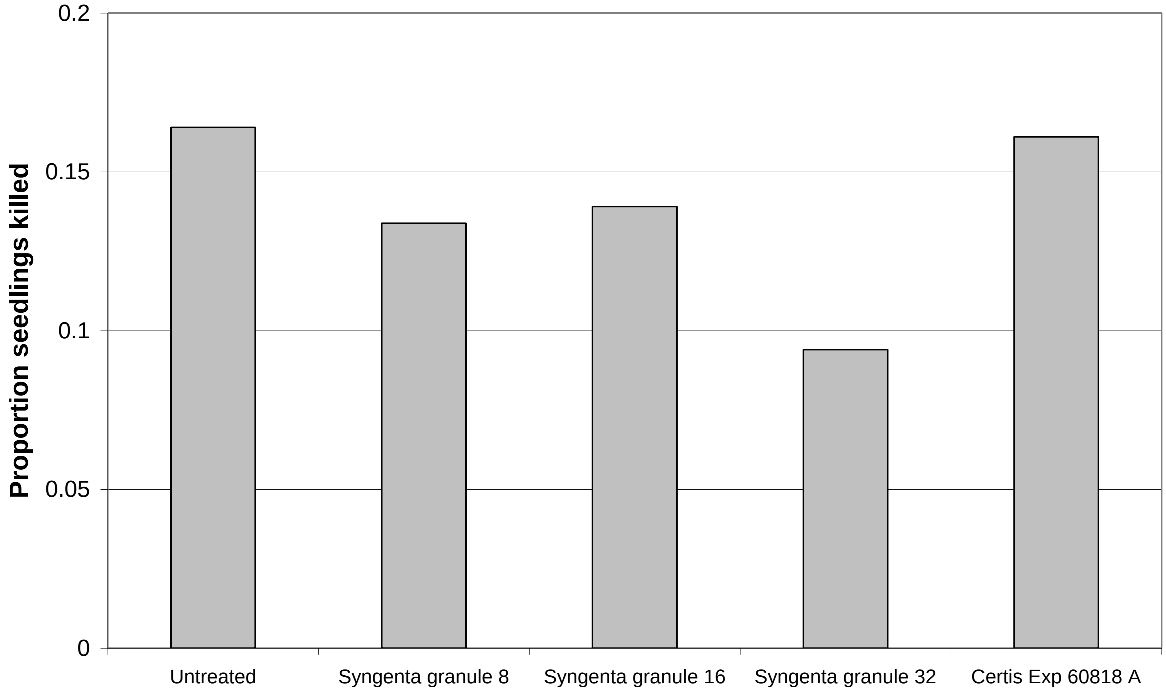
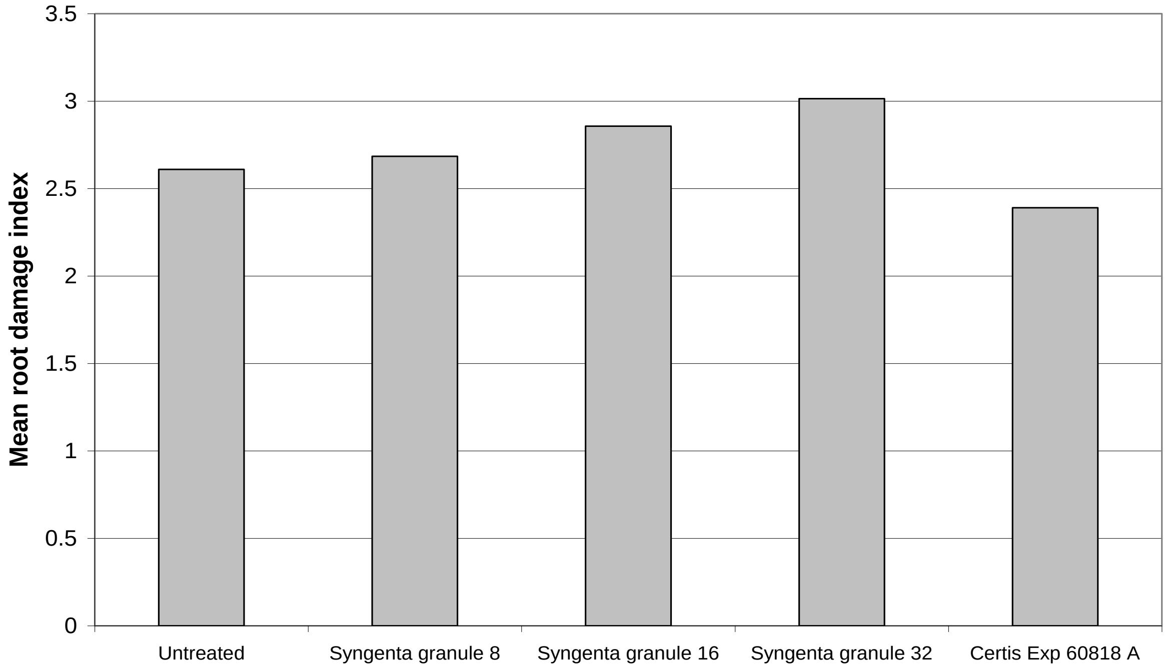


Figure 7. The effect of granule treatment on the proportion of swede seedlings killed by 10 August after exposure to 2nd generation cabbage root fly



There were significant differences in the root damage index between the treatments (p-value = 0.016). The Syngenta granule 32 treatment increased the root damage index compared with the insecticide-free control (p=0.05) (Figure 8).

Figure 8. The effect of granule treatments on the root damage index of swede plants after exposure to 2nd generation cabbage root fly



The Syngenta granule treatments increased the numbers of pupae recovered from around the swede plants compared with the insecticide-free control and Certis Exp 60818 A granules (p=0.002). There was evidence of a dose response effect with the Syngenta granules (Fig. 9).

There was a large variation in the average number of flea beetle feeding holes between plots of the same treatment. The most obvious case of this was for treatment Certis Exp 60618 A where plot 1 had an average count of 230.5, which was nearly twice as large as the other three plot averages for this treatment. Analysis of Variance was conducted with this data point kept in the analysis and also with it removed. The overall conclusion in terms of treatment differences remained the same. The results of the analysis showed that the treatments formed two groups, which were significantly different from each other. The control treatment and Certis Exp 60618 A formed one group, while Syngenta granules 8, 16 and 32 formed the second group. The overall p-value associated with the F-test for treatment differences in both analyses was <0.001.

Figure 9. The effect of granule treatments on the mean number of pupae recovered from swede plants after exposure to 2nd generation cabbage root fly

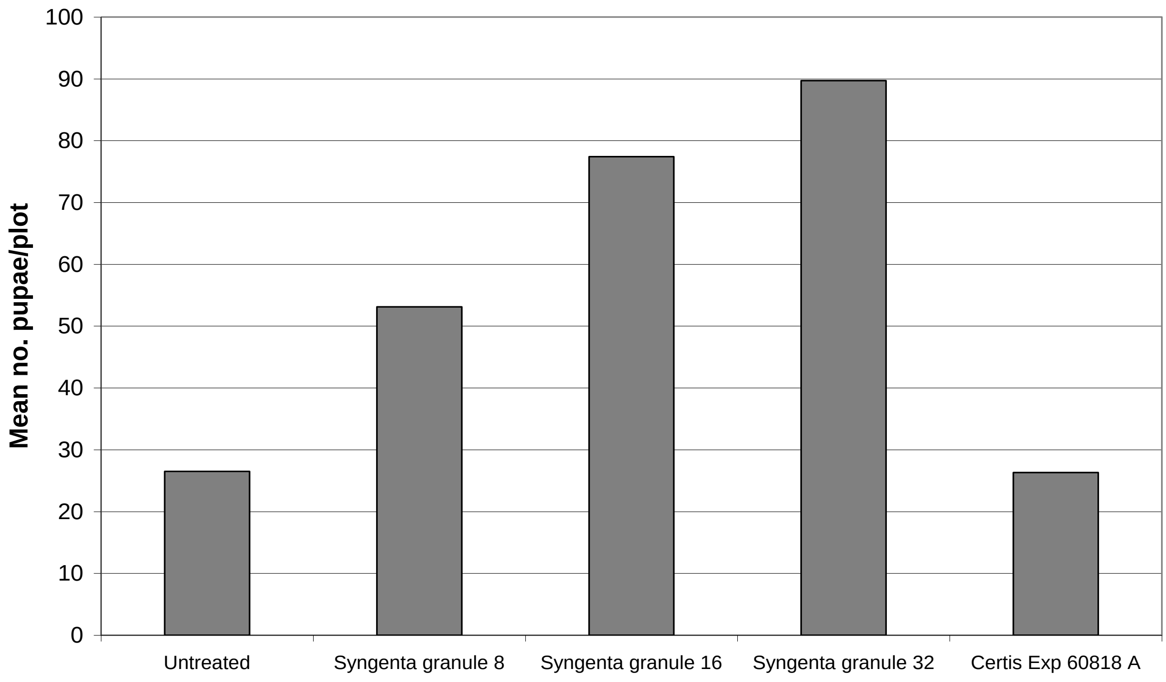
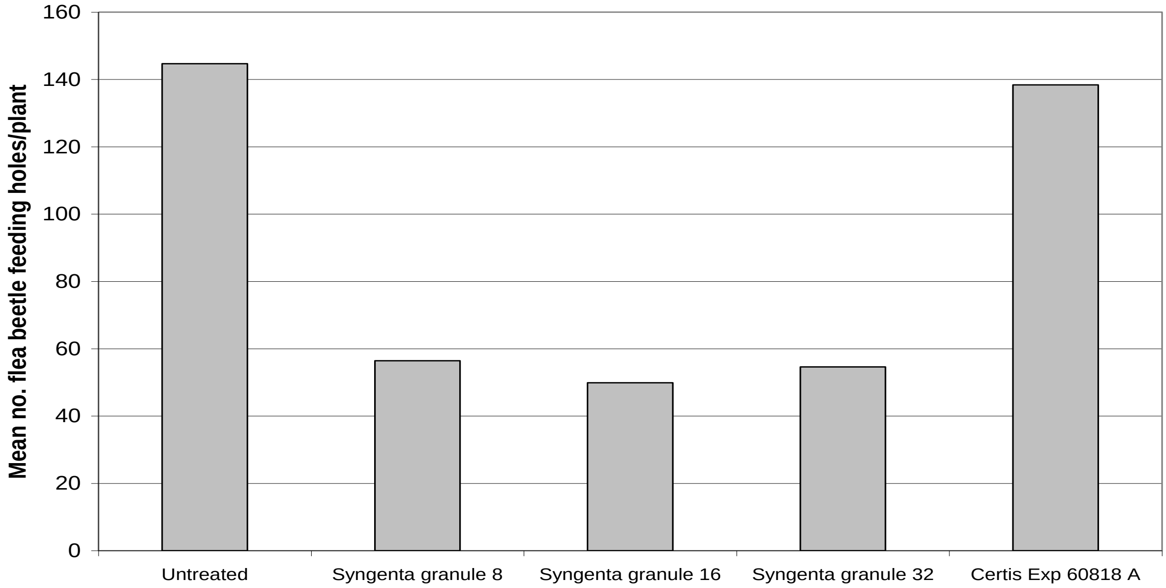


Figure 10. The mean numbers of feeding holes per plant caused by flea beetle feeding on swede foliage.



Experiment 3.

Can in-furrow sprays of spinosad be used to control cabbage root fly on swede?

Materials and methods

The in-furrow liquid applicator used is a custom built device with the liquid being carried in a reservoir mounted on the seed drill. The liquid is delivered using a peristaltic pump driven by the land wheels on the seed drill unit mounted on the tractor. The liquid is delivered to the seed furrow just after the coulter on the seed box. On 2 July the delivery rate from the pump was measured as 1798 ml/100m row.

The linear doses required were calculated (Table 3) based on the recommended rate of 200 ml product/ha. The amount of product needed to treat all five replicate plots (100 m row) plus 50% extra to prime the pump was measured into sealed plastic containers and made up to 2697 ml (1798 ml x 1.5) to give the correct dose at the measured delivery rate.

Table 3. In-furrow treatments: Insecticides and doses.

		Dose	
Treatment code	Treatment	ml product/ha	ml product/plot (20 m row)
A	Untreated		
B	Spinosad	100	0.092
C	Spinosad	200	0.183
D	Spinosad	400	0.366

Seven (1.83 m wide x 23 m long) seedbeds were prepared in the experimental area (Sheep Pens field) at Warwick HRI Wellesbourne. On 5 July, the inner five seedbeds were divided into four, 5 m long, plots (with 5 m between plots) to give a total of 20 plots. Each plot was assigned a treatment using an extended Latin square design. The plots were drilled with the appropriate treatment on 5 July using the tractor mounted Stanhay seed drill unit with attached in-furrow applicator. All of the plots were drilled at 13 seeds/m row, 4 rows/bed and with 38 cm between rows. The outer two (Guard) beds were drilled with untreated seed.

On 13, 20, 27 July and 3, 10 August seedling survival was assessed by counting the numbers of seedlings in a marked 2 m portion of each row.

On 15 September, six plants were sampled from each of the plots that had been exposed to second generation cabbage root fly. A 15 cm diameter x 15 cm deep soil core was taken from around the roots of each plant. In addition, approximately 50 roots were harvested from each of the plots. Cabbage root fly larvae and 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 mean root damage index was calculated based on the damage to each root, which was scored on a scale from 0 (no damage) to 4 (>50% damage).

Additionally, on 30 July, flea beetle damage was assessed by counting the numbers of holes in the foliage of 10 plants (five from each of the middle two rows of the uncovered areas) of each plot.

The seedling counts were subjected to Analysis of Variance. Seedling survival between July and August was analysed using GLM analysis assuming a binomial distribution and a logit link function. The mean numbers of cabbage root flies recovered from the soil samples, the mean root weight and the mean root damage index were subjected to Analysis of Variance. The insect counts were square root transformed prior to analysis.

To provide background information, cabbage root fly activity was monitored in a small plot of cauliflower near to the main experimental plots. Soil samples were taken from 20 plants twice a week from April until October 2004 (see Figure 1 above).

<u>Results</u>

The seedling count data are summarised in Figure 11. Differences between the insecticide-free control treatment and the two higher rates of spinosad are evident for 13 July, 3 August and 10 August (p=0.05). The results of an analysis of the proportion of seedlings at the last sampling date compared with the maximum number of seedlings recorded at any time suggest there was no significant difference between treatments in seedling survival between July and August (Figure 12).

The damage to roots caused by second generation cabbage root fly did not appear to be affected by treatment (p-value = 0.312) (Figure 13).

Figure 11. The effect of in-furrow liquid treatment on the number of swede seedlings after exposure to 2nd generation cabbage root fly.

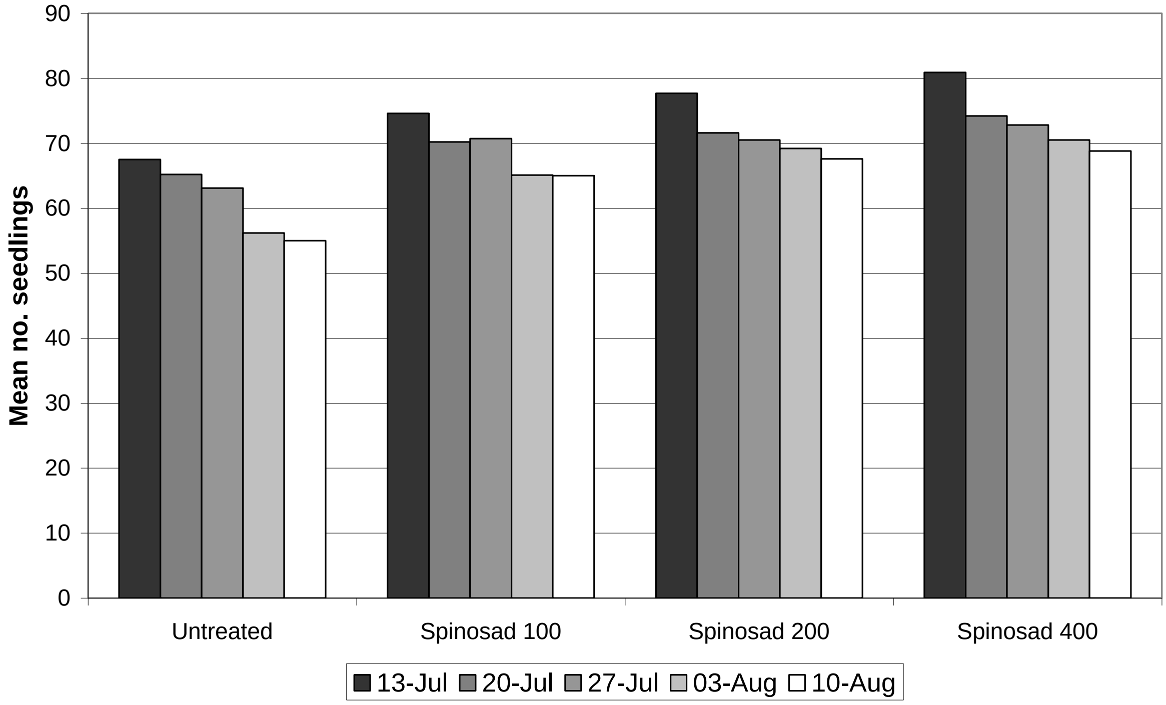


Figure 12. The effect of in-furrow liquid treatments on the proportion of swede seedlings killed by 10 August after exposure to 2nd generation cabbage root fly

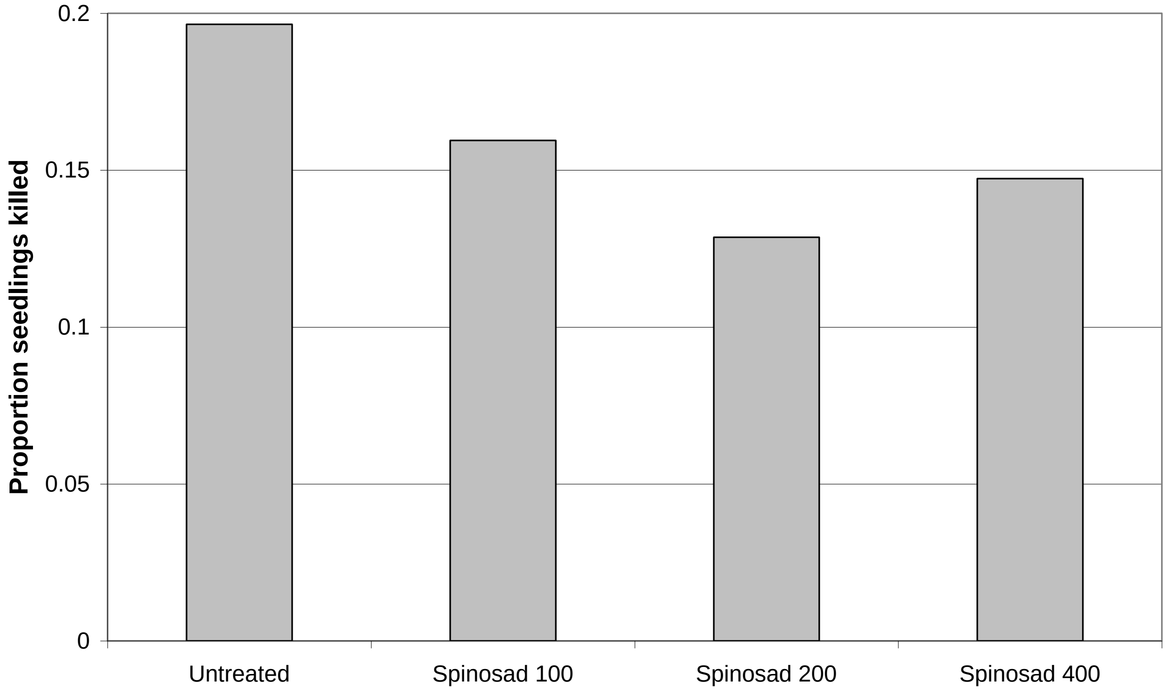
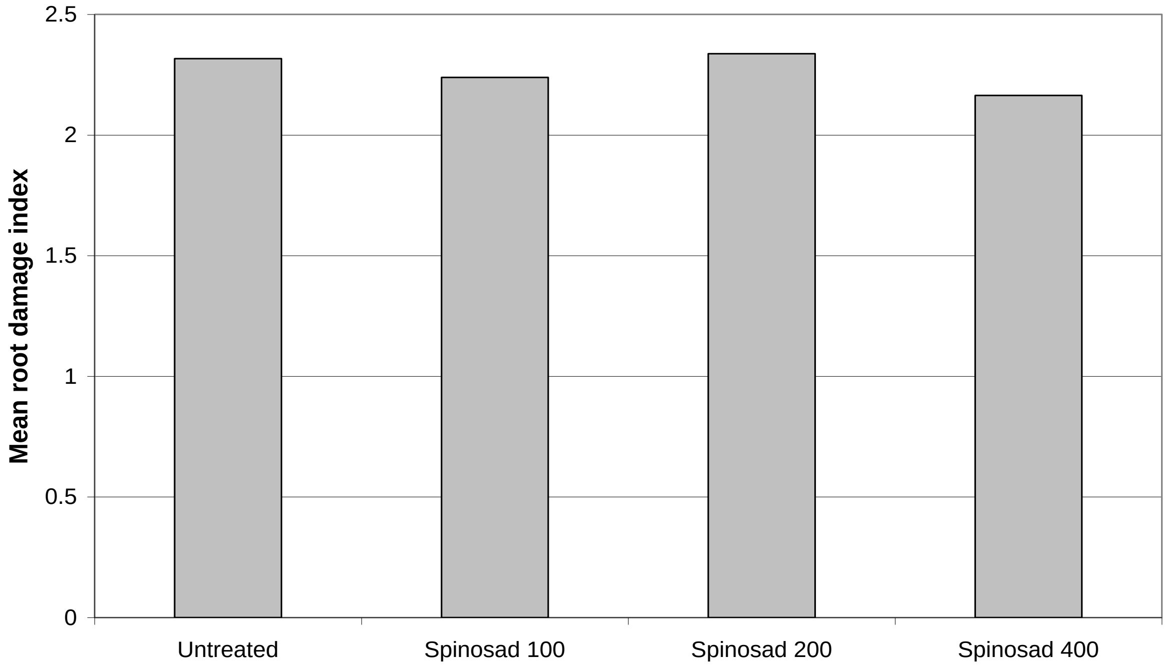
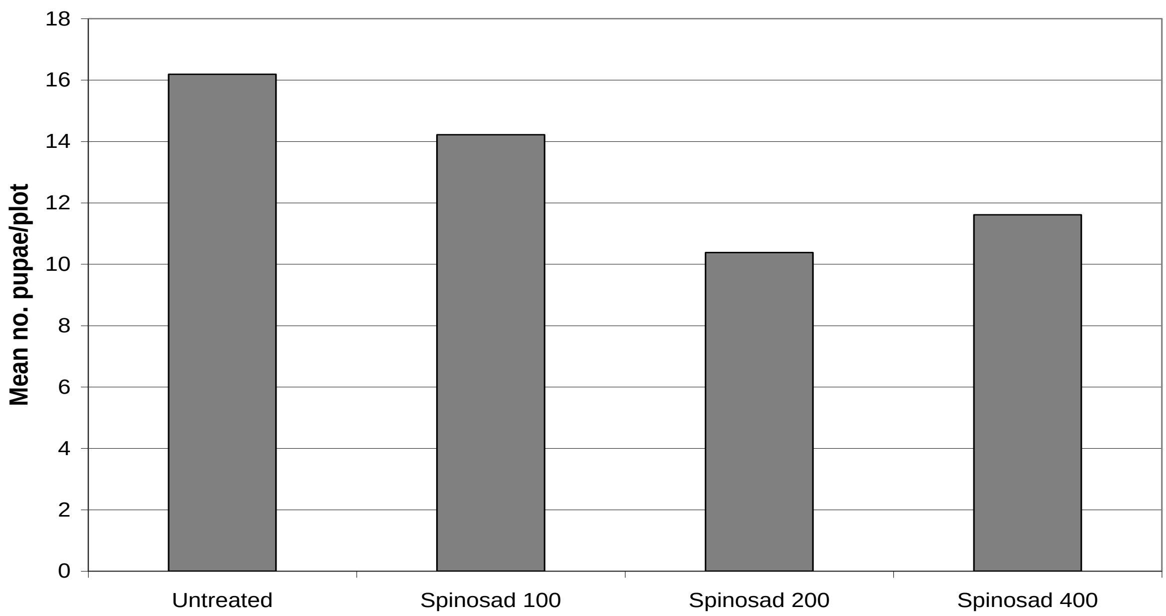


Figure 13. The effect of in-furrow liquid treatments on the root damage index of swede plants after exposure to 2nd generation cabbage root fly



The pupal counts required a square root transformation to improve the constant variance assumption and the analysis showed there was no significant difference between the total number of pupae recovered from the four treatments (p-value = 0.725) (Figure 14). There was no evidence of flea beetle control due to any of the treatments.

Figure 14. The effect of in-furrow liquid treatments on the mean numbers of pupae recovered from swede plants after exposure to 2nd generation cabbage root fly (back-transformed means).



Experiment 4.

How effective are drench treatments (cyromazine, diflubenzuron, teflubenzuron, spinosad and chlorpyrifos) at controlling cabbage root fly on leafy brassicas in the field?

<u>Materials and methods</u>

Five insecticides (Table 4) were evaluated as drench treatments. On 27 May, untreated cauliflower seed (cv Skywalker) was sown in 308 Hassy trays containing Levington compost. On 5 July, 5 sets of 56 plants (4 rows of modules) were transferred to clean Hassy trays. Each set of plants was treated with one of the five test insecticides at 5 mg a.i./plant (the recommended dose for Dursban 4). The process was repeated for each of the five test insecticides. Each treatment was applied by adding 1 ml of a solution in water using a laboratory pipette to each module. In each case, the insecticide solution was washed into the peat with a similar volume of clean water, immediately after the insecticide had been applied. One Hassy tray was left untreated.

Table 4. Pre-planting drench treatments: Insecticides and doses.

Treatment code	Active ingredient	Product	Dose	
			mg a.i./plant	Product/100 plants
A	Untreated			
B	Cyromazine	Triguard	5	0.67 g
C	Teflubenzuron	Nemolt	5	3.33 ml
D	Chlorpyrifos	Dursban 4	5	1.04 ml
E	Spinosad	Tracer	5	1.04 ml
F	Diflubenzuron	Dimilin Flo	5	1.04 ml

An (11 m wide x 26 m long) area was prepared in the experimental field (Sheep Pens) at Warwick HRI Wellesbourne. On 7 July, the area was divided into 24, 2.5 m wide by 4 m long, plots. Each plot was assigned a treatment using an extended Trojan square design. On 7 July, 2 days after application of the insecticide treatments, 40 plants from each treatment were transplanted into each of 4 replicate plots at 50 cm spacing. On 21 July the plants were inspected for phytotoxic effects of the insecticide treatments

On 15 September, six plants were sampled from each of the plots that had been exposed to second generation cabbage root fly. A 15 cm diameter x 15 cm deep soil core was taken from around the roots of each plant. Cabbage root fly larvae and pupae were extracted from the soil samples by flotation in water and the numbers of pupae recovered were counted.

On 27 October, when most of the cauliflowers had formed curds, the curds were measured. On the following day (28 October) a further sample of six roots was taken from each plot. The roots were washed, weighed and scored for cabbage root fly damage. The mean root damage index was calculated based on the damage to each root, which was scored on a scale from 0 (no damage) to 4 (>50% damage).

All of the data were subjected to Analysis of Variance.

Results

There were no significant phytotoxic effects due to any of the treatments (p=0.403). The spinosad treatment reduced the numbers of cabbage root fly pupae compared with the insecticide-free control (p=0.05) (Figure 15).

There was no significant difference in the level of stem damage for the six treatments (p-value = 0.670) (Figure 16). For the amount of root damage, the p-value was 0.063 which suggests there were marginally significant differences between the treatments. Roots treated with spinosad were less damaged than those from the insecticide-free control or from the plots treated with cyromazine or chlorpyrifos (p=0.05) (Figure 17).

At harvest, all of the treated curds were at least as big as the untreated curds. When the mean diameters of curds from the six treatments were compared, the p-value for the overall F-test was 0.010, suggesting that there were statistically significant differences between the treatments. Curds from plants treated with cyromazine, teflubenzuron or spinosad had larger diameters than those from the insecticide-free control plots (p=0.05) (Figure 18).

Figure 15. The effect of pre-planting drench treatments on the numbers of pupae recovered from cauliflower plants after exposure to 2nd generation cabbage root fly

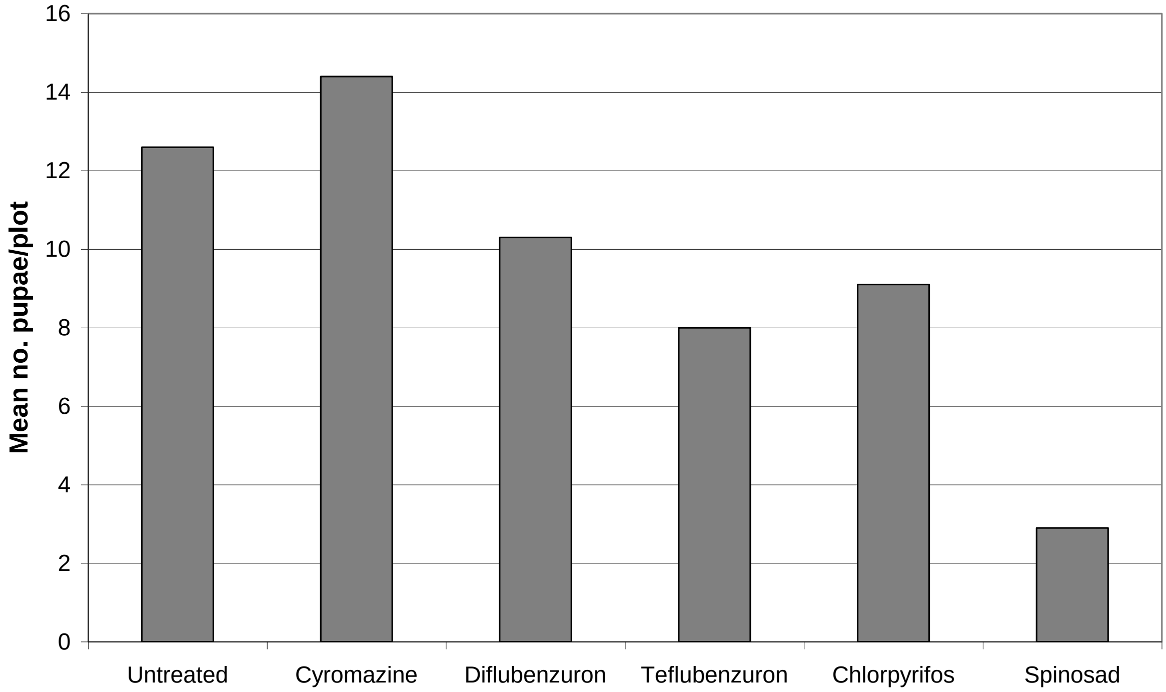


Figure 16. The effect of pre-planting drench treatments on the stem damage index of cauliflower plants after exposure to 2nd and 3rd generation cabbage root fly

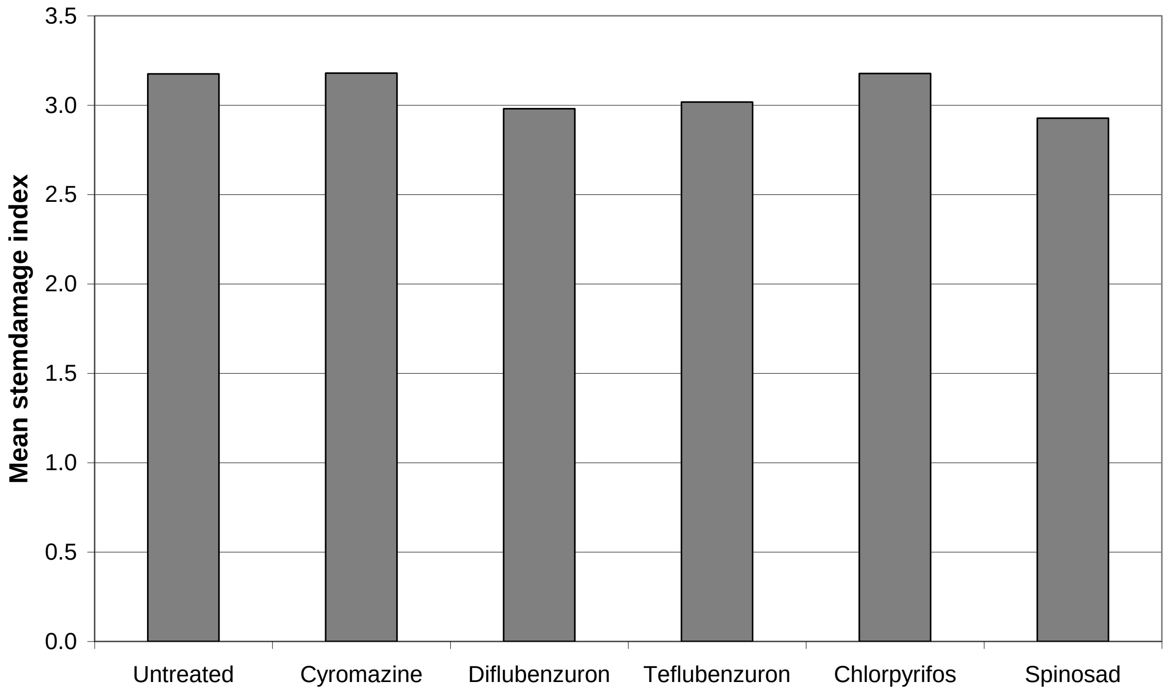


Figure 17. The effect of pre-planting drench treatments on the root damage index of cauliflower plants after exposure to 2nd and 3rd generation cabbage root fly.

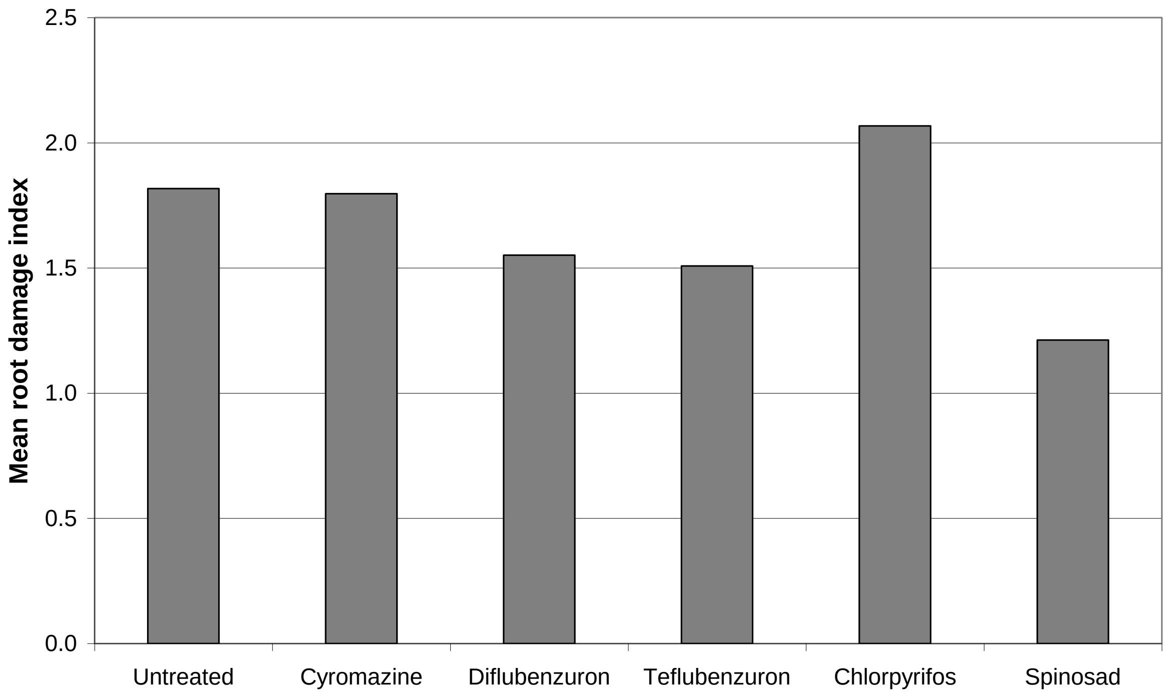
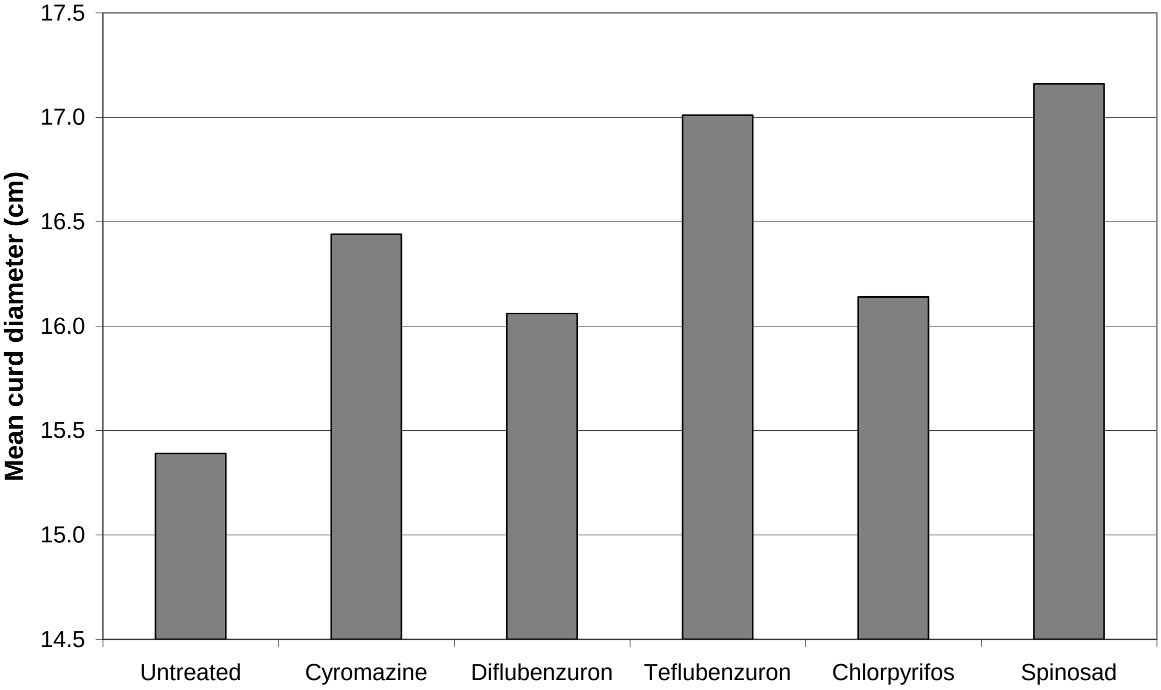


Figure 18. The effect of pre-planting drench treatments on the curd diameter of cauliflower plants after exposure to 2nd and 3rd generation cabbage root fly.



CONCLUSIONS

Spinosad - film-coated seed

In 2002, 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) (Jukes *et al.*, 2003). In 2003, lower doses of spinosad (100 g ai./unit for the first drilling and 72 g a.i. for subsequent drillings) gave reasonable control of first generation larvae and continued to give some control of second generation larvae, but there was no clear pattern of decreasing efficacy over time. In 2004, all three doses of spinosad tested (96, 125 and 150 g a.i./unit) and the chlorpyrifos treatment provided excellent protection of the seedlings. As the plants grew, control diminished, but the spinosad treatments still reduced damage by third generation larvae >90 days after sowing. The chlorpyrifos treatment was less effective and did not reduce damage by second or third generation larvae. The results confirm that spinosad seed treatment shows potential for being an effective first generation control measure, both in terms of reduction in root damage and increase in seedling stand. However, increasing dose has little effect on control. The limiting factor for control of cabbage root fly in swede could well be the size of the root and the inability of the seed treatment (a small "point" dose when applied at sowing) to diffuse out through the soil as the root grows. 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.

Granular treatments

Neither of the treatments tested provided any control of cabbage root fly larvae. The Syngenta granule provided excellent control of flea beetle and probably aphids (not assessed) but has a marked negative effect on control of cabbage root fly larvae. It is possible that a component of the granule is effectively eliminating natural predators and therefore increasing the survival of the larvae. This phenomenon has been observed at Warwick HRI in previous years with the use of pyrethroid insecticides. The dose of Certis Exp 60818 A used was simply too low. The granule supplied is only 0.5% a.i. which equates to a dose of only 25 g a.i./ha.

In-furrow liquid treatments

The two higher doses of spinosad protected the swede seedlings to a certain extent, but these applications of spinosad were not as effective as the seed treatments. This is not surprising when one considers that the likely dose around each seedling is less than 1 mg/plant at the highest dose (400 ml/ha) tested compared to the seed treatments, which gave at least 96 mg a.i./plant. This application method appears to be more effective than spraying over the foliage mid-season, but is still some way from giving economic control of the cabbage root fly. This may well be a simple issue of dose, but it seems unlikely that higher doses would be available.

Novel insecticides

The four 'new' insecticides tested had previously been identified (in glasshouse trials) as potentially effective pre-planting (module drench) cabbage root fly control treatments. Chlorpyrifos was included as a positive control. In this trial, spinosad was the best treatment and chlorpyrifos was less effective than would be expected. The closely related compounds diflubenzuron and teflubenzuron performed similarly. Results from this and previous years suggest that spinosad could be used as a direct replacement for chlorpyrifos drenches with little further research (subject to residue evaluations). While not performing particularly well in this trial, there is sufficient evidence that both teflubenzuron and diflubenzuron could be used to protect leafy brassicas. Cyromazine performance has been patchy in past trials and its failure in this trial would suggest that further research is not justified.

TECHNOLOGY TRANSFER

Cabbage root fly control was discussed at the following events:

13 Oct 2004	Nickersons grower meeting on cabbage root fly
7 Dec 2004	Lancashire growers meeting
9 Feb 2005	HDC Roadshow - Stockbridge Technology Centre
2 Mar 2005	HDC Roadshow - Warwick HRI Kirton
16 Mar 2005	Syngenta brassica growers meeting - Boston
21 Mar 2005	VTS training day brassicas - Warwick HRI Kirton

Articles:

Collier, R.H. & Jukes, A.A. (2005). Update on cabbage root fly. HDC News, April 2005, No112, 25-26.

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

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REFERENCES

Jukes, A. A., Collier, R.H. & Elliott, M.S. (2003). Brassica crops: evaluation of non-organophosphorus insecticides for controlling the cabbage root fly. *Final report 2002-2003 HDC Project* FV 242.