FINAL REPORT

To:
Horticultural Development Council
Bradbourne House
Stable Block
East Malling
Kent, ME19 6DZ

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

FV 242c

Andrew Jukes, Rosemary Collier,
Marian Elliott

April 2006 (updated December 2006)

Grower Summary

FV 242c

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

Final report 2006

Project title:	**Brassica crops: Evaluation of non-organophosphorus insecticides for controlling the cabbage root fly**
Project number:	FV 242c
Project Leader:	Rosemary Collier and Andrew Jukes Warwick HRI**,** Wellesbourne, Warwick CV35 9EF
Final report:	2005/2006
Previous reports:	2003/2004, 2004/2005
Key workers:	Mr Andrew Jukes (Insecticide trials/residue analysis) Ms Marian Elliott (Insect rearing/glasshouse trials)
Location of project:	Horticulture Research International**,** Wellesbourne, Warwick CV35 9EF
Project co-ordinators:	Mr Ian Morrison, Kettle Produce Ltd, Balmalcolm Farm, Cupar, Fife, KY15 7TJ Mr Fred Tyler, Alphagrow Ltd, ACRS, Tarnside, Dimples Lane, Barnacre, Garstang, Lancashire, PR3 1UA
Date project commenced:	1 April 2005
Date project completed:	31 March 2006
Key words:	Swede, cauliflower, cabbage root fly, Tracer (spinosad), Dursban (chlorpyrifos), Syngenta ExpA, Certis Exp 60818A, Dimilin (diflubenzuron), film-coated seed, module drench treatment, foliar spray, granular treatments, in-furrow treatments
Signed on behalf of:	**Warwick HRI**

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

Name Professor Simon Bright
Director and Head of Department

CONTENTS

FV 242c

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

Headline

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

<u>Glasshouse experiments on cauliflower</u>

- Chlorpyrifos, diflubenzuron and spinosad drenches all gave protection to transplants for at least 8 weeks.
- Spinosad was almost as persistent as chlorpyrifos and diflubenzuron was the least persistent.
- Drench treatments with any of the test insecticides remained effective for up to 16 weeks when the plants were maintained in module trays.
- Certis Exp 60818A granules incorporated into seed compost provided excellent control of fly larvae in glasshouse grown cauliflowers at doses equivalent to 2.5 g a.i./ha.

<u>Field experiment on swede</u>

- When applied as a seed treatment to swede, spinosad provided substantial control of cabbage root fly (second generation) when the plants were small. Spinosad continued to provide partial control of the third generation of fly larvae
- Certis Exp 60818A granules were tested, but increasing the dose to 10-fold greater than the specified dose was still insufficient to control cabbage root fly.
- Home-made spinosad granules also failed to control cabbage root fly larvae.
- Insecticide solutions were applied in-furrow at sowing. However, they did not improve cabbage root fly control by spinosad-treated seed. Syngenta ExpA applied alone appeared to increase survival of cabbage root fly larvae, but provided excellent control of flea beetle.
- Spray treatments with Syngenta ExpA acted similarly to in-furrow treatments, increasing cabbage root fly numbers but reducing flea beetle damage.
- A drench treatment with spinosad was applied to module grown swedes and this provided similar control to spinosad seed treatment. However, it was not sufficiently effective to warrant adoption of a system which is less suitable for swede production than direct drilling.

<u>Field experiment on cauliflower</u>

- Drench treatments with spinosad or chlorpyrifos applied to module-grown cauliflowers were similarly effective. Syngenta ExpA and diflubenzuron had little effect on fly control but Syngenta ExpA provided excellent control of flea beetle and led to a decrease in maturation time of 1-2 weeks.

Summary

- 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 £200M/annum [*Basic Horticultural Statistics for the United Kingdom 2005, Department for the 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 three approved chemicals; carbosulfan (Marshall), chlorpyrifos (Dursban) and spinosad (Tracer), 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, chlorpyrifos and diflubenzuron applied as a module-drench for control of cabbage root fly.
- An evaluation of the effective dose of Certis Exp 60818A granules under controlled conditions.
- An evaluation of the field performance of novel insecticide granules against the cabbage root fly.
- An indication of the effectiveness of in-furrow application of insecticide solutions at drilling.
- An evaluation of the performance of spinosad, diflubenzuron and Syngenta ExpA when drenched onto modules pre-planting.
- An evaluation of all field treatments against flea beetles, aphids and caterpillars.

Summary of the project and main conclusions

Four experiments were done in 2005 using five insecticides (Tracer (spinosad), Dimilin (diflubenzuron), Dursban (chlorpyrifos), Syngenta ExpA and Certis Exp 60818A).

Experiments were done to answer the following questions:

1. How persistent are drench treatments (diflubenzuron, spinosad and chlorpyrifos) at controlling cabbage root fly on leafy brassicas? (Glasshouse experiment)
2. What dose of Certis Exp 60818A granules is needed to control cabbage root fly? (Glasshouse experiment)
3. How effective are drench treatments (diflubenzuron, Syngenta ExpA, spinosad and chlorpyrifos) at controlling cabbage root fly on leafy brassicas? (Field experiment)
4. Can novel insecticide granules or sprays be used to control cabbage root fly on swede? (Field experiment)

Experiment summaries and main conclusions

1. *How persistent are drench treatments (diflubenzuron, spinosad and chlorpyrifos) at controlling cabbage root fly on leafy brassicas?*

The experiment was initially done in a cold frame at Warwick HRI, Wellesbourne during the summer and autumn of 2005 but very few pupae were recovered from the untreated plants from the 4-week inoculation onwards. The experiment was repeated in a glasshouse using larger pots.

At the 4-leaf stage, module grown cauliflower plants were drenched with chlorpyrifos, diflubenzuron or spinosad and 40 plants from each treatment were potted-on. The remaining plants were kept in the module trays. After 2, 4, 8, 12 and 16 weeks from transplanting, 8 potted plants were inoculated with 20 cabbage root fly eggs. At the same time, 8 of the plants from each treatment that had been kept in the module trays were transplanted into pots and similarly inoculated. All plants were maintained in the glasshouse. Four weeks after inoculation, inoculated pots were removed from the glasshouse and kept in a cold store until assessed. The roots were harvested, washed and scored for larval damage. Cabbage root fly pupae were washed out from the compost and counted.

Results

- All of the test insecticides provided good cabbage root fly control in cauliflowers transplanted at Time 0 for at least 8 weeks
- Chlorpyrifos was the most persistent treatment and diflubenzuron the least. Spinosad was almost as effective as chlorpyrifos.
- After 8 weeks, insect survival in the control treatmnet declined dramatically, so the effects of the treatments could no longer be assessed.
- Treatments to plants kept in the module trays and then inoculated immediately after transplanting continued to be effective up to the end (16 weeks) of the trial. This suggests that treated modules can be left for several weeks before transplanting without any loss in insecticide performance.

2. What dose of Certis Exp 60818A granules is needed to control cabbage root fly?

The study was conducted in a glasshouse at Warwick HRI, Wellesbourne. Certis Exp 60818A granules were incorporated into compost at 5 doses (plus untreated control) and 308 Hassy trays were filled with compost from each treatment. Cauliflower seeds (cv Skywalker) were sown on 4 August 2005. At the 4-leaf stage, 18 plants from each treatment were potted-on and allowed to establish. Two weeks after transplanting, 15 plants were inoculated with 20 cabbage root fly eggs. Four weeks after inoculation, inoculated pots were removed from the glasshouse and kept in a cold store until assessed. The roots were harvested, washed and scored for larval damage (root damage score: 0 - 5). Cabbage root fly pupae were washed out and counted.

Results

- Certis Exp 60818A granules incorporated into seed compost provided excellent control of fly larvae in glasshouse grown cauliflowers at doses equivalent to 2.5 g a.i./ha.

3. How effective are drench treatments (diflubenzuron, Syngenta ExpA, spinosad and chlorpyrifos) at controlling cabbage root fly on leafy brassicas?

The experiment was conducted in the field at Warwick HRI, Wellesbourne. Cauliflower seeds (cv Skywalker) were sown in 308 Hassy trays in mid May and kept in a glasshouse. When the plants reached the 4-leaf stage, pre-planting drenches were applied to 180 plants per treatment on 28 June 2005, three days before transplanting.

At the end of the second generation of cabbage root fly (15 August 2005) a sample of six roots was harvested from each plot and soil samples were taken from around the roots to extract the fly pupae. The roots were kept in a cold store until the assessment was conducted. The roots were washed and scored for larval damage and the pupae were extracted from the soil samples in water and counted. Flea beetle damage and the presence of aphids and caterpillar damage were also recorded.

At maturity (on 7 October 2005), the cauliflower curds were harvested, weighed and scored for quality. The roots were also harvested and assessed as before.

Results

- Drench treatments with spinosad or chlorpyrifos were similarly effective. Syngenta ExpA and diflubenzuron had little effect on fly control, but Syngenta ExpA provided excellent control of flea beetle and led to a decrease in maturation time of 1-2 weeks.

4. Can novel insecticide granules or sprays be used to control cabbage root fly on swede?

The study was conducted at Warwick HRI, Wellesbourne. One batch of swede (cv Helenor) seeds was film-coated with spinosad at target loadings of 150 g a.i./unit (1 unit = 100,000 seeds). The remaining treatments were applied once the seed had been drilled. These consisted of in-furrow drench treatments and granular treatments. In addition, module-grown swedes were drenched with spinosad and were transplanted into field plots, along with untreated controls, at the same time as the seed was drilled. Foliar spray treatments were applied using a standard knapsack sprayer delivering 1000l/ha.

Plant stand was assessed weekly between mid July and early August and flea beetle damage was assessed once. After the end of the second generation, roots were harvested from each plot and scored for cabbage root fly damage. Soil samples were taken from the roots to extract the cabbage root fly pupae. Similarly, roots were assessed at the time of final harvest and pupal samples were taken. The roots were washed and scored for larval damage.

Results

- When applied as a seed treatment to swede, spinosad provided substantial control of cabbage root fly (2^{nd} generation) when the plants were small. Spinosad continued to provide partial control of the 3^{rd} generation of fly larvae.
- Certis Exp 60818A granules were tested, but increasing the dose to 10-fold greater than the specified dose was still insufficient to control cabbage root fly.
- Similarly home-made spinosad granules also failed to control cabbage root fly larvae.
- Insecticide solutions were applied in-furrow at sowing. However, they did not improve cabbage root fly control by spinosad-treated seed. Syngenta ExpA applied alone appeared to increase survival of cabbage root fly larvae but provided excellent control of flea beetle.
- Spray treatments with Syngenta ExpA acted similarly to in-furrow treatments, increasing cabbage root fly numbers but reducing flea beetle damage.
- A drench treatment with spinosad was applied to module grown swedes and this provided similar control to spinosad seed treatment. However, it was not sufficiently effective to warrant adoption of a system which is less suitable for swede production than direct drilling.

Summary

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’?

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 £25M/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 £30-40M per annum from the area of crop that needs protecting currently against attacks by the cabbage root fly.

Action points for growers

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.

Granular treatments (field experiment – swede; glasshouse experiment- cauliflower)

- **Certis Exp 60818A** Was an extremely effective compound for the control of cabbage root fly larvae in the glasshouse experiment, but in the field experiment on swede the dose was insufficient to have an effect. The discrepancy between the effectiveness of these granules in the two experiments is probably due to their different distributions in the compost/soil relative to the plant roots.

In-furrow treatments (field experiment - swede)

- **Spinosad** In 2004, 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 cabbage root fly larvae. In 2005, this treatment was combined with spinosad seed treatment and did not improve control compared with the seed treatment alone.
- **Syngenta ExpA** Did not control cabbage root fly but was very effective for flea beetle control.

Foliar spray treatment (field experiment - swede)

- **Syngenta ExpA** Did not control cabbage root fly but was very effective for flea beetle control.

Module drench treatments (field experiment – cauliflower; glasshouse experiment-cauliflower)

- **Chlorpyrifos** Was comparable to the spinosad treatment. In the glasshouse experiment, it remained effective for at least 8 weeks when the plants were transplanted into pots immediately after treatment or 16 weeks when the plants were kept in module trays.

- **Spinosad** Was the best treatment tested in 2004, but was comparable to the chlorpyrifos treatment in 2005. In the glasshouse experiment, it remained effective for at least 8 weeks when the plants transplanted into pots immediately after treatment or 16 weeks when the plants were kept in module trays.
- **Diflubenzuron** Had little effect on cabbage root fly control in the field, but in the glasshouse experiment it remained partially effective for at least 8 weeks when the plants were transplanted into pots immediately after treatment or very effective for 16 weeks when the plants were kept in module trays.
- **Syngenta ExpA** Had little effect on cabbage root fly control in the field, but provided excellent control of flea beetle.

Module drench treatment (field experiment – swede)

- **Spinosad** Gave comparable control to spinosad seed treatment.

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 and glasshouse experiments and was developed from results of the 2004 experiments conducted at Warwick HRI.

Experiments were done to answer the following four questions:

1. How persistent are drench treatments (diflubenzuron, spinosad and chlorpyrifos) at controlling cabbage root fly on leafy brassicas?
2. What dose of Certis Exp 60818A granules is needed to control cabbage root fly?
3. How effective are drench treatments (diflubenzuron, Syngenta ExpA, spinosad and chlorpyrifos) at controlling cabbage root fly on leafy brassicas?
4. Can novel insecticide granules or sprays be used to control cabbage root fly on swede?

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: spinosad (Tracer), chlorpyrifos (Dursban), diflubenzuron (Dimilin), Certis Exp 60818A and Syngenta ExpA.

Experiment 1.

How persistent are drench treatments (diflubenzuron, spinosad and chlorpyrifos) at controlling cabbage root fly on leafy brassicas?

Materials and methods

The trial was initially done in a cold frame at Warwick HRI, Wellesbourne during the summer and autumn of 2005 but very few pupae were recovered from the untreated plants from the 4-week inoculation onwards. The trial was therefore repeated in Glasshouse D5 at Warwick HRI, Wellesbourne.

On 14 December 2005, untreated cauliflower seed (cv Skywalker) was sown in 308 Hassy trays containing Levington compost. On 25 January 2006, four sets of 80 plants were transferred to clean Hassy trays. Each set of plants was treated with one of the three test insecticides at the doses shown in Table 1. Each treatment was applied to each module by adding 1 ml of a solution in water using a laboratory pipette. 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. On 26 January 2006 (Time 0), 40 plants of each treatment were transplanted into 15 cm round pots containing a loam based compost. The remaining treated plants were maintained in their Hassy trays. Two weeks after transplanting, a further 8 plants from each treatment were transplanted as before and these plants, together with 8 plants of each treatment transplanted at Time 0 were inoculated with 20 cabbage root fly eggs. This process was repeated on 27 February, 24 march, 7 April and 5 May (4, 8, 12 and 16 weeks after transplanting) so that on each occasion, for each treatment, 8 plants transplanted at Time 0 and 8 freshly-transplanted plants were inoculated. The inoculated plants were maintained in the glasshouse.

Table 1. Pre-planting drench treatments: Insecticides and doses.

Treatment code	Active ingredient	Product	Dose	
			mg a.i./plant	Product/100 plants
H1	Chlorpyrifos	Dursban WG	4.5	0.60 g
H2	Diflubenzuron	Dimilin Flo	5	1.04 ml
H3	Spinosad	Tracer	8	1.67 ml
H4	Untreated			

Assessments

Visual assessments of phytotoxicity were made 14 days after treatment. Four weeks after inoculation, inoculated pots were removed from the glasshouse and kept in a cold store until assessed. The plant roots were washed and scored for larval damage (root damage index: 0 – 4, where 4 = severe damage). Cabbage root fly pupae were washed out and counted. 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.

Results

Phytotoxicity

The insecticide treatments had no phytotoxic effects.

Root assessments

a) Root weight

The results are shown in Tables 2 and 3. Root weight increased with time and the change in root weight over time is presented in Figure 1. Untreated roots were generally smaller, in both sets of plants, than treated roots, due to increased larval feeding.

Table 2. Effect of treatment x inoculation time on mean root weight (g). Plants transplanted at Time 0. A=transformed mean; *B=back-transformed mean*.

Time (weeks)	2		4		8		12		16	
Treatment	A	*B*	A	*B*	A	*B*	A	*B*	A	*B*
Dursban	2.544	*6.473*	3.270	*10.696*	3.63	*13.18*	4.792	*22.961*	5.674	*32.19*
Dimilin	1.926	*3.708*	3.096	*9.582*	5.467	*29.891*	6.557	*43.000*	5.723	*32.749*
Tracer	1.956	*3.827*	3.25	*10.564*	5.369	*28.828*	6.374	*40.629*	5.231	*27.366*
Untreated	1.823	*3.324*	3.173	*10.067*	4.676	*21.861*	4.761	*22.663*	4.742	*22.484*

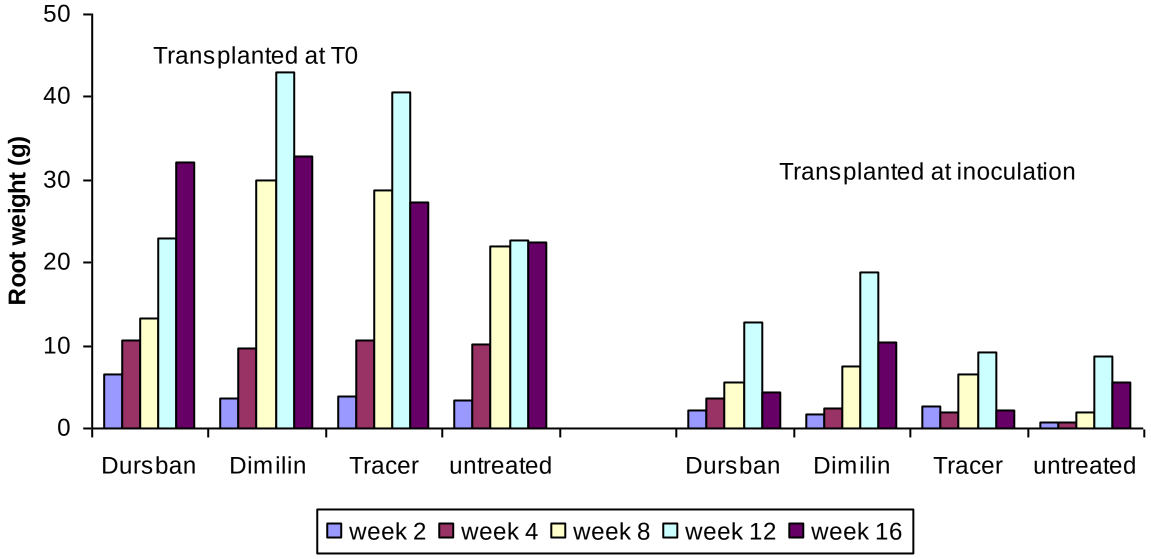
p-value	0.002
df	139
sed	0.4983
LSD (P<0.05)	0.9852

Table 3. Effect of treatment x inoculation time on mean root weight (g). Plants transplanted at time of inoculation. A=transformed mean; *B=back-transformed mean*.

Time (weeks)	2		4		8		12		16	
Treatment	A	*B*	A	*B*	A	*B*	A	*B*	A	*B*
Dursban	1.489	*2.216*	1.914	*3.663*	2.376	*5.646*	3.587	*12.870*	2.114	*4.467*
Dimilin	1.278	*1.633*	1.581	*2.500*	2.751	*7.565*	4.332	*18.767*	3.212	*10.314*
Tracer	1.654	*2.734*	1.418	*2.01*	2.565	*6.578*	3.041	*9.248*	1.468	*2.156*
Untreated	0.806	*0.650*	0.832	*0.692*	1.348	*1.816*	2.929	*8.580*	2.350	*5.524*

p-value	<0.001
df	137
sed	0.2866
LSD (P<0.05)	0.5667

Figure 1. The change in root weight (g) over time after treatment with insecticide and inoculation with cabbage root fly eggs.



b) Root damage Score

The results are expressed as a mean root damage score on a 0-4 scale and are presented in Tables 4-5 and in Figure 2. With plants transplanted at time 0, the damage on the untreated roots declined over time. All treated roots were less damaged than untreated roots and the level of damage increased between 2 and 4 weeks. However later assessments indicated that damage had declined again.

With plants transplanted at the time of inoculation, the damage on the untreated roots remained fairly constant up to 12 weeks and then declined. There was very little damage on treated roots until the 16 week assessments.

Table 4. Effect of treatment x inoculation time on mean root damage score. Plants transplanted at Time 0.

Time (weeks)	2	4	8	12	16
Treatment					
Dursban	0.000	0.500	0.625	0.500	0.000
Dimilin	1.625	2.875	1.875	1.500	0.000
Tracer	1.625	2.250	2.500	1.429	0.375
Untreated	3.875	3.000	3.000	1.875	0.250

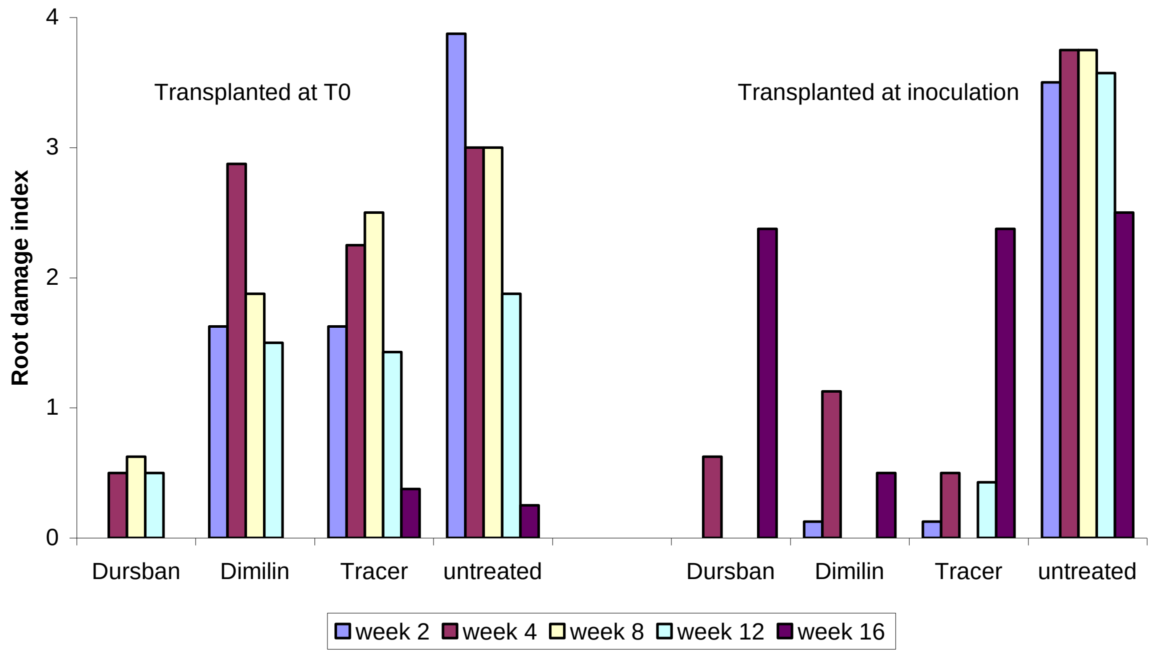
p-value	<0.001
df	139
sed	0.3541
LSD (P<0.05)	0.7001

Table 5. Effect of treatment x inoculation time on mean root damage score. Plants transplanted at time of inoculation.

Time (weeks)	2	4	8	12	16
Treatment					
Dursban	0.000	0.625	0.000	0.000	2.375
Dimilin	0.125	1.125	0.000	0.000	0.500
Tracer	0.125	0.500	0.000	0.429	2.375
Untreated	3.500	3.750	3.750	3.571	2.500

p-value	<0.001
df	137
sed	0.4535
LSD (P<0.05)	0.8967

Figure 2. The change in root damage score (0 – 4 scale) over time after treatment with insecticide and inoculation with cabbage root fly eggs.



Numbers of pupae

The results are shown in Tables 6-7 and are expressed as the square root of the numbers of pupae recovered per plant. Back-transformed means are also shown. The change in pupal numbers over time is shown in Figure 3.

With plants transplanted at Time 0, the numbers of pupae recovered from the insecticide-free plants followed a similar pattern to the damage score. Over the first 3 assessments (2, 4 and 8 weeks after transplanting) over 50% of inoculated eggs produced pupae. Interestingly, pupal numbers declined rapidly after 8 weeks, as the roots became more pot-bound, but the exact cause of this effect is unclear. Because of these effects, it is difficult to assess accurately the decline in performance of the insecticides over time. However, it is clear that all three insecticides were initially very effective and this efficacy did decline over time. Dursban appears to be the most persistent and Dimilin the least, but all three would appear to be offering some protection for at least 8 weeks after transplanting.

With plants transplanted at the time of inoculation, at Week 2, the plants were too small to sustain the numbers of cabbage root fly eggs added (20) and therefore most of the resulting larvae died due to a lack of food. Subsequently, root size was not such a constraint and pupae numbers peaked at 40% recovery at 8 weeks and declined thereafter to 20% at 16 weeks. Control in the treated plants was almost complete at all time points and there were no differences between treatments

Table 6. Effect of treatment x inoculation time on numbers of pupae recovered. Plants transplanted at Time 0. A=transformed mean; *B=back-transformed mean*.

Time (weeks)	2		4		8		12		16	
Treatment	A	*B*	A	*B*	A	*B*	A	*B*	A	*B*
Dursban	0.000	*0.000*	0.306	*0.094*	0.729	*0.531*	0.342	*0.117*	0.125	*0.016*
Dimilin	0.125	*0.016*	1.960	*3.840*	1.718	*2.951*	0.956	*0.914*	0.125	*0.016*
Tracer	0.768	*0.590*	1.246	*1.553*	1.343	*1.803*	0.488	*0.238*	0.250	*0.062*
Untreated	3.203	*10.260*	3.538	*12.514*	3.450	*11.902*	0.608	*0.370*	0.217	*0.047*

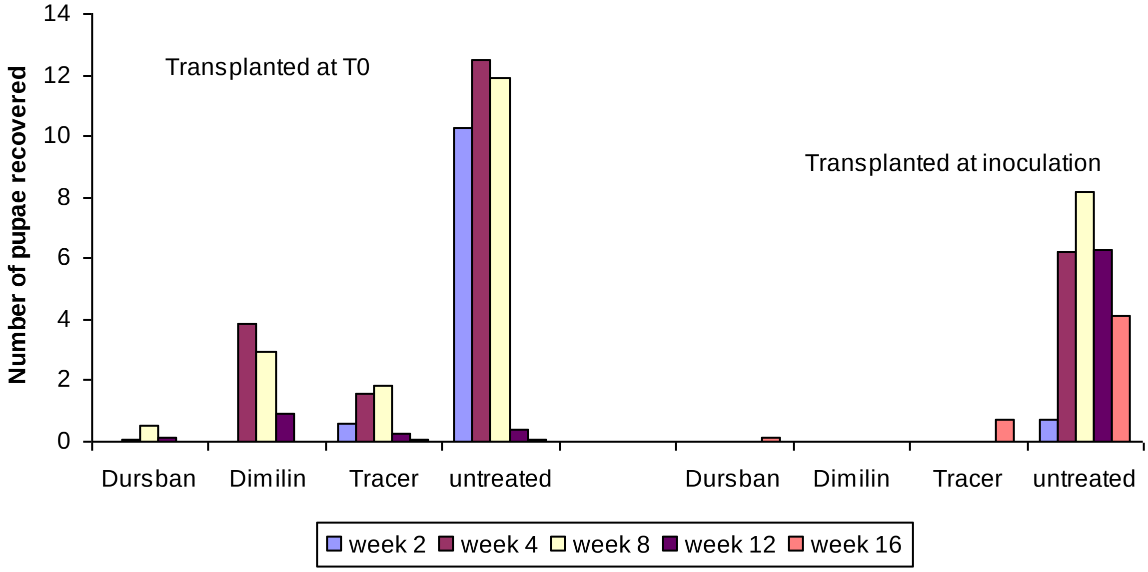
p-value	<0.001
df	139
sed	0.3355
LSD (P<0.05)	0.6633

Table 7. Effect of treatment x inoculation time on numbers of pupae recovered. Plants transplanted at time of inoculation. A=transformed mean; *B=back-transformed mean*.

Time (weeks)	2		4		8		12		16	
Treatment	A	*B*	A	*B*	A	*B*	A	*B*	A	*B*
Dursban	0.000	*0.000*	0.000	*0.000*	0.125	*0.016*	0.000	*0.000*	0.393	*0.155*
Dimilin	0.125	*0.016*	0.125	*0.016*	0.000	*0.000*	0.000	*0.000*	0.000	*0.000*
Tracer	0.000	*0.000*	0.125	*0.016*	0.000	*0.000*	0.143	*0.020*	0.860	*0.739*
Untreated	0.831	*0.691*	2.487	*6.187*	2.865	*8.206*	2.509	*6.296*	2.025	*4.101*

p-value	<0.001
df	137
sed	0.2690
LSD (P<0.05)	0.5319

Figure 3. The change in the numbers of cabbage root fly pupae recovered over time after treatment with insecticide and inoculation with cabbage root fly eggs



Experiment 2.

What dose of Certis Exp 60818A granules is needed to control cabbage root fly?

Materials and methods

The study was conducted in Glasshouse 7 at Warwick HRI, Wellesbourne. Certis Exp 60818A granules were incorporated into compost at 5 doses (plus untreated control) before 308 Hassy trays were filled with compost from each treatment. Certis Exp 60818A doses were calculated based on the recommendation of 5 g a.i/ha (from Certis), a planting rate of 40,000 plants/ha and 4.5 litre compost/308 Hassy tray. The five doses were the recommended dose R, 0.5R, 2R, 4R and 8R. The granules were mixed with the compost in a polythene bag which was shaken to mix them evenly. A volume of 1800 ml of compost was treated at each dose and was used to fill 126 modules in a 308 Hassy tray. Cauliflower seeds (cv Skywalker) were sown on 4 August 2005. At the 4-leaf stage (2 September 2005), 18 plants from each treatment were potted-on into 11 cm pots and allowed to establish (2 weeks). Two weeks after transplanting (16 September 2005), 15 plants were inoculated with 20 cabbage root fly eggs. The experiment was laid out as a randomised block design with 15 replicates of 6 treatments (Table 8).

Table 8. The doses of Certis Exp 60818A assessed against cabbage root fly on cauliflower – glasshouse experiment.

No.	Treatments	Rate			Application method
		g a.i./ha (40,000 plants)	mg a.i./plant	g product/ 1800 ml compost	
1	Untreated		nil		
2	Certis Exp 60818A	2.5	0.063 [2]	7.88	Incorporation pre-sowing
3	Certis Exp 60818A	5 [1]	0.125 [2]	15.75	Incorporation pre-sowing
4	Certis Exp 60818A	10	0.25[2]	31.5	Incorporation pre-sowing
5	Certis Exp 60818A	20	0.5 [2]	63.0	Incorporation pre-sowing
6	Certis Exp 60818A	40	1.0 [2]	126.0	Incorporation pre-sowing

[1] The rate recommended for 2004 field experiment
[2] Assuming 40,000 plants/ha

<u>Assessments</u>

Visual assessments of phytotoxicity were made 14 days post emergence. Seedling weight was assessed by weighing three batches of 10 seedlings/treatment on the day of transplanting. Four weeks after inoculation, inoculated pots were removed from the glasshouse and kept in a cold store until assessed. The roots were harvested, washed and scored for larval damage (root damage score: 0 - 5). Cabbage root fly pupae were washed out and counted. The mean numbers of cabbage root flies recovered from the soil samples, the mean root weight and the mean root damage score were subjected to Analysis of Variance. The insect counts were square-root transformed prior to analysis.

<u>Results</u>

There were no signs of phytotoxicity 14 days after emergence, but seedling growth was reduced by the higher rate treatments. This was confirmed by the seedling weights recorded at transplanting (Figure 4; Table 9). Both of the higher rate treatments yielded lighter plants than the untreated control ($p=0.001$). By the time the plants were harvested to assess root damage and pupal numbers, differences between the different doses were no longer apparent (Figure 5; Table 9) with all Certis Exp 60818A treatments having a greater root weight than the untreated plants ($p<0.001$).

There were no statistically significant differences between Certis Exp 60818A treatments in the root damage score (Figure 6; Table 9) or numbers of pupae recovered (Figure 7; Table 9), but all treatments provided almost complete control of cabbage root fly larvae when compared with the untreated plants ($p=<0.001$).

Table 9. Summary of statistical analysis – Experiment 2.

Dose g a.i./ha	Mean seedling weight	Mean root weight (g) at harvest	Mean root damage score	Mean numbers of pupae (square-root transformed data)
0	2.227	2.98	3.467	3.347
2.5	2.044	11.33	0.600	0.687
5	2.171	10.29	0.067	0.612
10	1.586	10.08	0.267	0.694
20	0.995	12.70	0.000	0.612
40	1.129	10.20	0.000	0.612
df	12	84	84	84
p	0.001	<0.001	<0.001	<0.001
sed	0.256	1.09	0.1553	0.1021
lsd (p=0.05)	0.558	2.16	0.309	0.203

Figure 4. The mean weight of cauliflower seedlings at the time of transplanting following treatment with various doses of Certis Exp 60818A.

Figure 5. The mean weight of cauliflower roots at harvest following treatment with various doses of Certis Exp 60818A.

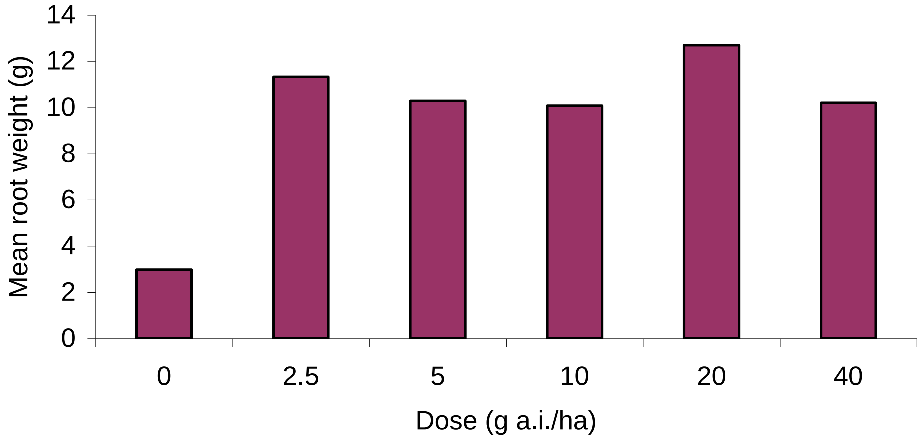


Figure 6. The effect of Certis Exp 60818A treatment on the root damage score of cauliflower plants after inoculation with cabbage root fly eggs.

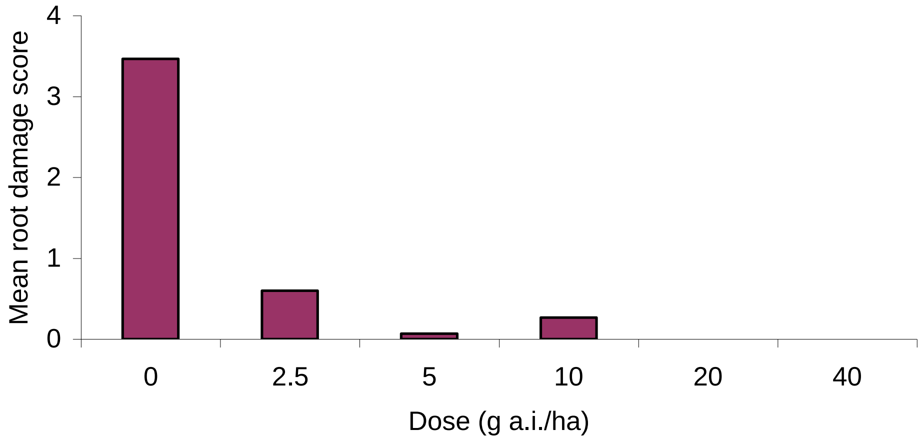
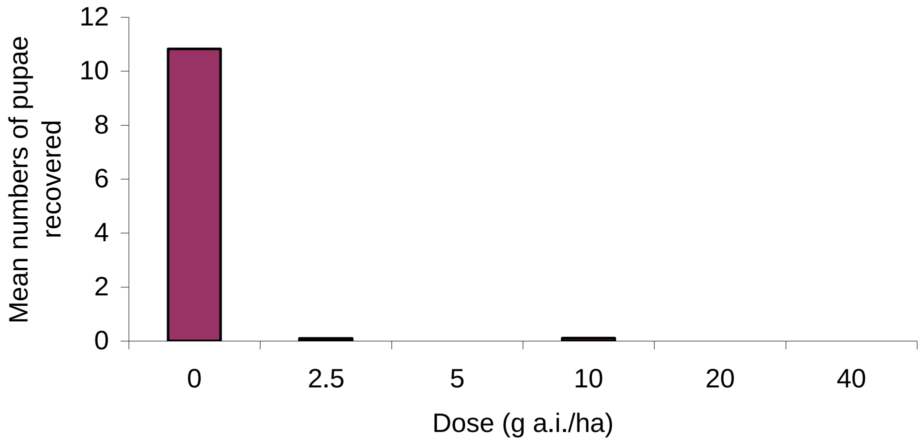


Figure 7. The effect of Certis Exp 60818A treatment on the numbers of pupae recovered from cauliflower plants after inoculation with cabbage root fly eggs (back-transformed means).



Experiment 3.

How effective are drench treatments (diflubenzuron, Syngenta ExpA, spinosad and chlorpyrifos) at controlling cabbage root fly on leafy brassicas?

Materials and methods

The experiment was conducted within the field known as Big Cherry at Warwick HRI, Wellesbourne. Cauliflower seeds (cv Skywalker) were sown in 308 Hassy trays on 27 May 2005 and kept in a glasshouse. When the plants reached the 4-leaf stage, pre-planting drenches were applied to 180 plants per treatment on 28 June 2005, three days before transplanting. All of the treatments (Table 10) were applied using an automatic pipette and 1 ml of treatment solution was added to each module. The treatments were watered-in with a similar volume of water. The planting date (1 July 2005) was chosen to target the second (peak in mid July) and third (late August) generations of cabbage root fly. The experiment was laid out as a randomised block design. Plots were 3.5 x 2 m in size (40 plants) and there were 4 replicates of 5 treatments. Plants were planted at 50 cm spacing within and between rows.

Mid-season and harvest assessments

Visual assessments of phytotoxicity were made 14 days after treatment. An assessment of damage due to aphids (presence or absence) and flea beetles (damage scores - scale: 0 = no damage; 5 = severe damage) and of plant size (maximum plant width) were made on 15 August 2005. Plant stand was assessed weekly.

At the end of the second generation of cabbage root fly (15 August 2005) a sample of six roots was harvested from each plot and soil samples were taken from around the roots to extract the fly pupae. The roots were kept in a cold store until the assessment was conducted.

The roots were washed and scored for larval damage (root damage score: 0 – 5; 0 = no damage; 5 = severe damage) and the pupae were extracted from the soil samples in water and counted.

At maturity (on 7 October 2005), the cauliflower curds were harvested, weighed and scored for quality (20 plants/plot). The roots were also harvested and assessed as before.

The data were subjected to Analysis of Variance. The insect counts were square-root transformed prior to analysis and the data on percentage plants infested were arcsine transformed.

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 around 20 plants twice a week from April until October 2005 and cabbage root fly eggs were extracted from the soil by flotation and counted.

Table 10. Treatments applied in Experiment 3.

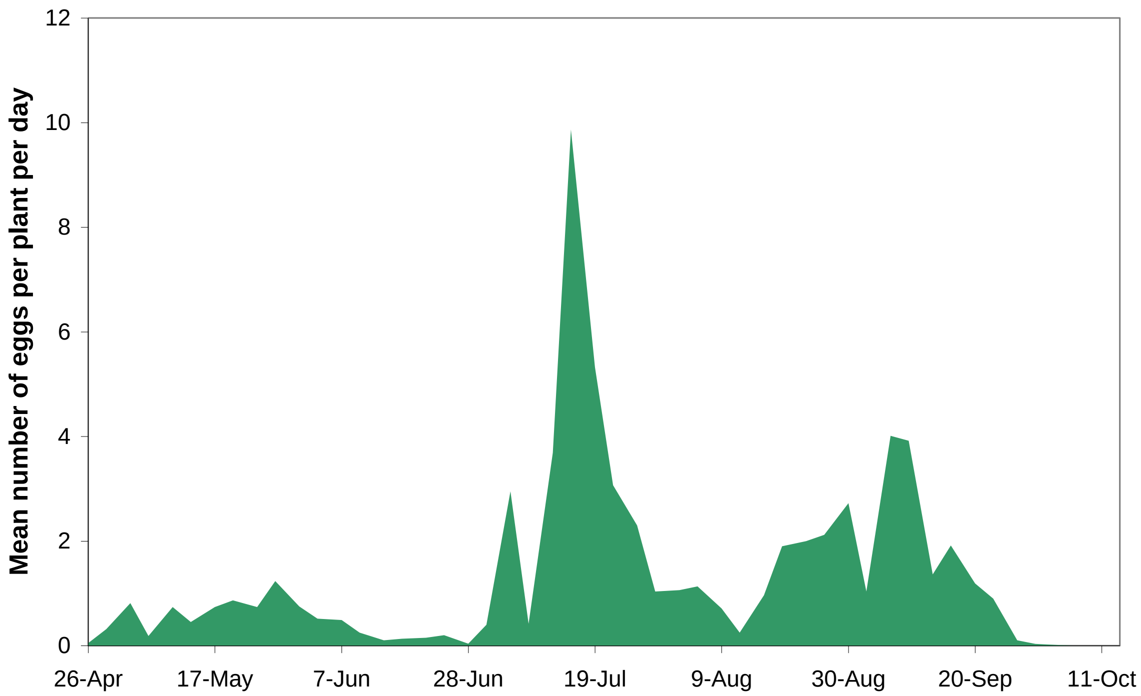
Treatments	Rate		Active ingredient	Application method
	mg ai/plant	product/200 plants		
Untreated	nil			
Dursban 75WG	6	1.6 g	Chlorpyrifos	Pre-planting drench
Tracer (480g/l)	8 [1]	3.33 ml	Spinosad	Pre-planting drench
Syngenta ExpA 25WG	6 [2]	4.8 g	Syngenta ExpA	Pre-planting drench
Dimilin Flo (480 g/l)	6 [2]	2.5 ml	Diflubenzuron	Pre-planting drench

[1] Rate proposed by Dow
[2] Dursban rate

Results

The numbers of eggs laid on cauliflower plants in the nearby monitoring plot are shown in Figure 8. The second fly generation started in early July, soon after planting, and the third generation in mid August.

Figure 8. Cabbage root fly monitoring data – mean number of eggs/plant/day.



There was no visual evidence of phytotoxicity 14 days after treatment. On 15 August 2005, there was a difference between treatments in the flea beetle damage score, the percentage plants infested with aphids and the plant width (Table 11; Figures 9-11). The Syngenta ExpA treatment reduced flea beetle damage and the percentage of plants infested with aphids, and also increased plant size (width). There was no difference between treatments in the root damage score, the stem damage score and the numbers of pupae recovered (Table 11; Figures 12-13).

Table 11. Summary of statistical analysis of assessments made on 15 August 2005 – Experiment 3.

	Flea beetle damage score	Percent plants infested with aphids (arcsine transform)	Mean plant width (cm)	Mean root damage score	Mean stem damage score	Number of cabbage root fly per plot (square-root transform)
Untreated	3.151	30.05	51.65	1.48	1.71	1.77
Chlorpyrifos	3.129	34.89	59.53	0.99	1.26	1.44
Spinosad	2.957	39.73	61.55	1.06	1.38	0.90
Syngenta ExpA	1.201	7.89	74.24	1.41	2.27	1.00
Diflubenzuron	3.124	37.77	57.79	1.31	1.39	1.50
d.f.	8	8	8	8	8	8
p	<0.001	0.002	<0.001	0.555	0.244	0.146
s.e.d.	0.122	5.38	2.074	0.337	0.445	0.337
l.s.d. (p=0.05)	0.281	12.41	4.78	0.78	1.03	0.78

Figure 9. Flea beetle damage score on cauliflower plants assessed on 15 August 2005 (Scale: 0 = no damage; 5 = severe damage).

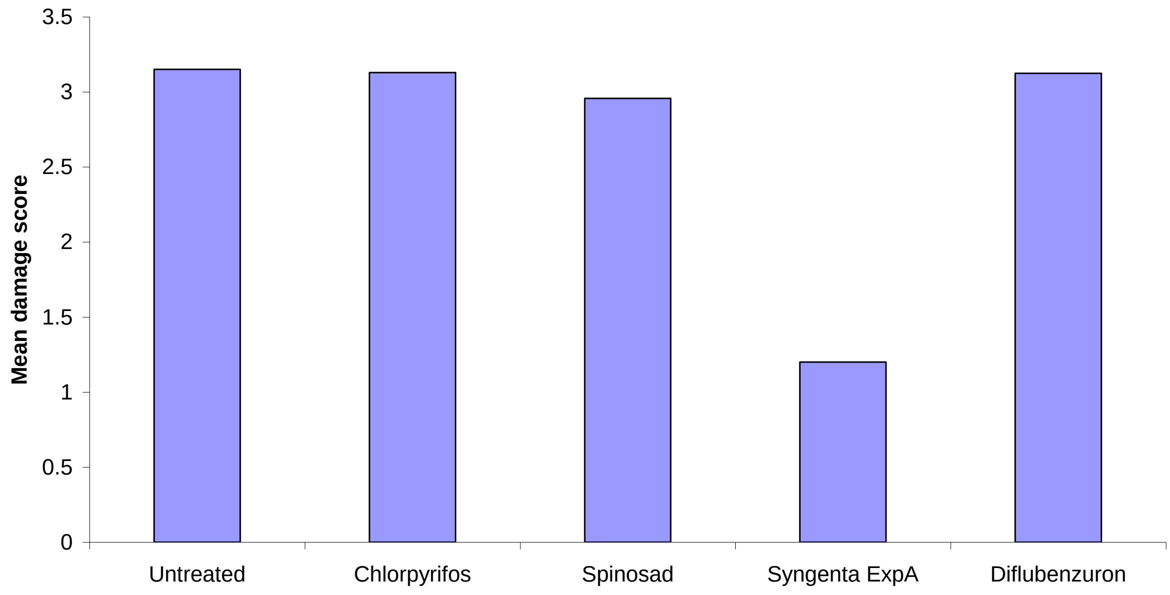


Figure 10. Percentage of plants on which aphids were present on cauliflower plants assessed on 15 August 2005 (back-transformed data).

Figure 11. Width of cauliflower plants on 15 August 2005.

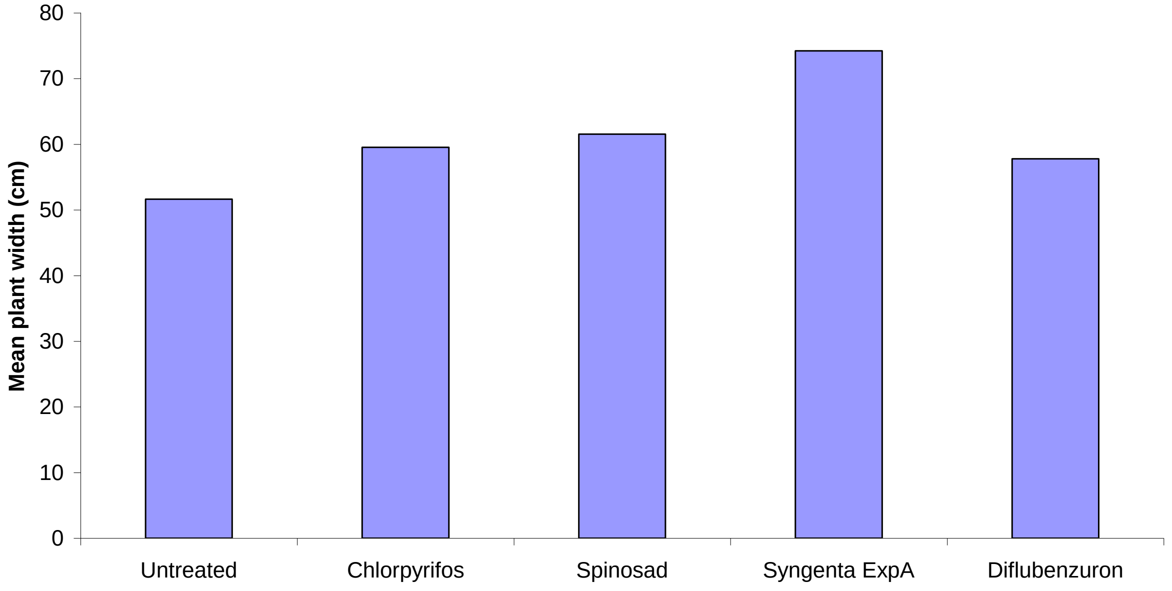


Figure 12. Cauliflower root and stem damage scores on 15 August 2005 (0=undamaged; 5=severe damage).

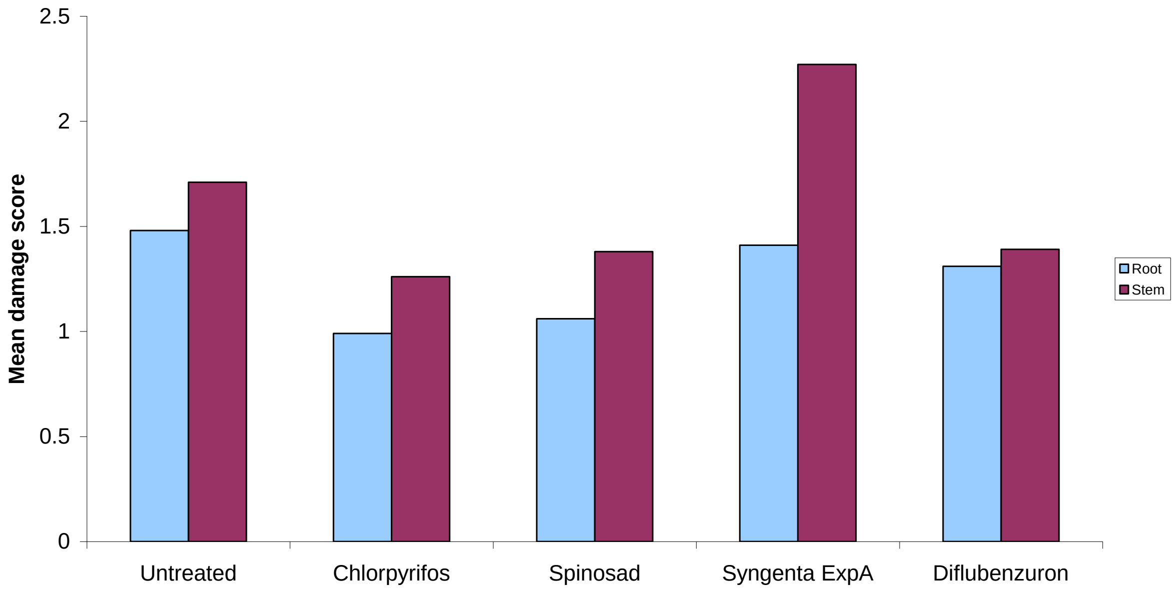
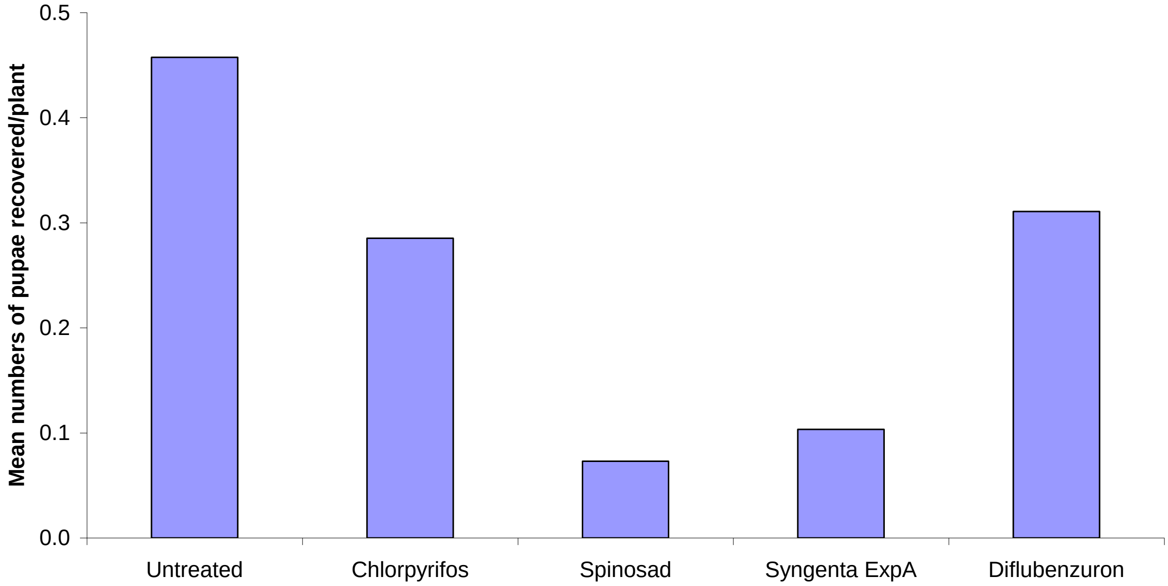


Figure 13. Numbers of pupae recovered from around the roots of cauliflower plants on 15 August 2005 (back-transformed data).



At harvest, treatment had affected the curd weight, curd diameter and the percentage of blown (over mature) curds (Table 12, Figure 14). All of these effects were a reflection of the differing maturity times of the treatments. Curds treated with Syngenta ExpA matured the most rapidly and were the largest when cut; the insecticide-free curds matured the least rapidly. Both root damage and stem damage scores were also affected by treatment (Table 12; Figure 15). The insecticide-free plants suffered the greatest root damage and the least stem damage. Plants treated with Syngenta ExpA suffered very little caterpillar damage (Table 12; Figure 16).

Table 12. Summary of analysed harvest data – Experiment 3.

	Mean curd weight (g)	Mean curd diameter (cm)	Percentage blown curds (arcsine transformed data)	Mean root damage score	Mean stem damage score	Percentage plants with caterpillar damage (arcsine transformed data)
Untreated	1062	13.91	7.7	2.263	3.721	9.84
Chlorpyrifos	1339	16.40	24.2	1.493	3.969	16.60
Spinosad	1515	18.56	36.8	1.45	4.268	13.83
Syngenta ExpA	2034	20.93	76.7	1.72	4.561	1.02
Diflubenzuron	1369	15.68	11.9	1.88	4.310	20.60
df	8	8	8	8	8	8
p	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
sed	126.5	0.679	8.14	0.2049	0.2935	4.30
lsd (p=0.05)	292	1.57	18.8	0.472	0.677	9.9

Figure 14. The percentage of cauliflower curds which had "blown" at harvest (back-transformed data).

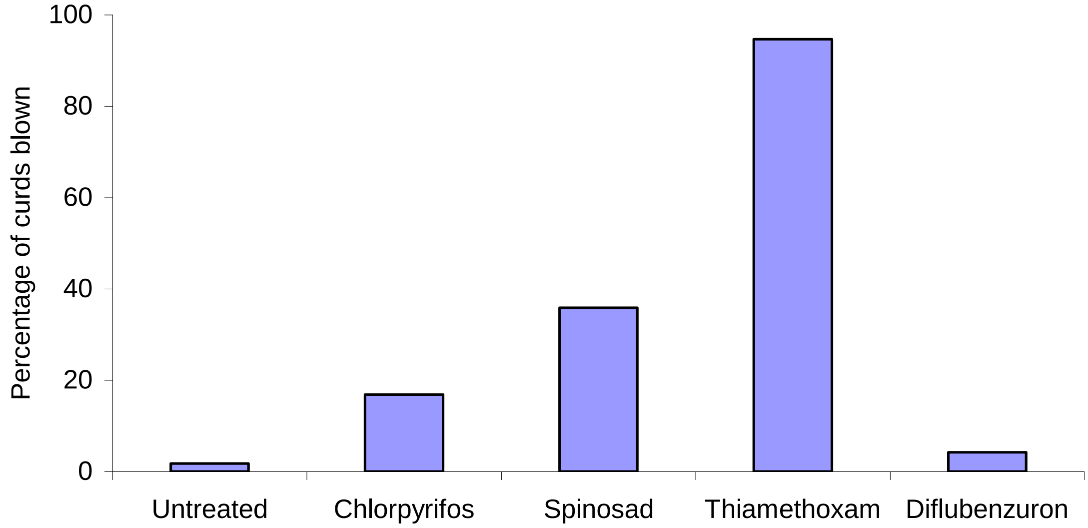


Figure 15. Cauliflower root and stem damage scores at harvest.

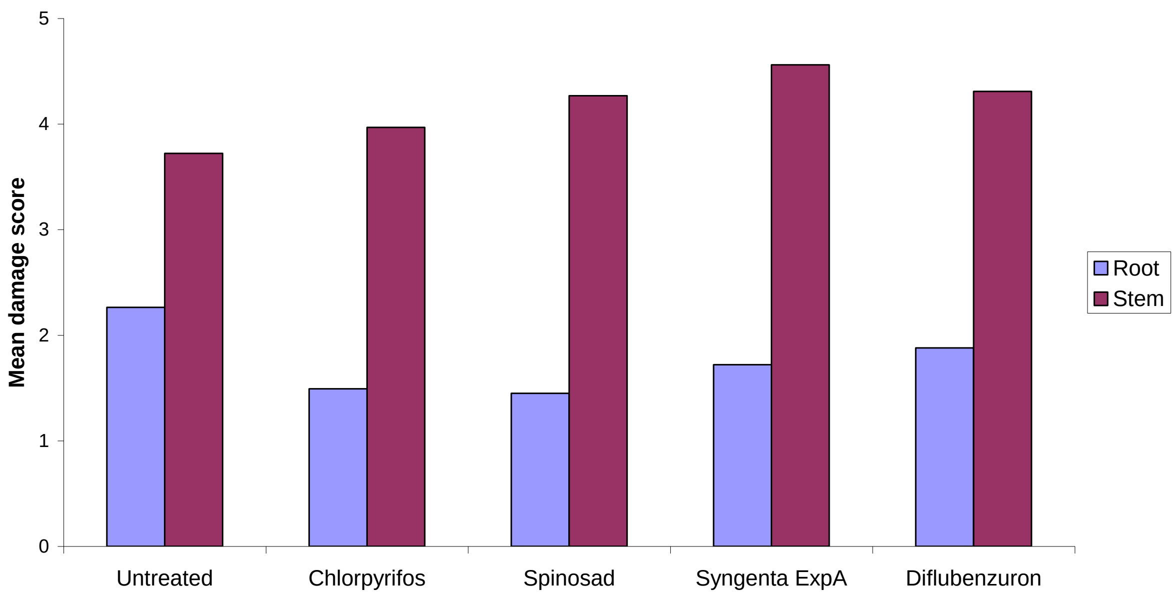
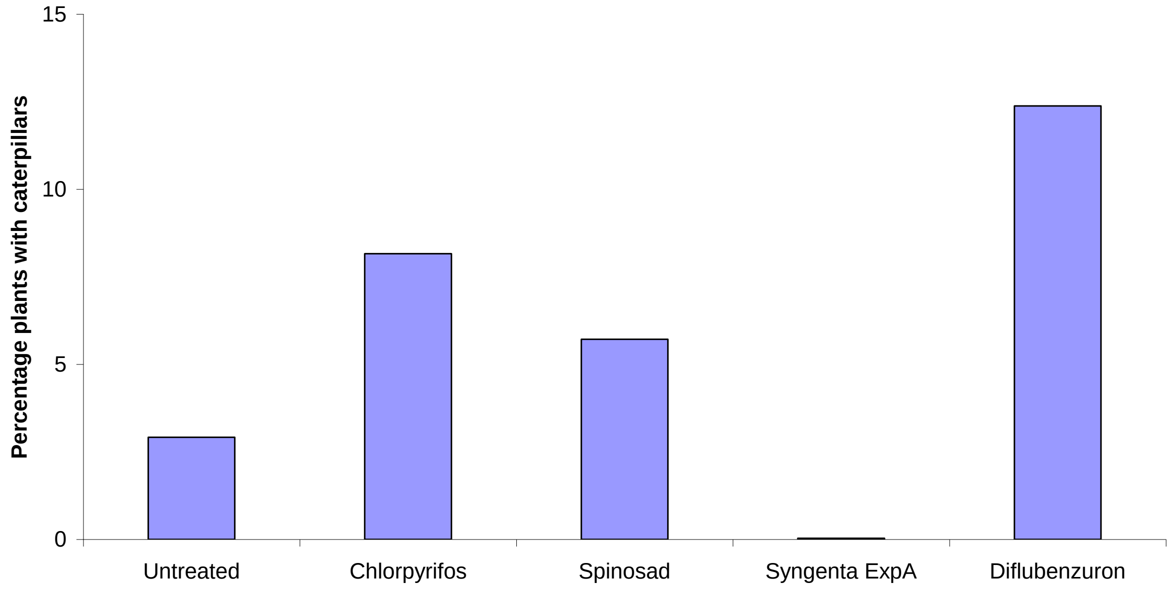


Figure 16. The percentage of cauliflowers infested with caterpillars at harvest (back-transformed data).



Experiment 4.

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

<u>Materials and methods</u>

The study was conducted within the field known as Big Cherry at Warwick HRI, Wellesbourne. The sowing date (early July) was chosen to target the second (mid July) and third (late August) generations of cabbage root fly.

One batch of swede (cv Helenor) seeds was film-coated with spinosad (Tracer 480SC) at target loadings of 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. A further batch of seed was left insecticide-free.

The remaining treatments (Table 13) were applied once the seed had been drilled. The experiment was laid out in a randomised block design and plots were 5 m x 1.83 m (1 bed). There were 4 replicates of 10 treatments. Plants and seeds were placed at 13 plants/seeds per metre. Granular treatments were applied using a Stanhay drill. In-furrow drench treatments were applied using a drill mounted peristaltic pump unit. The treated seed was drilled with the in-furrow treatments on 30 June 2005 and the granular treatments were applied at drilling the following day.

Module-grown swedes (sown 27 May) were treated with spinosad using a calibrated watering can on 28 June 2005 and were transplanted into field plots, along with untreated controls, at the same time as the seed was drilled.

Foliar spray treatments were applied using a standard knapsack sprayer delivering 1000l/ha. The first spray was applied on 15 July 2005 (10 days after seedling emergence) and then at 2-weekly intervals (to give a total of 4 sprays).

Table 13. Treatments in Experiment 4.

No.	Treatments	Rate		Active	Application method
		active	product		
1	Untreated	nil			
2	Fipronil	50 g a.i./ha [1]	2.287 g/m [5]	Fipronil	Granule
3	Tracer 2.3% granule	384 g a.i./ha [2]	1.097 g/m [5]	Spinosad	Granule
4	Syngenta ExpA	100 g a.i./ha [3]	400 g/ha	Syngenta ExpA	Foliar spray x 4
5	Tracer	150 g a.i./unit	312.5 g/unit	Spinosad	Seed Treatment
6	Tracer	150 g a.i./unit + 384 g a.i./ha [2]	312.5 g/unit + 800 ml/ha	Spinosad + Spinosad	Seed Treatment + In-furrow
7	Tracer Syngenta ExpA	150 g a.i./unit + 400 g a.i./ha [4]	312.5 g/unit + 1.6 kg/ha	Spinosad + Syngenta ExpA	Seed Treatment + In-furrow
8	Syngenta ExpA	400 g a.i./ha [4]	1.6 kg/ha	Syngenta ExpA	In-furrow
9	Tracer	1.28 mg a.i./plant [6]	800 ml/ha [2]	Spinosad	Pre-planting drench
10	Untreated transplant	nil			

[1] Ten times the rate recommended for 2004 experiment
[2] Four times the rate recommended by Dow for foliar sprays, as sprays can be applied up to 4 times and this is a single dose.
[3] The rate used in carrot fly experiments
[4] Four times the rate used in carrot fly experiments. As sprays can be applied up to 4 times and this is a single dose.
[5] Assuming 21,858 m row/ha
[6] Assuming 300,000 plants/ha.

Mid-season and harvest assessments

Visual assessments of phytotoxicity were made 14 days after emergence. Plant stand was assessed weekly between 13 July and 5 August on a 2 m length of row in each of the four rows of each plot. Flea beetle damage was assessed on 10 plants/plot on 4 August 2005. After the end of the second generation, 6 roots/plot were harvested from each plot and scored for cabbage root fly damage. Soil samples were taken from around six roots to extract the cabbage root fly pupae. Similarly, 50 roots/plot were assessed at the time of final harvest and pupal samples were taken from around 6 roots/plot. Harvested roots were stored in a cold store until assessed. The roots were washed and scored for larval damage (root damage score: 0 – 5 where 0 = no damage and 5 = severe damage).

The data were subjected to Analysis of Variance. The insect counts were square-root transformed prior to analysis and the data on percentage plants infested were arcsine transformed.

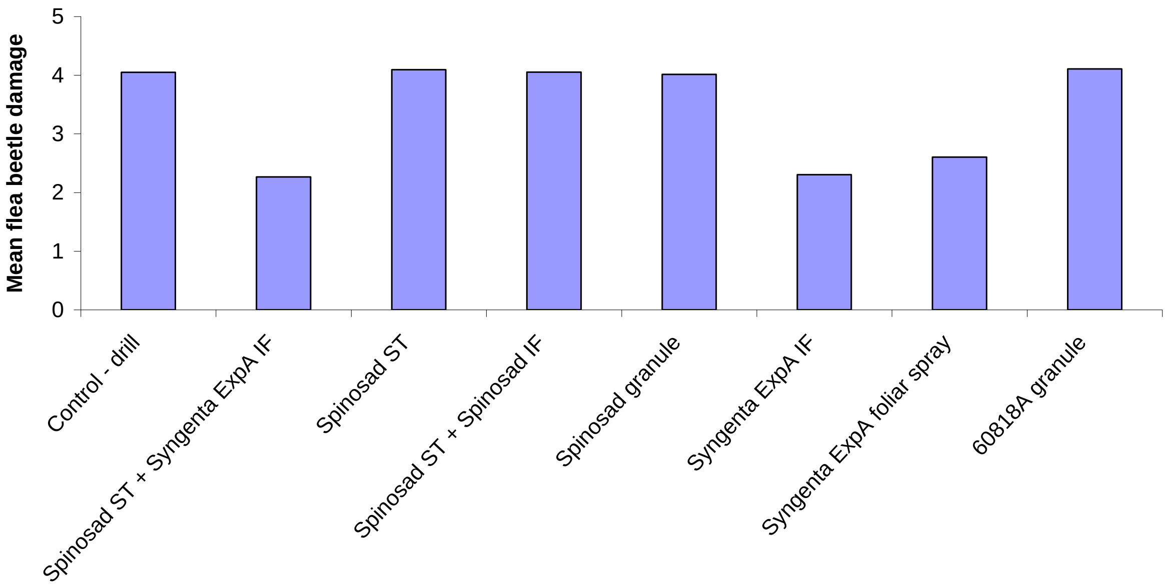
Results

There was no evidence of phytotoxicity due to any of the treatments 14 days after emergence of the seedlings. Also, there was no change in plant stand over the assessment period and no differences due to treatment. The swede seedlings were quite heavily attacked by flea beetle and Syngenta ExpA was the only insecticide that reduced flea beetle damage, either as an in-furrow treatment at sowing or as a foliar spray (Table 14: Figure 17).

Table 14. Analysis of data on flea beetle damage – Experiment 4.

	Mean flea beetle damage score
Control - drill	4.05
Spinosad ST + Syngenta ExpA IF	2.27
Spinosad ST	4.09
Spinosad ST + Spinosad IF	4.05
Spinosad granule	4.02
Syngenta ExpA IF	2.30
Syngenta ExpA foliar spray	2.60
60818A granule	4.11
d.f.	15
p	<0.001
s.e.d.	0.21
l.s.d. (p=0.05)	0.45

Figure 17. Flea beetle damage to swede foliage on 4 August 2005.



When applied as a seed treatment to swede, spinosad provided substantial control of second generation cabbage root fly when the plants were small (Table 15; Figures 18-19). Spinosad continued to provide partial control of the third generation of fly larvae (Table 15; Figures 20-21). The drench treatment with spinosad, applied to module grown swedes, provided similar control to the spinosad seed treatment.

Two types of granule were tested and neither controlled cabbage root fly (Table 15: Figures 18-21). In the case of the Certis Exp 60818A granules, the dose was 10-fold greater than the specified dose, but was still insufficient to control cabbage root fly.

Insecticide solutions were applied in-furrow at sowing. However, they did not improve cabbage root fly control by spinosad-treated seed and Syngenta ExpA alone appeared to increase survival of cabbage root fly larvae. Spray treatments with Syngenta ExpA acted similarly to in-furrow treatments, increasing cabbage root fly numbers.

Table 15. Summary of statistical analysis of Experiment 4.

	Mean root damage score on	Mean number of pupae per plot mid-season (square-root transformed data)	Mean root damage score at harvest	Mean number of pupae per plot at harvest (square-root transformed data)
Control - drill	2.15	4.51	3.03	8.28
Spinosad ST + Syngenta ExpA IF	1.50	2.34	2.63	5.97
Spinosad ST	1.03	1.75	2.73	5.32
Spinosad ST + Spinosad IF	1.39	2.54	2.59	5.43
Spinosad granule	2.29	1.69	3.00	5.51
Syngenta ExpA IF	2.65	5.43	3.06	7.67
Syngenta ExpA foliar spray	2.60	6.93	3.08	9.68
60818A granule	2.25	8.13	3.05	9.54
Control - transplant	2.20	5.99	2.86	9.18
Spinosad - transplant	1.20	5.62	2.46	6.87
d.f.	21	21	21	21
p	<0.001	<0.001	<0.001	<0.001
s.e.d.	0.199	0.85	0.056	0.769
l.s.d. (p=0.05)	0.413	1.80	0.18	1.6

Figure 18. Swede root damage on 19 August (after second generation of cabbage root fly). ST = seed treatment and IF = In-furrow.

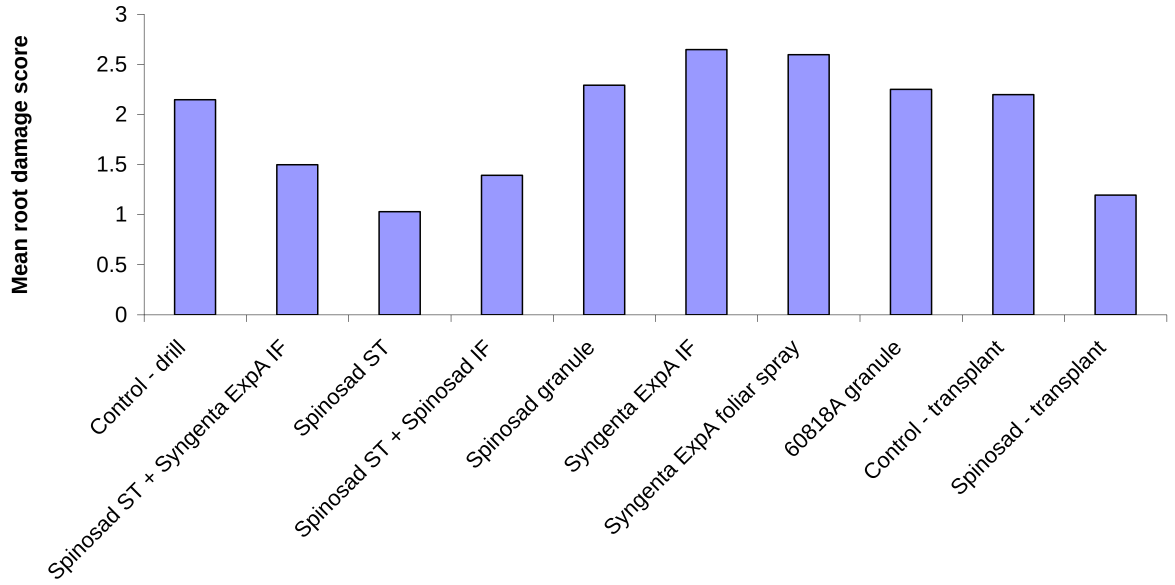


Figure 19. The numbers of pupae recovered from around swede roots on 19 August (after second generation of cabbage root fly) (back-transformed data). ST = seed treatment and IF = in-furrow.

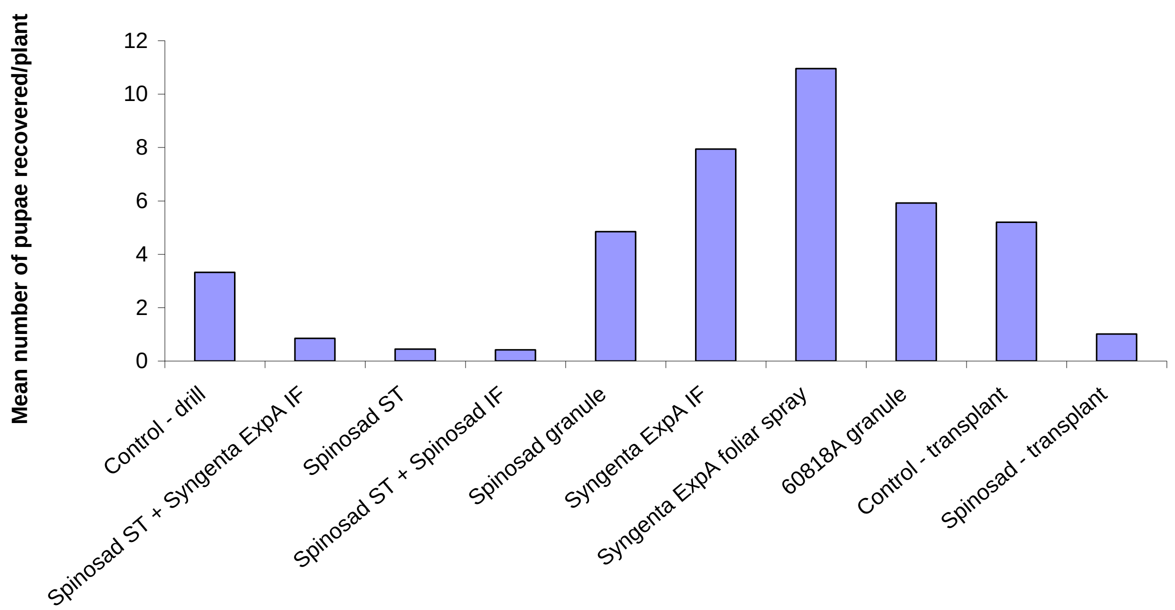


Figure 20. Swede root damage score at harvest (0 = no damage; 5 = severe damage). ST = seed treatment and IF = in-furrow.

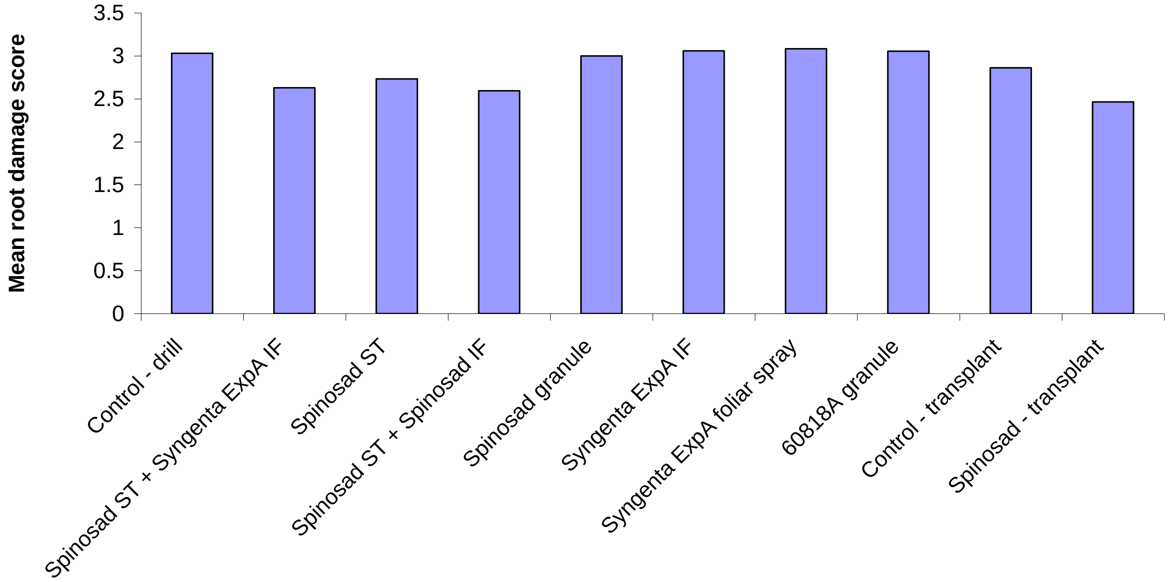
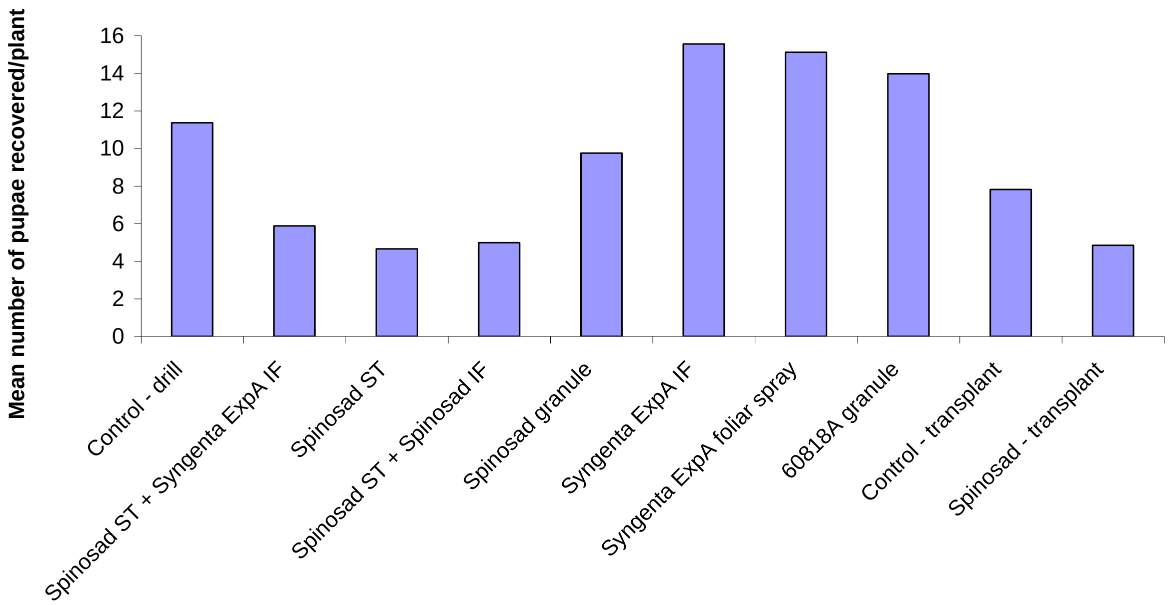


Figure 21. Number of pupae recovered from around swede roots at harvest (back-transformed data). ST = seed treatment and IF = in-furrow.



CONCLUSIONS

Persistence of module drench treatments

It is clear from the glasshouse experiment conducted during 2006 that chlorpyrifos, spinosad and diflubenzuron will provide good control of cabbage root fly larvae for at least 8 weeks after transplanting. Chlorpyrifos was the best treatment, but spinosad was not far behind, reducing numbers of pupae by 85% compared with the untreated control plants 8 weeks after transplanting. Unfortunately, after 8 weeks, it became impossible to assess the impact of the insecticides accurately because insect survival was so low on the insecticide-free control plants.

When the treated modules were left to age in the module trays prior to inoculation with cabbage root fly eggs, all of the treatments provided almost complete control over the 16 week test period. This suggests that the time between treatment and transplanting is not at all critical and effective treatments will remain so for several weeks at least.

Spinosad on swede

In 2004, all three doses of spinosad tested (96, 125 and 150 g a.i./unit) and the chlorpyrifos treatment provided excellent protection of swede seedlings (Jukes *et al*, 2005). As the plants grew, control diminished, but the spinosad treatments still reduced damage by third generation larvae >90 days after sowing and were more effective than the chlorpyrifos treatment. The results confirmed that spinosad seed treatment has potential for being an effective first generation control measure, both in terms of reduction of root damage and increase in seedling stand.

In the current experiment (2005), seedling stand was unaffected by cabbage root fly damage. This was presumably due to the size of the cabbage root fly population present when the seedlings had reached a stage that was attractive to the fly. However, both the seed treatment and drench treatment reduced root damage and numbers of pupae recovered after one generation (second) of the fly and partial cabbage root fly control continued up to harvest (after 2 generations of the fly). The limiting factor for control of cabbage root fly in swede could well be the large 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. Although occupying a larger area in the soil, the drench treatment was no more effective and, as it is not the best method of growing swede, it can be dismissed as a solution to the problem.

Granular treatments

The Certis Exp 60818A granule provided excellent control of cabbage root fly on cauliflower under glasshouse conditions at a dose equivalent to only 2.5 g a.i./ha. However, at 20 times this dose, the treatment provided no control of cabbage root fly larvae on swede in the field. The treatment is presumably too diffuse, never being at a sufficient concentration in the area where the eggs are laid to kill newly-hatched larvae. Spinosad granules at 384 g a.i./ha were similarly ineffective, probably for the same reason.

In-furrow liquid treatments

A spinosad in-furrow treatment in addition to spinosad treated seed provided no more control than the seed treatment on its own. In contrast, while the Syngenta ExpA in-furrow treatment showed no efficacy against cabbage root fly, it provided excellent control of flea beetle. In the absence of spinosad seed treatment it actually caused an increase in the numbers of pupae recovered. At this dose, it appears that Syngenta ExpA may be eliminating natural predators and therefore increasing survival of cabbage root fly larvae. This phenomenon has been observed at Warwick HRI in previous years and probably explains the similar effects observed with the Syngenta granule tested in 2004. This is a neat method of applying an insecticide treatment and is more effective for targeting insecticide applications than spraying over the foliage mid-season, but it seems unlikely that the higher doses needed for cabbage root fly control would be available.

Cauliflower drenches

The three 'new' insecticides tested had previously been identified (in glasshouse experiments) as potentially effective pre-planting (module drench) treatments for cabbage root fly control. Chlorpyrifos was included as a positive control. In this experiment, all of the treatments showed some activity against cabbage root fly larvae. Spinosad was the best treatment, reducing numbers of pupae by about 80% after one generation of the fly. Syngenta Exp A provided excellent control of flea beetle (it also controlled aphids and caterpillars) and this was reflected in increased plant size mid-season and decreased maturation time. Spinosad and chlorpyrifos also reduced maturation time compared with the untreated plants and as neither treatment controlled flea beetle, aphids or caterpillars it must be assumed that this was due to cabbage root fly control.

Results from this and previous studies (Jukes *et al*, 2003, 2004, 2005) suggest that spinosad could be used as a direct replacement for chlorpyrifos in drench treatments, with little further need for research (subject to residue evaluations). Syngenta ExpA provided excellent control of other pests, but the dose is insufficient to control cabbage root fly and diflubenzuron continued to show some activity against cabbage root fly, but is undoubtedly not as effective under field conditions as either the commercial standard (chlorpyrifos) or spinosad.

TECHNOLOGY TRANSFER

Cabbage root fly control was discussed at the following events:

11 January 2006	Cabbage root fly control in swedes – presentation by Andrew Jukes at Brassica Growers Association Conference
15 February 2006	Project summary to BGA R & D Committee
4 April 2006	Control of cabbage root fly with spinosad – presentation by Andrew Jukes and Rosemary Collier at BGA Swede growers meeting

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), Syngenta for the supply of Syngenta ExpA and Certis for the supply of Certis Exp 60818A granules

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.

Jukes, A. A., Collier, R.H. & Elliott, M.S. (2004). Brassica crops: evaluation of non-organophosphorus insecticides for controlling the cabbage root fly. *Final report 2003-2004 HDC Project* FV 242a.

Jukes, A. A., Collier, R.H. & Elliott, M.S. (2005). Brassica crops: evaluation of non-organophosphorus insecticides for controlling the cabbage root fly. *Final report 2004-2005 HDC Project* FV 242b.

