FINAL REPORT

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Brassicas: Evaluation of novel insecticides for control of cabbage root fly and aphids

FV 328a

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Project title:	Brassicas: Evaluation of novel insecticides for control of cabbage root fly and aphids – continuation of FV 328.
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GROWER SUMMARY

SCIENCE SECTION

Headline

- Several insecticidal seed treatments reduced cabbage root fly feeding damage and/or had a positive effect on plant count and/or plant size. Populations of aphids and flea beetles were too low to assess the impact of seed treatments on these pests.

- All pre-planting insecticidal drench treatments had some positive effects on cabbage root fly feeding damage and/or plant size, and an experimental treatment was more consistent in its effect than the other treatments (Dursban and Tracer).

- Foliar sprays of Tracer, Dursban and two novel insecticide treatments did not cause high mortality when applied to control adult cabbage root flies on swede.

Background and expected deliverables

The cabbage root fly (*Delia radicum*) is one of the most serious pests of Brassica crops in the United Kingdom. There are currently two approved chemicals, chlorpyrifos (e.g. Dursban) and spinosad (Tracer) (SOLA) for cabbage root fly control on leafy Brassica crops in the UK. No product has been available to control the cabbage root fly on swede and turnip since 2003 and cabbage root fly control on these crops relies increasingly on the use of physical barriers consisting of fine mesh netting. Only chlorpyrifos is approved for control of cabbage root fly on radish and alternative treatments using spinosad, evaluated in 2006 (FV 242d), do not appear promising. In addition, there is no very effective insecticide treatment to control cabbage root fly larvae infesting Brussels sprout buttons and calabrese heads. Thus the need to find alternative treatments for cabbage root fly control is still pressing.

Aphids also continue to cause major problems for Brassica growers and although several active ingredients are available, they do not provide a sufficient 'armoury' to control *B. Brassicae* and *M. persicae* effectively when pest pressure is high and where insecticide resistant clones of *M. persicae* are present. A greater reliance on neonicotinoid insecticides (imidacloprid, thiacloprid) also increases the risk of selecting populations of *M. persicae* that are resistant to this group of insecticides. This would have severe consequences for Brassica and other vegetable growers and for the production of crops such as potatoes and sugar beet.

Fortunately, the agrochemicals industry is developing a number of novel insecticides, some of which have novel modes of action (which would relieve selection pressure for insecticide resistance) and some of which also appear to be quite mobile within the plant, which may improve their performance against one or more pests. Although the companies are developing these products for certain pests and crops, they are unlikely to evaluate some of the 'minor' uses in any detail.

The aim of this project was to evaluate novel insecticides for the control of the pest insects of Brassica crops, principally the cabbage root fly and aphids, but also taking account of efficacy against other Brassica pests such as flea beetle and whitefly.

The expected deliverables from this work include:

- An evaluation of novel seed and drench treatments for the control of cabbage root fly and aphids.
- An evaluation of foliar sprays for control of cabbage root fly on swede.
- An evaluation of novel insecticide sprays for the control of aphids on Brussels sprout.

Summary of the project and main conclusions

The following experiments were done at Warwick HRI, Wellesbourne:

<u>Experiment 1</u> <u>Novel insecticide treatments to control aphids, flea beetle and cabbage root fly on cauliflower</u>

There were 6 insecticide treatments (3 seed treatments and 3 drench treatments) and 3 insecticide-free treatments, as two batches of insecticide-treated seed had their own insecticide-free control treatment of the same variety. The cauliflower seed was sown on 3 June 2008, the plants were raised in a greenhouse and transplanted on 16 July 2008.

<u>Experiment 2</u> <u>Novel insecticide treatments to control cabbage root fly on spring cabbage</u>

Including the untreated controls, there were 8 treatments (all cv Sparkel). Four of the treatments were direct-drilled, three of them using insecticide-treated seed, and the other four were transplanted, three of them having been treated with pre-planting drenches. The direct-drilled seed was sown on 6 June 2008. The remaining seed was sown on 3 June 2008 in 308 Hassy trays which were placed in a greenhouse. Drench treatments were applied to the transplants on 17July 2008 and the plants were transplanted on 18 July.

Experiment 3 Novel insecticide treatments to control cabbage root fly on swede

Swede seed (cv Magres) was sown in the field on 23 May 2008. Just after the seedlings had emerged, all of the plots were covered with insect proof netting to exclude the first generation of the cabbage root fly. Including an untreated control, there were 5 treatments. After removing the insect netting, each spray treatment was applied on 3 occasions (14 July, 24 July and 30 July). All sprays were applied in 300 l/ha using a knapsack sprayer fitted with 02F110 nozzles. One week after the final spray, the plots were re-covered to exclude any remaining second generation cabbage root fly.

Experiment 4 Novel insecticide treatments to control aphids and whitefly on Brussels sprout

Brussels sprout seed (cv Montgomery) was sown on 13 May 2008 into 308 Hassy trays and the trays were placed in a greenhouse. The plants were transplanted on 27 June 2008. Including an untreated control, there were 6 treatments. All sprays were applied in 300 l/ha using a knapsack sprayer fitted with 02F110 nozzles.

Experiment 5 Do novel insecticides Exp X1 and Exp X2 kill adult cabbage root fly?

In this experiment, foliar sprays of two of the experimental treatments, Exp X1 and Exp X2 were applied to potted cauliflower plants. The plants were then placed in insect cages containing 20 male and 20 female cabbage root flies. Cabbage root fly mortality on treated and insecticide-free plants was recorded over a week.

Experiment summaries and main conclusions

The wet weather in summer 2008 suppressed populations of aphids and whitefly and there were insufficient aphids to make spray treatment application worthwhile until late September 2008. There were few statistically significant differences in aphid numbers in the trial on cauliflower when assessed in early August and again in early September and this probably reflects the overall low numbers of aphids present rather than an absence of treatment effects. Flea beetle damage was also low overall and again may be a reason for the lack of treatment effects, particularly with the seed treatments, some of which have provided flea beetle control in previous experiments.

The cauliflower experiment was planted on 16 July, when the second generation of cabbage root fly was laying eggs at Wellesbourne. When the plants were measured *in situ* in early August, all of the plants treated with insecticides were larger than the insecticide-free control plants (Table A). Destructive samples were taken from all plots at the end of August, the roots were washed and the roots and foliage weighed, and the washed roots and stems were examined and scored for feeding damage by cabbage root fly larvae. All three insecticide drench treatments (Dursban (chlorpyrifos), Tracer (spinosad), Exp X1) reduced cabbage root fly feeding damage to the plant roots compared with the insecticide-free control treatment. In contrast, the seed and sowing treatments, Exp B (an experimental seed treatment) and Sanokote® (imidacloprid), appeared to increase root damage. This is not surprising, since imidacloprid, in particular, has been shown previously to increase feeding damage when applied at the commercial rate. This is because the dose is too low to kill cabbage root fly larvae and merely delays their development. Sanokote® (imidacloprid) also increased stem damage, although none of the other insecticide treatments had any effect compared with the insecticide-free control. The plants treated with Exp B, Exp S (another experimental seed treatment), Dursban and Tracer had heavier roots than the insecticide-free control plants. With the exception of Exp S and Sanokote® (imidacloprid), all plants treated with insecticide also had heavier foliage. Finally, with the exception of Dursban, all of the treatments increased curd size (weight or diameter) at harvest and hastened maturity compared with the control treatment, although the spread of maturity was relatively unaffected.

Table A: Summary of treatment effects in Experiment 1 (cauliflower). Comments refer to statistically significant treatment effects compared with the appropriate insecticide-free control treatment

Assessment		Exp B	Exp S	Sanokote® (imidacloprid)	Dursban	Tracer	Exp X1
Aphids	07-Aug					Increased	
	02-Sep						
Flea beetle	07-Aug			Reduced			
	02-Sep						
Plant size	07-Aug	Increased	Increased	Increased	Increased	Increased	Increased
Root damage	29-Aug	Increased		Increased	Reduced	Reduced	Reduced
Stem damage	29-Aug		Increased				
Root weight	29-Aug	Increased	Increased		Increased	Increased	
Foliage weight	29-Aug	Increased			Increased	Increased	Increased
Curd weight		Increased	Increased	Increased		Increased	Increased
Curd diameter		Increased	Increased			Increased	Increased
Class 1 curds			More			Less	
50 % maturity		Increased	Increased	Increased	Increased	Increased	Increased
10-90% spread maturity			Smaller				

Some of the treatments evaluated on spring cabbage (Experiment 2) were similar to those used on cauliflower. The three seed treatments (fipronil, spinosad, chlorpyrifos) increased the plant count and reduced cabbage root fly feeding damage on the roots of the drilled plants compared with the insecticide-free control treatment (Table B). They also increased root weight and head weight. The effects of the drench treatments were less pronounced and only Exp X1 reduced root damage and increased root weight. Direct comparisons between the drilled and transplanted cannot be made because of the difference in sowing/planting dates, which meant that they were exposed to ‘different’ levels of pressure from cabbage root fly and other pests.

Table B: Summary of treatment effects in Experiment 2 (spring cabbage). Comments refer to statistically significant treatment effects compared with the appropriate insecticide-free control treatment

		Seed treatments			**Drench treatments**		
		Fipronil	**Tracer**	**Chlorpyrifos**	**Tracer**	**Dursban**	**Exp X1**
Root damage	22-Aug	Reduced	Reduced	Reduced			Reduced
Plant count	22-Aug	Increased	Increased	Increased			
Root weight	22-Aug	Increased	Increased	Increased	Increased		Increased
Head weight	22-Aug	Increased	Increased	Increased			
Plant count	24-Jul	Increased	Increased	Increased			
Plant count	20-Aug	Increased	Increased	Increased			

Again, some of the insecticides used in Experiments 1 and 2 were also applied as foliar sprays to swede in Experiment 3. However, none of the treatments reduced cabbage root fly damage to the roots compared with the insecticide-free control. This is disappointing, but not surprising, since previous experiments have shown that neither Tracer nor Dursban are effective as foliar sprays on this crop. Previous laboratory experiments showed that it was necessary to apply these insecticides with a bait (food for adult cabbage root flies) in order to encourage them to ingest the insecticides, which then lead to increased levels of kill. What is disappointing is that the novel insecticides, Exp X1 and Exp X2, did not control cabbage root fly on swede. This is in contrast to their activity against carrot fly, which they controlled very effectively in a field experiment at Wellesbourne in 2008 (article in HDC News).

To explore the properties of Exp X1 and Exp X2 further, foliar sprays of the two experimental treatments were applied to potted cauliflower plants (Experiment 5). The plants were then placed in insect cages containing male and female cabbage root flies. The mortality of flies exposed to treated and insecticide-free plants was recorded. Overall, mortality was very low during the 8-day observation period (<5%). However, Exp X1 appeared to kill more flies than Exp X2 and more male flies than female flies were affected. Thus whilst Exp X1 appears to be very effective when applied as a drench treatment to control cabbage root fly larvae, its activity against adult flies is poor through foliar application.

Finally, evaluation of aphicide sprays was limited because of the low numbers of aphids. However, aphid numbers were sufficient to make one set of spray applications to Brussels sprout plots in late September (Experiment 4). All of the treatments reduced aphid numbers compared with the insecticide-free control treatment. There was no difference between four of the treatments (Exp X1, Exp U, Biscaya, Plenum) although Exp X2 was less effective than all but Exp X1.

Conclusions

- Several seed treatments (Exp B, Exp S, fipronil, spinosad, chlorpyrifos, imidacloprid) reduced cabbage root fly feeding damage and/or increased plant count and/or plant size compared with insecticide-free controls.
- Populations of aphids and flea beetles were too low to assess the impact of seed treatments on these pests.
- All drench treatments (Dursban, Tracer, Exp X1) reduced cabbage root fly feeding damage and/or increased plant size compared with insecticide-free controls and Exp X1 was more consistent in its effect than the other treatments.
- Foliar sprays of Tracer, Dursban and two novel compounds Exp X1 and Exp X2 did not cause high mortality when applied to control adult cabbage root flies.

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 root crops, such as swede, turnip and radish, 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

- Both of the approved pre-planting drench treatments (Dursban, Tracer) had some positive effects on cabbage root fly feeding damage and/or plant size in experiments on cauliflower and spring cabbage.
- Both of the approved pre-planting drench treatments (Dursban, Tracer) and Sanokote® (imidacloprid) reduced the time to cauliflower maturity compared with insecticide-free plants.
- Sanokote® (imidacloprid) treatment increased the amount of damage to cauliflower roots due to feeding by cabbage root fly larvae compared with the insecticide-free plants.
- Fipronil seed treatment reduced cabbage root fly damage to the roots of direct-drilled spring cabbage plants compared with the insecticide-free control treatment. Fipronil seed treatment also increased plant count, root weight and foliage weight of plants compared with the insecticide-free control treatment.
- The two currently approved insecticides applied as foliar sprays to control aphids on Brussels sprout (pymetrozine (Plenum), thiacloprid (Biscaya)) provided effective control of cabbage aphid.

SCIENCE SECTION

Introduction

The cabbage root fly (*Delia radicum*) is one of the most serious pests of Brassica crops in the United Kingdom. There are currently two approved chemicals, chlorpyrifos (e.g. Dursban)) and spinosad (Tracer) (SOLA) for cabbage root fly control on leafy Brassica crops in the UK. No product has been available to control the cabbage root fly on swede and turnip since 2003 and cabbage root fly control on these crops relies increasingly on the use of physical barriers consisting of fine mesh netting. Only chlorpyrifos is approved for control of cabbage root fly on radish and alternative treatments using spinosad, evaluated in 2006 (FV 242d), do not appear promising. In addition, there is no very effective insecticide treatment to control cabbage root fly larvae infesting Brussels sprout buttons and calabrese heads. Thus the need to find alternative treatments for cabbage root fly control is still pressing.

Aphids also continue to cause major problems for Brassica growers and although several active ingredients are available, they do not provide a sufficient 'armoury' to control *Brevicoryne Brassicae* and *Myzus persicae* effectively when pest pressure is high and where insecticide resistant clones of *M. persicae* are present. A greater reliance on neonicotinoid insecticides (imidacloprid, thiacloprid, acetamiprid) also increases the risk of selecting populations of *M. persicae* that are resistant to this group of insecticides. This would have severe consequences for Brassica and other vegetable growers and for the production of crops such as potato and sugar beet.

Fortunately, the agrochemicals industry is developing a number of novel insecticides, some of which have novel modes of action (which would relieve selection pressure for insecticide resistance) and some of which also appear to be quite mobile within the plant, which may improve their performance against one or more pests. Although the companies are developing these products for certain pests and crops, they are unlikely to evaluate some of the 'minor' uses in any detail.

The aim of this project extension is to continue to evaluate novel insecticides for the control of the pest insects of Brassica crops, principally the cabbage root fly and aphids, but also taking account of efficacy against other Brassica pests such as whitefly and flea beetle.

There were 4 field experiments in 2008 and one laboratory experiment in 2009.

The field experiments were as follows:

Experiment 1 - Novel insecticide treatments to control aphids, flea beetle and cabbage root fly on cauliflower

Experiment 2 - Novel insecticide treatments to control cabbage root fly on spring cabbage

Experiment 3 - Novel insecticide treatments to control cabbage root fly on swede

Experiment 4 - Novel insecticide treatments to control aphids and whitefly on Brussels sprout
Experiment 5 - Do novel insecticides Exp X1 and Exp X2 kill adult cabbage root fly

Experiment 1 - Novel insecticide treatments to control aphids, flea beetle and cabbage root fly on cauliflower

Materials and methods

The experiment was done in field known as Big Cherry at Warwick HRI, Wellesbourne. There were 6 insecticide treatments and 3 insecticide-free treatments, as two batches of insecticide-treated seed had their own insecticide-free control of the same variety (Table 1.1). The cauliflower seed was sown in 308 Hassy trays on 3 June 2008 and the trays were placed in a greenhouse. On 16 July 2008 (at the 4 leaf stage), drench treatments were applied using a 1 ml automatic pipette. Treatments were washed on to the modules with an equivalent volume of water. Treatment details are shown in Table 1.1 and all plants were transplanted on 16 July 2008. The trial was laid out as a partially balanced row and column design with 4 rows and 9 columns. Each plot was 5 m x 1 bed (1.83 m wide) and there were 4 rows per bed. The plants were spaced at 50 cm along rows and 38 cm between rows. In total, each plot contained 44 plants.

On 31 July and 6 August, one part of each plot (the left hand row facing north) of each plot was inoculated with 10 cabbage root fly eggs per plot on each occasion. The eggs were obtained from the cabbage root fly culture maintained at Warwick HRI, Wellesbourne.

Table 1.1: Treatments used in trial on cauliflower

	Active ingredient	Product	Cultivar	Application method	Rate
1	Exp S	Exp S	Marine	Seed treatment	140 g [2]
2	Exp S Untreated	Exp S Untreated	Marine	Untreated	
3	Exp B	Exp B	Skywalker	Seed treatment	120 + 40 g [2]
4	Exp B Untreated	Exp B Untreated	Skywalker	Untreated	
5	Imidacloprid	Sanokote® (imidacloprid)	Skywalker	Sowing treatment	140 g [2]
6	Exp X1	Exp X1	Skywalker	Pre-planting drench	45 ml [1]
7	Chlorpyrifos	Dursban WG	Skywalker	Pre-planting drench	6 g [1]
8	Spinosad	Tracer	Skywalker	Pre-planting drench	12 ml [1]
9	Untreated control	Untreated Control	Skywalker	Untreated	

[1] ml or g product/1000 plants

[2] g a.i./100,000 seeds

The trial was designed as a partially balanced row and column design with 4 rows and 9 columns.

Foliar pest assessments were made on two occasions; 7 August and 2 September. On each date, a sample of 12 cauliflowers was examined. Data were collected on the numbers of the various species of aphids present and, on 7 August only; the maximum plant maximum width of each cauliflower plant was recorded. A score based on the scale below was used to indicate the extent of flea beetle damage on each plant on both dates.

Flea beetle damage score

Damage level	none	slight	moderate	Severe
Score	0	1	2	3

On 29 August, 12 cauliflower plants were sampled from each plot. The roots and stems of each plant were assessed for damage caused by cabbage root fly larvae and given a score from 0 – 5. The foliage and root weights were also recorded.
Up to 32 Cauliflower plants were harvested from each plot between 7 September and 19 November. Data were collected on the harvest date of each plant, the curd weight, the curd diameter and the class of each curd.

Statistical analysis

All analyses were performed using analysis of variance (ANOVA). To enable analysis using ANOVA, each of the treatments were expressed as a combination of two pseudo factors 'ps1' and 'ps2'. Where the treatment factor itself was not balanced within the trial, the pseudo factors were. Because of this, there were two sets of SED and 5% LSD values presented within the results, one for where treatments have the same level of a pseudo factor ('SED – ps', '5% LSD – ps'), and one set for treatments that have different levels of pseudo factors.

Pair-wise comparisons within this trial focus on the differences between the treated and untreated plots. There were direct comparisons between treatments Exp S and Exp S Untreated and Exp B and Exp B untreated. The other insecticide treatments were compared with the untreated control (cv Skywalker).

Results

Pest Assessments

A square root transformation was used for the analysis of the aphid counts to ensure homogeneity between treatments. Tables present the means for each treatment together with F-Values and P-Vales. SEDs and 5% LSDs were presented for pair-wise comparisons.

7 August

The treatment factor was significant at a 5% level for the analyses of the total number of aphids, the mean flea beetle score and the maximum plant widths (Table 1.2).

Table 1.2: Cauliflower - assessments made on 7 August 2008

Treatments	ps1	ps2	Mean number of aphids per plot		Flea beetle score	Max plant width
			Back transformed	Transformed		
Exp S	1	1	3.68	1.921	0.52	27.2
Exp S Untreated	2	2	4.03	2.007	0.88	20.7
Exp B	3	3	1.49	1.220	0.29	29.9
Exp B untreated	2	3	3.54	1.882	0.56	17.3
Sanokote® (imidacloprid)	3	1	0.91	0.954	0.31	24.2
Exp X1	1	2	0.93	0.964	0.49	25.2
Dursban	3	2	9.97	3.158	1.07	27.1
Tracer	1	3	19.58	4.424	0.98	28.9
Untreated Control	2	1	4.25	2.062	0.85	15.9
F Value				3.220	4.910	9.070
P Value				0.022	0.003	<.001
SED				0.933	0.194	2.301
5% LSD				1.978	0.412	4.879
SED – ps				0.899	0.187	2.218
5% LSD – ps				1.906	0.397	4.701
Df				16	16	16

Considering the analysis of the aphid counts, there were no significant pair-wise differences between either Exp S and its untreated control or between Exp B and its untreated control. For all other treatments, Tracer had a mean significantly larger than the untreated control. Similarly the analysis of the flea beetle score showed no differences between either Exp S and its untreated control or between Exp B and its untreated control. The untreated control had a mean significantly larger than Sanokote® (imidacloprid).

Exp S had a mean maximum plant width significantly larger than its untreated control and similarly, Exp B had a mean maximum plant width significantly larger than its untreated control. The other four insecticide treatments all had mean maximum plant widths significantly larger than their untreated control.

2 September

The treatment factor was significant at a 5% level both for the total number of aphids per plot and the mean flee beetle score (Table 1.3).

Table 1.3: Cauliflower - assessments made on 2 September 2008

Treatments	ps1	ps2	Mean number of aphids per plot		
			Back transformed	Transformed	Flea beetle score
Exp S	1	1	0.16	0.400	0.31
Exp S Untreated	2	2	0.73	0.857	0.48
Exp B	3	3	0.50	-0.706	0.47
Exp B untreated	2	3	1.69	1.298	0.32
Sanokote® (imidacloprid)	3	1	0.05	-0.228	0.32
Exp X1	1	2	0.03	-0.178	0.47
Dursban	3	2	3.80	1.949	0.64
Tracer	1	3	19.79	4.448	0.54
Untreated Control	2	1	3.62	1.902	0.48
F Value				2.250	1.100
P Value				0.080	0.410
SED				1.570	0.155
5% LSD				3.329	0.329
SED – ps				1.513	0.149
5% LSD – ps				3.208	0.317
Df				16	16

Pair-wise comparisons of the total number of aphids showed no significant differences between Exp S and its untreated control and Exp B and its untreated control. None of the treatments was significantly different from the untreated control. The significance of the treatments factor was explained because the numbers of aphids on the Tracer treatment were larger than Exp S and its control, Exp B and Sanokote® (imidacloprid) and Exp X1. There were no significant differences of interest for the flea beetle damage score. Figure 1.1 shows the mean numbers of aphids per plot on 7 August and 2 September. Figure 1.2 shows the mean flea beetle damage score on the same two dates and Figure 1.3 shows the mean maximum plant width on 7 August.

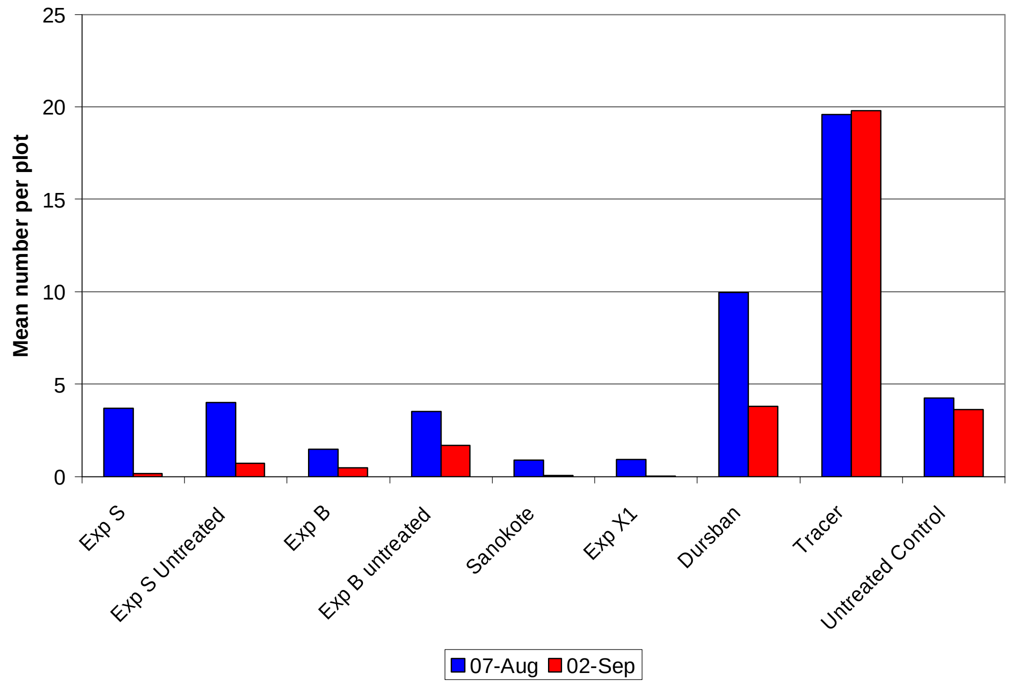

Figure 1.1: Cauliflower - mean numbers of aphids per plot on 7 August and 2 September 2008

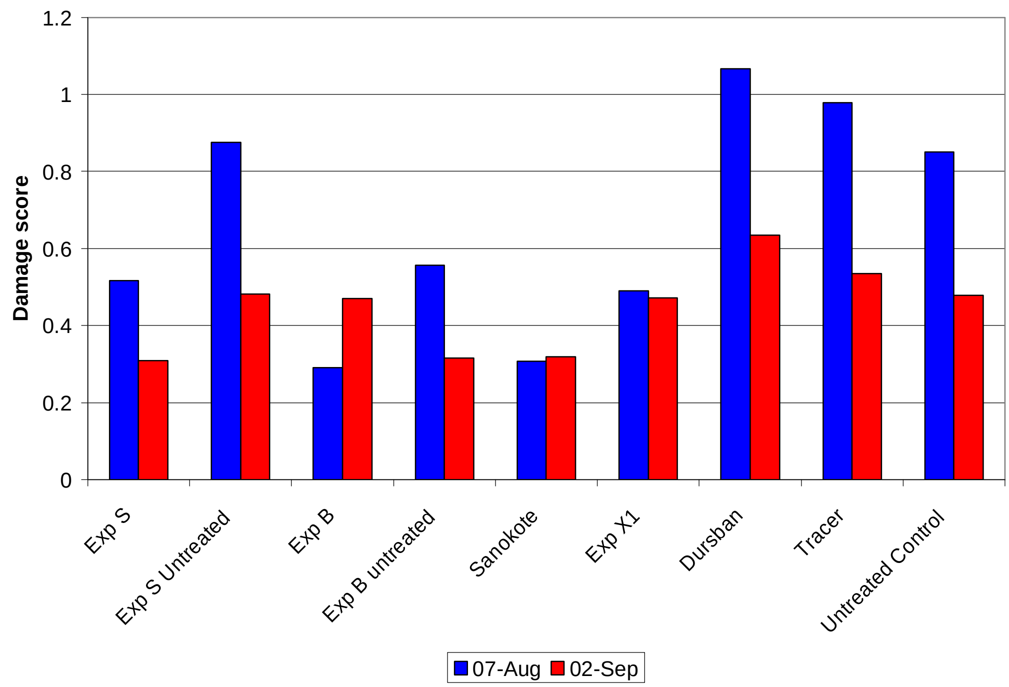

Figure 1.2: Cauliflower - mean flea beetle score on 7 August and 2 September 2008

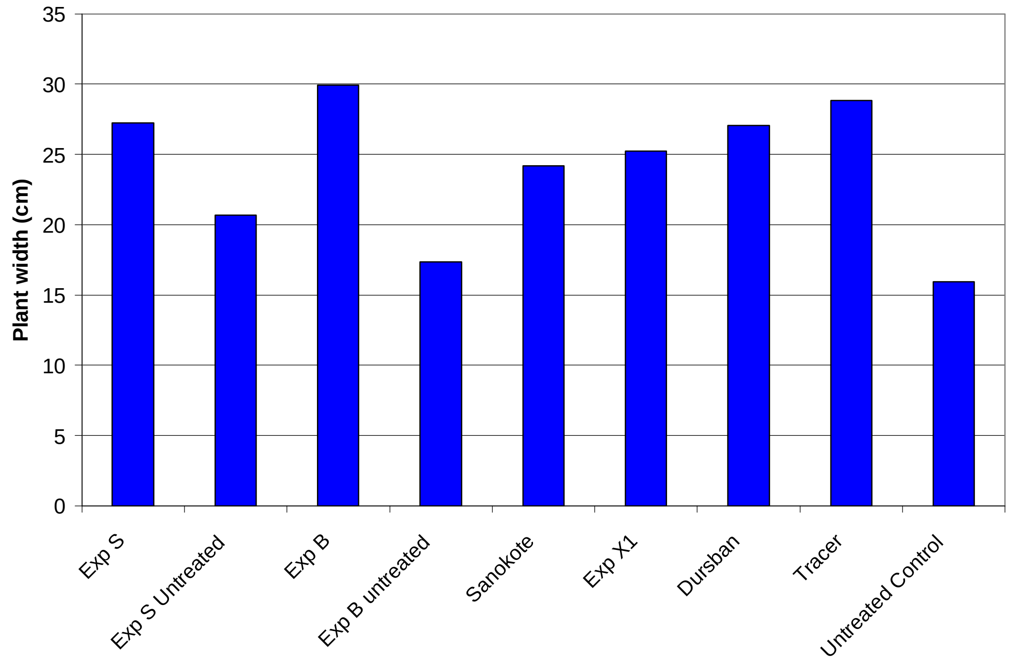

Figure 1.3: Cauliflower - mean maximum plant width on 7 August 2008

Assessments on 29 August 2008

No transformations of the data were required for the analysis. For each of the four analyses carried out (root damage score, stem damage score, root weight, foliage weight) the treatment factor was significant at a 5% level (Table 1.4).

Table 1.4: Cauliflower – assessments made on 29 August 2008

Treatment	ps1	ps2	Root damage score	Stem damage score	Root weight	Foliage weight
Exp S	1	1	2.64	2.86	14.54	337.4
Exp S Untreated	2	2	1.68	2.12	6.65	236.8
Exp B	3	3	1.98	2.64	20.48	418.1
Exp B untreated	2	3	1.86	1.72	10.73	234.3
Sanokote® (imidacloprid)	3	1	3.04	4.04	13.79	313.5
Exp X1	1	2	1.13	2.27	15.01	358.6
Dursban	3	2	1.20	2.13	19.86	382.5
Tracer	1	3	1.13	2.80	22.00	464.7
Untreated Control	2	1	2.07	2.60	9.63	212.3
F – Value			7.500	3.750	5.950	5.440
P – Value			<0.001	0.012	0.001	0.002
SED			0.343	0.482	2.99	51.8
5% LSD			0.726	1.023	6.33	109.9
SED – ps			0.330	0.465	2.88	49.9
5% LSD – ps			0.700	0.986	6.10	105.9
Df			16	16	16	16

Considering the mean root damage score per plot, there was a statistically significant difference between treatment Exp S and its control, the treated roots being more damaged, but not between Exp B and its control. The drench treatments with Exp X1, Dursban and Tracer all had significantly lower damage scores than the untreated control, which in turn was significantly less damaged than the Sanokote® (imidacloprid) treatment.

For the mean stem score per plot, there were no statistically significant differences between either Exp S and its untreated control or between Exp B and its untreated control. The Sanokote® (imidacloprid) treatment had a significantly larger stem damage score than the untreated control, but there were no other statistically significant differences of interest.

The mean root weight of Exp S was significantly larger than its untreated control and similarly, the mean root weight of Exp B was significantly larger than its control. The Dursban and Tracer drench treatments had mean root weights that were significantly larger than their untreated control.

For foliage weight, there was no statistically significant difference between Exp S and its untreated control but there was a significant difference between Exp B and its control. Drench treatments Exp X1, Dursban and Tracer all had means significantly larger than the untreated control, although the Sanokote® (imidacloprid) treatment did not.

The root and stem damage scores are shown in Figure 1.4, root weight in Figure 1.5 and Figure 1.6.

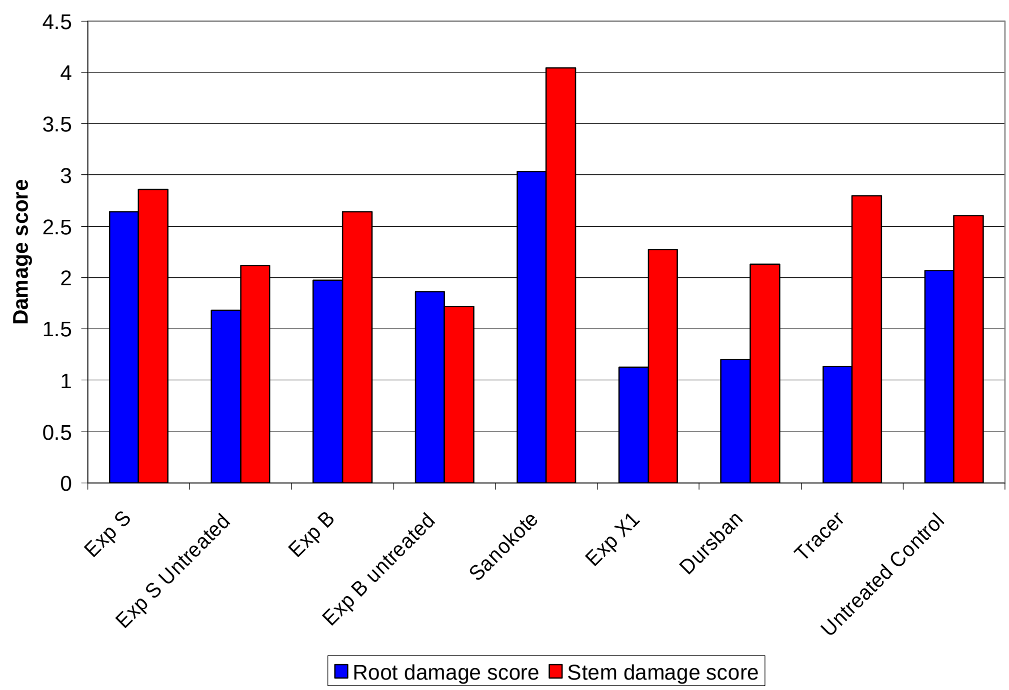

Figure 1.4: Cauliflower – root and stem damage scores on 29 August 2008

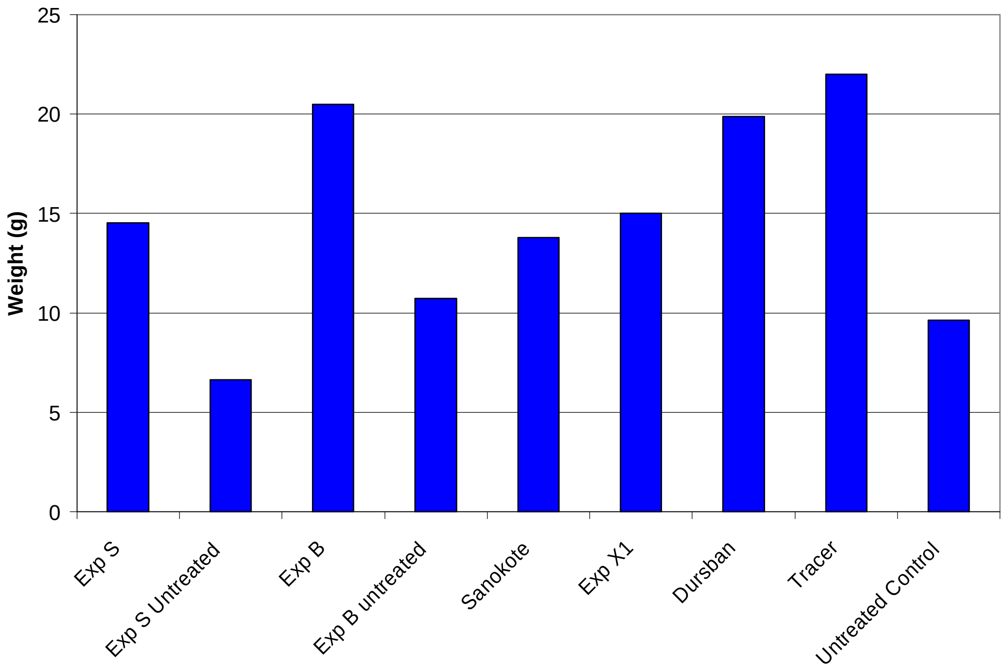

Figure 1.5: Cauliflower – root weight on 29 August 2008

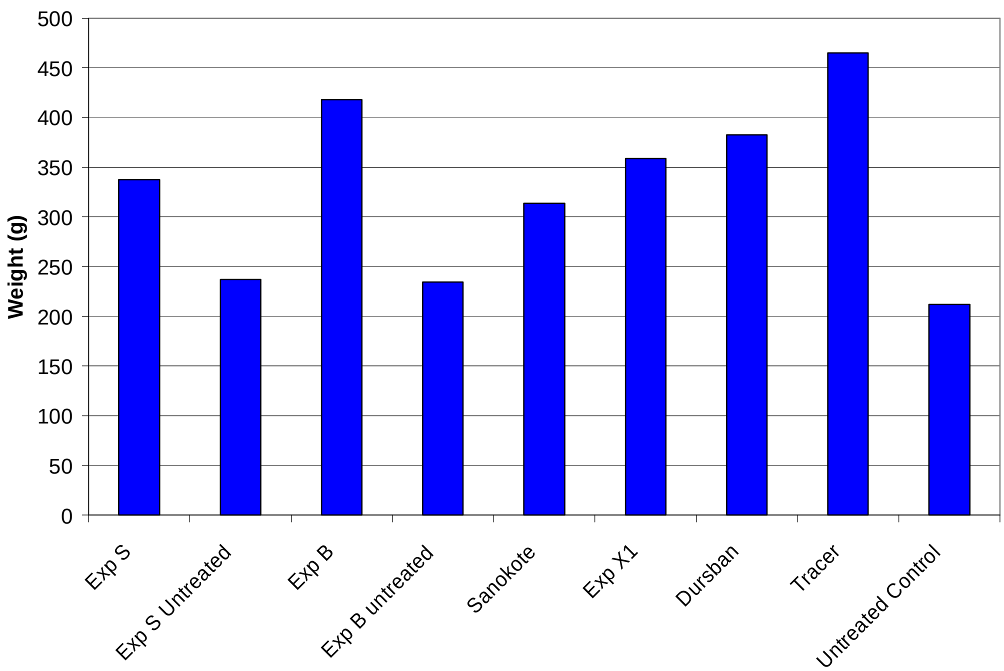

Figure 1.6: Cauliflower – foliage weight on 29 August 2008

<u>Harvest assessments</u>

There were no occurrences of unmarketable curds and analysis was carried out on the proportion of Class 1 curds within each plot. An angular transformation was used to ensure homogeneity between treatments. Analyses were also carried out on the mean curd weight per plot and mean curd diameter per plot.

Finally, the times to 50% maturity for each plot were calculated using linear interpolation. These give a measure of the average time to maturity of the curds. Two differences, 10 – 90% and 25 – 75% maturity give an indication of the spread of maturity times. These were also calculated using linear interpolation.

The treatment factor was significant at a 5% level for the curd weight, curd diameter and the proportion of Class 1 curds (Table 1.5).

Table 1.5: Cauliflower – maturity assessments

Treatment	ps1	ps2	Curd weight	Curd diameter	Proportion Class 1 curds	
					Back Transformed	Transformed
Exp S	1	1	834.6	13.40	0.455	42.4
Exp S Untreated	2	2	651.9	11.71	0.726	58.4
Exp B	3	3	767.1	11.84	0.887	70.3
Exp B untreated	2	3	611.7	10.33	0.819	64.8
Sanokote® (imidacloprid)	3	1	757.0	11.54	0.924	74.0
Exp X1	1	2	777.3	11.82	0.87	68.8
Dursban	3	2	731.2	11.55	0.903	71.9
Tracer	1	3	773.1	11.88	0.727	58.5
Untreated Control	2	1	621.6	10.53	0.906	72.1
F - Value			2.63	5.09		6
P - Value			0.05	0.003		0.001
SED			66.3	0.559		6
5% LSD			140.5	1.185		12.73
SED - ps			63.9	0.539		5.79
5% LSD – ps			135.4	1.142		12.27
df			16	16		16

Exp S had a mean curd weight that was significantly larger than its untreated control and similarly Exp B had a mean curd weight significantly larger than its control. The Sanokote® (imidacloprid), Exp X1 and Tracer treatments had curd weights that were significantly larger than their untreated control, but the Dursban treatment did not (Figure 1.7).

Similarly for the curd diameter, Exp S had a mean significantly larger than its untreated control and Exp B had a mean significantly larger than its control. Drench treatments Exp X1 and Tracer had means significantly larger than their untreated control, but Sanokote® (imidacloprid) and Dursban did not (Figure 1.8).

Exp S had more Class1 curds than its untreated control, but there was no significant difference between Exp B and its control. The Tracer drench treatment had fewer Class 1 curds than its untreated control, but there were no other significant differences of interest (Figure 1.9).

The treatment factor was significant at a 5% level for the time to 50% maturity and the 10 – 90% spread of maturity. It was not significant for the 25 – 75% spread of maturity (Table 1.6).

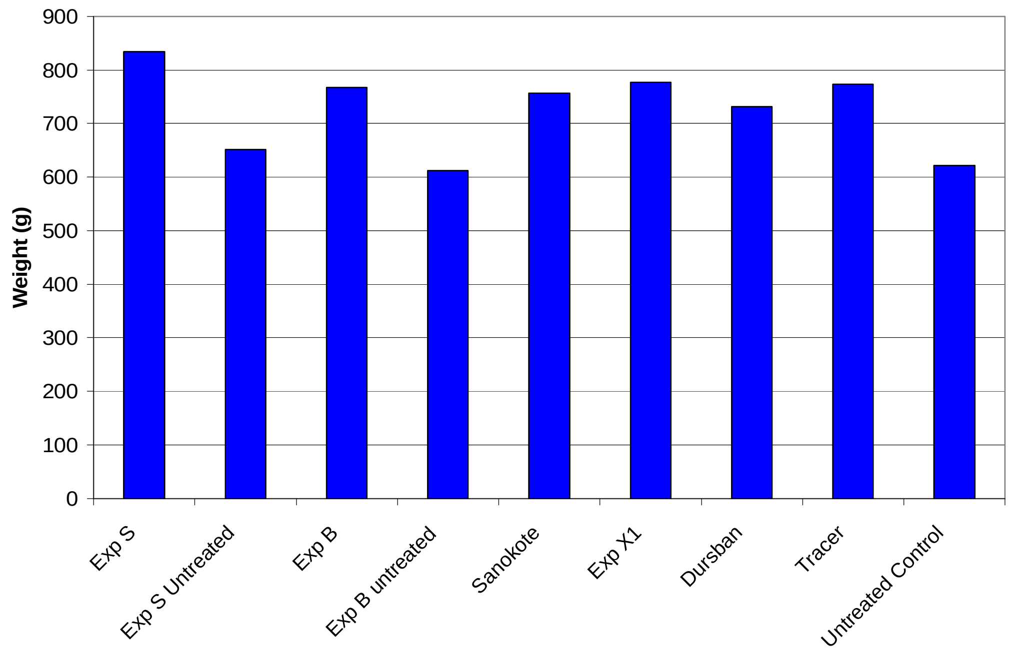

Figure 1.7: Cauliflower – mean curd weight

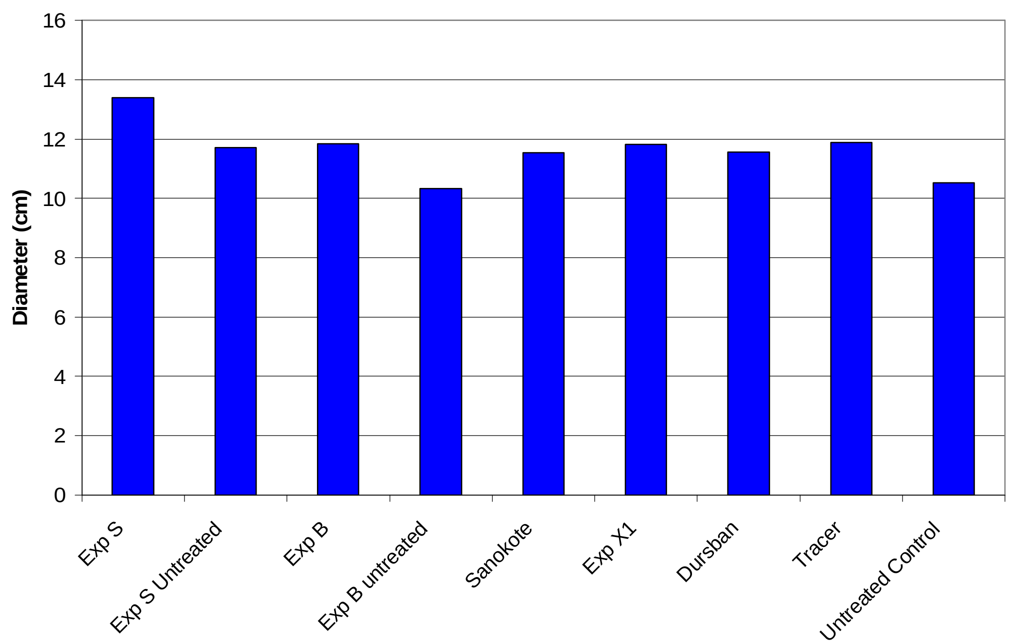

Figure 1.8: Cauliflower – mean curd diameter

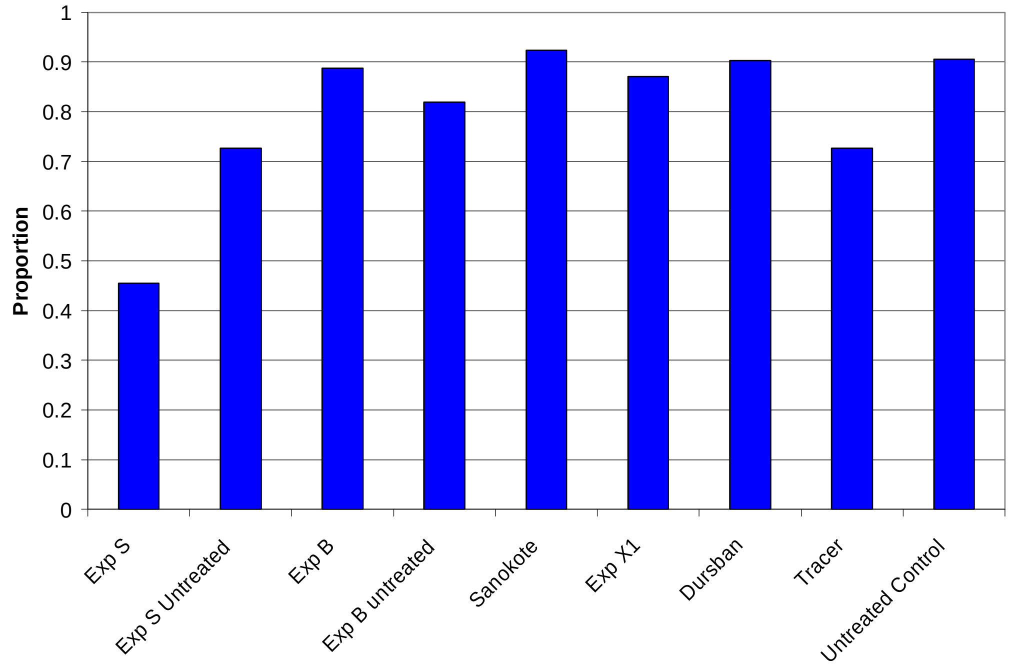

Figure 1.9: Cauliflower – Proportion Class 1 curds

Table 1.6: Cauliflower – maturity assessments

Treatment	ps1	ps2	50% maturity	25-75% spread	10-90% spread
Exp S	1	1	21.7	15.8	28.0
Exp S Untreated	2	2	38.3	16.8	38.7
Exp B	3	3	35.9	11.8	28.1
Exp B untreated	2	3	56.2	14.2	24.9
Sanokote® (imidacloprid)	3	1	38.0	9.2	21.7
Exp X1	1	2	38.1	18.7	28.9
Dursban	3	2	37.4	10.0	23.2
Tracer	1	3	30.0	16.5	31.4
Untreated Control	2	1	51.8	9.9	21.8
F - Value			15.020	1.740	2.980
P - Value			<.001	0.165	0.030
SED			3.783	3.698	4.576
5% LSD			8.019	7.839	9.701
SED - ps			3.645	3.563	4.410
5% LSD – ps			7.727	7.554	9.348
Df			16	16	16

Exp S and Exp B matured significantly earlier than their respective untreated controls. The control treatment matured significantly later than the Sanokote® (imidacloprid), Exp X1, Dursban and Tracer treatments (Figure 1.10).

For the 25-75% analysis, the spread of maturity for Exp X1 was significantly larger than the untreated control.

For the 10 – 90% spread of maturity, Exp S had a significantly smaller spread of maturity than its untreated control whilst there was no difference between Exp B and its control. There were no other significant differences between the treatments (Figure 1.11).

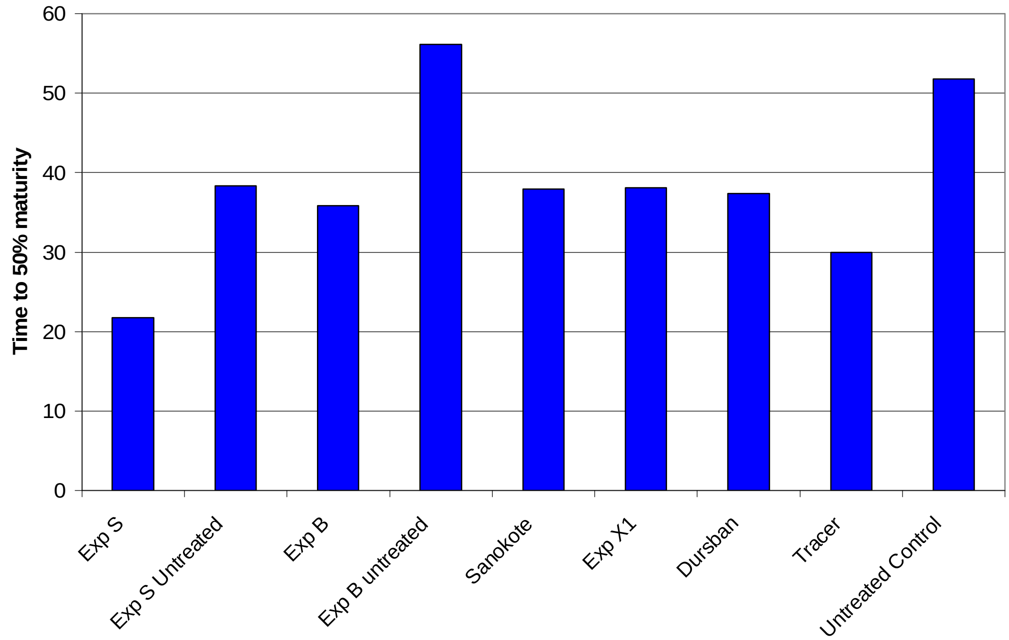

Figure 1.10: Cauliflower – time to 50% maturity

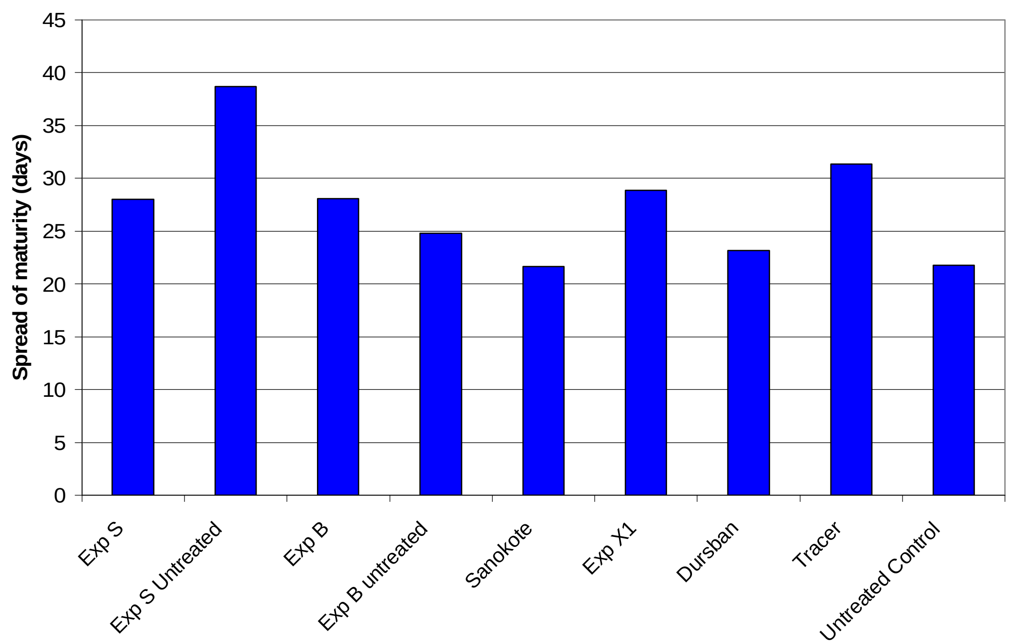

Figure 1.11: Cauliflower – 10-90% spread of maturity

Experiment 2 - Novel insecticide treatments to control cabbage root fly on spring cabbage

Materials and methods

The experiment was planted in the field known as Big Cherry at Warwick HRI Wellesbourne. Including the untreated controls, there were 8 treatments. Four of the treatments were direct-drilled, three of them using insecticide-treated seed, and the other four were transplanted, three of them having been treated with pre-planting drenches. The treatments are shown in Table 2.1.

The direct-drilled seed cv Sparkel F1 was sown on 6 June 2008 and the other seed was sown on 3 June 2008 in 308 Hassy trays which were placed in a greenhouse. On 17July 2008 (at the 4 leaf stage), drench treatments were applied using a 1 ml automatic pipette. Treatments were washed on to the modules with an equivalent volume of water. Treatment details are shown in Table 2.1 and all plants were transplanted on 8 July 2008. The plots were 4 m x 1.83 m wide (1 bed) and there were 4 rows per bed in the drilled crop and 3 rows per bed in the transplanted crop. The experiment was laid out as Trojan square design with 4 rows and 8 columns.

Table 2.1: Treatments applied to spring cabbage

	Active ingredient	Product	Planting method	Application method	Rate (1 unit = 100,000 seeds)
1	Fipronil		Drilled	Seed treatment	12.5 g a.i./unit
2	Spinosad	Tracer	Drilled	Seed treatment	72 g a.i./unit
3	Chlorpyrifos	Dursban WG	Drilled	Seed treatment	9.6 g a.i./unit
4	Untreated-D		Drilled	Seed treatment	
5	Spinosad	Tracer	Transplanted	Pre-planting drench	5.76 g a.i/1000 plants
6	Chlorpyrifos		Transplanted	Pre-planting drench	4.5 g a.i./1000 plants
7	Exp X1		Transplanted	Pre-planting drench	9 g a.i./1000 plants
8	Untreated-T		Transplanted	Pre-planting drench	

Assessments

A sample of 12 plants was taken from each plot on 22 August to assess the damage sustained to their roots and stems. Each root and stem was given a damage score on a scale of 0 – 5. The combined weights of the plant roots and stems were also measured. Assessments of the number of live, wilted and dead plants were made on two occasions, 24 July and 20 August. For the 20 August assessment, counts were also made of the number of missing plants.

Assessments of the head weights of each plant were made on 22 August. Between 6 and 16 plants were sampled and weighed.

Analysis

All analyses were carried out using ANOVA. An additional contrast was set up within each analysis to assess the overall difference between the drilling and transplanted sowing treatments.

<u>Results</u>

Root and stem damage

The plot means for the root damage score and stem damage score were analysed using ANOVA. The combined weights of the plant roots and stems were also analysed.

Table 2.2 shows the treatment means together with F-Values, P-Values and the associated SED and 5% LSD values. The results of the analysis of the contrast are also shown. This tests the overall difference between the transplanted and drilled plants. There was an F-Value and P-Value for the contrast (Cont. F and Cont. P) as well as an estimate of the difference between the two treatment types (Drill – Trans). Here a positive value represents a higher overall mean for drilled treatments; a negative value represents a higher overall mean for transplanted treatments.

The treatment factor was significant at a 5% level for all the analyses shown in Table 2.2. The contrast was also significant for each analysis and provided a consistently positive result. The means for the drilled treatments were significantly larger overall than the means for the transplanted treatments (despite the drilled plants being closer together than the transplants).

There were two 'Controls' within each analysis, one for drilled plots (Control D) and one for transplanted plots (Control T). Pair-wise comparisons for each treatment were made against their respective control.

Table 2.2: Spring cabbage – analysis of root damage score, stem damage score and root weight

Treatments	Root damage score	Stem damage score	Root weight
Fipronil-D	3.06	3.41	9.97
Spinosad-D	3.17	3.15	8.34
Chlorpyrifos-D	3.52	2.78	6.45
Untreated-D	4.60	3.27	5.20
Spinosad-T	1.47	1.50	4.01
Chlorpyrifos-T	1.66	1.18	2.34
Exp X1-T	0.90	1.15	4.74
Untreated-T	1.89	1.33	1.82
F – Value	22.010	5.840	14.110
P – Value	<.001	0.002	<.001
SED	0.380	0.600	1.060
5% LSD	0.800	1.270	2.250
Df	15	15	15
Cont. F	125.490	39.200	64.640
Cont. P	<.001	<.001	<.001
Drill – Trans	2.1	1.9	4.2

Root damage score

For the drilled treatments, all insecticide treatments (Fipronil-D, Spinosad-D & Chlorpyrifos-D) had mean root damage scores significantly smaller than the untreated control. For the transplanted treatments, only Exp X1-T had a mean score that was significantly smaller than the untreated control. Spinosad-D had a mean score that was significantly larger than Spinosad-T and Chlorpyrifos-D also had a mean score that was significantly larger than Chlorpyrifos-T (Figure 2.1). However, these are not strictly comparable because of the different planting/sowing dates.

Stem damage score

For the drilled treatments, there were no significant differences between treatments. For the transplanted treatments there were also no significant differences. However, Spinosad-D had a mean significantly larger than Spinosad-T and Chlorpyrifos-D had a mean significantly larger than Chlorpyrifos-T (Figure 2.1). Although again, these are not strictly comparable due to the different planting/sowing dates.

Mean root weight

Analysis of the mean root weight for each plot showed that for the drilled treatments, Fipronil-D and Spinosad-D had means significantly larger than the untreated control. Considering the transplanted treatments, Spinosad-T and Exp X1-T had means significantly larger than the untreated control. In addition, Spinosad-D had a mean significantly larger than Spinosad-T and Chlorpyrifos-D had a mean significantly larger than Chlorpyrifos-T (Figure 2.2). Although again, these are not strictly comparable due to the different planting/sowing dates.

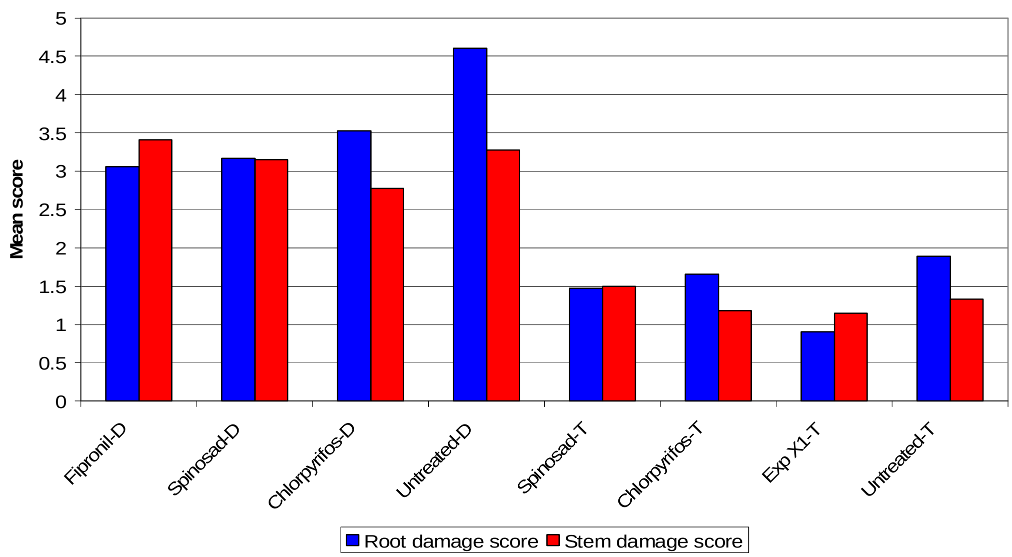

Figure 2.1: Spring cabbage – mean root and stem damage scores

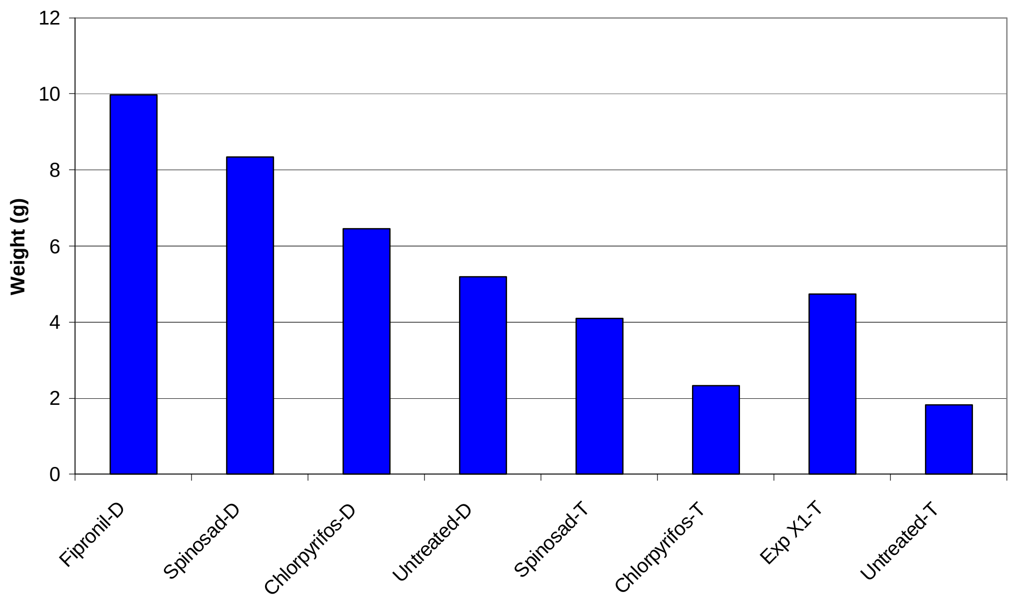

Figure 2.2: Spring cabbage – mean root weight

Live and Wilted Plants

There were insufficient non-zero data to carry out formal analysis on the counts of wilted, dead or missing plants. Simple tables of means were presented instead.

24 July 2008

The counts of live plants per plot were analysed using ANOVA. An analysis of variance table (Table 2.3) shows the treatment term to be significant at a 5% level using an F probability value. There was no overall difference between the drilled and transplanted treatments, resulting in an F probability of 1 for the contrast term.

Table 2.3: Analysis of variance table for number of live plants on 24 July 2008

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
rows stratum	3	20.625	6.875	0.88	
cols stratum	3	65.625	21.875	2.8	
rows.cols.plots stratum					
Tmt	7	709.875	101.411	12.97	<.001
Contrast Drill - Trans	1	0	0	0	1
Residual	18	140.75	7.819		
Total	31	936.875			

Considering the drilled treatments, all treatments had mean numbers of plants that were significantly larger than the untreated control (Table 2.4). For the transplanted treatments, there were no significant differences. The Spinosad-D treatment had more plants than the Spinosad-T treatment. There were no differences between the two Chlorpyrifos treatments.

Table 2.4: Number of live plants on 24 July 2008

Treatment	Mean number of live plants
Fipronil-D	24.0
Spinosad-D	34.25
Chlorpyrifos-D	26.75
Untreated-D	15.75
Spinosad-T	26.0
Chlorpyrifos-T	24.0
Exp X1-T	25.75
Untreated-T	25.0
SED	1.977
5% LSD	4.154

Table 2.5 shows counts of wilted and dead plants.

Table 2.5: Number of wilted and dead plants on 24 July 2008

	Wilted	Dead
Fipronil-D	0.25	0
Spinosad-D	0.5	0
Chlorpyrifos-D	0	0.25
Untreated-D	1.5	0.25
Spinosad-T	0.25	0.25
Chlorpyrifos-T	1.75	1.25
Exp X1-T	0	0.25
Untreated-T	0.25	1

20 August

The counts of live plants per plot were analysed using ANOVA. Table 2.6 shows that the treatment term was significant at a 5% level. The contrast between the two treatment applications shows an estimate of -2.0. This difference was not significant at the 5% level.

Table 2.6: Analysis of variance table for number of live plants on 20 August 2008

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rows stratum	3	23.12	7.71	0.73	
cols stratum	3	50.12	16.71	1.58	
rows.cols.plots stratum					
tmt	7	744.88	106.41	10.09	<.001
Contrast Drill - Trans	1	32	32	3.04	0.099
Residual	18	189.75	10.54		
Total	31	1007.88			
<u>Contrast</u>					
Contrast:	-2				
Standard error	1.15				

Considering only the drilled treatments, every insecticide treatment had a mean significantly larger than the untreated control. For the transplanted treatments, there were no significant differences. However, the Spinosad-D treatment had a mean significantly larger than the Spinosad-T treatment. There was no significant difference between the two Chlorpyrifos treatments (Table 2.7).

Table 2.7: Number of live plants on 20 August 2008

Treatment	Mean number of live plants
Fipronil-D	22.75
Spinosad-D	32.25
Chlorpyrifos-D	25.5
Untreated-D	13.75
Spinosad-T	26.5
Chlorpyrifos-T	25.75
Exp X1-T	25.5
Untreated-T	24.5
SED	2.296
5% LSD	4.823

Table 2.8 shows the counts of wilting, dead and missing plants. Overall there was a larger number of missing plants for the treatments that were transplanted. Figure 2.3 shows the mean number of live plants on 24 July and 20 August 2008.

Table 2.5: Number of wilted, dead and missing plants on 20 August 2008

	Wilted	Dead	Missing
Fipronil-D	0	0	0
Spinosad-D	0	0	0
Chlorpyrifos-D	0	0	0
Untreated-D	2	0	0
Spinosad-T	0	0	0.5
Chlorpyrifos-T	0	0	0.5
Exp X1-T	0	0	1.25
Untreated-T	0.5	0	2

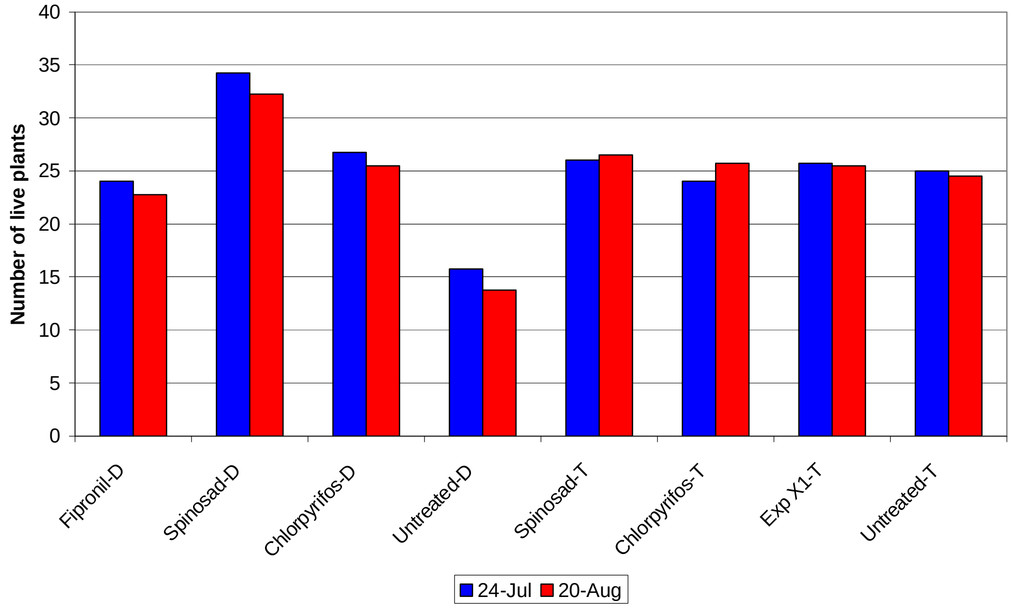

Figure 2.3: Spring cabbage - mean number of live plants on 24 July and 20 August 2008

Head Weight

Analysis was carried out using ANOVA. Table 2.9 shows the Analysis of Variance table.

Table 2.9: Analysis of variance table for head weight on 22 August 2008

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rows stratum	3	41110	13703	2.81	
cols stratum	3	5756	1919	0.39	
rows.cols.plots stratum					
tmt	7	528116	75445	15.49	<.001
Contrast Drill - Trans	1	446446	446446	91.64	<.001
Residual	18	87691	4872		
Total	31	662673			
Contrast					
Contrast:	236				
Standard error	24.7				

Considering only the drilled treatments, Fipronil-D, Spinosad-D and Chlorpyrifos-D all had means significantly larger than the untreated control (Table 2.10). For the transplanted treatments, there were no significant differences. The mean head weight of plants from the Spinosad-D treatment was significantly larger than the Spinosad-T treatment and plants from the Chlorpyrifos-D treatment were significantly larger those from the Chlorpyrifos-T treatment. Figure 2.4 shows the mean head weight on 22 August 2008.

Table 2.10: Mean head weight on 22 August 2008

Treatment	Mean head weight (g)
Fipronil-D	410.0
Spinosad-D	379.7
Chlorpyrifos-D	405.8
Untreated-D	246.9
Spinosad-T	155.2
Chlorpyrifos-T	97.2
Exp X1-T	144.3
Untreated-T	100.8
SED	49.4
5% LSD	103.7

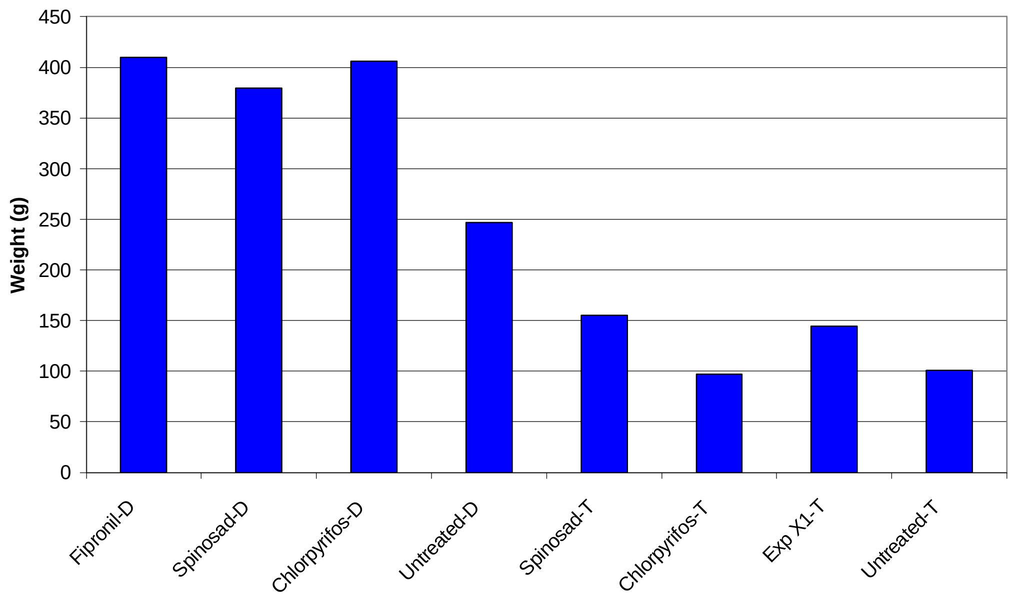

Figure 2.4: Spring cabbage – mean head weight on 22 August 2008

Experiment 3 - Novel insecticide treatments to control cabbage root fly on swede

Materials and methods

Swede seed (cv Magres) was sown into plots in the field known as Big Cherry on 23 May 2008. The plots were 4 m x 1 bed (1.83 m) wide and the seed was drilled at 13 seeds/m row. There were 4 rows per bed spaced at 38 cm. Just after the seedlings had emerged all of the plots were covered with insect proof netting to exclude the first generation of the cabbage root fly. The trial was designed as a balanced row and column design with 4 rows and 5 columns. Including an untreated control, there were 5 treatments (Table 3.1). After removing the insect netting, each treatment was applied on 3 occasions (14 July, 24 July and 30 July). All sprays were applied in 300 l/ha using a knapsack sprayer fitted with 02F110 nozzles. One week after the final spray the plots were re-covered to exclude any remaining second generation cabbage root flies, so in total the plots were exposed to cabbage root flies for 24 days.

Table 3.1: Insecticides applied as foliar sprays to control cabbage root fly on swede

	Active ingredient	**Product**	**Rate g or ml product/ha**	**Wetter**
1	Untreated Control			
2	Exp X1		1500 ml	Agral @ 0.03%
3	Exp X2		175 ml	Agral @ 0.03%
4	Spinosad	Tracer	300 ml	Agral @ 0.03%
5	Chlorpyrifos	Dursban WG	1200 g	Agral @ 0.03%

Assessments

The swede roots were harvested on 27 August and then washed. Each root was assessed for damage and categorised as having no damage or 0-5%, 5-10%, 10-25%, 25-50% or 50-100% of its surface area damaged.

Analysis

Analysis using ANOVA was carried out on the mean damage score per plot, the mean plant weight per plot and the total number of harvested plants per plot. No transformations were required.

Results

Table 3.2 summarises the mean number of roots which fell into each damage category. From this, it was difficult to identify any obvious differences between treatments.
Formal analysis using ANOVA was used for the proportion of plants showing 5-10%, 10 - 25%, 25 – 50% and 50 – 100% damage.

Table 3.2: Swede - the mean number of roots in each damage category

	Undamaged	**0 - 5%**	**5 - 10%**	**10 - 25%**	**25 - 50%**	**50 - 100%**
Untreated Control	0	0.5	3.5	13.75	17.25	4
Exp X1	0	0	1.5	12.25	19.25	5
Exp X2	0	0	1	11.75	19.75	7
Spinosad	0	0	2	10.25	18	8.25
Chlorpyrifos	0	0.25	2	11.75	19.75	5.25

Table 3.3 shows the proportion of roots showing 5 - 10%, 10 – 25%, 25 – 50% and 50 – 100% damage. The treatment factor was not significant at the 5% level for any of the analyses. Pair-wise comparisons did not show any significant differences between the control and any of the treatments.

Table 3.3: The proportion of roots showing 5 - 10%, 10 – 25%, 25 – 50% and 50 – 100% damage

Treatment	**5 - 10%**	**10 - 25%**	**25 - 50%**	**50 - 100%**
Untreated Control	0.089	0.371	0.432	0.097
Exp X1	0.033	0.337	0.507	0.124
Exp X2	0.035	0.296	0.479	0.188
Spinosad	0.051	0.241	0.472	0.235
Chlorpyrifos	0.050	0.290	0.514	0.140
F-Value	0.250	0.580	0.270	0.670
P-Value	0.901	0.684	0.890	0.633
SED	0.063	0.092	0.089	0.095
5% LSD	0.145	0.211	0.206	0.219
df	8	8	8	8

Table 3.4 shows means for the total number of harvested plants per plot, the mean damage score per plot and the mean weight per plot. None of the treatment terms were significant at a 5% level. Pair-wise comparisons showed no differences between the untreated control and the treatments.

Table 3.4: Means for the total number of harvested plants per plot, the mean damage score per plot and the mean weight per plot

Treatment	**Total number**	**Mean damage score**	**Mean Root Weight (g)**
Untreated Control	39.40	3.51	11.88
Exp X1	38.00	3.73	13.72
Exp X2	38.73	3.82	14.09
Spinosad	36.87	3.89	14.22
Chlorpyrifos	41.00	3.73	13.67
F-Value	0.300	0.500	0.750
P-Value	0.870	0.737	0.583
SED	4.000	0.283	1.540
5% LSD	9.220	0.651	3.551
Df	8	8	8

Experiment 4 - Novel insecticide treatments to control aphids and whitefly on Brussels sprout

Materials and methods

The experiment was planted in the field known as Big Cherry. Brussels sprout seed (cv Montgomery) was sown on 13 May 2008 into 308 Hassy trays and the trays were placed in a greenhouse. The plants were transplanted on 27 June 2008. The plots were 5.5 m x 1 bed (1.83 m wide) and there were 3 rows per bed. The plants were spaced at 50 cm within and 50 cm between rows. The trial was designed as a partially balanced row and column design with 4 rows and 6 columns. Including an untreated control, there were 6 treatments (Table 4.1). All sprays were applied in 300 l/ha using a knapsack sprayer fitted with 02F110 nozzles.

Table 4.1: Treatments applied to Brussel sprout plots to control aphids

	Active ingredient	**Product**	**Rate (g or ml product/ha)**	**Wetter**
1	Untreated Control			
2	Exp X1		1500 ml	Agral @ 0.03%
3	Exp X2		175 ml	Agral @ 0.03%
4	Exp U		480 ml	Phase II @ 0.5%
5	Thiacloprid	Biscaya	400 ml	Phase II @ 0.5%
6	Pymetrozine	Plenum	400 g	Phase II @ 0.5%

Assessments

Pest assessments were made on two occasions, 25 October (pre-spray) and 1 September (post-spray). For each assessment, counts of winged and wingless aphids were made. At each assessment, each plant was also assessed for whitefly infestation and given a score on a scale of 0 – 3.

Analysis

The vast majority of aphids were wingless *Brevicoryne Brassicae* (Table 4.2).

On 25 September, there was a large number of wingless *Myzus persicae* in plots of the Exp U treatment. However, all 213 of these aphids occurred in a single plot. Similarly, 63 of the 64 wingless *Myzus persicae* in plots of the Biscaya treatment occurred within a single plot. The other point of note is the large count of wingless *Myzus persicae* in the untreated control relative to other treatments on 1 October.

Table 4.2: Numbers of aphids recorded on 25 September and 1 October 2008

25 September

	Myzus persicae	***Myzus persicae***	***Brevicoryne Brassicae***	***Brevicoryne Brassicae***	**Macrosiphum euphorbiae**	**Macrosiphum euphorbiae**
	Winged	**wingless**	**winged**	**wingless**	**winged**	**wingless**
Untreated Control	0	213	3	5449	0	0
Exp X1	0	0	1	3695	0	0
Exp X2	0	2	9	3368	0	0
Exp U	0	1	0	1747	0	0
Biscaya	0	64	1	1781	0	0
Plenum	0	0	2	1472	0	0

1 October

	Myzus persicae	***Myzus persicae***	***Brevicoryne Brassicae***	***Brevicoryne Brassicae***	**Macrosiphum euphorbiae**	**Macrosiphum euphorbiae**
	Winged	**wingless**	**winged**	**wingless**	**winged**	**wingless**
Untreated Control	0	7	10	6011	0	0
Exp X1	0	15	4	1454	0	0
Exp X2	0	7	5	2551	0	0
Exp U	0	8	0	413	0	0
Biscaya	0	0	8	995	0	0
Plenum	0	6	0	492	0	0

The formal analysis using ANOVA was performed only on wingless *Brevicoryne Brassicae* using the pre-treatment data as a covariate within the analysis. The treatment term was significant at the 5% level. A square root transformation of both the response and the covariate was used to ensure homogeneity between treatments.

Table 4.3 shows the back transformed means together with the transformed means in brackets. SED and 5% LSD values are presented for the transformed means. All treatments have means significantly smaller than the untreated control (Table 4.3; Figure 4.1).

Table 4.3: Mean number of wingless *Brevicoryne Brassicae* per plot on 1 October 2008

	ps	**Back-transformed mean**	**Transformed mean**
Untreated	1	1220.5	34.94
Exp X1	2	349.6	18.70
Exp X2	2	589.2	24.27
Exp U	2	160.8	12.68
Biscaya	1	175.0	13.23
Plenum	1	117.9	10.86
	SED		3.91
	LSD		8.85
	SED - ps		3.91
	LSD - ps		8.85

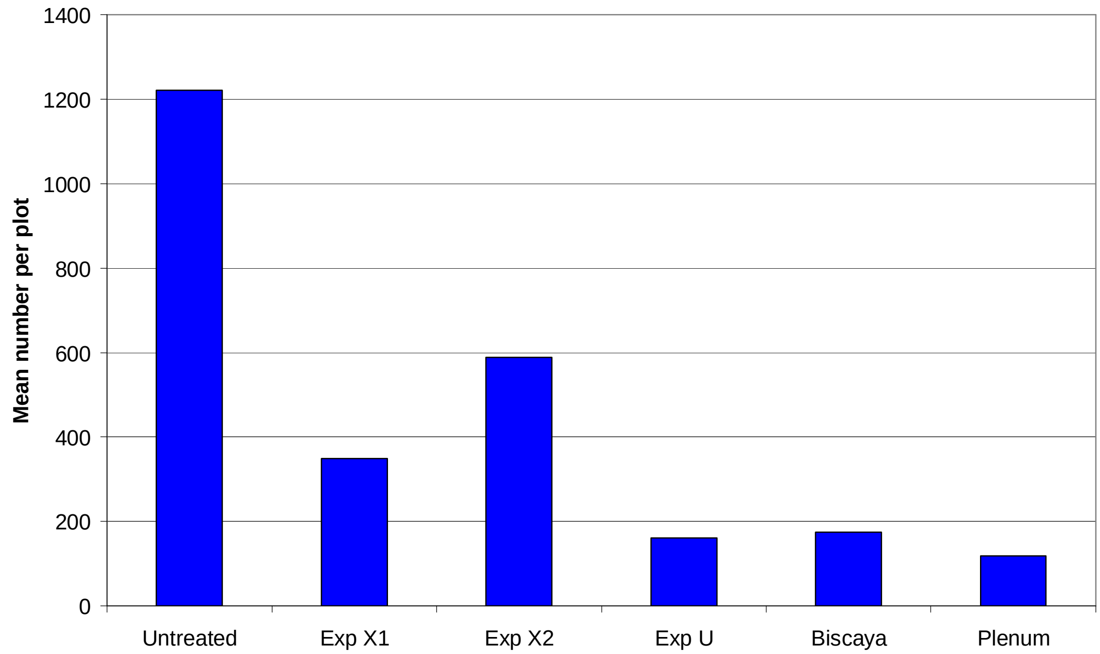

Figure 4.1: Mean number of wingless *Brevicoryne Brassicae* per plot on 1 October 2008

White Fly

A similar analysis was done for the whitefly score. There were no significant differences between any of the treatment means (Table 4.4).

Table 4.4: The mean whitefly score on 1 October 2008

Treatment	**ps**	**White fly score**
Untreated	1	0.849
Exp X1	2	0.919
Exp X2	2	0.997
Exp U	2	0.792
Biscaya	1	1.071
Plenum	1	0.789
SED		0.1723
LSD		0.3897
SED - ps		0.1655
LSD - ps		0.3744

Experiment 5 - Do novel insecticides Exp X1 and Exp X2 kill adult cabbage root fly?

Materials and methods

Nine glasshouse-grown cauliflower (cv Skywalker) were selected to fit into 35 cm x 35 cm x 35 cm insect proof mesh cages. Solutions of Exp X1 and Exp X2 were prepared at the same concentration as used in field experiments (Table 5.1). Agral was used as a wetter. Three plants were sprayed with each solution using a hand sprayer. The sprays were applied to "run off" and allowed to dry before being placed in an insect cage (1 plant/cage). 15 male and 15 female laboratory reared cabbage root fly (5-7 days old) were placed in each cage along with a supply of food (yeast extract and sucrose solution) and water. The cages were placed in a controlled environment room (18 ^{o}C, 16:8 hours Light:Dark). The mortality of the flies was assessed 1, 4, 5, 6 and 8 days after treatment.

Table 5.1: Spray solutions used to try and kill adult cabbage root fly

Treatment	Volume product (ml)	Volume water (ml)
Exp X1	1.00	200
Exp X2	0.17	300

Results

The data were not subjected to statistical analysis as this was a small 'look-see' experiment to establish whether Exp X1 and Exp X2 were toxic to adult cabbage root flies as residues on plant foliage. Overall, mortality was very low during the 8-day observation period. However, Exp X1 appeared to kill more flies than Exp X2 and more male flies than female flies were affected.

Table 5.2: Cumulative mean percentage mortality of adult cabbage root fly

Day	1		4		5		6		8	
Treatment	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Untreated	0.33	0	1.00	0	1.00	0.33	1.00	0.67	1.67	0.67
Exp X1	0.67	0	3.33	0.67	4.00	1.00	4.00	2.00	4.67	2.00
Exp X2	0.67	0	1.00	0.33	1.00	0.33	1.33	0.67	1.33	1.33

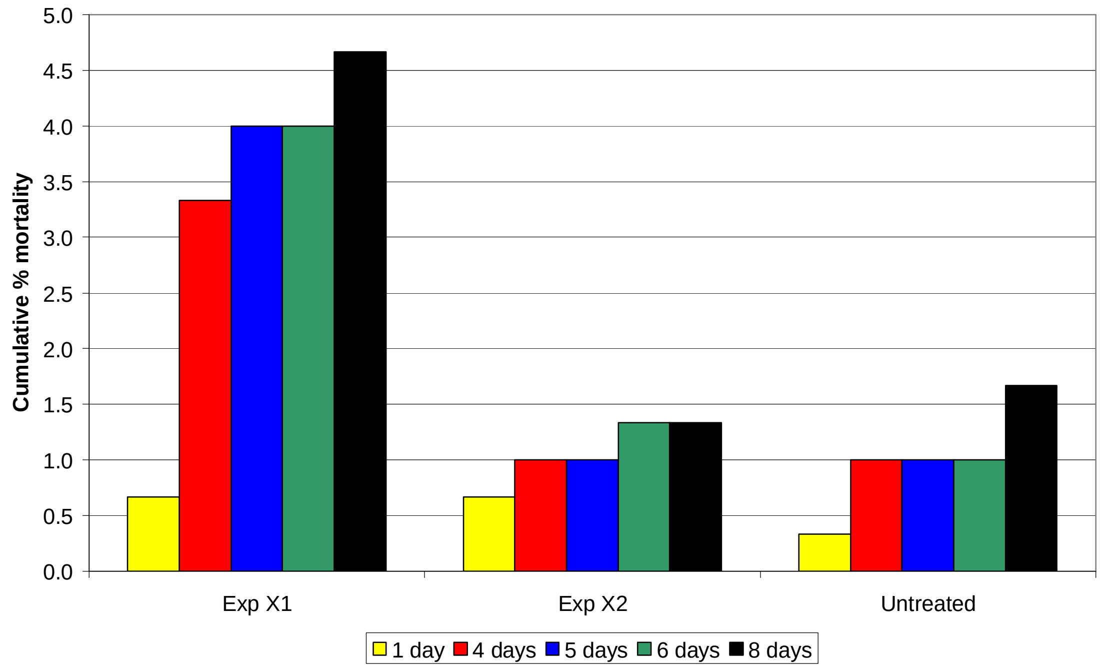

Figure 5.1: The cumulative mortality of male cabbage root flies

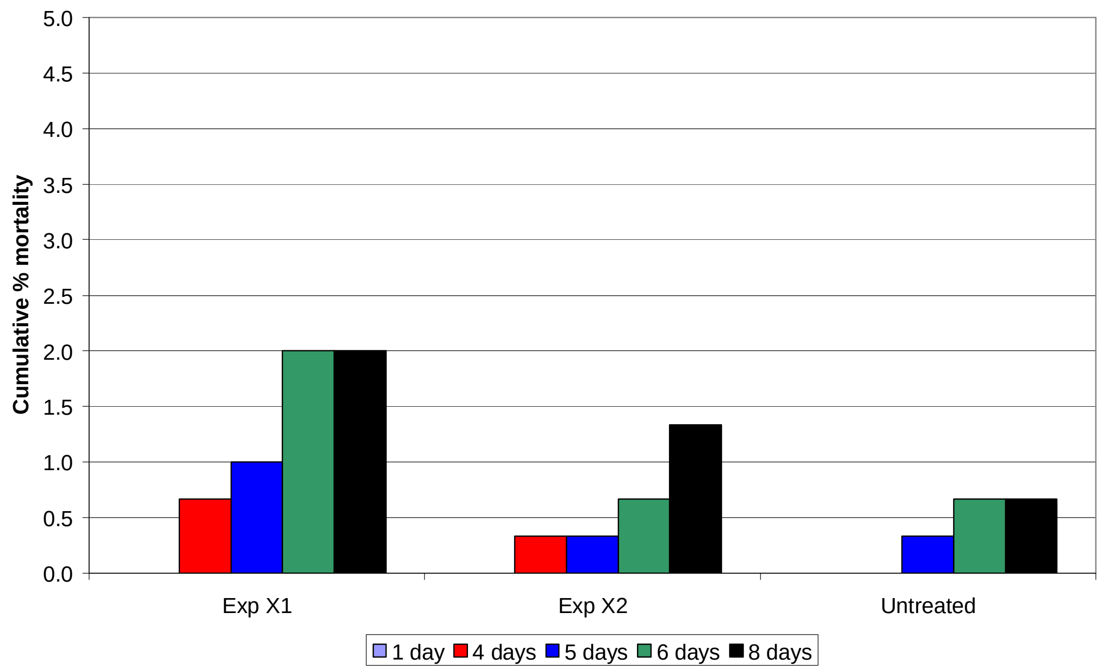

Figure 5.2: The cumulative mortality of female cabbage root flies

Discussion

The wet weather in summer 2008 suppressed populations of aphids and whitefly and there were insufficient aphids to make spray treatment application worthwhile until late September 2008. There were few statistically significant differences in aphid numbers in the trial on cauliflower when assessed in early August and again in early September and this probably reflects the low numbers of aphids present overall rather than an absence of treatment effects. Flea beetle damage was also low overall and again may be a reason for the lack of treatment effects, particularly with the seed treatments, some of which have provided flea beetle control in previous experiments.

On cauliflower, all insecticide treatments increased plant size compared with insecticide-free controls when plants were measured *in situ* on 7 August and Exp B, Exp S, Dursban and Tracer increased root weight when plants were assessed on 29 August (Table 6.1). All treatments apart from Exp S and Sanokote® (imidacloprid) also increased foliage weight on 29 August. Direct evidence of a reduction in cabbage root fly feeding damage to the plant roots were shown by all three drench treatments, but not by the seed treatments. Indeed, Exp B and Sanokote® (imidacloprid) appeared to increase root damage compared with the insecticide-free control treatments and this is not surprising, since imidacloprid, in particular, has been shown previously to delay cabbage root fly development (and thereby increase feeding damage) when applied at the commercial rate, which is a sub-lethal does for cabbage root fly larvae. Sanokote® (imidacloprid) also increased stem damage, although none of the other treatments had any effect. Finally, with the exception of Dursban, all of the treatments increased curd size (weight or diameter) at harvest compared with the control treatments and all insecticide treatments hastened maturity compared with the control treatments, although the spread of maturity was relatively unaffected.

Table 6.1: Summary of treatment effects in Experiment 1 (cauliflower). Comments refer to statistically significant treatment effects compared with the appropriate insecticide-free control treatment

Assessment		Exp B	Exp S	Sanokote® (imidacloprid)	Dursban	Tracer	Exp X1
Aphids	07-Aug					Increased	
	02-Sep						
Flea beetle	07-Aug			Reduced			
	02-Sep						
Plant size	07-Aug	Increased	Increased	Increased	Increased	Increased	Increased
Root damage	29-Aug	Increased		Increased	Reduced	Reduced	Reduced
Stem damage	29-Aug		Increased				
Root weight	29-Aug	Increased	Increased		Increased	Increased	
Foliage weight	29-Aug	Increased			Increased	Increased	Increased
Curd weight		Increased	Increased	Increased		Increased	Increased
Curd diameter		Increased	Increased			Increased	Increased
Class 1 curds			More			Less	
50 % maturity		Increased	Increased	Increased	Increased	Increased	Increased
10-90% spread maturity			Smaller				

Some of the treatments evaluated on spring cabbage were similar to those used on cauliflower. The three seed treatments (fipronil, spinosad, chlorpyrifos) increased the plant count and reduced cabbage root fly feeding damage on the roots of the drilled plants compared with insecticide-free controls (Table 6.2). They also increased root weight and head weight. The effects of the drench treatments were less pronounced and only Exp X1 reduced root damage and increased root weight compared with insecticide-free controls. Direct comparisons between drilled and transplanted plants cannot be made because of the difference in sowing/planting dates which meant that they were exposed to ‘different’ levels of pressure from cabbage root fly and other pests.

Table 6.2: Summary of treatment effects in Experiment 2 (spring cabbage). Comments refer to statistically significant treatment effects compared with the appropriate insecticide-free control treatment

		Seed treatments			Drench treatments		
		Fipronil	**Tracer**	**Chlorpyrifos**	**Tracer**	**Dursban**	**Exp X1**
Root damage	22-Aug	Reduced	Reduced	Reduced			Reduced
Plant count	22-Aug	Increased	Increased	Increased			
Root weight	22-Aug	Increased	Increased	Increased	Increased		Increased
Head weight	22-Aug	Increased	Increased	Increased			
Plant count	24-Jul	Increased	Increased	Increased			
Plant count	20-Aug	Increased	Increased	Increased			

Again, some of the insecticides used in Experiments 1 and 2 were also applied as foliar sprays to swede in Experiment 3. However, none of the treatments reduced cabbage root fly damage to the roots compared with the insecticide-free control. This is disappointing, but not surprising, since previous experiments have shown that neither Tracer nor Dursban are effective as foliar sprays on this crop and previous laboratory experiments, similar to Experiment 5, showed that it was necessary to apply these insecticides with a bait (food for adult cabbage root flies) in order to encourage them to ingest the insecticides, which then lead to increased levels of kill. What is disappointing is that both Experiments 3 and 5 indicate that the novel insecticides Exp X1 and Exp X2 do not kill adult cabbage root fly through foliar application. This is in stark contrast to their activity against carrot fly, against which they performed very well in a field experiment at Wellesbourne in 2008.

Finally, evaluation of aphicide sprays was limited because of the low numbers of aphids. However, aphid numbers were sufficient to make one set of spray applications to Brussels sprout plots in late September. All of the treatments reduced aphid numbers compared with the insecticide-free control treatment. There was no difference between four of the treatments (Exp X1, Exp U, Biscaya, Plenum) although Exp X2 was less effective than all but Exp X1.

CONCLUSIONS

- Several seed treatments (Exp B, Exp S, fipronil, spinosad, chlorpyrifos, imidacloprid) reduced cabbage root fly feeding damage and/or increased plant count and/or plant size compared with insecticide-free controls.
- Populations of aphids and flea beetles were too low to assess the impact of seed treatments on these pests.
- All drench treatments (Dursban, Tracer, Exp X1) reduced cabbage root fly feeding damage and/or increased plant size compared with insecticide-free controls and Exp X1 was more consistent in its effect than the other treatments.
- Foliar sprays of Tracer, Dursban and two novel compounds Exp X1 and Exp X2 did not cause high mortality when applied to control adult cabbage root flies.

TECHNOLOGY TRANSFER

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