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Authentication

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

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Grower Summary

Headline

This project identifies new solutions to control key pests of Brassicas, carrots, leeks and lettuce.

Background and expected deliverables

Pest damage can often be the factor that determines whether a field vegetable crop is marketable or not and can occur at a time when considerable investment has already been made in land preparation, plant raising, fertiliser application etc. A number of key pest insects are particularly difficult to control with the range of treatments available and this armoury may be reduced as a result of EU and other pesticide reviews. It is therefore important to ensure that any potential opportunities for the development of new control methods are evaluated for the pest/crop combinations for which they might be appropriate.

Whilst it might be hoped that agrochemical companies would undertake this work themselves, in reality most field vegetable crops represent a small market and some initial demonstration work is often required to convince a company that support or development of a new control method would be economically viable. The overall aim of this project is to evaluate novel methods of pest control for pest/crop combinations which are causing difficulties to growers.

Leafy Brassicas and radish: The cabbage root fly (*Delia radicum*) is one of the most serious pests of Brassica crops. There are currently two approved chemicals, chlorpyrifos (e.g. Dursban WG) and spinosad (Tracer) for cabbage root fly control on leafy Brassica crops in the UK. 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 broccoli heads.

Aphids also continue to cause major problems for Brassica growers and although several chemicals are available, they do not provide a sufficient 'armoury' to control *Brevicoryne brassicae* (cabbage aphid) and *Myzus persicae* (peach-potato aphid) effectively when pest pressure is high and where insecticide resistant clones of *M. persicae* are present. A greater reliance on neonicotinoid insecticides also increases the risk of selecting populations of *M. persicae* that are resistant to this group of insecticides. This would have severe consequences for growers of Brassica and other susceptible crops.

Carrot: Carrot fly (*Psila rosae*) has been controlled effectively using pyrethroid insecticides, and foliar sprays of Hallmark with Zeon Technology (will be referred to subsequently as Hallmark) have been particularly effective. Whilst there is no evidence that populations of carrot fly have become resistant to pyrethroids, reliance on a single group of active ingredients is a risky strategy in the long-term.

Leek: Onion Thrips (*Thrips tabaci*) is the most important pest of leek grown in the UK. Thrips may attack other allium crops. Thrips cause blemishes to the leaves, which reduce quality and may make the crop unmarketable. Insecticide resistance to pyrethroid insecticides in field populations of *T. tabaci* was confirmed by scientists at Rothamsted Research in 2006 (Defra-funded project PS2710). Effective control is constrained by the limited range of treatments and treatment applications available, especially now that resistance to pyrethroids has been demonstrated. The range of effective alternative treatments is very limited and needs to be expanded. Bean seed fly (*Delia* spp.) is also an important pest of allium crops and can reduce seedling emergence (particularly of salad onion) dramatically. Current control relies on seed treatment with tefluthrin (Force). It is likely that some of the newer seed treatments being developed currently may be effective against bean seed fly.

Lettuce: Several aphid species infest the foliage of lettuce, of which *Nasonovia ribisnigri* (currant–lettuce aphid), *M. persicae* and *Macrosiphum euphorbiae* (potato aphid) are the most important. *Nasonovia ribisnigri* is particularly difficult to control, as it infests the heart of the plant and is therefore inaccessible to foliar sprays of insecticide. The difficulties of controlling lettuce aphids and the occurrence in the past of insecticide resistance in *N. ribisnigri* mean that there is a need to find alternative and effective methods of control.

The aim of this project is to evaluate novel insecticides for the control of the pests described above. The expected deliverables from this work include:

- An evaluation of novel treatments for the control of cabbage root fly (including control in broccoli florets), aphids, whitefly, flea beetle and caterpillars in Brassicas and radish
- An evaluation of novel treatments for the control of carrot fly and aphids on carrot

- An evaluation of novel treatments for the control of Thrips and bean seed fly on leek
- An evaluation of novel treatments for the control of aphids on lettuce

Summary of the project and main conclusions

Brassicas: A novel active ingredient was effective against a range of pests when applied pre-planting or as a foliar spray. Control of cabbage root fly in roots and broccoli florets, aphids, caterpillars, flea beetle, leaf miners and whitefly was observed, together with an increase in plant size and cauliflower yield. Gaucho, a novel seed treatment and Movento showed activity against whitefly and the efficacy of approved aphid and caterpillar treatments was confirmed.

Carrot: A novel active ingredient was more effective than Hallmark with Zeon Technology (lambda cyhalothrin) for carrot fly control and also controlled willow-carrot aphid. Several approved products were also effective.

Leek: Control of Thrips is difficult. A novel seed treatment gave some early control and several sprays were partially effective, the most effective being Mesurol (methiocarb – not approved for this use in the UK and used as a positive control).

Several biological products showed little significant activity in the crop/pest combinations tested.

1. *Novel insecticide treatments to control aphids, caterpillars, flea beetle and cabbage root fly on cauliflower*

Including an untreated control, there were 9 treatments (all pre-planting). The cauliflower seed (cv Skywalker) was sown on 28 May 2010 and modules were transplanted on 1 July. Mid-season, roots and foliage were weighed, and the roots and stems were scored for damage by cabbage root fly larvae. HDCI 003a and Steward drench treatments reduced root damage compared with the untreated control. None of the treatments reduced damage to the stem. The plants treated with HDCI 003a had heavier foliage than the untreated control.

Aphid numbers and flea beetle damage were reduced by HDI 003a (pre-planting) compared with the untreated control. At harvest, HDCI 003a (pre-planting) and Movento (pre planting) increased curd weight, and HDCI 003a also increased curd diameter.

2. Novel insecticide treatments to control aphids, caterpillars and whitefly on Brussles sprout

Including an untreated control, there were 13 treatments (7 sprays and 6 pre-planting). Brussels sprout seed (cv Doric F1) was sown on 13 May 2010 and modules were transplanted on 16 June. All sprays were applied using a knapsack sprayer fitted with 02F110 nozzles.

Aphids (*B. brassicae* and *M. persicae*) appeared during July. Numbers were assessed pre-spraying and the pre-planting treatments, HDCI 003a – Drench, HDCI 003a – 'Phytodrip', HDCI 006 – Dead seed, and Sanokote® – Gaucho had reduced aphid numbers compared with the untreated control. The post-spray assessment indicated that HDCI 003b, HDCI 005, Biscaya (thiacloprid), Movento and Plenum (pymetrozine) reduced numbers of both aphid species and HDCI 007 had a small effect on *M. persicae* only. There were no further significant aphid infestations.

Whitefly and flea beetle damage were also assessed pre- and post-spray in July. At the time of the pre-spray assessment, HDCI 006 – Dead seed and Sanokote® – Gaucho had reduced whitefly infestations and HDCI 006 also had reduced flea beetle damage. The post-spray assessment indicated that HDCI 003b and Movento sprays also reduced whitefly infestations. Plant width was also measured and the pre-planting treatments HDCI 003a, Steward, HDCI 006 and Gaucho all increased plant width compared with the untreated control.

Caterpillar damage and whitefly infestations were further evaluated on 6 September. HDCI 003a (pre-planting), HDCI 003b – Spray, and HDCI 005 – Spray reduced caterpillar damage compared with the control. HDCI 003b and Movento sprays were still controlling whitefly.
A second spray was applied in September. Caterpillar numbers were assessed pre- and post-spray. HDCI 003b, HDCI 005, Steward, Biscaya and Movento all reduced numbers of caterpillars.

3. Novel insecticide treatments to control cabbage root fly in broccoli florets

Including an untreated control, there were 8 treatments (6 sprays and 1 module-drench). Broccoli seed (cv Fiesta) was sown on 28 May 2010 and modules were transplanted on 1 July. All sprays were applied using a knapsack sprayer fitted with 02F110 nozzles.

When florets had reached about 4 cm in diameter they were inoculated with cabbage root fly eggs and sprayed 4 days later. About 4 weeks after spraying, the florets were harvested and the numbers of live larvae were counted. Dursban WG and HDCI 003b performed similarly well compared with the untreated control and Tracer showed signs of reducing larval survival. The pre-planting treatment (HDCI 003a) was ineffective.

4. Novel insecticide treatments to control cabbage root fly and flea beetles in radish

Including an untreated control, there were 13 treatments (10 conventional sprays, 1 spray with bait and 1 seed treatment). Radish seed (cv Rudi) was drilled on 7 July 2010. All conventional sprays were applied using a knapsack sprayer fitted with 02F110 nozzles.
Sprays were applied pre- or post-emergence. Flea beetle damage was assessed by counting feeding holes and root damage was scored after harvesting. Hallmark increased damage due to cabbage root fly compared with the untreated control and there was no control with the other treatments. There was also little evidence of any flea beetle control.

5. Novel insecticide treatments to control Thrips and bean seed fly in leeks

Insecticide-treated and leek seed with no insecticide (cv Jolant) were drilled on 7 May 2010 into all plots. Including an untreated control, there were 12 additional 'spray' treatments. All sprays were applied using a knapsack sprayer fitted with 02F110 nozzles.
Pre-spray assessments were made to assess the seed treatments and HDCI 006 reduced feeding damage compared with the control but Force (tefluthrin) had no effect. Sprays were applied to plants sown from insecticide-treated and insecticide-free seed and damage assessments were done about 1 week after spraying. Sprays were applied on four occasions. Mesurol (methiocarb – used as a positive control but not approved for this use in the UK) was consistently the most effective spray, reducing damage after each spray and by more than most other treatments. Dursban, Steward, HDC 003b, Dynamec (abamectin) and Tracer reduced damage after some spray events.

6. Novel insecticide treatments to control aphids in lettuce

Including an untreated control, there were 7 treatments (5 sprays and 1 'Phytodrip'). Lettuce seed (cv Saladin) was sown on 28 July 2010 and modules were transplanted on 25 August. All sprays were applied using a knapsack sprayer fitted with 02F110 nozzles.

Lettuce plants were infested with *N. ribisnigri* and numbers were counted before and after spraying. HDCI 003 was effective when applied to the peat block at sowing but not as a spray. Movento and Aphox (pirimicarb) sprays were effective but the novel sprays tested were not.

7. Novel insecticides to control carrot fly in carrot

Insecticide-treated and insecticide-free carrot seed (cv Nairobi) were drilled on 19 April 2010. Including an untreated control, there were 6 additional 'spray' treatments (programmes). All sprays were applied using a knapsack sprayer fitted with 02F110 nozzles. Sprays were applied to control the second generation of carrot fly.
Roots were lifted mid-season and at harvest to assess damage due to first and second generation carrot fly larvae respectively. First generation damage was light and no differences due to the seed treatments could be seen. All spray programmes reduced second generation carrot fly damage. HDCI 003b was more effective than HDCI 005 and the standard Hallmark programme. Spray programmes with HDCI 003b were equally effective with or without additional Hallmark.

8. Novel insecticides to control aphids in carrot

Carrot seed (cv Laguna) was sown on 16 April 2010 into a field plot. Including an untreated control, there were 8 treatments (6 sprays and 1 seed treatment). All sprays were applied using a knapsack sprayer fitted with 02F110 nozzles.

Numbers of willow-carrot aphids were counted pre-spray and on 4 occasions post-spray. The sprays were applied on 1 occasion. The seed treatment (HDCI 006) was very effective throughout. Movento, Biscaya, HDCI 003b, Aphox, and Plenum were similarly effective. HDCI 005 reduced aphid numbers but was not as effective as the other sprays.

Conclusions

- **Brassicas:** Cabbage root fly control was observed with HDCI 003a and Steward. Aphids were controlled with Sanokote® – Gaucho, HDCI 006 – Dead seed and HDCI 003b – 'Phytodrip' and Drench (all applied at sowing) and HDCI 003b, HDCI 005, Biscaya, Movento and Plenum (all applied as sprays). Flea beetle damage was reduced by HDCI 003a and HDCI 006 (both pre-planting). Whitefly was reduced by HDCI 006 and Gaucho (both applied at sowing) and HDCI 003b and Movento (both applied as sprays). Caterpillars were controlled by HDCI 003a (pre-planting) and HDCI 003b, HDCI 005, Steward, Biscaya and Movento (all sprays)

- **Carrot:** HDCI 003b sprays were more effective for carrot fly control than Hallmark. HDCI 003b, Aphox, Biscaya, HDCI 005 and Movento (all sprays) and HDCI 006 (applied at sowing) all controlled willow-carrot aphid.

- **Leek:** HDCI 006 (applied at sowing) provided some early season control of thrips. No sprays tested were as effective as Mesurol. HDCI 003b, Tracer, Dursban WG and Dynamec gave some control

- **Lettuce:** HDCI 003 was effective applied at sowing but not as a spray. Movento and Aphox sprays were effective.

Financial benefits

- Without adequate insecticidal control, crop losses to pests would be considerable. For example, it is estimated that about 24% field grown Brassicas would be rendered unmarketable by the cabbage root fly without effective control methods.

Action points for growers

- There was no evidence to suggest that there was any difference in efficacy between the two standard cabbage root fly control treatments (Tracer and Dursban).
- Some insecticide treatments can reduce the time to cauliflower maturity.
- Hallmark sprays can increase cabbage root fly damage.
- The novel insecticide HDCI 003 shows excellent potential for controlling a wide range of pests in a range of crops by a variety of application methods.
- Movento sprays can reduce whitefly infestations in Brassicas.
- Biological treatments tested had very limited effects.

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 WG)) and spinosad (Tracer) 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 broccoli heads. Thus the need to find alternative treatments for cabbage root fly control is still pressing.

Whitefly control is of increasing concern and there are no chemicals available which have been shown to be particularly effective so any indications of control could provide pointers for future research on this insect.

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 cabbage aphid (*Brevicoryne brassicae*) and peach-potato aphid (*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.

For almost 10 years, carrot fly (*Psila rosae*) has been controlled effectively using pyrethroid insecticides, and foliar sprays of Hallmark with Zeon technology (will be referred to subsequently as Hallmark - the active ingredient is Lambda-cyhalothrin) have been particularly effective. Whilst there is no evidence that populations of carrot fly have become resistant to pyrethroids, reliance on a single group of active ingredients is a risky strategy in the long-term.

Onion thrips, *Thrips tabaci,* is the most important pest of leek grown in the UK. Thrips may also attack other allium crops, particularly salad onion. Large populations of Thrips can develop, causing blemishes to the leaves, which reduce quality and may make the crop unmarketable. In 2003, approximately 83% of the area of allium crops treated with insecticides/nematicides in the UK was treated for Thrips and the pyrethroid insecticide,

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Deltamethrin, was the main insecticide used. However, there is evidence that Thrips cannot be controlled effectively with Deltamethrin and insecticide resistance to pyrethroid insecticides in field populations of *T. tabaci* was confirmed by scientists at Rothamsted Research in 2006. The most effective strategy for season-long control of *T. tabaci* has yet to be determined. Effective control is constrained by the limited range of treatments and treatment applications available, especially now that resistance to pyrethroids has been demonstrated. The range of effective alternative treatments is very limited. Bean seed fly *Delia* spp. is also an important pest of allium crops and can reduce seedling emergence particularly of salad onion dramatically. Current control relies on seed treatment with tefluthrin (Force – Specific Off-Label Approval). It is likely that some of the newer seed treatments being developed currently may be effective against bean seed fly.

Several aphid species infest the foliage of lettuce, of which currant–lettuce aphid (*Nasonovia ribisnigri*), *M. persicae*) and potato aphid (*Macrosiphum euphorbiae*) are the most important. *Nasonovia ribisnigri* is particularly difficult to control, as it infests the heart of the plant and is therefore inaccessible to foliar sprays of insecticide. The difficulties of controlling lettuce aphids and the occurrence of insecticide resistance in *N. ribisnigri* in the past mean that there is a need to find alternative and effective methods of control.

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 is to evaluate novel insecticides for the control of the pest insects of a range of horticultural crops. All experimental products are coded.

There were 8 field experiments in 2010 as follows.

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

Experiment 2 - Novel insecticide treatments to control aphids, caterpillars and whitefly on Brussels sprout

Experiment 3 - Novel insecticide treatments to control cabbage root fly in broccoli floret

Experiment 4 - Novel insecticide treatments to control cabbage root fly and flea beetles in radish

Experiment 5 - Novel insecticide treatments to control Thrips and bean seed fly in leek

Experiment 6 - Novel insecticide treatments to control aphids in lettuce

Experiment 7 - Novel insecticide treatments to control carrot fly in carrot

Experiment 8 - Novel insecticide treatments to control aphids in carrot

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

Materials and methods

The experiment was done in the field known as Sheep Pens at Warwick HRI, Wellesbourne (now Warwick Crop Centre).

There were 8 insecticide treatments (Table 1.1), one of which was biological. The cauliflower seed was sown in 308 Hassy trays on 28 May 2010. Each seed in one of the trays was treated with 0.2 ml of a solution containing HDCI 003a (using a 0.2 ml automatic pipette) to mimic a 'Phytodrip' treatment and five trays were sown with untreated seed. All of the trays were placed in a greenhouse. On 30 June 2010 (at the 4 leaf stage), the drench treatments were applied using a 1 ml automatic pipette. Treatments were washed onto the modules with an equivalent volume of water. Treatment details are shown in Table 1.1 and all plants were transplanted on 1 July 2010. The trial was laid out as a 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 35 cm between rows. In total, each plot contained 44 plants.

Table 1.1 Treatments used in trial on cauliflower

Code	Application	Product	a.i.	Rate mg a.i./plant	product
1		Untreated			
2	Drench	Dursban WG	Chlorpyrifos	4.5	6 g/1000 plants
3	Drench	Tracer	Spinosad	5.76	12 ml/1000 plants
4	Drench	HDCI 003a	HDCI 003	4	20 ml/1000 plants [3]
5	Drench	Steward	Indoxacarb		10.2 g/1000 plants [2]
6	Drench	Movento	Spirotetramat	4.6	19.2 ml/1000 plants[1]
7	Drench	HDCI 004[4]	HDCI 004		14 ml/1000 plants
8	Drench	HDCI 003a	HDCI 003	1	5 ml/1000 plants
9	'Phytodrip'	HDCI 003a	HDCI 003	4	20ml /1000 seeds

[1] At 25000 plants/ha = 480 ml product/ha

[2] At 25000 plants/ha = 255 g (3 x Brassica spray rate) product/ha

[3] At 25000 plants/ha = 100 g a.i. (500 ml product)/ha

[4] Biological treatment

Assessments

On 12 July a visual assessment was made of phytotoxicity. Plants were classified as healthy or sick. On 24 August (replicates 1 and 2) and 26 August (replicates (3 and 4), 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 and foliage height were also recorded and foliar pest assessments were made. Data were also collected on these plants on the numbers of the various species of aphids and caterpillars present, the presence of whitefly (on a scale of 0 = none, 1 = adults only, 2 = 1 leaf with scales, 3 = 2 leaves with scales and 4 = more than 2 leaves with scales) and the amount of flea beetle damage (on a scale of 0 = none, 1 = slight, 2 = moderate and 3 = severe). The foliar pests were assessed again on 30 September (12 plants) and at this assessment insect damage was observed in some leaves. This was subsequently identified as a leaf miner and the number of plants affected was assessed on 4 October.

Up to 32 cauliflower plants (all remaining plants) were harvested from each plot between 29 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.

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Results

Statistical analysis

All analyses were performed using analysis of variance (ANOVA). Interpretations were made using the treatment means together with standard errors of the difference (SED) and least significance difference (LSD) values. Where appropriate, transformations of the data were used to ensure homogeneity of variance between treatments. There were 4 replicates of each treatment arranged in a balanced row and column design with 9 rows and 4 columns.

Cabbage root fly activity

The numbers of eggs laid on cauliflower plants in a nearby monitoring plot are shown in Figure 1.1. The second fly generation started in late June and the third generation in the middle of August.

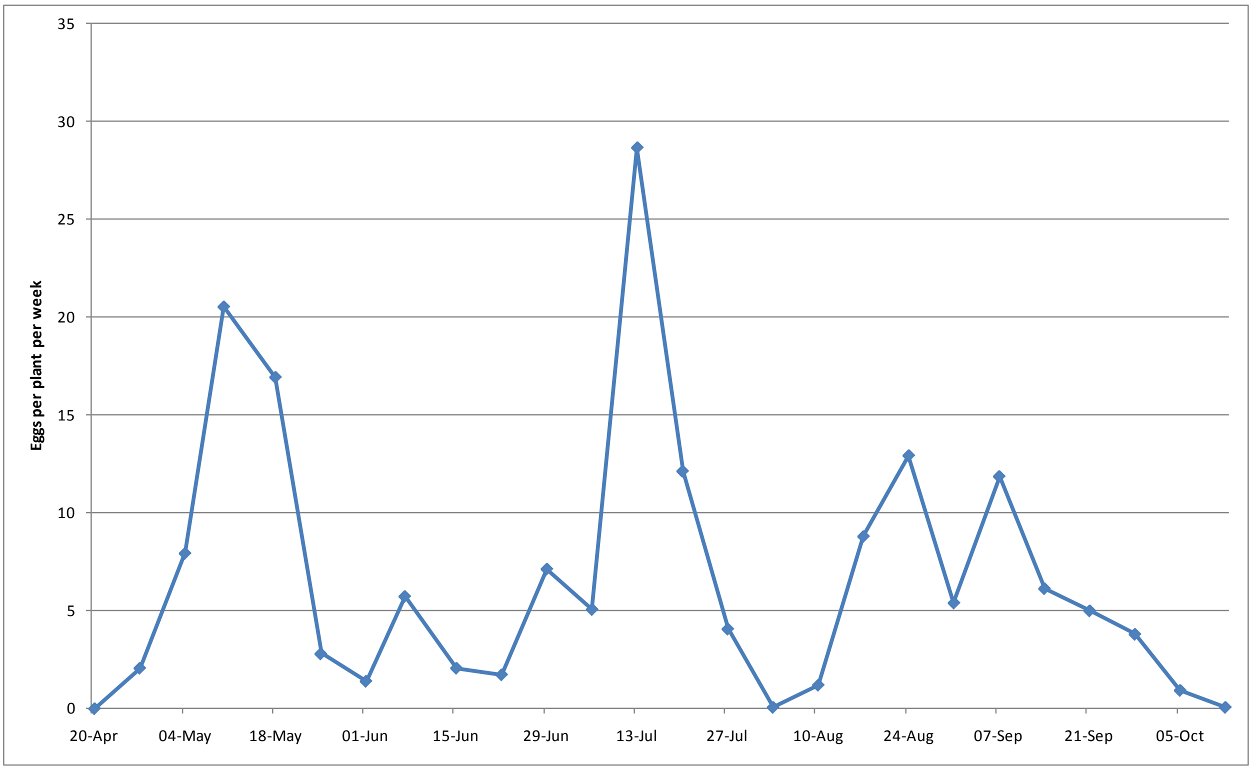

Figure 1.1 The numbers of cabbage root fly eggs laid per plant per week on cauliflower plants at Warwick HRI, Wellesbourne in 2010

Phytotoxicity

None of the insecticide treatments had phytotoxic effects, with the exception of the Movento treatment which had 16, 8, 4 and 5 sick or dead plants in replicates 1 – 4 respectively.

Mid-season assessments

Root and foliage assessments

Root and stem damage were assigned a score based on the estimated surface area which had been visibly damaged due to feeding by larvae of the cabbage root fly. The scale used was 0 = no damage, 1 = 0 - 5%, 2 = 5 - 10%, 3 = 10 - 25%, 4 = 25 - 50% and 5 = >50%. Root and foliage weights were also recorded together with foliage height. No transformations were required for the analysis of weight and height. Damage scores required a square root transformation before analysis. The treatment factor was significant at the 5% level using an F-test for all of the analyses and the results are presented in Tables 1.2 and 1.3 and Figures 1.2 (root and stem damage), 1.3 (foliage weight) and 1.4 (root weight) and 1.5 (foliage height). HDCI 003a (4mg) had a mean foliage weight significantly greater than the untreated control and the industry standard Dursban WG treatment. HDCI 003a (1mg and 'Phytodrip') also had mean weights greater than the Dursban WG treatment. Only HDCI 003a ('Phytodrip') had a mean root weight significantly larger than the Dursban WG treatment and no treatment was larger than the untreated control. For foliage height, plants treated with HDCI 003a (4mg, 1mg and 'Phytodrip') were all taller than those from both the untreated control and the Dursban WG treatments. Both HDCI 003a (4 mg) and Steward significantly reduced root damage compared with the untreated control but not the Dursban WG treatment. However the Dursban WG treatment was not significantly less damaged than the untreated control. There was little difference between treatments in the stem damage score but HDCI 003a (1mg) significantly increased damage relative to the untreated control and the Dursban WG treatment and HDCI 003a ('Phytodrip') also increased damage compared with the Dursban WG treatment.

Table 1.2 Cauliflower – Root and foliage weight plus foliage height mid-season (24-26 August 2010)

Treatment	Foliage height (cm)	Weight (g)	
		Root	Foliage
Untreated	46.0	21.16	488.8
Dursban WG	42.9	18.50	319.9
Tracer	51.3	36.67	648.4
HDCI 003a – 4 mg	58.6	37.88	905.9
Steward	43.7	20.79	379.9
Movento	39.6	13.80	293.9
HDCI 004	42.7	18.10	361.6
HDCI 003a – 1 mg	61.7	36.13	787.6
HDCI 003a - 'Phytodrip'	60.2	39.33	824.2
F-val	4.01	2.37	3.31
P-val	0.004	0.048	0.011
SED	6.04	9.44	185.3
LSD	12.47	19.48	382.4
df	24	24	24

Table 1.3 Cauliflower – Root and stem damage mid-season (24-26 August 2010)

Treatment	**Root damage score**		**Stem damage score**	
	Square root	**Back trans.**	**Square root**	**Back trans.**
Untreated	1.079	1.165	1.621	2.628
Dursban WG	0.957	0.916	1.487	2.212
Tracer	0.878	0.771	1.508	2.275
HDCI 003a – 4 mg	0.712	0.507	1.617	2.613
Steward	0.740	0.547	1.616	2.613
Movento	1.189	1.414	1.529	2.339
HDCI 004	1.164	1.354	1.609	2.590
HDCI 003a – 1 mg	1.029	1.059	1.894	3.588
HDCI 003a - ‘Phytodrip’	0.889	0.791	1.784	3.179
F-val	2.97		4.99	
P-val	0.018		<0.001	
SED	0.141		0.084	
LSD	0.290		0.173	
df	24		24	

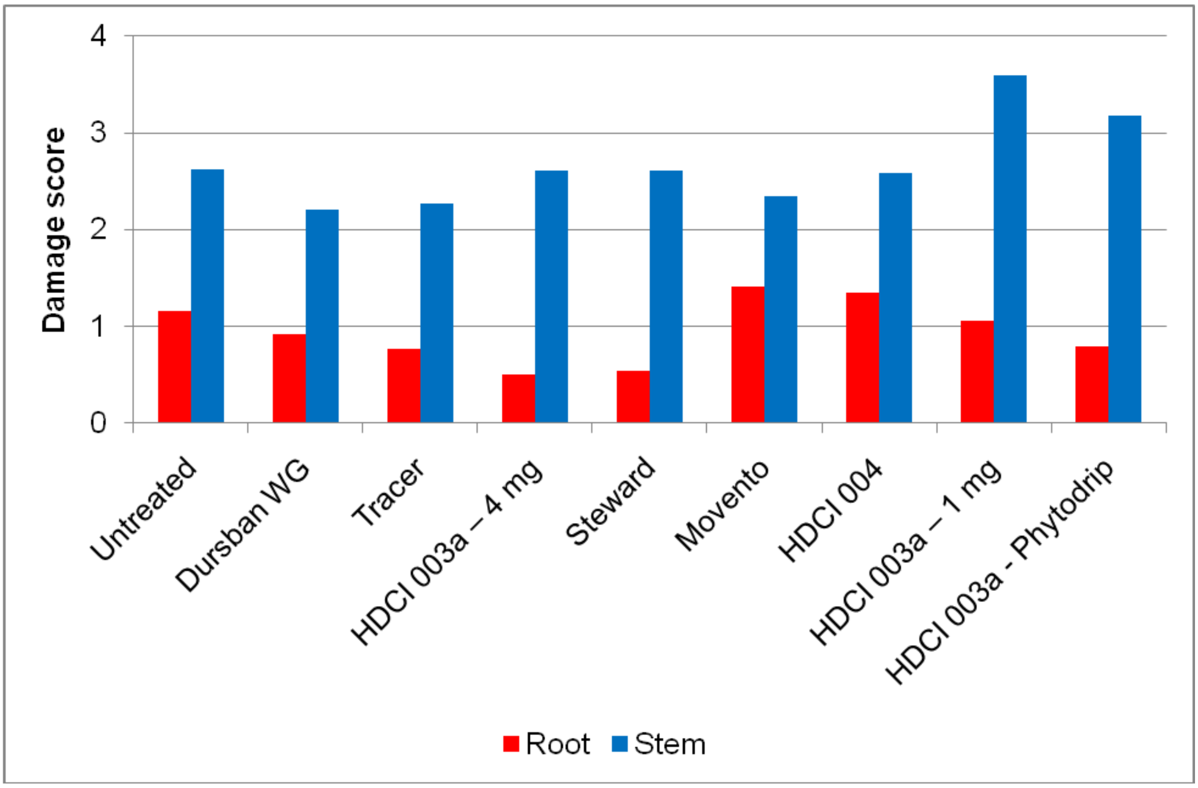

Figure 1.2 Cauliflower - mean root and stem damage score due to cabbage root fly larvae on 24-26 August 2010

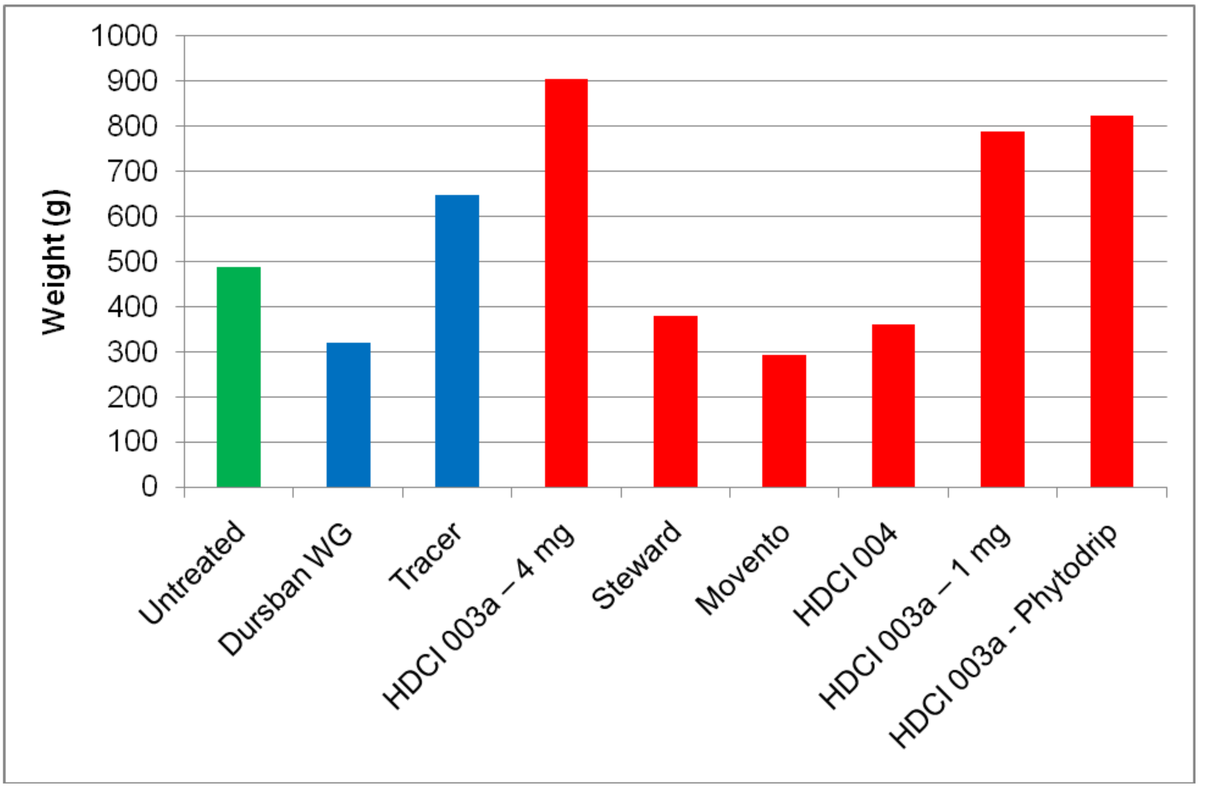

Figure 1.3 Cauliflower - mean foliage weight on 24-26 August 2010

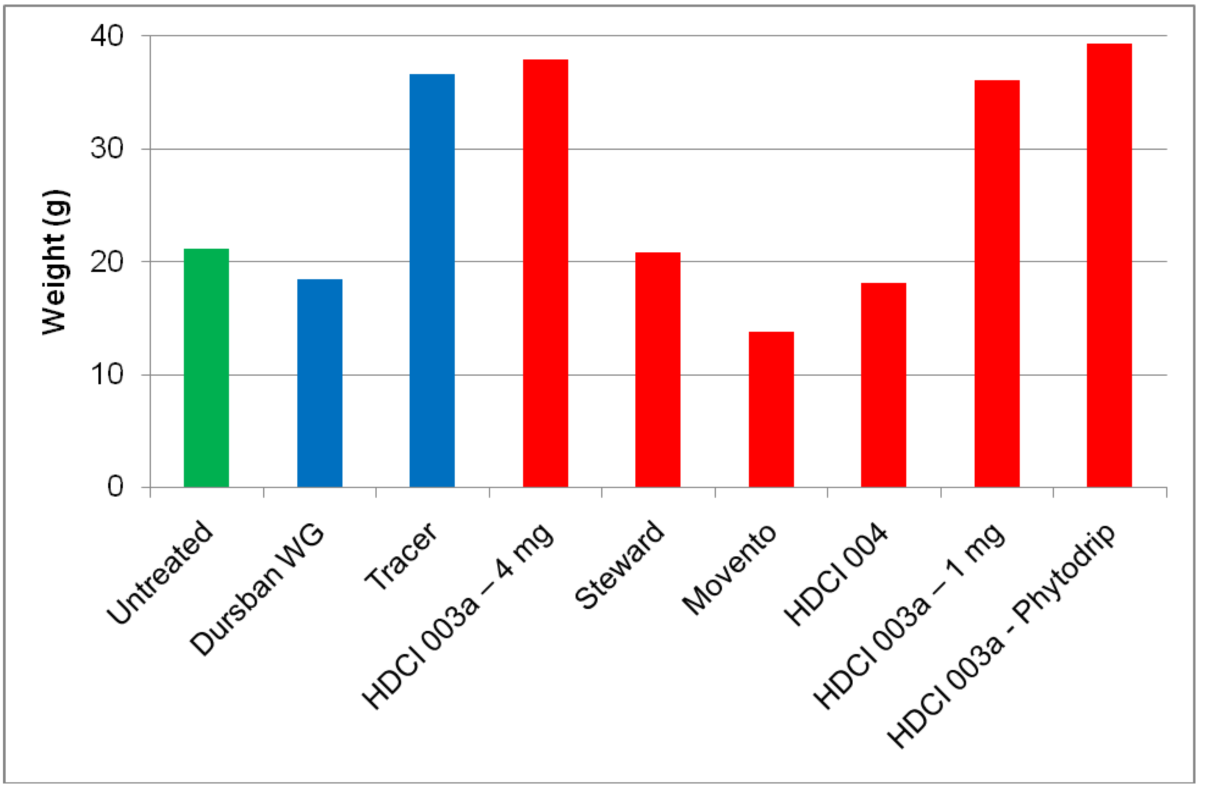

Figure 1.4 Cauliflower - mean root weight on 24-26 August 2010

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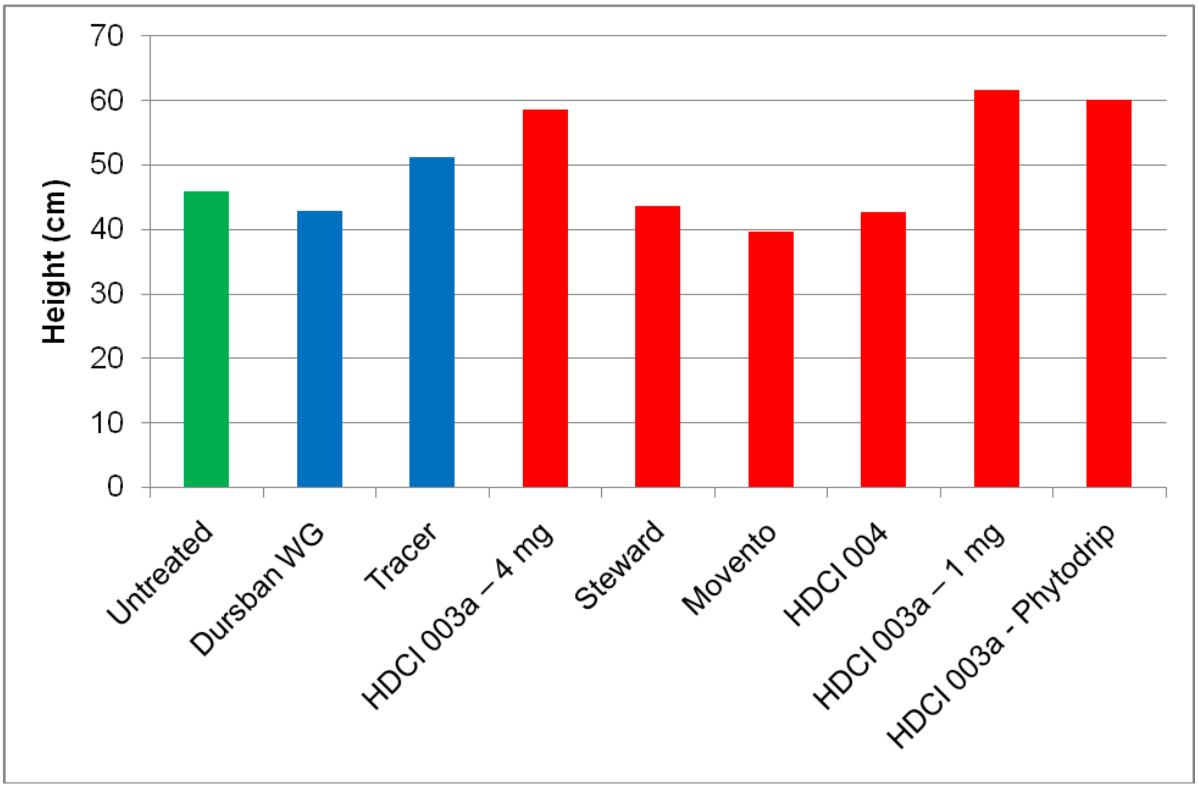

Figure 1.5 Cauliflower - mean foliage height on 24-26 August 2010

Foliar Pest Assessments

a) Aphids

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

Only *Brevicoryne brassicae* (cabbage aphid) was observed and no analyses were carried out on winged aphids as the counts were too small. Aphid numbers were generally low throughout the season. Counts of parasitized aphids were also analysed. For wingless aphids, the treatment factor for both dates was significant at the 5% level using an F-test. On 24-26 August, HDCI 003a (4mg and 'Phytodrip') both significantly reduced aphid numbers compared with the untreated control. On 30 September, the only treatment significantly different from the untreated control was Movento which had increased numbers of aphids; however, HDCI 003a (4mg and 'Phytodrip') treatments had no recorded aphids. On 24-26 August, numbers of parasitized aphids were significantly lower than the untreated control with HDCI 003a (4mg, 1mg and 'Phytodrip') and Movento. On 30 September, numbers were very low and the treatment factor was not significant. The mean numbers of aphids per plant are presented in Table 1.4 and Figure 1.6 (24-26 August) and Table 1.5 and Figure 1.7 (30 September).

Table 1.4 Cauliflower - Mean numbers of wingless *Brevicoryne brassicae* and parasitized aphids on 24-26 August 2010

Treatment	**Wingless**		**Parasitized**	
	Square root	**Back trans.**	**Square root**	**Back trans.**
Untreated	1.977	3.91	2.618	6.85
Dursban WG	1.051	1.11	1.860	3.46
Tracer	2.114	4.47	3.726	13.89
HDCI 003a – 4 mg	0.339	0.12	0.295	0.09
Steward	2.359	5.57	2.066	4.27
Movento	1.286	1.65	1.268	1.61
HDCI 004	0.970	0.94	1.993	3.97
HDCI 003a – 1 mg	0.697	0.49	1.315	1.73
HDCI 003a - 'Phytodrip'	0.197	0.04	0.557	0.31
F-val	2.99		10.87	
P-val	0.018		<0.001	
SED	0.638		0.450	
LSD	1.316		0.928	
df	24		24	

Table 1.5 Cauliflower - Mean numbers of wingless *Brevicoryne brassicae* and parasitized aphids on 30 September 2010

Treatment	Wingless		Parasitized	
	Square root	**Back trans.**	**Square root**	**Back trans.**
Untreated	1.770	3.13	0.359	0.129
Dursban WG	0.000	0.000	0.072	0.005
Tracer	0.368	0.14	0.161	0.026
HDCI 003a – 4 mg	0.000	0.00	0.000	0.000
Steward	1.484	2.20	0.072	0.005
Movento	4.006	16.05	0.144	0.021
HDCI 004	0.706	0.50	0.370	0.137
HDCI 003a – 1 mg	0.776	0.60	0.000	0.000
HDCI 003a - 'Phytodrip'	0.000	0.00	0.246	0.061
F-val	3.07		1.25	
P-val	0.016		0.315	
SED	1.044		0.178	
LSD	2.155		0.367	
df	24		24	

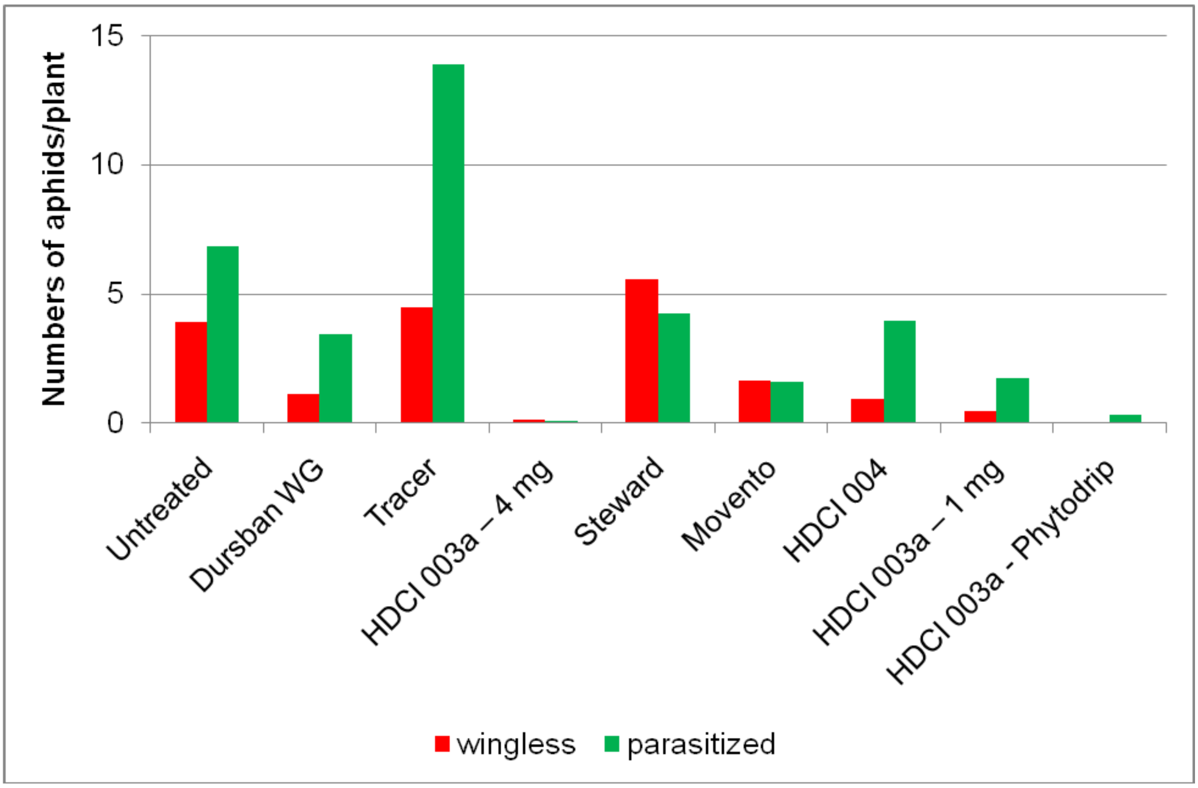

Figure 1.6 Cauliflower - Mean numbers of wingless *Brevicoryne brassicae* and parasitized aphids on 24-26 August 2010

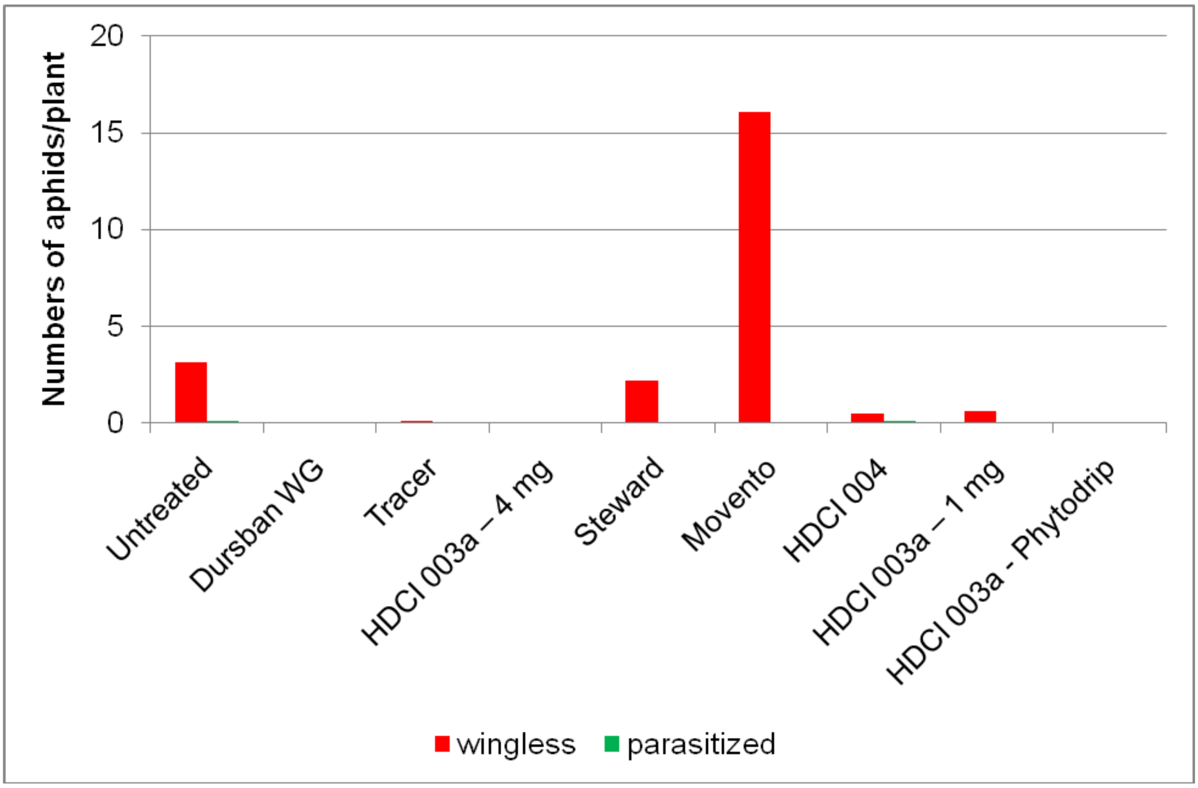

Figure 1.7 Cauliflower - Mean numbers of wingless *Brevicoryne brassicae* and parasitized aphids on 30 September 2010

b) Whitefly

Numbers were generally low and whitefly numbers were higher towards one side of the trial, making assessment of treatment effects difficult. The presence of whitefly was scored on individual cauliflower plants. No transformations were required for the analysis. The treatment factor was not significant at a 5% level using an F-test at either date. None of the treatments had a mean which was significantly smaller than that for the untreated control. The results are presented in Table 1.6.

Table 1.6 Cauliflower - Mean whitefly score

Treatment	**24-26 August**	**30 September**
Untreated	0.938	1.667
Dursban WG	0.691	1.833
Tracer	0.886	1.646
HDCI 003a – 4 mg	0.911	1.729
Steward	0.938	1.813
Movento	0.841	2.000
HDCI 004	0.850	1.646
HDCI 003a – 1 mg	1.104	2.196
HDCI 003a - ‘Phytodrip’	0.930	2.021
F-val	0.49	0.36
P-val	0.850	0.933
SED	0.2199	0.461
LSD	0.4539	0.951
df	24	24

c) Flea beetle

Flea beetle damage was scored on 24-26 August only. No transformations of the data were required. Damage was relatively high and the treatment factor was significant at a 5% level using an F-test. HDCI 003a (4mg and ‘Phytodrip’) treatments had significantly less damage than the untreated control and the Dursban WG treatment. Additionally HDCI 003a (1mg) and Movento also had less damage than the Dursban WG treatment. The results are presented in Table 1.7 and Figure 1.8.

Table 1.7 Cauliflower - Mean flea beetle damage score

Treatment	**24-26 August**
Untreated	1.833
Dursban WG	2.261
Tracer	2.114
HDCI 003a – 4 mg	1.216
Steward	1.833
Movento	1.576
HDCI 004	1.877
HDCI 003a – 1 mg	1.437
HDCI 003a - ‘Phytodrip’	1.231
F-val	4.72
P-val	0.001
SED	0.2403
LSD	0.4959
df	24

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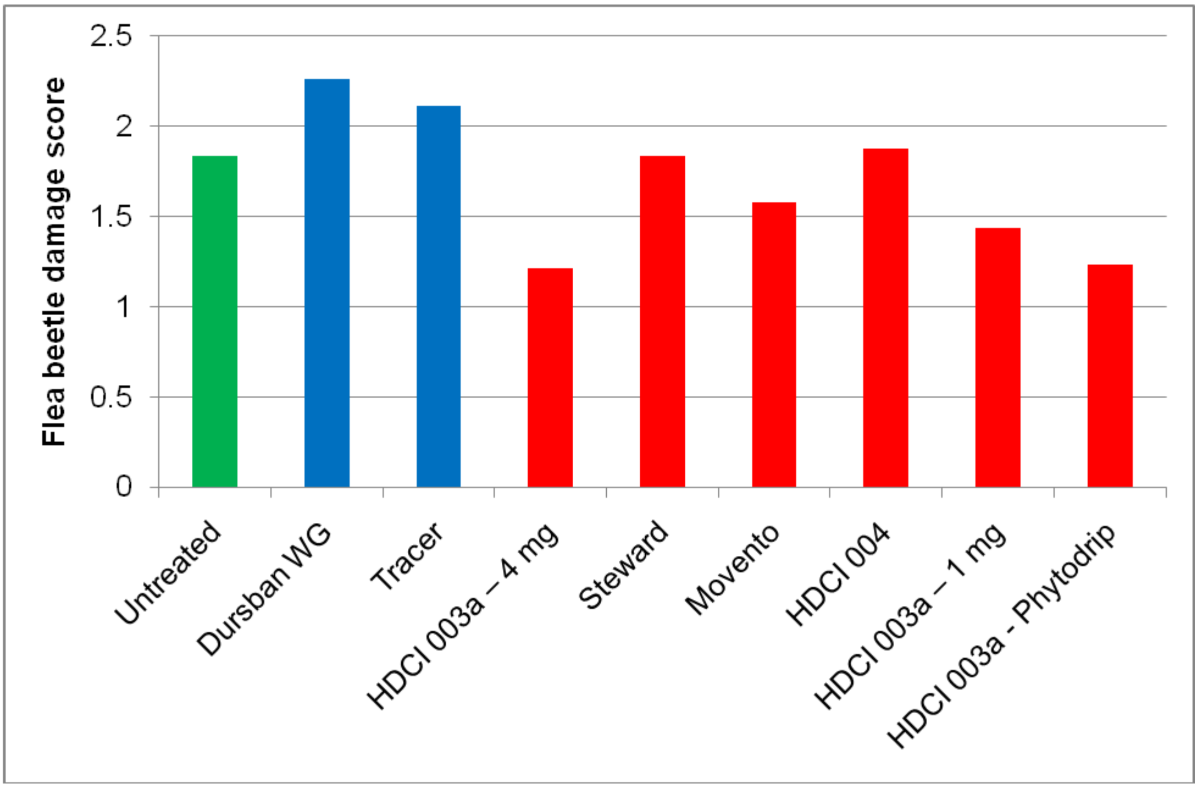

Figure 1.8 Cauliflower - Mean flea beetle damage score on 24-26 August 2010

d) Caterpillars

The presence or absence of caterpillars on individual plants was recorded. Caterpillars of small and large white butterflies and diamond-back, garden pebble, cabbage and silver-Y moths were observed. The small white butterfly was the most common in August and the garden pebble moth was the most common in September. Total numbers of caterpillars were similar on the two assessment dates. The percentage number of plants with any type of caterpillar was analysed on both dates (Table 1.8 and Figure 1.9). There were insufficient numbers of individual species for valid analysis. An angular transformation was used to ensure homogeneity of the variance between the treatments. The treatment factor was significant for the assessments on 24-26 August at the 10% level using an F-test. At this level all of the treatments except Tracer and Dursban appeared to reduce caterpillar numbers compared with the untreated control.

Table 1.8 Cauliflower - Mean percentage of plants with any caterpillars

Treatment	24-26 August		30 September	
	Angular	Back Trans.	Angular	Back Trans.
Untreated	40.34	41.91	31.32	27.01
Dursban WG	19.95	11.64	38.54	38.82
Tracer	19.64	11.30	31.52	27.33
HDCI 003a – 4 mg	8.39	2.13	7.50	1.70
Steward	11.89	4.24	27.58	21.44
Movento	10.70	3.45	12.58	4.75
HDCI 004	4.19	0.54	20.27	12.00
HDCI 003a – 1 mg	7.50	1.70	31.16	26.77
HDCI 003a - 'Phytodrip'	4.19	0.54	21.40	13.31
F-val	2.16		1.70	
P-val	0.070		0.150	
SED	11.00		10.88	
LSD	22.69		22.46	
df	24		24	

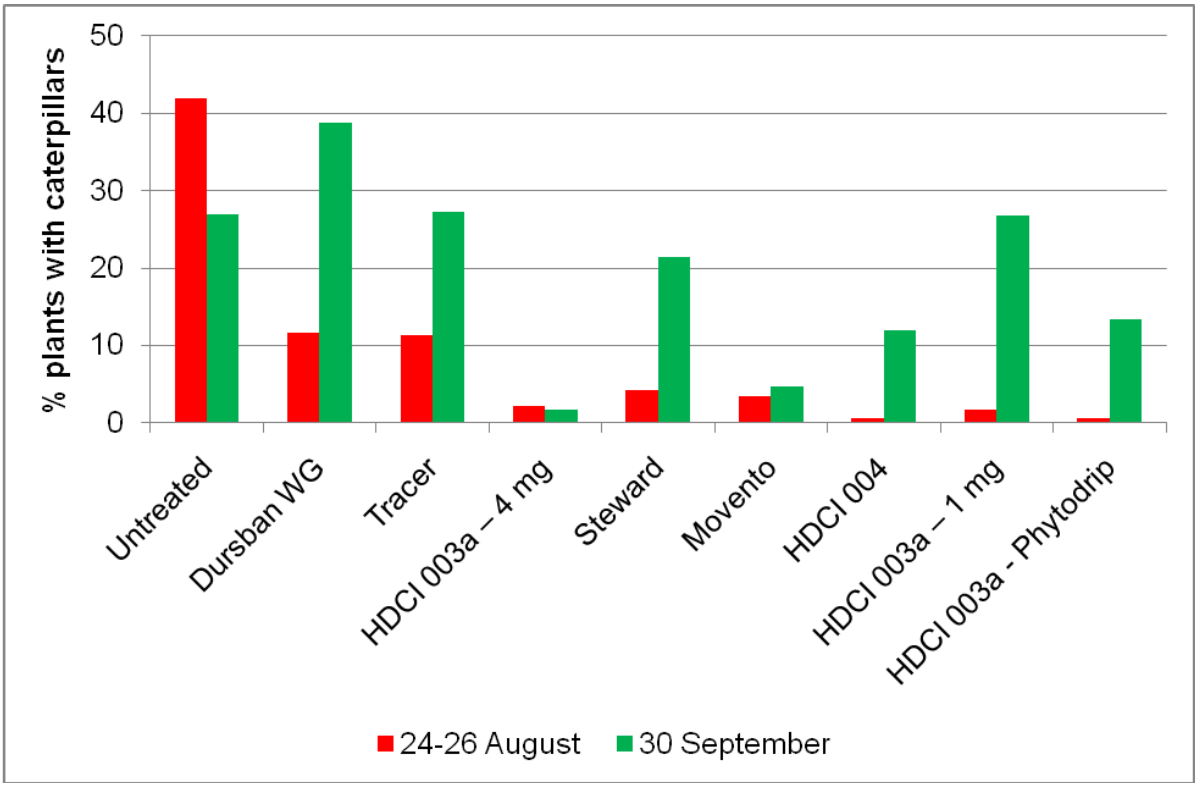

Figure 1.9 Cauliflower - mean percentage of plants with caterpillars on 24-26 August and 30 September 2010

e) Leaf miner

The presence or absence of damage on 12 plants was recorded and the percentage of damaged plants was analysed after an angular transformation. The treatment factor was significant at the 5% level using an F-test. HDCI 003a (4mg drench and 'Phytodrip') reduced the numbers of damaged plants compared with the untreated control. The results are shown in Table 1.9 and Figure 1.10

Table 1.9 Cauliflower - Mean percentage of plants with leaf miners

Treatment	**Angular**	**Back trans.**
Untreated	48.8	56.5
Dursban WG	64.5	81.5
Tracer	63.5	80.0
HDCI 003a – 4 mg	6.0	1.1
Steward	65.0	82.09
Movento	42.8	46.24
HDCI 004	60.3	75.52
HDCI 003a – 1 mg	35.4	33.55
HDCI 003a - 'Phytodrip'	8.4	2.13
F-val	11.35	
P-val	<0.001	
SED	9.75	
LSD	20.12	
df	24	

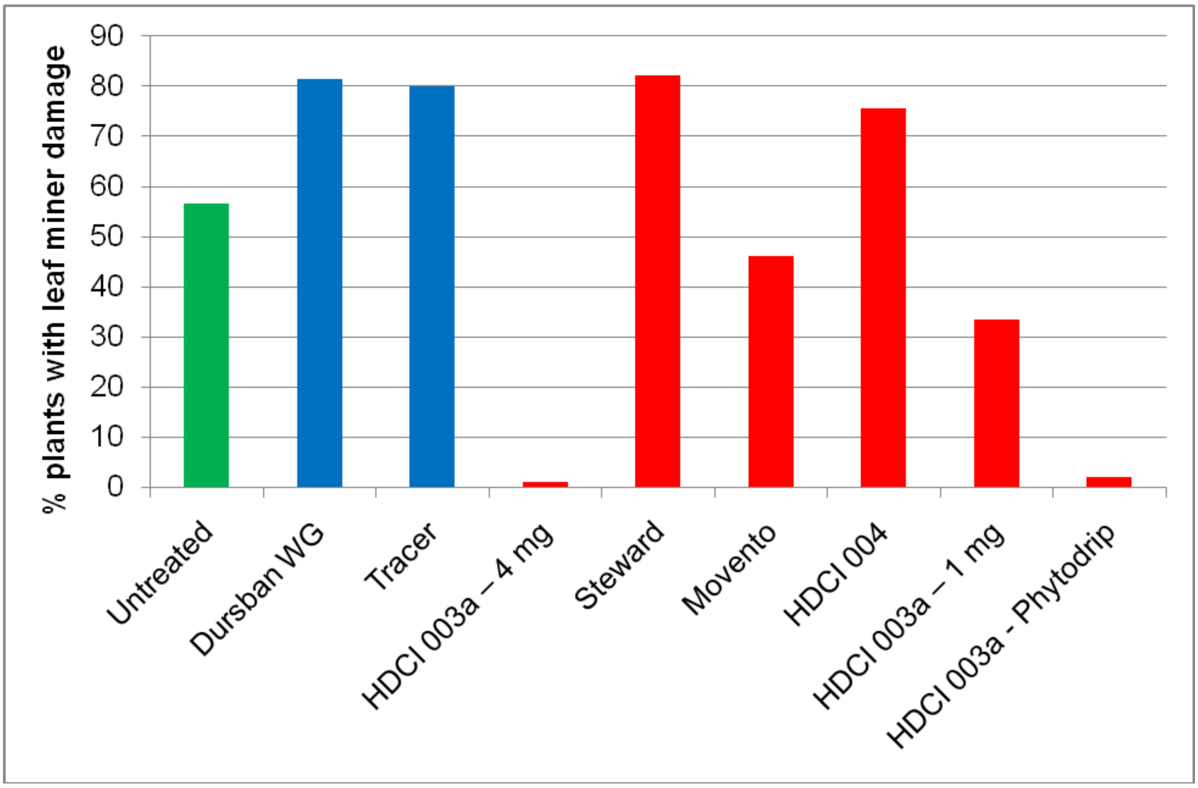

Figure 1.10 Cauliflower - mean percentage of plants with leaf miner damage

<u>Harvest</u>

Assessments were made of cauliflower curd weights, curd diameters and curd quality. Analyses were done on the curd weight, curd diameter and percentage of class 1 curds. Also, a linear interpolation was used to determine the time taken to achieve 10, 25, 50, 75 and 90% curd harvest assuming a start date of 3 days before the harvest commenced. For the analysis of the percentage of class 1 curds, an angular transformation was used to ensure homogeneity of the variance between treatments. No other data transformations were required. Curd weight (Figure 1.11), curd diameter (Figure 1.12) and percentage class 1 curds are presented in Table 1.10. Time to 50% harvest (Figure 1.13), time between 25 and 75% harvest and time between 10 and 90% harvest are presented in Table 1.11.

The treatment effect was significant at the 5% level using an F-test for the analyses of weight, diameter and time to 50%.

For curd weight, all of the HDCI 003a treatments (4mg, 1mg and 'Phytodrip') and Movento (despite phytotoxicity problems) had mean weights which were significantly larger than the untreated control and the Dursban WG treatment. Similarly all of the HDCI 003a treatments had mean curd diameters significantly greater than the untreated control and the Dursban WG treatment.

The plants treated with Movento reached 50% harvest significantly more slowly than the untreated control. The plants treated with Tracer or HDCI 003a reached 50% maturity significantly more quickly than the Dursban WG treatment. There were no significant differences in the spread of maturity time or the numbers of Class 1 curds.

Table 1.10 Cauliflower - Curd harvest data

Treatment	**Weight (g)**	**Diameter (cm)**	**Percent class 1 Angular**	**Back Trans.**
Untreated	970	132.1	67.51	85.37
Dursban WG	923	131.9	61.36	77.03
Tracer	1037	136.6	66.66	84.31
HDCI 003a – 4 mg	1400	148.8	67.62	85.51
Steward	918	131.9	60.19	75.29
Movento	1291	144.6	71.42	89.85
HDCI 004	926	129.7	68.00	85.97
HDCI 003a – 1 mg	1418	153.2	60.98	76.46
HDCI 003a - 'Phytodrip'	1537	157.9	66.93	84.65
F-val	5.41	4.40	1.49	
P-val	<0.001	0.002	0.213	
SED	152.7	7.15	4.47	
LSD	315.2	14.76	9.22	
df	24	24	24	

Table 1.11 Cauliflower – Spread of curd harvest (days)

Treatment	**Time to 50% harvest (days)**	**Spread of harvest (days)**	
		25 - 75%	**10 - 90%**
Untreated	17.73	9.29	19.39
Dursban WG	25.32	14.31	23.82
Tracer	10.43	8.31	19.10
HDCI 003a – 4 mg	15.08	10.64	19.21
Steward	23.43	11.59	21.99
Movento	34.63	13.69	22.85
HDCI 004	19.31	12.75	23.04
HDCI 003a – 1 mg	12.04	10.33	17.73
HDCI 003a - 'Phytodrip'	14.45	11.20	20.96
F-val	3.93	1.16	0.56
P-val	0.004	0.363	0.800
SED	5.43	2.601	4.035
LSD	11.20	5.368	8.329
df	24	24	24

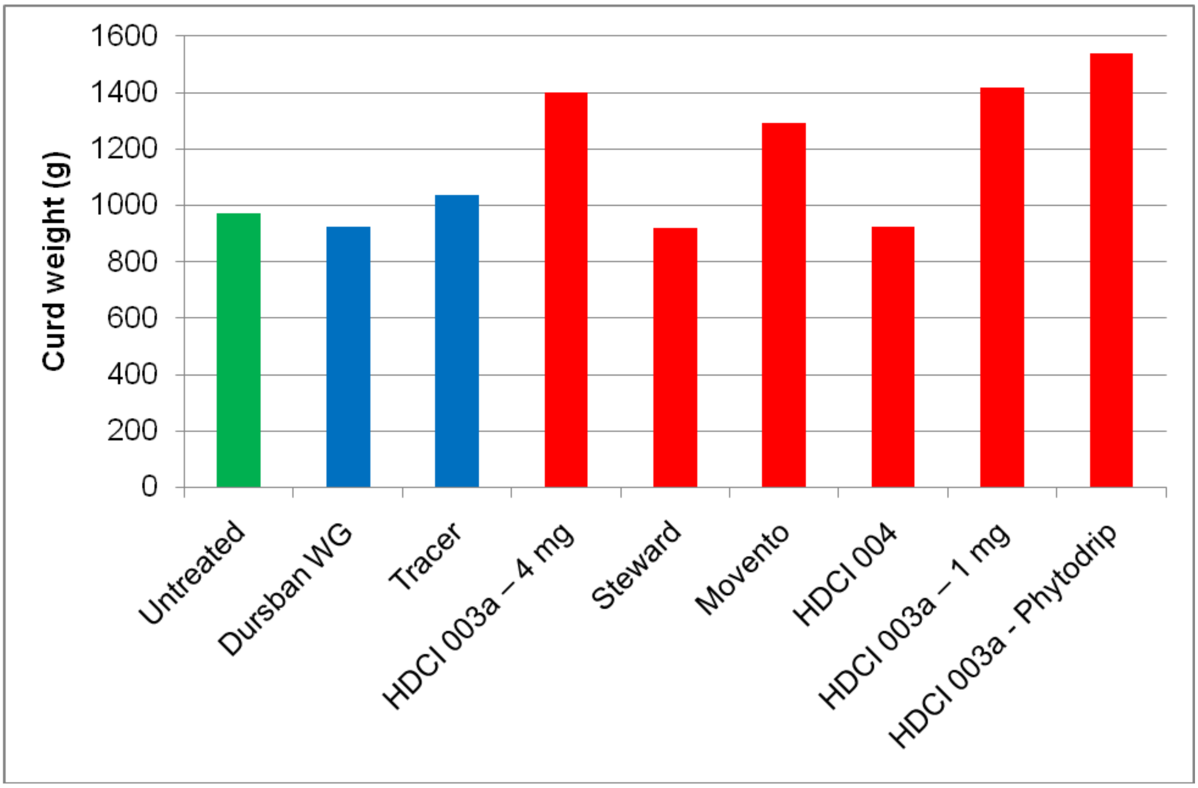

Figure 1.11 Cauliflower – mean curd weight at harvest

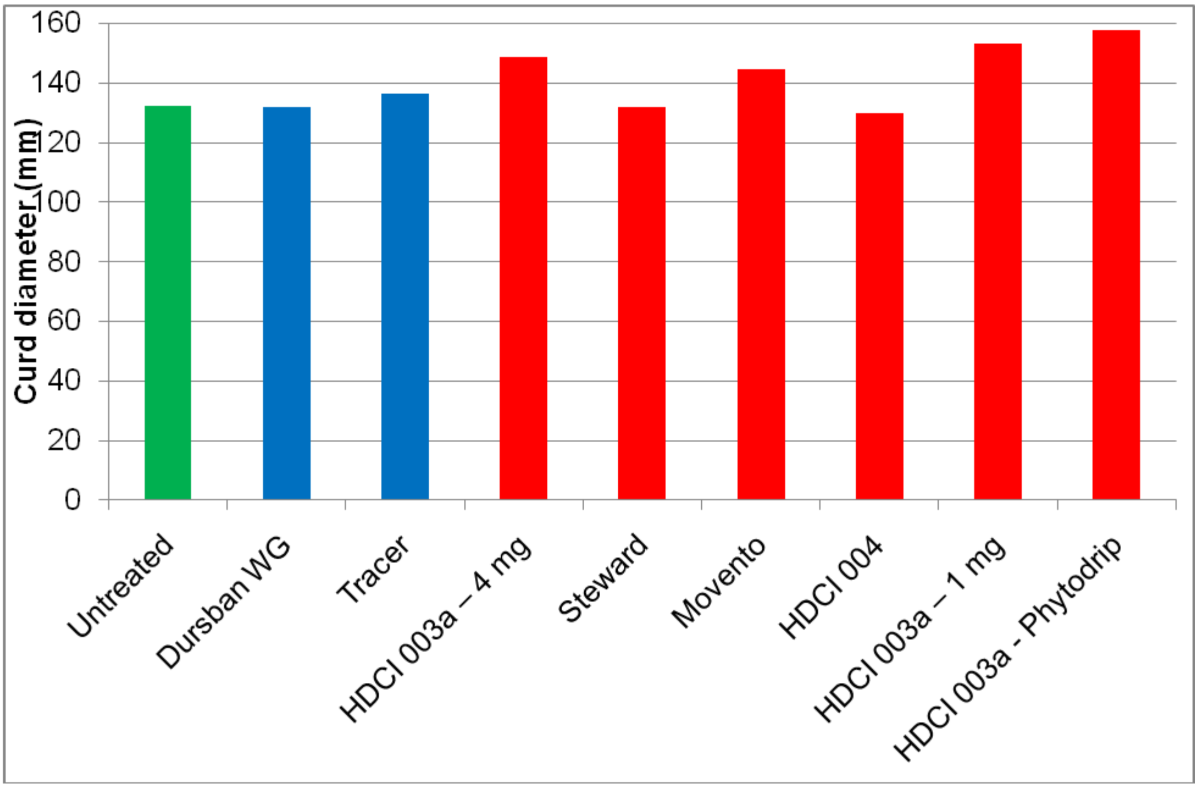

Figure 1.12 Cauliflower – mean curd diameter at harvest

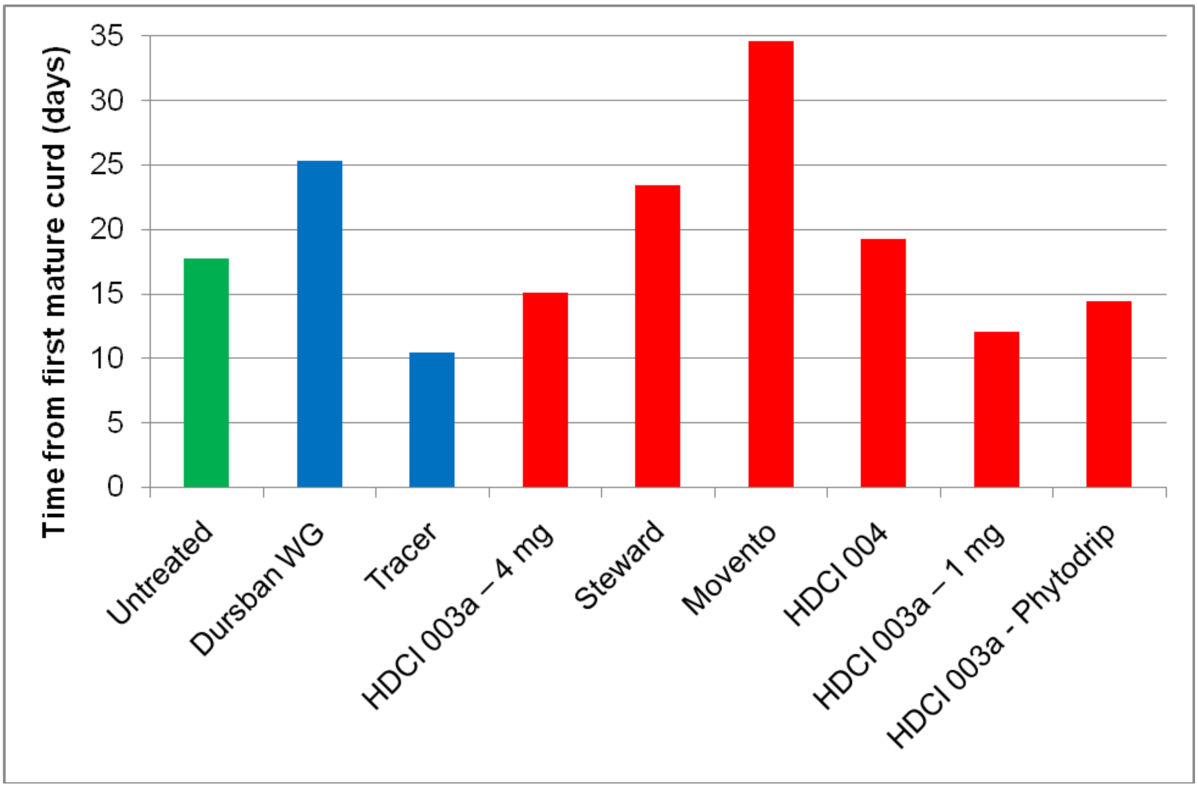

Figure 1.13 Cauliflower – time to 50% maturity from first mature curd.

Discussion

Cabbage root fly damage was relatively light compared with some years and there was little difference in levels of damage between treatments. Only HDCI 003a – 4mg drench and Steward reduced root damage compared with the control. Neither of the positive control treatments (Dursban WG and Tracer) had much effect. This may well have been due to difficulties in discriminating between low levels of damage rather than a failure in control.

Foliar pests (aphids, caterpillars and flea beetle) were controlled well by HDCI 003a applied at sowing ('Phytodrip') or as a pre planting drench and in most cases there was little to choose between the two methods of application. Both treatments continued to control foliar pests right up to harvest including control of leaf miners just before harvest. HDCI 003a also increased curd weight and size compared with the untreated control.

Experiment 2 - Novel insecticide treatments to control aphids, caterpillars and whitefly on Brussels sprout

Materials and methods

The experiment was planted in the field known as Sheep Pens. Brussels sprout seed (cv Doric) was sown on 13 May 2010 into 308 Hassy trays. One of the trays was sown with the addition of HDCI 006 - Sanokote®, one with the addition of Imidacloprid - Sanokote® and then each seed in a further tray was treated with 0.2 ml of a solution containing HDCI 003a (using a 0.2 ml automatic pipette) to mimic a 'Phytodrip' treatment. Six trays were sown with untreated seed and all of the trays were placed in a greenhouse.

On 15 June 2010 (at the 4 leaf stage), the 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 16 June 2010. The plots were 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 laid out in an un-resolvable row and column design. Including an untreated control, there were 13 treatments (Table 2.1), one of which was biological. All sprays were applied using a knapsack sprayer fitted with 02F110 nozzles. The first series of sprays (applied 23 July) were applied in 300 l water/ha and the second (applied 23 September) and third (applied 1 November) series of sprays were applied in 600 l water/ha. An adjuvant, Phase II, at 0.5%

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of water volume was used for all spray treatments except Movento and HDCI 007 for which it was not required.

Table 2.1 Treatments applied to Brussels sprout plots to control aphids, caterpillars and whitefly

Code	Product	a.i.	Application method	Rate	
				a.i.	Product
1	HDCI 003a	HDCI 003	Drench	4 mg/plant [1]	20 ml/1000 plants [1]
2	HDCI 003a	HDCI 003	'Phytodrip'	4 mg/plant [1]	20 ml/1000 plants [1]
3	HDCI 003b	HDCI 003	Spray	150 g/ha	1500 ml/ha
4	HDCI 005	HDCI 005	Spray	35 g/ha	175 ml/ha
5	Steward	Indoxacarb	Spray	36 g/ha	85 g/ha
6	Steward	Indoxacarb	Drench	3.1 mg/plant[2]	10.2 g/1000 plants[2]
7	HDCI 006	HDCI 006	Dead seed		213 g/unit [3]
8	HDCI 007[4]	HDCI 007	Spray		4000 ml/ha
9	Biscaya	Thiocloprid	Spray	96 g/ha	400 ml/ha
10	Movento	Spirotetramat	Spray	75 g/ha	500 ml/ha
11	Plenum	Pymetrozine	Spray	200 g/ha	400 g/ha
12	Sanokote® Smart - Gaucho	Imidacloprid	Dead seed	1.4 mg a.i./seed	
13	Untreated				

[1] At 25000 plants/ha = 100 g a.i./ha

[2] At 25000 plants/ha = 255g product/ha

[3] 1 unit = 100,000 seeds

[4] Biological treatment

<u>Assessments</u>

Pest assessments were made on seven occasions. On 21 July (pre-spray) and 29 July (post first spray), counts of winged aphids, wingless aphids and caterpillars were made on 6 plants per plot. Whitefly infestation was scored (0-4 scale - Table 2.2), flea beetle damage

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was also scored (0-3 scale – Table 2.2) and plant width was measured. On 6 September, caterpillar damage and whitefly infestations were scored on a whole plot basis (0-3 scale for both – Table 2.2). On 22 September (pre second spray), caterpillar numbers were assessed on 3 plants per plot (spray treatments only) and whitefly infestation was assessed on a whole plot basis. On 28 September (post second spray), caterpillar numbers were re-assessed. On 25 October (pre third spray), whitefly infestation was scored (0-4 scale – Table 2.2) on a whole plot basis (spray treatments only) and re-assessed on 2 November (post third spray).

Table 2.2 Pest scoring scales for Brussels sprout trial

Date	Assessment	Score	Description
21 and 29 July	Whitefly infestation	0	None
		1	Adults only
		2	One leaf with scales
		3	Two leaves with scales
		4	More than two leaves with scales
	Flea beetle damage	0	None
		1	Slight
		2	Moderate
		3	Heavy
6 September	Caterpillar damage	0	Negligible damage
		1	Small amount of damage
		2	Moderate amount of damage
		3	Large amount of damage
	Whitefly infestation	0	Negligible
		1	Small number of scales
		2	Moderate number of scales
		3	Large number of scales
22 September, 25 October and 2 November	Whitefly infestation	0	Negligible
		1	Small number of scales on some plants
		2	Moderate number of scales on most plants
		3	Large number of scales on most plants
		4	Large number of scales on all plants

Results

Statistical analysis

All analyses were carried out using Analysis of Variance (ANOVA) and interpretations have been made using treatment means together with standard errors of the difference (SED) and least significance difference (LSD) values.

23 July spray – pre-spray and post-spray assessments

a) Aphids

Both *B. brassicae* and *M. persicae* were observed. Analysis using ANOVA was performed on numbers of winged and wingless aphids and parasitized aphids. A square root transformation of all data sets was used to ensure homogeneity between treatments.

The treatment factor was significant for all analyses except those for winged *M. persicae.* The results are shown in Tables 2.3 – 2.5.

Pre-spray – 21 July

The pre planting treatments, HDCI 003a – Drench, HDCI 003a – 'Phytodrip', HDCI 006 – Dead seed and Sanokote® - Gaucho reduced numbers of wingless aphids of both species, winged *B. brassicae* and parasitized aphids compared with the untreated control but there were no differences between the effective treatments. The results for wingless and parasitized aphids are expressed graphically in Figure 2.1.

Post-spray – 29 July

Only the spray treatments were assessed on this date (6 days after spraying). HDCI 003b, HDCI 005, Biscaya, Movento and Plenum reduced numbers of wingless aphids of both species compared with the untreated control. HDCI 007 reduced numbers of *M. persicae* but was less effective than HDCI 003b, Biscaya, Movento and Plenum and was ineffective against *B. brassicae.* Steward reduced numbers of *B. brassicae* but was ineffective against *M. persicae.* Numbers of winged *B. brassicae* were reduced by HDCI 003b, HDCI 005, Biscaya and Plenum. Biscaya and Plenum also reduced numbers of parasitized aphids. The results for wingless and parasitized aphids are expressed graphically in Figure 2.2.

Table 2.3 Brussels sprout - Mean numbers of *Myzus persicae* per plot

Treatment	Winged *Myzus persicae*				Wingless *Myzus persicae*			
	21 July		**29 July**		**21 July**		**29 July**	
	Square root	**Back Trans**	**Square root**	**Back Trans**	**Square root**	**Back Trans**	**Square root**	**Back Trans**
HDCI 003a - Drench	2.45	6.00	*	*	3.51	12.33	*	*
HDCI 003a – 'Phytodrip'	3.61	13.04	*	*	5.31	28.16	*	*
HDCI 003b - Spray	2.80	7.83	0.25	0.06	14.68	215.39	0.85	0.73
HDCI 005 - Spray	2.37	5.64	1.16	1.35	12.25	150.11	5.24	27.41
Steward - Spray	2.30	5.28	1.31	1.72	8.71	75.95	9.04	81.65
Steward - Drench	1.88	3.54	*	*	9.02	81.31	*	*
HDCI 006 – Dead seed	3.02	9.09	*	*	1.43	2.05	*	*
HDCI 007 - Spray	3.13	9.80	1.39	1.94	11.73	137.62	8.06	64.94
Biscaya - Spray	2.23	4.99	0.60	0.36	9.91	98.20	0.35	0.13
Movento - Spray	2.96	8.77	0.60	0.36	11.82	139.63	3.47	12.03
Plenum - Spray	3.31	10.96	0.35	0.12	9.19	84.52	0.50	0.25
Sanokote® Smart - Gaucho	2.31	5.33	*	*	0.85	0.73	*	*
Untreated	2.66	7.09	2.68	7.19	12.79	163.53	11.84	140.08
F-val	1.47		2.12		7.16		13.22	
P-val	0.178		0.078		<0.001		<0.001	
SED vs control	0.501		0.798		2.110		1.646	
LSD vs control	1.012		1.655		4.265		3.413	
SED vs treatment	0.578		0.922		2.437		1.900	
LSD vs treatment	1.168		1.911		4.925		3.941	
df	40		22		40		22	

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Table 2.4 Brussels sprout - Mean numbers of *Brevicoryne brassicae* per plot

	Winged *Brevicoryne brassicae*				**Wingless *Brevicoryne brassicae***			
Treatment	**21 July**		**29 July**		**21 July**		**29 July**	
	Square root	Back Trans	Square root	Back Trans	Square root	Back Trans	Square root	Back Trans
HDCI 003a - Drench	0.60	0.36	*	*	0.23	0.05	*	*
HDCI 003a – 'Phytodrip'	0.59	0.34	*	*	1.36	1.85	*	*
HDCI 003b - Spray	1.22	1.49	0.35	0.13	7.28	52.99	2.57	6.63
HDCI 005 - Spray	1.37	1.89	0.60	0.36	6.92	47.89	6.28	39.39
Steward - Spray	1.21	1.46	1.70	2.88	9.41	88.60	8.32	69.14
Steward - Drench	1.23	1.52	*	*	9.55	91.26	*	*
HDCI 006 – Dead seed	0.31	0.09	*	*	0.00	0.00	*	*
HDCI 007 - Spray	0.79	0.62	2.14	4.59	7.76	60.29	15.19	230.85
Biscaya - Spray	1.10	1.20	0.85	0.73	7.97	63.45	5.00	25.02
Movento - Spray	1.20	1.44	1.50	2.25	9.29	86.31	3.32	11.05
Plenum - Spray	1.27	1.60	0.79	0.62	9.05	81.94	3.28	10.73
Sanokote® Smart - Gaucho	0.43	0.19	*	*	0.00	0.00	*	*
Untreated	1.11	1.23	2.00	4.01	7.98	63.64	14.63	214.14
F-val	2.40		3.81		7.52		7.26	
P-val	0.019		0.006		<0.001		<0.001	
SED vs control	0.2879		0.537		1.770		2.897	
LSD vs control	0.5819		1.114		3.578		6.009	
SED vs treatment	0.3324		0.620		2.044		3.346	
LSD vs treatment	0.6719		1.286		4.131		6.939	
df	40		22		40		22	

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Table 2.5 Brussels sprout - Mean numbers of parasitized aphids

Treatment	Parasitized aphids 21 July Square root	21 July Back Trans	29 July Square root	29 July Back Trans
HDCI 003a - Drench	0.246	0.06	*	*
HDCI 003a – 'Phytodrip'	0.911	0.83	*	*
HDCI 003b - Spray	3.125	9.77	4.80	23.03
HDCI 005 - Spray	2.801	7.85	4.07	16.59
Steward - Spray	2.851	8.13	4.03	16.22
Steward - Drench	2.106	4.44	*	*
HDCI 006 – Dead seed	0.177	0.03	*	*
HDCI 007 - Spray	2.877	8.28	5.88	34.57
Biscaya - Spray	3.058	9.35	3.37	11.36
Movento - Spray	2.743	7.52	4.50	20.25
Plenum - Spray	3.265	10.66	2.93	8.61
Sanokote® Smart - Gaucho	0.321	0.103	*	*
Untreated	3.188	10.163	5.96	35.57
F-val	14.65		2.97	
P-val	<0.001		0.021	
SED vs control	0.4061		1.177	
LSD vs control	0.8207		2.442	
SED vs treatment	0.4689		1.360	
LSD vs treatment	0.9477		2.820	
df	40		22	

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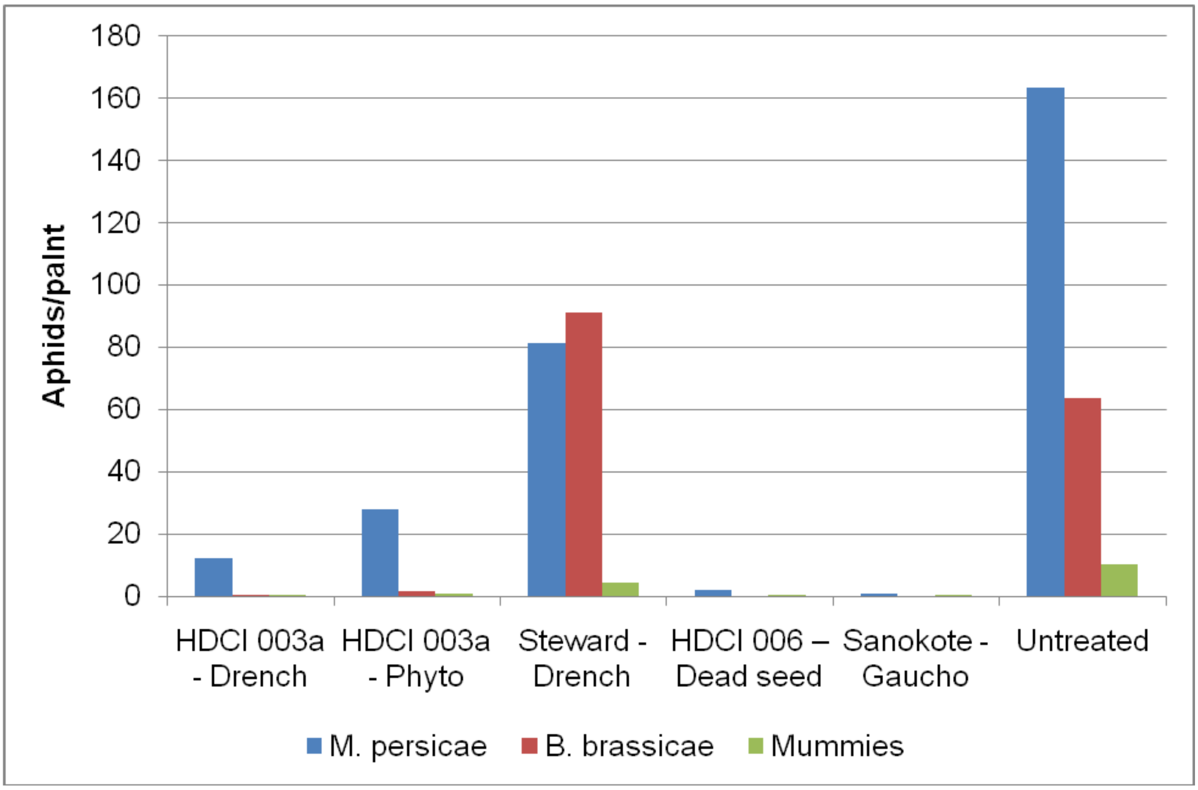

Figure 2.1 Brussels sprout – aphid numbers on pre-planting treatments on 21 July (N.B. Phyto = 'Phytodrip' treatment; mummies = parasitized aphids)

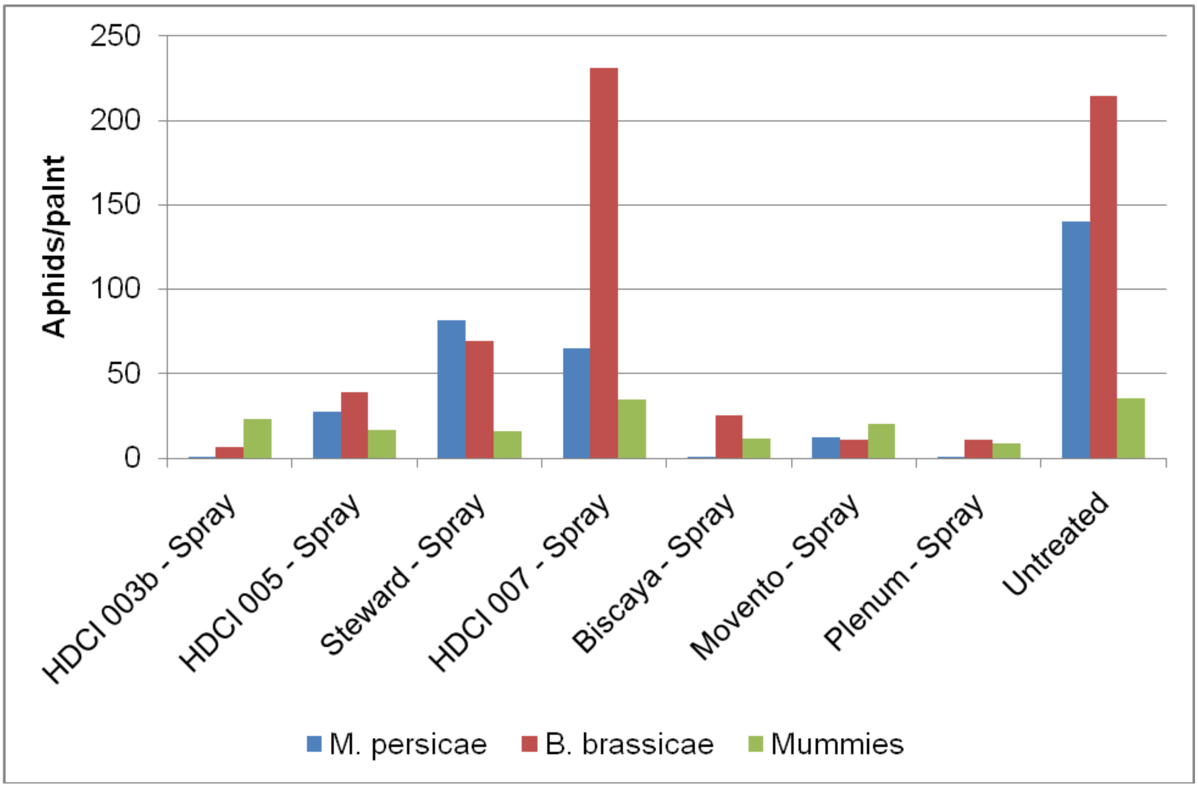

Figure 2.2 Brussels sprout – aphid numbers on spray treatments on 29 July

(N.B. Phyto = ‘Phytodrip’ treatment; mummies = parasitized aphids)

b) Whitefly

No transformations were required for the analysis of whitefly infestation. The treatment factor was significant for both analyses. The results are shown in Table 2.6.

Pre-spray – 21 July

The pre planting treatments, HDCI 006 – Dead seed and Sanokote® - Gaucho reduced whitefly scores compared with the untreated control, but there were no differences between the effective treatments. The results are expressed graphically in Figure 2.3.

Post-spray – 29 July

Only the spray treatments were assessed on this date. HDCI 003b and Movento reduced whitefly scores compared with the untreated control, but there were no differences between the effective treatments. The results are expressed graphically in Figure 2.4.

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Table 2.6 Brussels sprout - Mean whitefly score

	Whitefly score	
Treatment	21 July	29 July
HDCI 003a - Drench	1.54	*
HDCI 003a - Phyto	2.13	*
HDCI 003b - Spray	2.17	1.25
HDCI 005 - Spray	2.25	3.75
Steward - Spray	2.38	3.25
Steward - Drench	2.29	*
HDCI 006 – Dead seed	1.13	*
HDCI 007 - Spray	2.42	3.25
Biscaya - Spray	2.29	2.00
Movento - Spray	1.96	0.50
Plenum - Spray	1.88	3.50
Sanokote® Smart - Gaucho	0.71	*
Untreated	2.10	3.06
F-val	2.36	5.95
P-val	0.021	<0.01
SED vs control	0.4146	0.684
LSD vs control	0.8378	1.419
SED vs treatment	0.4787	0.790
LSD vs treatment	0.9675	1.638
df	40	22

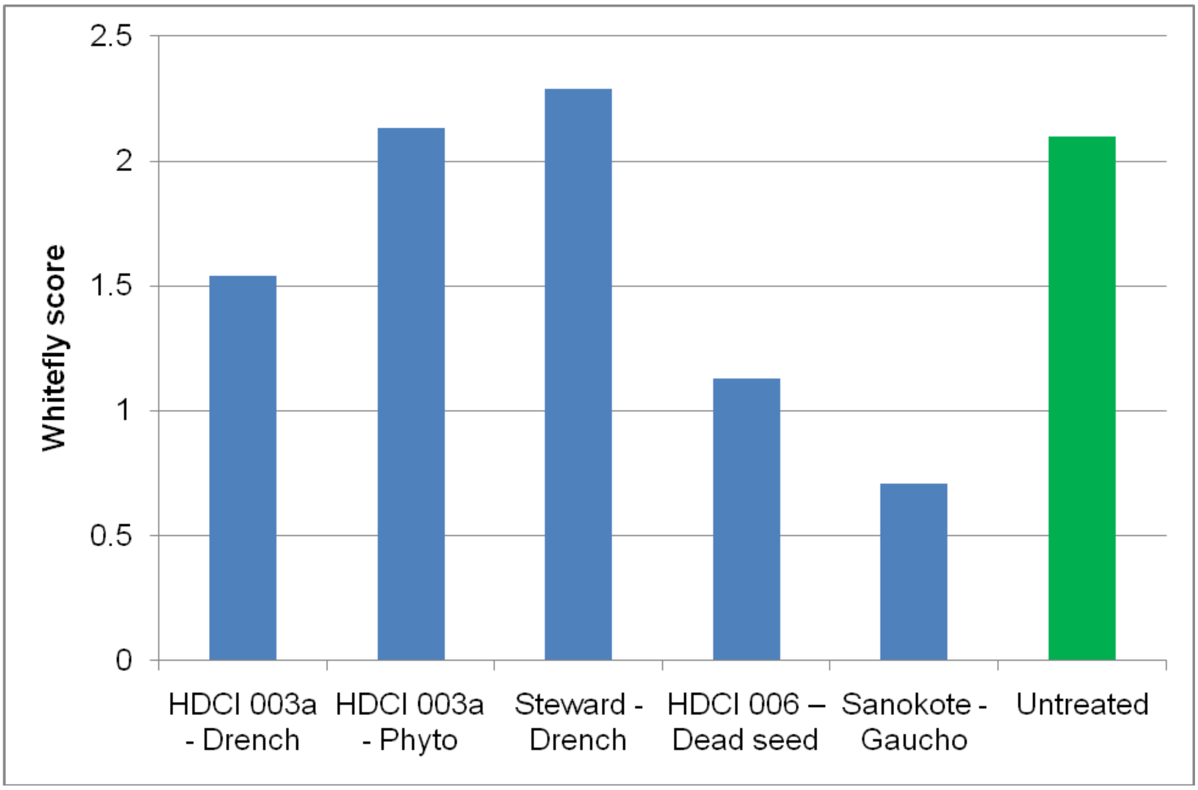

Figure 2.3 Brussels sprout – whitefly score on pre planting treatments on 21 July (N.B. Phyto = ‘Phytodrip’)

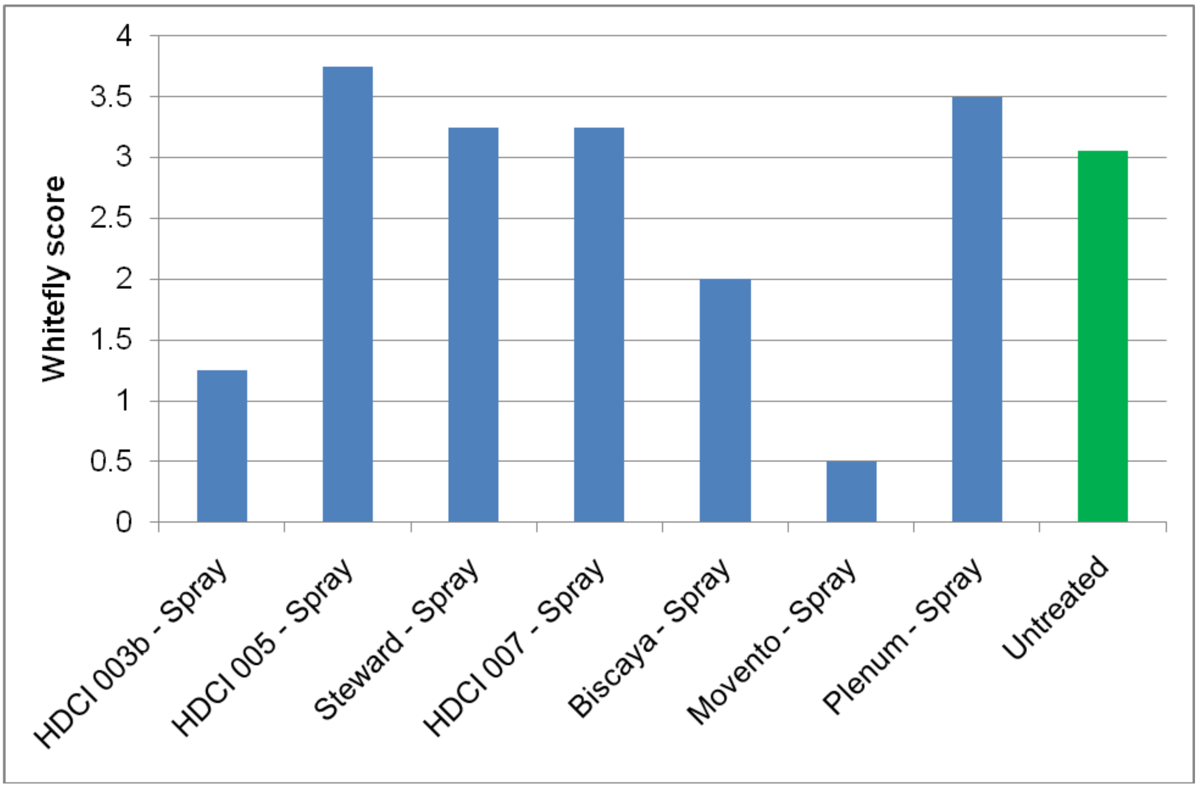

Figure 2.4 Brussels sprout – whitefly score on spray treatments on 29 July

c) Caterpillars

The numbers of caterpillars on individual plants were recorded. Caterpillars of small and large white butterflies and diamond-back and silver-Y moths were observed, but there were insufficient numbers to make any analyses.

d) Flea beetle

Flea beetle damage scores were recorded on 21 July (pre-spray) but, as the damage was light and there was no discernable flea beetle activity, no further assessments were made. As such, only the sowing-time treatments could be assessed for flea beetle control. No transformations were required before analysis and the results are presented in Table 2.7. The treatment factor was significant at the 5% level and HDCI 006 had significantly less damage than the untreated control.

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Table 2.7 Brussels sprout - Mean flea beetle damage score

Treatment	Flea beetle damage score 21 July
HDCI 003a - Drench	1.08
HDCI 003a - Phyto	1.38
HDCI 003b - Spray	1.21
HDCI 005 - Spray	1.29
Steward - Spray	1.13
Steward - Drench	1.04
HDCI 006 – Dead seed	0.79
HDCI 007 - Spray	1.08
Biscaya - Spray	1.08
Movento - Spray	1.13
Plenum - Spray	1.04
Sanokote® Smart - Gaucho	1.00
Untreated	1.042
F-val	2.37
P-val	0.02
SED vs control	0.1135
LSD vs control	0.2295
SED vs treatment	0.1311
LSD vs treatment	0.2650
df	40

e) Plant width

Plant widths were recorded on 21 July (pre-spray). As such, only the effects of the pre-planting treatments were assessed. No transformations were required before analysis and the results are presented in Table 2.8 and Figure 2.5. The treatment factor was significant at the 5% level. HDCI 003a – 'Phytodrip', Steward – Drench, HDCI 006 – Dead seed and Sanokote® - Gaucho all increased plant size compared with the untreated control. These differences are likely to be a result of physiological effects of the treatment on the plant, pest insect control or both.

Table 2.8 Brussels sprout - Mean plant width mid-season

Treatment	21 July Width (cm)
HDCI 003a - Drench	60.0
HDCI 003a - Phyto	71.8
HDCI 003b - Spray	59.4
HDCI 005 - Spray	53.5
Steward - Spray	62.8
Steward - Drench	64.5
HDCI 006 – Dead seed	72.2
HDCI 007 - Spray	60.4
Biscaya - Spray	59.9
Movento - Spray	55.8
Plenum - Spray	57.0
Sanokote® Smart - Gaucho	69.7
Untreated	55.0
F-val	3.32
P-val	0.002
SED vs control	4.365
LSD vs control	5.041
SED vs treatment	8.823
LSD vs treatment	10.188
df	40

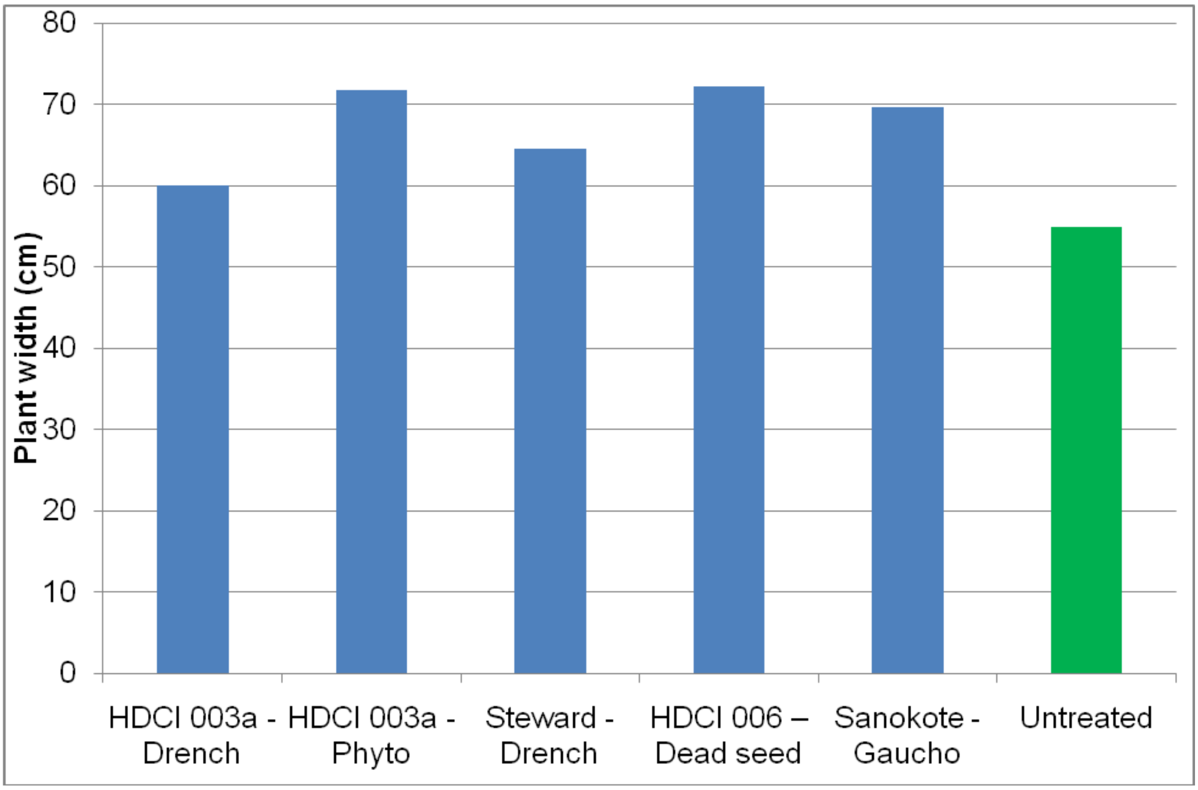

Figure 2.5 Brussels sprout – The effect of pre planting treatments on plant width (N.B. Phyto = 'Phytodrip')

6 September – whole plot assessments

A visual assessment of whitefly infestation and caterpillar damage across whole plots was made. Due to the limited amount of data collected, statistical analysis was difficult. Nevertheless, the results are indicative of the state of the crop at this time.

a) Whitefly

No transformations were required for the analysis of whitefly infestation. The treatment factor was not significant at the 5% level, but pair-wise comparisons using the LSD suggest that both HDCI 003b and Movento sprays could still have been reducing infestations even though they had not been applied since 23 July. The results are shown in Table 2.9.

b) Caterpillar damage

No transformations were required for the analysis of caterpillar damage. The treatment factor was significant at the 5% level. HDCI 003a – Drench, HDCI 003a – 'Phytodrip', HDCI 003b – Spray and HDCI 005 – Spray reduced caterpillar damage compared with the untreated control. The results are shown in Table 2.9 and Figure 2.7.

Table 2.9 Brussels sprout - Mean whitefly score and caterpillar damage score

Treatment	Whitefly score 6 September	Caterpillar damage score 6 September
HDCI 003a - Drench	1.75	0.00
HDCI 003a – ‘Phytodrip’	1.5	0.50
HDCI 003b - Spray	0.75	0.25
HDCI 005 - Spray	1.75	0.50
Steward - Spray	1.75	1.25
Steward - Drench	1.00	2.00
HDCI 006 – Dead seed	1.50	2.00
HDCI 007 - Spray	1.25	1.00
Biscaya - Spray	1.25	1.50
Movento - Spray	0.50	1.25
Plenum - Spray	1.00	2.00
Sanokote® Smart - Gaucho	1.50	2.25
Untreated	1.63	1.63
F-val	1.40	5.37
P-val	0.206	<0.001
SED vs control	0.4272	0.3971
LSD vs control	0.8634	0.8026
SED vs treatment	0.4933	0.4585
LSD vs treatment	0.9969	0.9268
df	40	40

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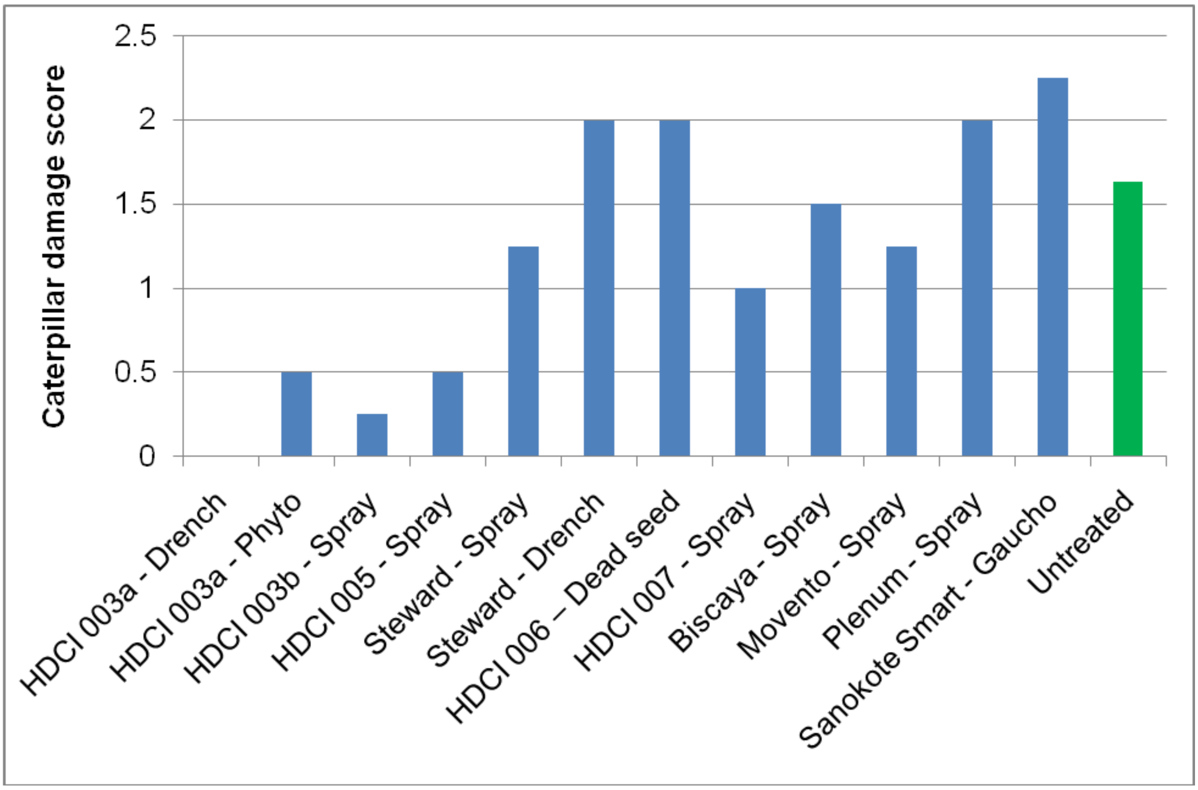

Figure 2.6 Brussels sprout – mean caterpillar damage score (N.B. Phyto = ‘Phytodrip’)

<u>23 September spray - pre-spray and post-spray assessments</u>

Aphid numbers were very low at this time so just whitefly and caterpillar infestations were assessed.

a) Whitefly

A visual assessment of whitefly infestation across whole plots was made. Due to the limited amount of data collected, statistical analysis was difficult. Nevertheless, the results are indicative of whitefly control. No transformations were required for the analysis and the treatment factor was significant at the 10% level on the pre-spray analysis and at the 5% level on the post-spray analysis. Post-spray, HDCI 003b and Movento both had significantly lower scores than the untreated control, but this only represented a reduction in score over pre-spray levels for HDCI 003b. The results are shown in Table 2.10 and Figure 2.7.

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Table 2.10 Brussels sprout - Mean whitefly score pre and post-spraying on 23 September

	Whitefly score	
Treatment	**22 September**	**25 October**
HDCI 003a - Drench	3.00	3.25
HDCI 003a – 'Phytodrip'	2.50	3.00
HDCI 003b - Spray	2.00	1.25
HDCI 005 - Spray	2.50	1.75
Steward - Spray	2.25	1.75
Steward - Drench	2.50	2.75
HDCI 006 – Dead seed	2.75	2.50
HDCI 007 - Spray	1.75	1.75
Biscaya - Spray	2.00	2.00
Movento - Spray	1.50	1.50
Plenum - Spray	2.00	2.50
Sanokote® Smart - Gaucho	1.75	2.25
Untreated	2.75	2.50
F-val	1.72	3.38
P-val	0.099	0.002
SED vs control	0.446	0.4048
LSD vs control	0.9013	0.8182
SED vs treatment	0.515	0.4675
LSD vs treatment	1.0408	0.9448
df	40	40

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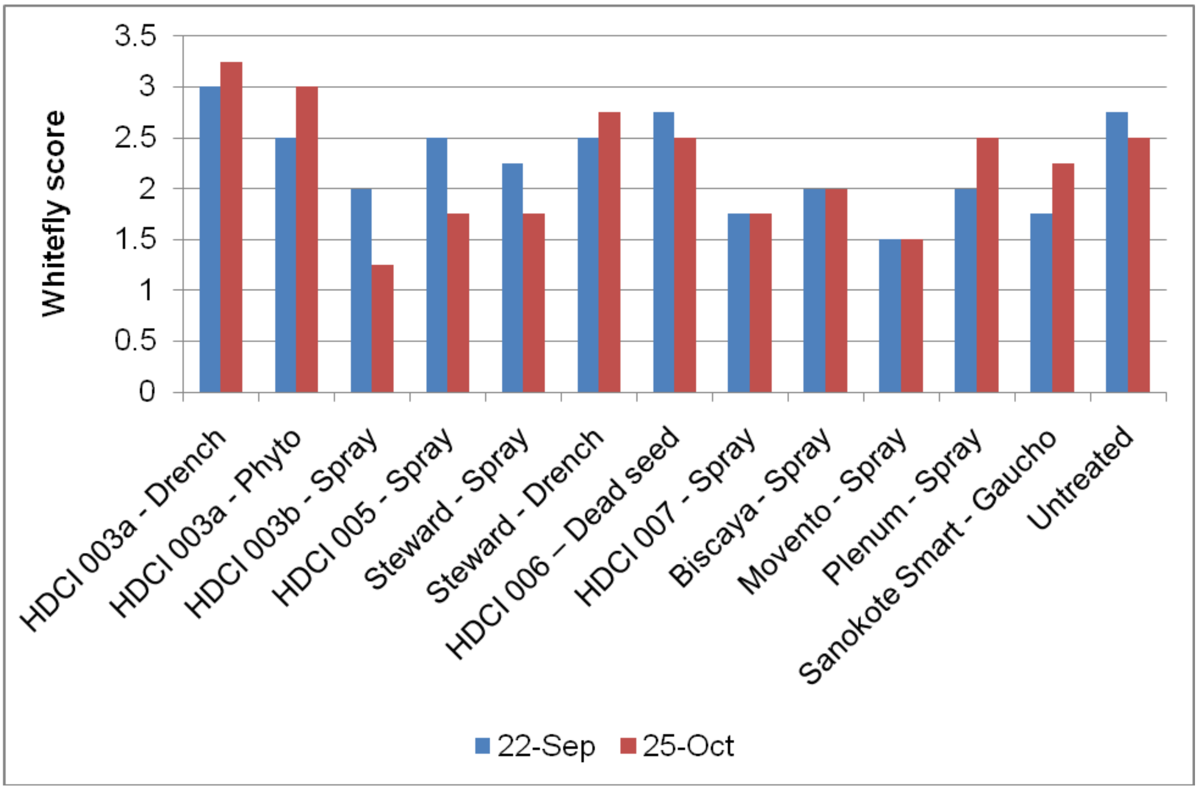

Figure 2.7 Brussels sprout - Mean whitefly score pre and post-spraying on 23 September (N.B. Phyto = 'Phytodrip')

b) Caterpillar numbers

The numbers of caterpillars on 3 plants were assessed before and after spraying. Small white and large white butterflies and diamond back, silver-Y, cabbage and garden pebble moths were found. The predominant species was the garden pebble moth but only the total of all species was analysed. Pre-planting treatments were not assessed and no transformations were required for the analysis. The treatment factor was significant at the 5% level before spraying and the 10% level after spraying. No treatment had significantly fewer caterpillars before spraying, but after spraying HDCI 003b, HDCI 005, Steward, Biscaya and Movento had all reduced numbers compared with the untreated control. The results are shown in Table 2.11 and Figure 2.8.

Table 2.11 Brussels sprout - Mean numbers of caterpillars before and after spraying on 23 September

	Caterpillar numbers	
Treatment	**22 September**	**28 September**
HDCI 003b - Spray	2.33	0.17
HDCI 005 - Spray	1.83	0.42
Steward - Spray	1.17	0.17
HDCI 007 - Spray	2.17	1.33
Biscaya - Spray	1.17	0.42
Movento - Spray	1.42	0.17
Plenum - Spray	1.33	1.00
Untreated	1.46	1.46
F-val	5.73	2.30
P-val	<0.001	0.059
SED vs control	0.2316	0.496
LSD vs control	0.4770	1.022
SED vs treatment	0.2674	0.573
LSD vs treatment	0.5508	1.180
df	25	25

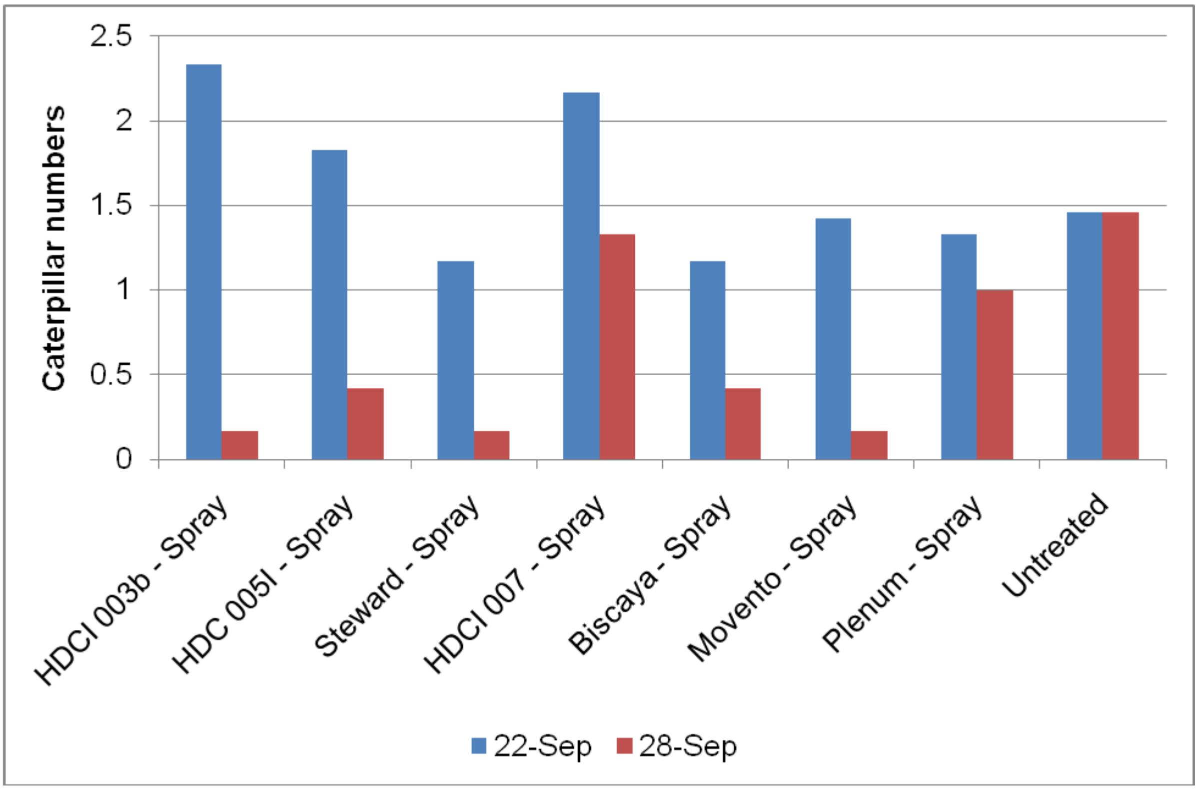

Figure 2.8 Brussels sprout – caterpillar numbers before and after spraying on 23 September

<u>1 November spray - pre-spray and post-spray assessments</u>

Whitefly was the only pest insect present in any numbers at this time. Whole plots were assessed as previously. The treatment factor was significant on both occasions at the 5% level but there was little change in score from pre- to post-spraying and the reduced levels of infestation compared with the untreated control seen with some treatments were in large part probably due to the sprays applied on 23 September. The results are shown in Table 2.12.

Table 2.12 Brussels sprout - Mean whitefly score pre and post-spraying on 1 November

	Whitefly score	
Treatment	**25 October**	**2 November**
HDCI 003a - Drench	3.25	2.75
HDCI 003a – 'Phytodrip'	3.00	3.00
HDCI 003b - Spray	1.25	1.00
HDCI 005 - Spray	1.75	2.50
Steward - Spray	1.75	2.75
Steward - Drench	2.75	2.50
HDCI 006 – Dead seed	2.50	2.75
HDCI 007 - Spray	1.75	2.50
Biscaya - Spray	2.00	1.50
Movento - Spray	1.50	2.00
Plenum - Spray	2.50	2.25
Sanokote® Smart - Gaucho	2.25	1.75
Untreated	2.50	3.00
F-val	3.38	2.88
P-val	0.002	0.006
SED vs control	0.4048	0.458
LSD vs control	0.8182	0.926
SED vs treatment	0.4675	0.529
LSD vs treatment	0.9448	1.070
df	40	40

Discussion

The trial had large infestations of aphids, caterpillars and whitefly. HDCI 003 applied pre-planting or as a foliar spray controlled all three to some extent and HDCI 005 also controlled aphids and caterpillars. The approved aphicides Movento, Biscaya and Plenum controlled aphids as expected and Steward controlled caterpillars (also as expected). Also Biscaya and Movento had some effect against caterpillars and Steward had some effect against aphids.

The biological product HDCI 007 had some effect on *M. persicae* which tended to reside on the top leaves of the plant, but no effect on *B. brassicae* which tended to reside on the underside of the older, bottom leaves, suggesting its action was, as expected,

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entirely by contact. However, Plenum did reduce numbers of *B. brassicae* and it has a similar ‘contact only’ mode of action.

Partial whitefly control was achieved by HDCI 006 and Sanokote® - Gaucho (both applied pre-planting) and Movento and HDCI 003b (both sprays). All four chemicals have a systemic action and none of the contact chemicals had an effect

Experiment 3 - Novel insecticide treatments to control cabbage root fly in broccoli florets

Materials and methods

The experiment was planted in the field known as Sheep Pens. Broccoli seed (cv Doric) was sown on 28 May 2010 into 308 Hassy trays. Six trays were sown with untreated seed and all of the trays were placed in a greenhouse.

On 30 June 2010 (at the 4 leaf stage), the drench treatment was 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 3.1 and all plants were transplanted on 1 July 2010. The plots were 5 m x 1 bed (1.83 m wide) and there were 4 rows per bed. The plants were spaced at 50 cm within and 35 cm between rows. The trial was designed as a Trojan square with 4 rows and 8 columns. Including an untreated control, there were 8 treatments (Table 3.1).

On 3 August, poor plant growth was observed in all plots except those drenched with HDCI 003a (treatment 4) and some plants in the first replicate (southern edge of the trial). Closer inspection revealed cabbage root fly larvae on the roots and aphids, flea beetle and caterpillars damaging the foliage. The drench-treated plots were largely free from these insects. Without chemical control all of these plants would have died so it was decided to apply Dursban WG (for cabbage root fly control) and Dovetail (to control the foliar pests). Two applications were made to the whole trial, at the recommended rates, using a tractor mounted sprayer, on 3 and 18 August. The plants subsequently recovered sufficiently to continue with the trial but the HDCI 003a drench treated plots remained substantially advanced in growth over all of the other plots. By late September the florets in the drench-treated plots were mature and there were sufficient mature florets across the first replicate (untreated plants) to assess the drench treatment. On 24 September, twelve plants in each drench-treated plot and 48 untreated plants from the first replicate were inoculated with 20 laboratory-reared cabbage root fly eggs. Florets of 4-8 cm diameter were chosen if possible. An incision (1-2 cm) was made in the top of the floret and the eggs were inserted on the end of a piece of black filter paper. Each inoculated plant was marked with a plant label.

The florets in the untreated plots of replicates 2-4 were sufficiently mature in early October. On 7 and 8 October, 6 plants in each plot (12 plants in total) were inoculated as before and on 12 October the sprays (Table 3.1) were applied using a knapsack sprayer fitted with 02F110 nozzles in 600 l water/ha. An adjuvant, Phase II, at 0.5% of water volume was used for all spray treatments except Movento, for which it was not required.

Table 3.1 Broccoli - Treatments applied to plots to control cabbage root fly in florets

Code	Product	a.i.	Application method	Rate	
				a.i.	**Product**
1	HDCI 003b	HDCI 003	Spray	150 g/ha	1500 ml/ha
2	HDCI 005	HDCI 005	Spray	35 g/ha	175 ml/ha
3	Steward	Indoxacarb	Spray	36 g/ha	85 g/ha
4	HDCI 003a	HDCI 003	Drench	4 mg/plant [1]	20 ml/1000 plants [1]
5	Tracer	Spinosad	Spray	96 g/ha	200 ml/ha
6	Dursban WG	Chlorpyrifos	Spray	900 g/ha	1200 g/ha
7	Movento	Spirotetramat	Spray	75 g/ha	500 ml/ha
8	Untreated				

[1] At 25000 plants/ha = 100 g a.i./ha

Assessments

The inoculated florets were harvested when the cabbage root fly larvae had had time to develop and damage the florets. Florets from the first inoculation (HDCI 003a - Drench) were harvested on 2 November, 5 weeks after inoculation. Replicates 2, 3 and 4 (spray treatments) were harvested on 8, 15 and 22 November respectively (4 – 6 weeks after inoculation). The florets were dissected, assessed for the presence or absence of damage and the numbers of larvae present were counted.

Results

Statistical analysis

All analyses were performed using analysis of variance (ANOVA). Interpretations were made using the treatment means together with standard errors of the difference (SED) and least significance difference (LSD) values. Where appropriate, transformations of the data were used to ensure homogeneity of variance between treatments. The original design had 4 replicates of each treatment arranged in Trojan square with 4 rows and 8 columns. Due to the problems discussed earlier, the drench treatment was analysed without design and the spray treatments were analysed as an incomplete Trojan square.

Drench treatment

No transformations were required. The treatment factor was not significant at the 5% level using an F-test and the results are presented in Table 3.2

Table 3.2 Broccoli – mean number of cabbage root fly larvae recovered from inoculated florets after pre-planting drench treatment

Treatment	**Number of larvae/plant**
HDCI 003a - drench	3.58
Untreated	2.19
F-val	2.73
P-val	0.133
SED	0.840
LSD	1.901
df	9

Spray treatments

The percentage of cabbage root fly larvae recovered after spray treatment compared with the number of eggs added was analysed after an Angular transformation. The treatment factor was significant at the 5% level using an F-test and the results are presented in Table 3.3 and Figure 3.1. Pair-wise comparisons suggest that HDCI 003b reduced survival of cabbage root fly larvae compared with all other treatments except Dursban WG and Tracer. Dursban WG gave significantly lower survival than HDCI 005, Steward and Movento but was marginally not significantly different from the untreated control. Tracer had lower numbers than the untreated control. This was not statistically significant, but may have been with full replication within the trial. The other treatments showed no evidence of control.

Table 3.3 Broccoli – the percentage of larvae recovered from florets after inoculation with 20 cabbage root fly eggs

Treatment	% recovery of larvae	
	Angular	Back trans.
HDCI 003b	6.7	1.4
HDCI 005	22.6	14.8
Steward	25.4	18.5
Tracer	17.9	9.5
Dursban WG	7.7	1.8
Movento	27.4	21.2
Untreated	21.4	13.3
F-val	3.04	
P-val	0.048	
SED	6.70	
LSD	14.59	
df	12	

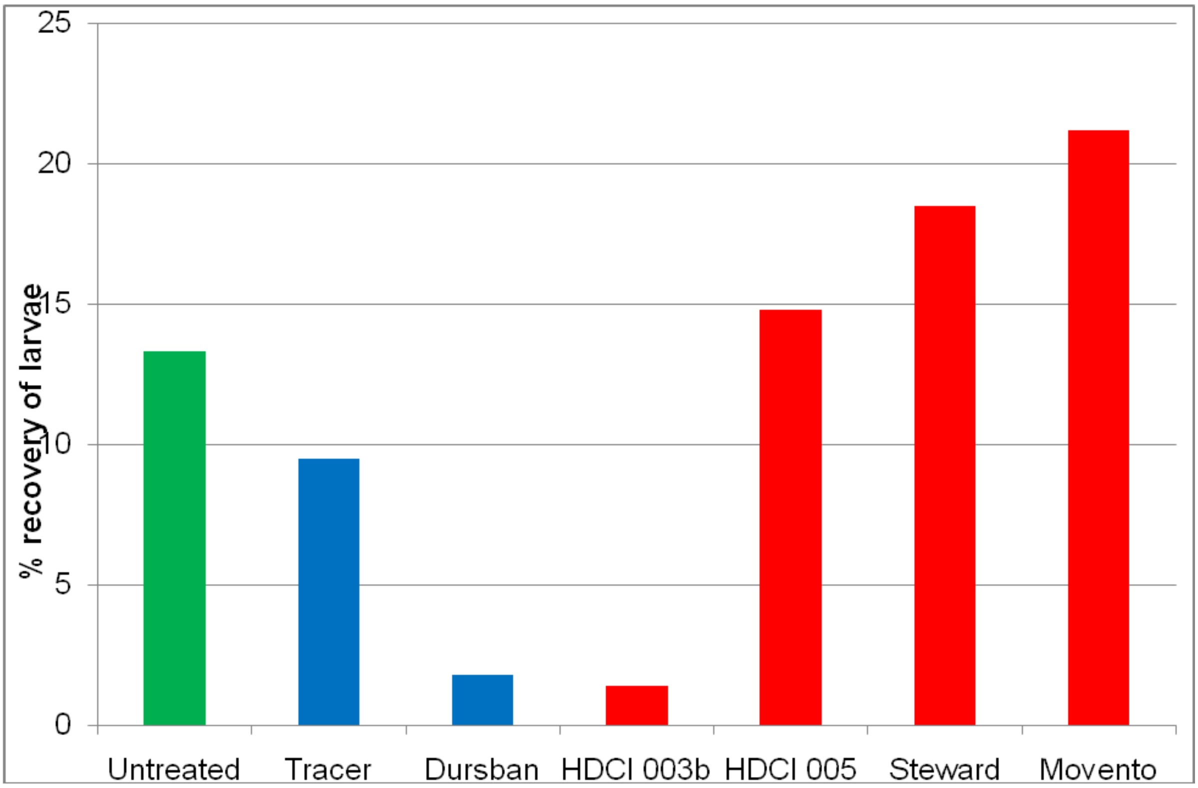

Figure 3.1 Broccoli – The percentage of larvae recovered from florets after inoculation with 20 cabbage root fly eggs

Discussion

The pre planting treatment (HDCI 003a) was ineffective. It has shown prolonged activity against caterpillars and aphids, but presumably here the activity of the greatly diluted and metabolized amounts present had insufficient activity to control cabbage root fly larvae. Although almost identical in terms of numbers of larvae recovered, HDCI 003b was statistically different from the untreated control and Dursban WG was not. However, it is clear that they are both effective treatments though the Dursban WG would be unlikely to fulfil harvest interval requirements, so the less effective Tracer treatment (not significantly different from the control in this trial) is the only approved chemical here which is likely to have any worthwhile activity against cabbage root fly in the aerial parts of brassicas.

Experiment 4 - Novel insecticide treatments to control cabbage root fly and flea beetles in radish

Materials and methods

The experiment was done within the field known as Sheep Pens at Warwick HRI, Wellesbourne. The trial was laid out as a Balanced Row and Column design. The field plots were 5 m x 1 bed (1.83 m each) in size and plots were separated by 1 m along beds. In total there were 12 insecticide treatments including one seed treatment and 1 spray with bait. There were 4 replicates of each treatment and 8 replicates of an insecticide-free control. The seed (cv Rudi) was drilled on 7 July 2010 at a spacing of 35 seeds/m within rows and 0.25 m between rows. All sprays were applied using a knapsack sprayer fitted with 02F110 nozzles except treatment 2 (spray with bait) which was applied using 05F110 nozzles. Treatments 3, 5 and 13 were applied (pre-emergence) on 8 July and treatments 2, 4, 6, 7, 8, 10, 11 and 12 were applied (post-emergence) on 14 July. Water volumes were 1000, 300 and 100l/ha for Pre-emergence sprays, Post-emergence sprays and the bait spray respectively. The treatments are listed in Table 4.1.

Table 4.1 Treatments used in trial on radish

Code	Product	Application method	a.i.	Rate (product/ha)
1	HDCI 003a	Seed treatment	HDCI 003	50 g product/Unit[1]
2	HDCI 014	Post-emergence spray + bait	HDCI 014	1500 ml
3	HDCI 003a	Pre-emergence spray	HDCI 003	750 ml
4	HDCI 003b	Post-emergence spray	HDCI 003	1500 ml
5	HDCI 005	Pre-emergence spray	HDCI 005	175 ml
6	HDCI 005	Post-emergence spray	HDCI 005	175 ml
7	Movento	Post-emergence spray	Spirotetramat	480 ml
8	Steward	Post-emergence spray	Indoxacarb	255 g [2]
9	Untreated			
10	Biscaya	Post-emergence spray	Thiacloprid	400 ml
11	Tracer	Post-emergence spray	Spinosad	200 ml
12	Hallmark[3]	Post-emergence spray	Lambda-cyhalothrin	150 ml
13	Dursban WG	Pre-emergence spray	Chlorpyrifos	1200 g

[1] 150 g a.i/ha at 1,500,000 seeds/ha

[2] 3 (max number of applications) x 85 g (max individual dose) for brassicas

[3] Hallmark refers to Hallmark with Zeon technology

Assessments

On 26 July, flea beetle damage was assessed by counting the number of holes in the cotyledons and first true leaves of 5 plants in each of the middle two rows. Roots were harvested from 0.5 m in each of the middle two rows in each plot, washed and assessed for cabbage root fly damage. Data were collected on the numbers of roots and the total weight of the roots per metre length of row, as well as classifying the roots into categories according to the extent of cabbage root fly damage. The damage categories were: 1 – No damage or superficial damage and 2 - Clear damage with larval mines.

Results

Statistical analysis

All analyses were performed using analysis of variance (ANOVA). Interpretations were made using the treatment means together with standard errors of the difference (SED) and least significance difference (LSD) values. Where appropriate, transformations of the data were used to ensure homogeneity of variance between treatments.

Phytotoxicity

There were no visible phytotoxic effects, so no data were collected

Flea Beetle

Damage was so severe that any treatment differences would have been largely irrelevant, so the assessment was abandoned after looking at the first replicate. This partial result set is displayed in Table 4.2

Table 4.2 Radish - Flea beetle damage to leaves (first replicate only)

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Code	Product	Application timing	Mean number of holes per leaf	
			Cotyledon	First true leaf
1	HDCI 003a	Seed treatment	11.7	57.9
2	HDCI 014 (bait)	Post-emergence	10.6	47.3
3	HDCI 003a	Pre-emergence	8.7	50.2
4	HDCI 003b	Post-emergence	8.4	45.2
5	HDCI 005	Pre-emergence	14.2	36.7
6	HDCI 005	Post-emergence	14.7	60.5
7	Movento	Post-emergence	11.4	34.3
8	Steward	Post-emergence	8.1	41.6
9	Untreated		11.4	56.4
10	Biscaya	Post-emergence	8.3	59.4
11	Tracer	Post-emergence	10.3	62.6
12	Hallmark	Post-emergence	9.0	50.2
13	Dursban WG	Pre-emergence	10.3	52.0

Cabbage root fly

Damage due to cabbage root fly larvae was moderate across the trial. The roots were divided into two categories: 1 – Superficial or no damage and 2 - Clear damage with larval mines. The percentage number of roots in category 1 was analysed after an Angular transformation. The treatment factor was significant at the 10% level using an F-test and the results are presented in Table 4.3 and Figure 4.1. The only significant difference from the control treatment was a reduction in the number of roots in category 1 in the Hallmark treatment. That is to say an increase in damage was observed in the Hallmark-treated plots. Root weight required no transformations before analysis and the treatment factor was not significant at the 5% level using an F-test. The results are presented in Table 4.4.

Table 4.3 Radish – cabbage root fly damage at harvest

			% number of roots with no or superficial damage	
Code	**Product**	**Application timing**	Angular	Back Trans
1	HDCI 003a	Seed treatment	45.75	51.3
2	HDCI 014 (bait)	Post-emergence	52.99	63.8
3	HDCI 003a	Pre-emergence	50.54	59.6
4	HDCI 003b	Post-emergence	47.53	54.4
5	HDCI 005	Pre-emergence	51.39	61.1
6	HDCI 005	Post-emergence	45.93	51.6
7	Movento	Post-emergence	52.50	62.9
8	Steward	Post-emergence	49.31	57.5
9	Untreated		49.27	57.4
10	Biscaya	Post-emergence	48.37	55.9
11	Tracer	Post-emergence	49.79	58.3
12	Hallmark	Post-emergence	41.68	44.2
13	Dursban WG	Pre-emergence	52.55	63.0
F-val			1.80	
P-val			0.081	
SED	vs Control		2.953	
LSD	vs Control		5.967	
SED	vs Treatment		3.409	
LSD	vs Treatment		6.891	
df			40	

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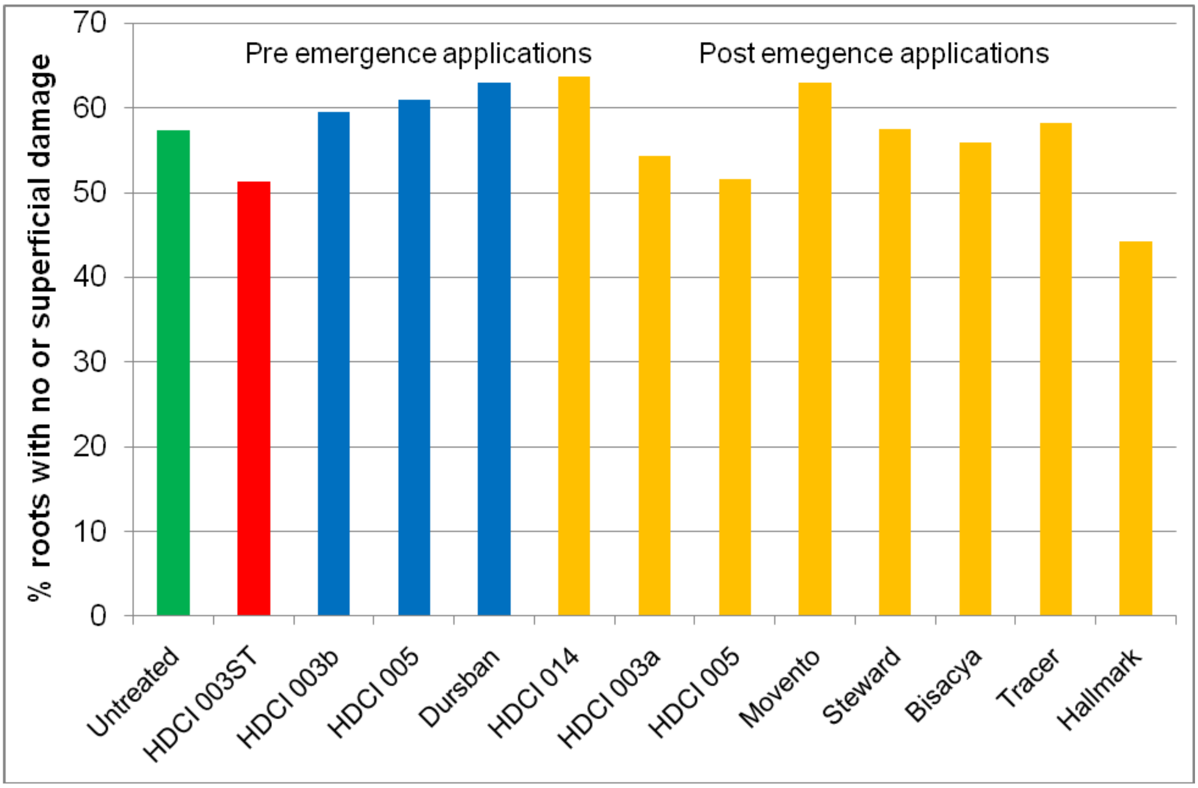

Figure 4.1 Radish – cabbage root fly damage at harvest

Table 4.4 Radish – root weight at harvest

Code	Product	Application timing	Weight of 1m row of roots (g)
1	HDCI 003a	Seed treatment	746
2	HDCI 014 (bait)	Post-emergence	621
3	HDCI 003a	Pre-emergence	566
4	HDCI 003b	Post-emergence	726
5	HDCI 005	Pre-emergence	692
6	HDCI 005	Post-emergence	570
7	Movento	Post-emergence	580
8	Steward	Post-emergence	560
9	Untreated		574
10	Biscaya	Post-emergence	666
11	Tracer	Post-emergence	568
12	Hallmark	Post-emergence	582
13	Dursban WG	Pre-emergence	504

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Discussion

Even treatments known to be effective against cabbage root fly (Dursban WG) or flea beetle (Hallmark) were ineffective, as was HDCI 003 which has shown activity in a number of trials on other crops. Hallmark has again exhibited the negative effect on cabbage root fly control observed in previous trials with pyrethroid insecticides.

Experiment 5 – Novel insecticide treatments to control Thrips and bean seed fly in leek

Materials and methods

The experiment was done within the field known as Sheep Pens at Warwick HRI, Wellesbourne. A population of onion Thrips (*Thrips tabaci*) was maintained on an overwintered leek crop in an adjacent field. The experiment was laid out as a partially balanced row and column design with 12 rows and 4 columns. Including an untreated control, there were 12 spray treatments (Table 5.2), two of which were biological treatments. Each plot was 5 m x 1 beds (1.83 m each in size) and plots were separated by 1 m along beds. There were 4 replicates of each treatment.

A batch of seed (cv Jolant) was treated with HDCI 006 on 29 April and a further batch was supplied treated with Force. Each plot was sown on 7 May 2010 with four rows of seed and these contained 1 each of the two seed treatments and 2 untreated rows (Table 5.1). The seed was sown at a spacing of 12 per metre with 4 rows (30 cm spacing) per bed. Spray treatments were applied on 5 July, 24 July, 24 August, 3 September and 6 October 2008. All treatments were applied at a rate of 200l water/ha except HDCI 004 (400l/ha) and HDCI 007 (400l/ha) using a knapsack sprayer fitted with 02F110 nozzles.

Table 5.1 Seed treatments used within each plot

Code	Product	a.i.	Rate
1	Untreated		
2	HDCI 006		77.1 g product/250,000 seeds
3	Force	Tefluthrin	Commercial

Table 5.2 Foliar spray treatments applied to leek plots

Code	**Treatment/product**	**Active ingredient**	**Rate l/ha or kg/ha**
1	HDCI 003b		1500 ml
2	HDCI 005		175 ml
3	Mesurol	Methiocarb	1500 ml
4	Dynamec + Phase II	Abamectin	480 ml + 1000 ml
5	Dynamec	Abamectin	480 ml
6	Tracer	Spinosad	200 ml
7	Dursban WG	Chlorpyrifos	1000 g
8	Biscaya	Thiacloprid	400 ml
9	Steward	Indoxacarb	85 g
10	HDCI 007[1]		4000 ml
11	Untreated		
12	HDCI 004[1]		2500 ml

[1] Biological treatment

Assessments

Damage was assessed before spraying commenced on 2 July (untreated spray plots only) and then after each spray occasion - on 15 July, 2 August, 1 September, 9 September and 13 October. All 4 rows were assessed in the untreated and Mesurol (positive control)-treated plots on 2 July, 15 July and 2 August. The effect of the seed treatments had diminished at this point, so subsequently just the Force treated rows were assessed. Ten plants per seed treatment per plot were assessed. The 5 youngest leaves (leaves were numbered 1 – youngest to 5 – oldest) on each plant were examined separately and scored for the presence of Thrips feeding damage (0=no damage, 10=10% area affected, 100 =100% area affected). A seedling count was conducted on 11 June with the intention of monitoring mortality due to bean seed fly larvae but the plant stand in the untreated rows was so low (for unknown reasons, unrelated to pest damage) subsequent assessments were abandoned and the Force treated rows were used for Thrips damage assessments.

Results

Statistical analysis

All analyses were performed using analysis of variance (ANOVA). Interpretations were made using the treatment means together with standard errors of the difference (SED) and least significance difference (LSD) values. Where appropriate, transformations of the data were used to ensure homogeneity of variance between treatments.

Comparison of seed treatments

The mean overall damage score per plant (5 youngest leaves) per plot and the mean damage score of the penultimate leaf per plot were calculated. Angular transformations were used throughout to ensure homogeneity between treatments. Means for each treatment are presented together with associated SEDs and 5% LSDs.

2 July 2010

Only the control plots were assessed. The treatment factor was significant at the 5% level using an F-test. Both the analysis of overall damage and damage to the penultimate leaf (leaf number 2) showed that HDCI 006 had significantly less damage than both the untreated control and the Force treatment. There was no difference between the control and the Force treatment. The results are displayed in Table 5.3 and Figure 5.1

Table 5.3 Leek - damage due to Thrips pre-spraying on 2 July

	% leaf damage			
Seed treatment	**Leaves 1 to 5**		**Penultimate leaf (number 2)**	
	Angular	**Back trans**	**Angular**	**Back trans**
Untreated	37.9	37.7	40.6	42.3
HDCI 006	27.8	21.8	30.4	25.6
Force	35.8	34.2	40.4	42.0
F-val	6.55		10.46	
P-val	0.031		0.011	
SED	2.93		2.56	
LSD	7.18		6.26	
df	6		6	

15 July and 2 August 2010

The control plots and the Mesurol-treated plots were assessed. The treatment factor was insignificant for both analyses on both dates at the 5% level using an F-test. However, it is clear from the mean values that HDCI 006 was likely still to be providing some control compared with the untreated control and the effect of the Mesurol spray is additive. The results are displayed in Table 5.4, Table 5.5 and Figure 5.1

Table 5.4 Leek - damage due to Thrips post-spraying on 15 July

Seed treatment	Spray treatment	% leaf damage Leaves 1 to 5		Penultimate leaf (number 2)	
		Angular	**Back trans**	**Angular**	**Back trans**
Untreated	Untreated	49.1	57.2	52.7	63.3
HDCI 006	Untreated	41.0	43.1	47.6	54.5
Force	Untreated	48.2	55.5	52.3	62.6
Untreated	Mesurol	40.3	41.8	43.7	47.7
HDCI 006	Mesurol	33.6	30.6	37.0	36.2
Force	Mesurol	40.5	42.2	41.1	43.2
F-val		0.09		0.17	
P-val		0.914		0.844	
SED		2.554		2.715	
LSD		5.444		5.786	
df		15		15	

Table 5.5 Leek - damage due to Thrips post-spraying on 2 August

Seed treatment	Spray treatment	% leaf damage Leaves 1 to 5		Penultimate leaf (number 2)	
		Angular	**Back trans**	**Angular**	**Back trans**
Untreated	Untreated	51.1	60.6	52.7	63.3
HDCI 006	Untreated	51.0	60.4	47.6	54.5
Force	Untreated	48.4	55.9	52.3	62.6
Untreated	Mesurol	40.2	41.7	43.7	47.7
HDCI 006	Mesurol	36.0	34.5	37.0	36.2
Force	Mesurol	38.9	39.3	41.1	43.2
F-val		1.83			
P-val		0.194			
SED		2.105			
LSD		4.486			
df		15			

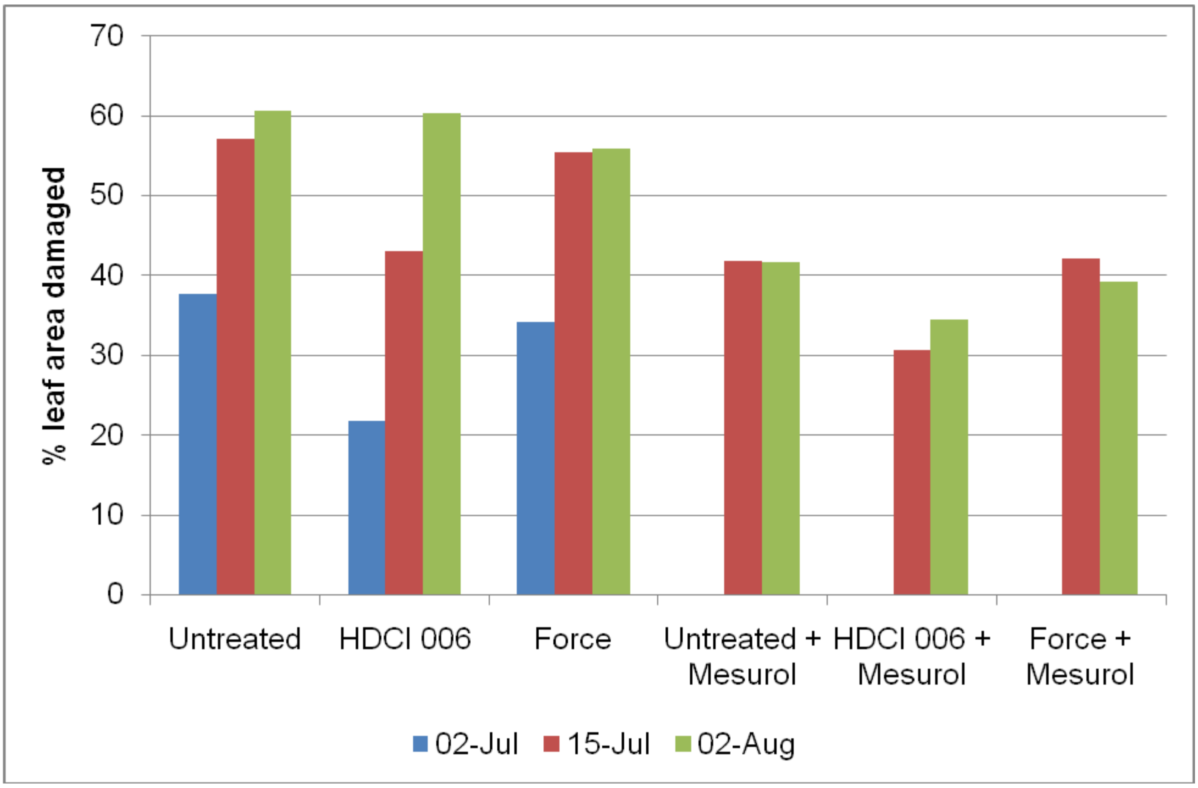

Figure 5.1 Leek - the effect of seed treatment on foliage damage (leaves 1 to 5)

Comparison of spray treatments

The mean overall damage score per plant (5 youngest leaves) per plot and the mean damage score of the penultimate leaf per plot were calculated. Angular transformations were used throughout to ensure homogeneity between treatments. Means for each treatment are presented together with associated SEDs and 5% LSDs.

15 July 2010

Overall leaf damage was relatively high. The treatment factor was significant at the 5% level using an F-test for both analyses. When considering the penultimate leaf, Mesurol reduced damage compared with the control and all other treatments. For leaves 1 to 5, Mesurol, Dursban WG and Steward reduced damage compared with the control and Mesurol also reduced damage compared with all of the other treatments except HDCI 005, Dursban WG and Steward. The results are presented in Table 5.6 and Figures 5.2 and 5.3.

Table 5.6 Leek - damage due to Thrips post-spraying on 15 July

Spray treatment	% leaf damage			
	Leaves 1 to 5		Penultimate leaf (number 2)	
	Angular	Back trans	Angular	Back trans
HDCI 003b	45.2	50.4	49.7	58.1
HDCI 005	44.7	49.5	50.4	59.3
Mesurol	40.3	41.8	41.1	43.2
Dynamec + Phase II	48.1	55.4	52.4	62.7
Dynamec	45.9	51.6	48.3	55.8
Tracer	45.6	51.0	48.6	56.3
Dursban WG	43.5	47.4	48.0	55.3
Biscaya	48.9	56.8	53.5	64.6
Steward	42.2	45.2	47.8	54.8
HDCI 007	49.9	58.5	52.3	62.6
Untreated	49.0	57.0	52.3	62.6
HDCI 004	45.8	51.4	50.4	59.3
F-val	3.10		2.31	
P-val	0.006		0.031	
SED	2.319		3.058	
LSD	4.719		6.221	
df	33		33	

2 August 2010

Overall leaf damage was relatively high. The treatment factor was not significant at the 5% level using an F-test for both analyses, but pair-wise comparisons suggest that Mesurol is the only spray to reduce leaf damage compared with the control. The results are presented in Table 5.7 and Figures 5.2 and 5.3.

Table 5.7 Leek - damage due to Thrips post-spraying on 2 August

Spray treatment	% leaf damage Leaves 1 to 5		Penultimate leaf (number 2)	
	Angular	**Back trans**	**Angular**	**Back trans**
HDCI 003b	47.4	54.1	44.6	49.3
HDCI 005	49.9	58.6	49.0	57.0
Mesurol	38.9	39.4	36.1	34.7
Dynamec + Phase II	50.5	59.6	49.9	58.5
Dynamec	46.8	53.6	45.4	50.8
Tracer	50.7	59.9	50.7	59.8
Dursban WG	51.8	61.7	52.5	63.0
Biscaya	51.8	61.8	51.4	61.0
Steward	49.0	56.9	49.3	57.5
HDCI 007	50.8	60.1	50.6	59.7
Untreated	49.2	57.3	48.4	55.9
HDCI 004	48.7	56.5	47.8	54.9
F-val	1.49		1.34	
P-val	0.183		0.245	
SED	4.052		5.36	
LSD	8.244		10.90	
df	33		33	

9 September 2010

Overall leaf damage had declined since the previous assessment. The treatment factor was significant at the 5% level using an F-test for both analyses. When considering the penultimate leaf, Mesurol, HDCI 003b and Abamectin (with or without Phase II) reduced damage compared with the control and Mesurol also reduced damage compared with all the other treatments. For leaves 1 to 5, Mesurol, HDCI 003b, Tracer and Abamectin (with or without Phase II) reduced damage compared with the control and Mesurol also reduced damage compared with all of the other treatments. The results are presented in Table 5.8 and Figures 5.2 and 5.3.

Table 5.8 Leek - damage due to Thrips post-spraying on 9 September

	% leaf damage			
Spray treatment	**Leaves 1 to 5**		**Penultimate leaf (number 2)**	
	Angular	**Back trans**	**Angular**	**Back trans**
HDCI 003b	29.1	23.6	23.7	16.2
HDCI 005	34.1	31.5	28.7	23.0
Mesurol	23.9	16.4	15.8	7.4
Dynamec + Phase II	31.0	26.5	22.8	15.1
Dynamec	31.7	27.6	25.2	18.2
Tracer	31.7	27.7	25.5	18.6
Dursban WG	33.5	30.5	27.7	21.6
Biscaya	33.3	30.2	28.9	23.4
Steward	36.2	34.8	30.4	25.7
HDCI 007	37.3	36.7	32.6	29.1
Untreated	36.2	34.8	30.5	25.8
HDCI 004	34.7	32.4	30.6	25.9
F-val	6.42		6.56	
P-val	<0.001		<0.001	
SED	2.045		2.545	
LSD	4.161		5.179	
df	33		33	

16 October 2010

Overall leaf damage had declined further since the previous assessment. The treatment factor was significant at the 5% level using an F-test for both analyses. When considering the penultimate leaf Mesurol, HDCI 003b, Tracer and Dynamec (with or without Phase II) reduced damage compared with the control. For leaves 1 to 5, Mesurol, HDCI 003b, Tracer, Dursban WG and Dynamec (with or without Phase II) reduced damage compared with the control and Mesurol also reduced damage compared with all of the other treatments except HDCI 003b and Dynamec (without Phase II). The results are presented in Table 5.9 and Figures 5.2 and 5.3.

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Table 5.9 Leek - damage due to Thrips post-spraying on 6 October

	% leaf damage			
Spray treatment	**Leaves 1 to 5**		**Penultimate leaf (number 2)**	
	Angular	**Back trans**	**Angular**	**Back trans**
HDCI 003b	21.1	13.0	13.8	5.7
HDCI 005	29.3	23.9	20.7	12.5
Mesurol	16.6	8.2	10.5	3.3
Dynamec + Phase II	23.0	15.2	15.8	7.4
Dynamec	21.4	13.3	12.7	4.8
Tracer	24.0	16.5	15.5	7.2
Dursban WG	24.9	17.8	18.0	9.5
Biscaya	30.3	25.5	22.7	14.9
Steward	32.1	28.2	23.8	16.3
HDCI 007	31.9	28.0	23.2	15.5
Untreated	32.7	29.2	23.6	16.0
HDCI 004	30.5	25.8	20.4	12.1
F-val	7.17		4.09	
P-val	<0.001		<0.001	
SED	2.811		3.255	
LSD	5.719		6.623	
df	33		33	

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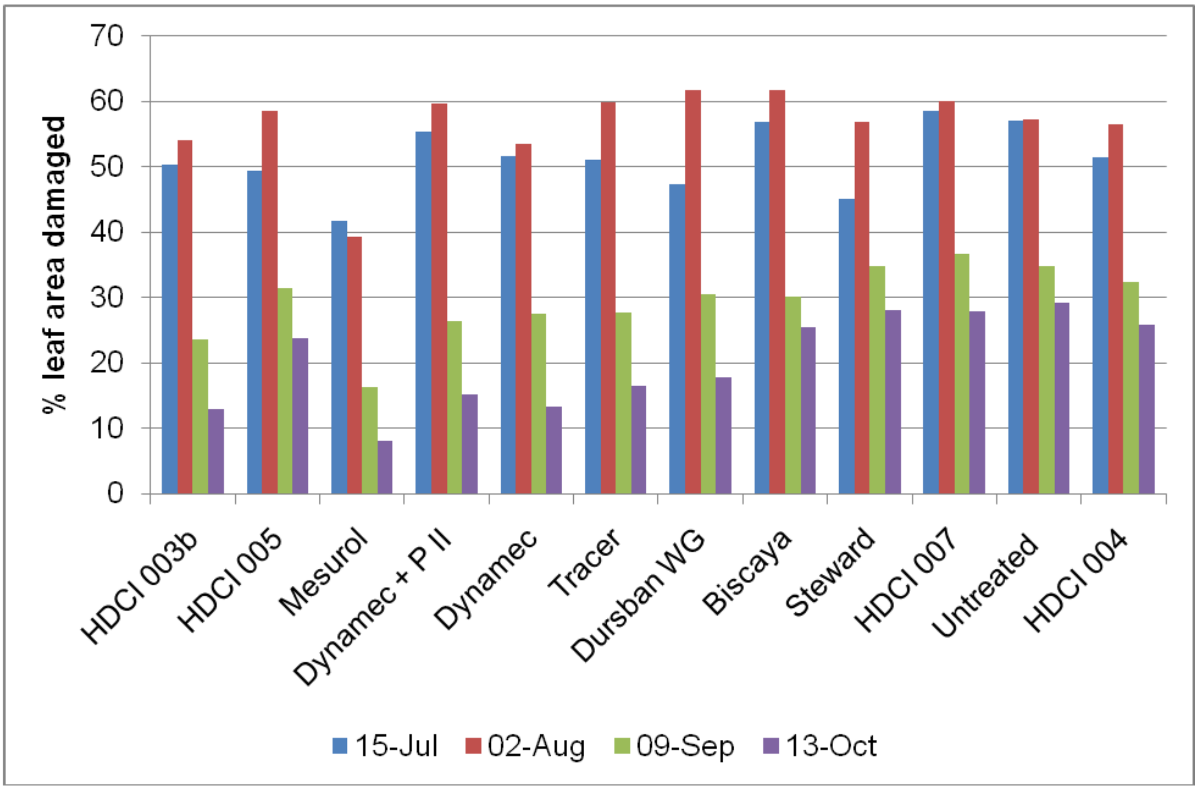

Figure 5.2 Leek - the effect of sprays on leaf damage (leaves 1 to 5)

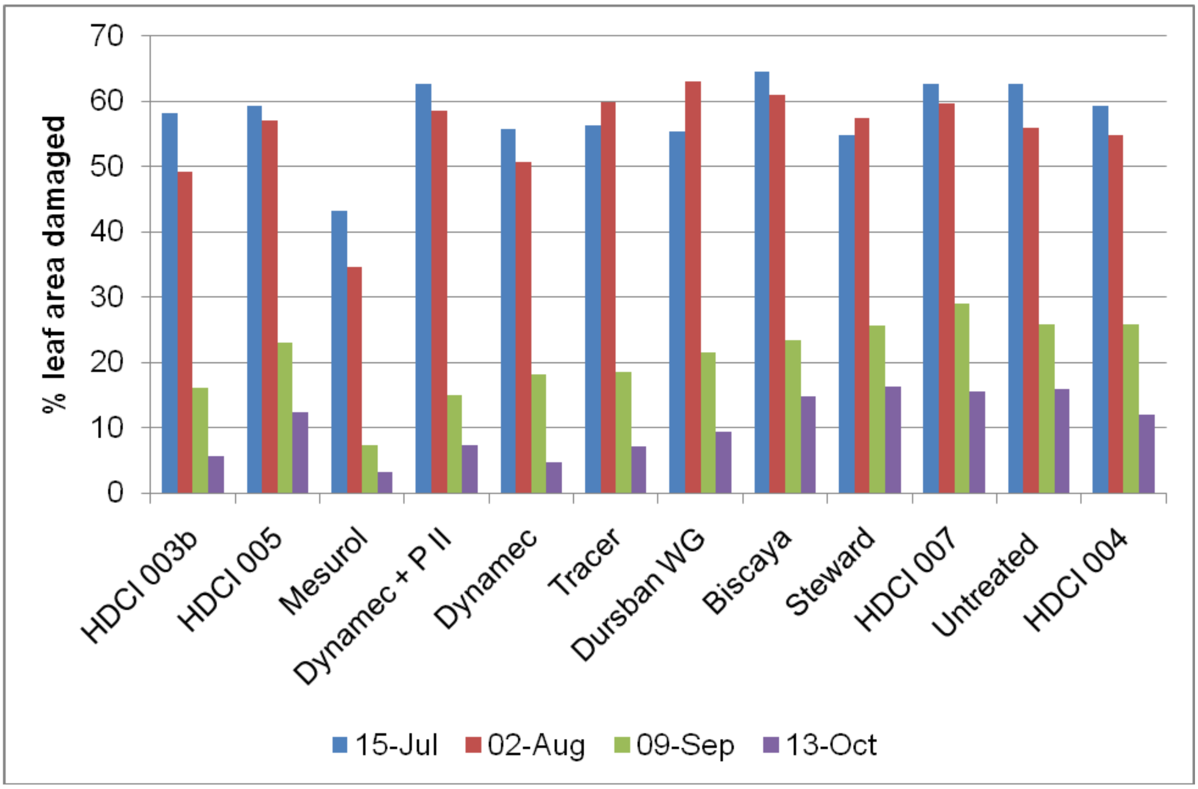

Figure 5.3 Leek - the effect of sprays on leaf damage (penultimate leaf – leaf 2)

Discussion

Onion Thrips are certainly difficult to control on leek. Seed treatment with HDCI 006 provided partial control of Thrips for around 10 weeks after sowing. Mesurol (positive control and not approved for this use in the UK) was consistently the most effective spray but HDCI 003b, Dynamec and Tracer also gave some control, particularly as the pest pressure diminished later in the season. It should be noted that the trial was not designed to test spray programmes and the leaves assessed were always the newest growth so each spray should be treated as a discrete event.

Experiment 6 - Novel insecticide treatments to control aphids in lettuce

Materials and methods

The experiment was done within the field known as Sheep Pens at Warwick HRI, Wellesbourne. The trial was laid out as balanced row and column design with 4 rows and 7 columns. The field plots were 4 m x 1 bed (1.83 m each) in size and plots were separated by 1 m along beds. In total there were 7 treatments including one 'Phytodrip' treatment and one biological treatment. There were 4 replicates of each treatment. The seed (cv Saladin) was sown on 28 July 2010 into peat blocks. One batch was treated with HDCI 003a using a simulated 'Phytodrip' technique (0.2ml of treatment solution was added to each seed, using an automatic pipette, at sowing). The growing plants were infested on 18 August with currant-lettuce aphid (*Nasonovia ribisnigri*) from the culture maintained at Warwick HRI. The plants were transplanted on 25 August into the field plot at 0.35cm between plants along the row and 0.35 cm between rows. Further aphids were introduced on potted lettuce plants and the plot was covered with insect-proof netting to exclude predators. The aphids were allowed to establish for about 2 weeks before removing the netting and applying the spray treatments. All sprays were applied on 9 September using a knapsack sprayer fitted with 02F110 nozzles in a water volume of 300l/ha. The treatments are listed in Table 6.1.

Table 6.1 Treatments used in trial on lettuce aphids

Code	Application	Product	a.i.	Rate (product)
1	'Phytodrip'	HDCI 003a		9.4 ml/1000 plants [1]
2	Spray	Movento	Spirotetramat	500 ml/ha
3	Spray	Aphox	Pirimicarb	420 g/ha
4	Spray	HDCI 007		4000 ml/ha
5	Spray	HDCI 003b		1500 ml/ha
6	Spray	HDCI 005		175 ml/ha
7		Untreated		

[1] At 80000 plants/ha = 150 g a.i. (750 ml product)/ha

Assessments

Ten plants in each plot were marked and the winged and wingless aphids were identified and counted. Counts were made pre-spray on 8 September and on 2 occasions post-spray (16 and 28 September). A visual assessment of phytotoxic effects was also made on 16 September.

Results

Statistical analysis

All analyses were performed using analysis of variance (ANOVA). Interpretations were made using the treatment means together with standard errors of the difference (SED) and least significance difference (LSD) values. Where appropriate, transformations of the data were used to ensure homogeneity of variance between treatments. The trial was a balanced row and column design with 4 rows and 7 columns.

Phytotoxicity

There were no visible phytotoxic effects, so no data were collected

Aphids

Nasonovia ribisnigri and *Macrosiphum euphorbiae* (potato aphid) were identified and counted. Numbers of winged aphids were consistently too low for analysis. Numbers of wingless aphids required no transformation before analysis. The numbers of *N. ribisnigri*, *M. euphorbiae* and the total number of wingless aphids were analysed on each assessment date and the results are presented in Table 6.2, Table 6.3 and Figure 6.1.

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Numbers of *M. euphorbiae* were always too low and too variable to show significant treatment effects, but the treatment factor for both the numbers of *N. ribisnigri* and the total numbers of aphids was significant at the 5% level using an F-test. Pre-spraying, the sowing-time treatment, HDCI 003a – 'Phytodrip' had significantly fewer aphids than any of the other treatments, which, in turn, were not significantly different from each other. On 16 September, post-spraying, HDCI 003a – 'Phytodrip', Movento and Aphox had significantly fewer *N. ribisnigri* and total aphids than the control. By 28 September, numbers were very variable, due in part to an influx of hoverfly larvae, and no differences were seen at the 5% level using an F-test.

Table 6.2 Aphid numbers on lettuce before spraying

Treatment	***Nasonovia ribisnigri***	***Macrosiphum euphorbiae***	**Total**
HDCI 003a - 'Phytodrip'	0.80	0.00	0.80
Movento	5.73	0.43	6.15
Aphox	3.58	0.12	3.70
HDCI 007	4.17	0.03	4.20
HDCI 003b	4.50	0.03	4.53
HDCI 005	4.70	0.33	5.03
Untreated	4.38	1.05	5.43
F-val	2.71	1.61	2.80
P-val	0.047	0.203	0.042
SED	1.325	0.420	1.459
LSD	2.784	0.882	3.065
df	18	18	18

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Table 6.3 Aphid numbers on lettuce after spraying

	16 September			28 September		
Treatment	***Nasonovia ribisnigri***	***Macrosiphum euphorbiae***	**Total**	***Nasonovia ribisnigri***	***Macrosiphum euphorbiae***	**Total**
HDCI 003a - 'Phytodrip'	1.27	0.00	1.27	1.05	0.00	1.05
Movento	0.35	0.00	0.35	0.17	0.03	0.20
Aphox	0.32	0.15	0.47	0.17	0.18	0.35
HDCI 007	2.17	0.62	2.80	0.85	0.00	0.85
HDCI 003b	3.22	0.00	3.22	3.67	0.03	3.70
HDCI 005	2.65	0.47	3.12	0.55	0.25	0.80
Untreated	3.80	0.95	4.75	1.57	0.50	2.08
F-val	3.77	2.01	3.35	2.16	1.65	1.86
P-val	0.013	0.118	0.021	0.097	0.190	0.143
SED	0.997	0.376	1.260	1.174	0.205	1.269
LSD	2.095	0.789	2.648	2.467	0.431	2.665
df	18	18	18	18	18	18

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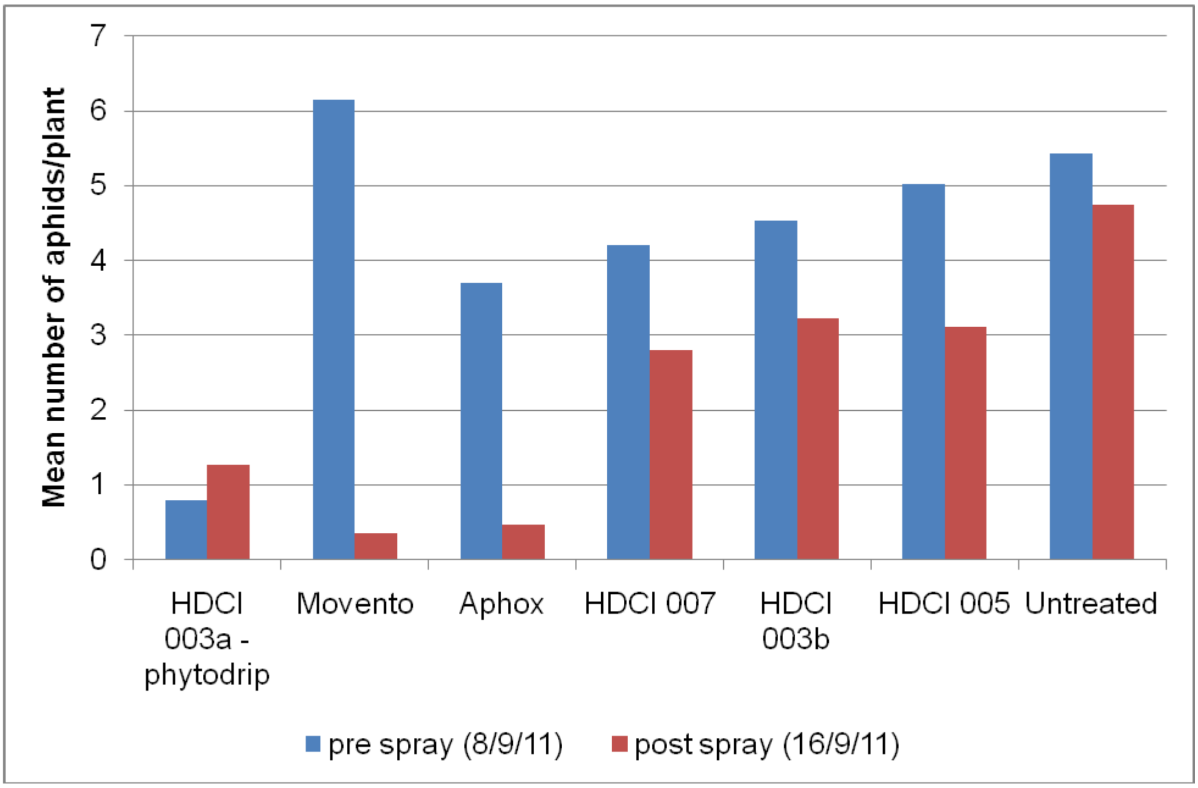

Figure 6.1 Total numbers of aphids on lettuce before and after spraying

Discussion

HDCI 003 applied at sowing was still controlling aphids 7 weeks later, but the spray treatment of the same active ingredient proved to be ineffective, as did HDCI 005 and HDCI 007. In the case of HDCI 003, which is obviously systemic, it is likely that insufficient material had made its way into the leaf from the spray to be effective. The aphicides Movento and Aphox were, as expected, very effective. Assessment of the persistence of control was confounded by the presence of predators.

Experiment 7 - Novel insecticide treatments to control carrot fly in carrot

Materials and methods

The experiment was done within the field known as Long Meadow West at Warwick HRI, Wellesbourne. The trial was laid out as a completely randomized block design with 4 different seed treatments which were balanced over the columns. The field plots were 5 m x 1 bed (1.83 m each) in size and plots were separated by 1 m along beds. In total there were 4 seed treatments and 6 spray treatment programmes and there were 4 replicates of each treatment. The seed (see Table 7.1) was drilled on 19 April 2010 at a spacing of 100

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seeds/m within rows and 0.35 m between rows. Carrot fly numbers were monitored in a nearby plot. Spraying was commenced when emergence of carrot fly was at 10% of its forecast maximum (HDC/HRI carrot fly forecast). Spraying commenced on 23 July and applications were made at fortnightly intervals thereafter until the last application on 1 October. All sprays were applied using a knapsack sprayer fitted with 02F110 nozzles in a water volume of 300l/ha. The treatments are listed in Table 7.2 and the spray programme in Table 7.3.

Table 7.1 Carrot seed used in carrot fly trial

Code	**Variety**	**Product**	**a.i.**
1	Nairobi	Untreated	
2	Nairobi	Force	Tefluthrin
3	Laguna	Untreated	
4	Laguna	HDCI 006	

Table 7.2 Sprays used in carrot fly trial

Code	**Product**	**a.i.**	**Rate (ml product/ha)**
H 100	Hallmark[1]	Lambda cyhalothrin	100
H 150	Hallmark[1]	Lambda cyhalothrin	150
D 500	Decis Protech	Deltamethrin	500
HDCI 003	HDCI 003a		1000
HDCI 005	HDCI 005		175

[1] Hallmark refers to Hallmark with Zeon Technology

Table 7.3 Spray programmes used in carrot fly trial

Date	23 Jul	6 Aug	20 Aug	3 Sept	17 Sept	1 Oct
Week	0	14	28	42	56	70
Code						
HDCI 003 + Hallmark	HDCI 003	HDCI 003	H 100	H 100	D 500	D 500
HDCI 003	HDCI 003	HDCI 003				
HDCI 005 + Hallmark	HDCI 005	HDCI 005	H 100	H 100	D 500	D 500
HDCI 005	HDCI 005	HDCI 005				
Hallmark	H 150	H 100	H 100	H 100	D 500	D 500
Untreated	Untreated	Untreated	Untreated	Untreated	Untreated	Untreated

Assessments

A visual assessment of phytotoxic effects was made on 6 August.

Roots were harvested from all 4 rows (all 4 seed types) in the control plots before spraying commenced on 14 July to assess the effect of the seed treatment on control of first generation larvae. All rows in all plots were harvested on 26 November. On both dates the roots were taken from 1 m in each row in each plot, washed and assessed for carrot fly damage. Data were collected on the numbers of roots and the total weight of the roots per metre length of row, as well as classifying the roots into categories according to the extent of carrot fly damage. The damage categories were 0%, <5%, 5-10%, 10-25%, 25-50% and >50% of the surface area affected by carrot fly. These equate to damage scores of 0, 1, 2, 3, 4 and 5 respectively. The Root Damage Index (RDI) was calculated as the number of roots in each category multiplied by the category value and divided by the total number of roots in each sample.

Results

Statistical analysis

All analyses were performed using analysis of variance (ANOVA). Interpretations were made using the treatment means together with standard errors of the difference (SED) and least significance difference (LSD) values. Where appropriate, transformations of the data

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were used to ensure homogeneity of variance between treatments. The trial was designed as a completely randomised block.

<u>Phytotoxicity</u>

There were no visible phytotoxic effects, so no data were collected

<u>Carrot fly damage</u>

14 July 2010

The Root Damage Index (RDI) and percentage numbers of undamaged roots after Angular transformation were analysed. Levels of damage were very low and the treatment factor was not significant at the 5% level using an F-test.

Table 7.4 The effect of seed treatment on first generation carrot fly control

Programme	**RDI**	**% undamaged roots**	
		Angular	**Back Trans**
Nairobi-untreated	0.076	75.3	93.6
Nairobi-Force	0.192	71.0	89.4
Laguna-untreated	0.250	68.1	86.1
Laguna-HDCI 006	0.098	75.9	94.1
F-val	3.71	2.72	
P-val	0.086	0.133	
SED	0.0982	5.22	
LSD	0.223	11.81	
df	9	9	

26 November 2010

The RDI, percentage numbers of undamaged roots after Angular transformation and root weight were analysed.

Results for the analysis of RDI are shown in Table 7.5 with seed variety, seed treatment and spray taken as separate variables. With all seed variety/seed treatments, HDCI 003b and HDCI 005 were equally effective with, or without, Hallmark in a spray programme. HDCI 003b was more effective than HDCI 005 or the standard Hallmark programme. Plants treated with HDCI 005 and Hallmark had lower RDIs than the untreated control with some of the variety/seed treatments. There was little evidence of either seed treatment having any effect.

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Results for the analysis of undamaged roots are shown in Table 7.6 with seed variety, seed treatment and spray taken as separate variables. The treatment factor was insignificant at the 5% level but clear differences can be seen, similar to the pattern seen with the RDI.

It is easier to see the difference between sprays if the seed variety and seed treatment factors are ignored. Results considering just the spray treatments are displayed in Table 7.7 for RDI and % undamaged roots. In both cases the treatment factor was significant at the 5% level and the results are alos displayed in Figures 7.1 and 7.2. The HDCI 003b programme was equally effective with, or without, Hallmark and more effective than both HDCI 005 programmes and the Hallmark programme. All programmes reduced damage compared with the untreated control.

Root weight is shown in Table 7.8. Whether the seed variety, seed treatment and spray are considered as separate factors, or the spray is considered irrespective of variety or seed treatment, the treatment factor was not significant at the 5% level.

While assessing root damage a number of roots were seen with damage associated with a large white caterpillar, which was identified as a Swift Moth. In the most severe cases the caterpillar had eaten through the centre of the carrot from top to bottom. The numbers of damaged carrots in each plot were recorded and the proportion damaged was analysed after a square root transformation. The results are displayed in Table 7.9

Table 7.5 The effect of sprays, seed variety and seed treatment on second generation carrot fly control – Root Damage Index

	Root Damage Index			
Programme	**Laguna Untreated**	**Laguna HDCI 006**	**Nairobi Untreated**	**Nairobi Force**
HDCI 003 + Hallmark	0.830	0.694	0.283	0.333
HDCI 003	0.770	0.723	0.293	0.309
HDCI 005 + Hallmark	1.657	2.186	1.584	1.343
HDCI 005	1.947	2.217	1.270	1.662
Hallmark	2.335	1.903	1.702	1.735
Untreated	2.363	3.098	2.411	2.176
F-val	2.82			
P-val	0.025			
SED	0.2984			
LSD	0.6004			
df	46.8			

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Table 7.6 The effect of sprays, seed variety and seed treatment on second generation carrot fly control – % undamaged roots

Programme	% undamaged roots Laguna Unt Angular	Laguna Unt Back Trans	Laguna HDCI 006 Angular	Laguna HDCI 006 Back Trans	Nairobi Unt Angular	Nairobi Unt Back Trans	Nairobi Force Angular	Nairobi Force Back Trans
HDCI 003 + Hallmark	47.0		49.4		62.9		63.5	
HDCI 003	50.3		47.7		62.1		59.4	
HDCI 005 + Hallmark	30.8		21.3		33.4		34.4	
HDCI 005	27.1		17.3		40.2		29.7	
Hallmark	21.2		26.2		30.2		31.8	
Untreated	8.2		7.5		17.7		24.9	
F-val	0.51							
P-val	0.766							
SED	6.441							
LSD	12.910							
df	54.9							

Table 7.7 The effect of spray only (irrespective of variety or seed treatment) on second generation carrot fly control

Programme	RDI	% undamaged roots Angular	Back Trans
HDCI 003 + Hallmark	0.535	55.7	68.2
HDCI 003	0.524	54.9	66.9
HDCI 005 + Hallmark	1.693	30.0	25.0
HDCI 005	1.774	28.6	22.8
Hallmark	1.919	27.4	21.1
Untreated	2.512	14.6	6.3
F-val	28.62	30.89	
P-val	<0.001	<0.001	
SED	0.2113	4.207	
LSD	0.4504	8.966	
df	15	15	

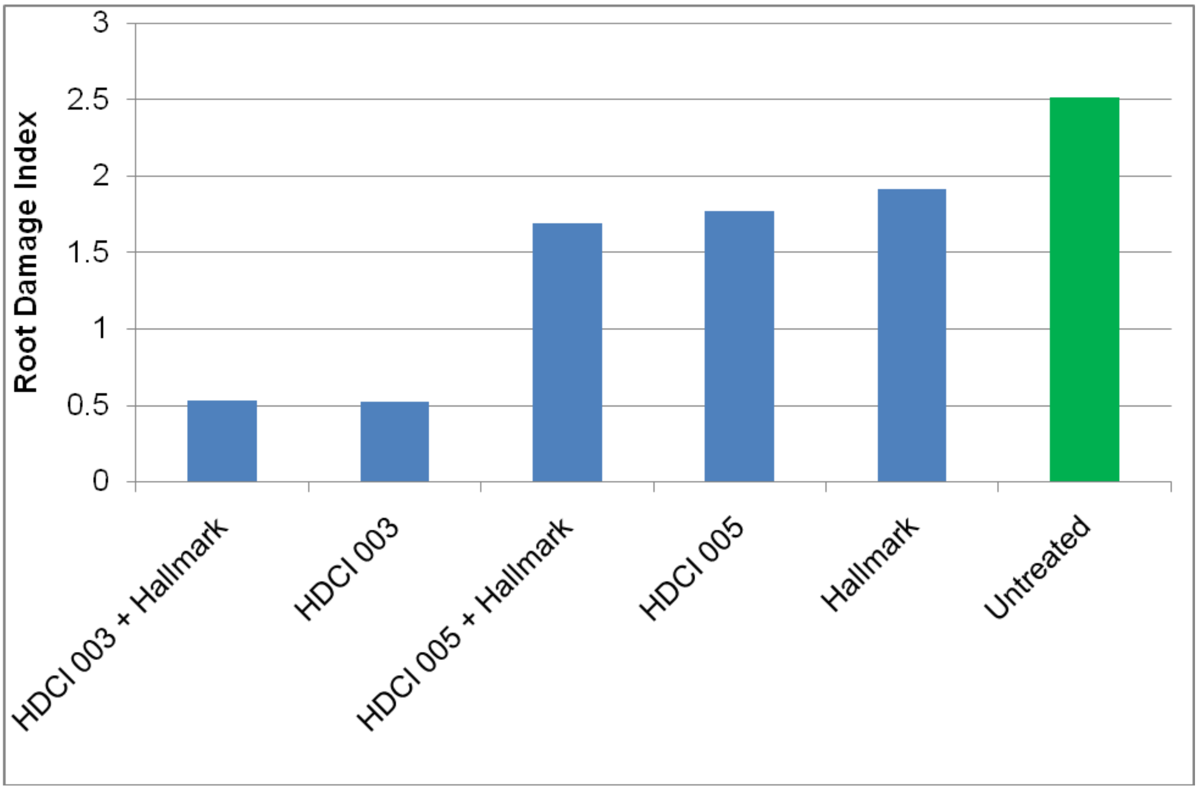

Figure 7.1 The RDI of carrot roots after second generation carrot fly damage

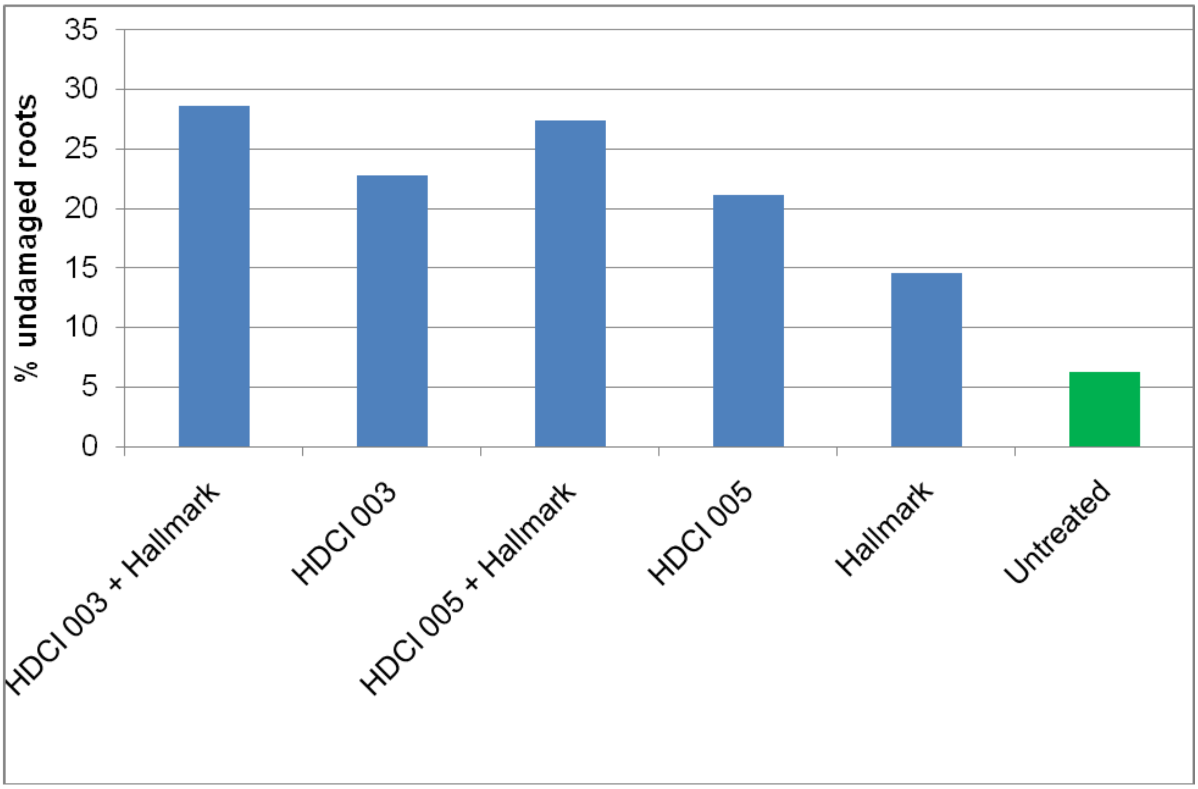

Figure 7.2 The percentage undamaged carrot roots after the second generation of the carrot fly

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Table 7.8 The effect of sprays, seed variety and seed treatment on second generation carrot fly control – Root weight

	Root weight (g)				
Programme	**Laguna Untreated**	**Laguna HDCI 006**	**Nairobi Untreated**	**Nairobi Force**	**All**
HDCI 003 + Hallmark	3299	5176	3655	3658	3947
HDCI 003	2624	4684	2491	3770	3392
HDCI 005 + Hallmark	4077	3683	2749	3672	3545
HDCI 005	3100	2918	3953	3588	3390
Hallmark	3565	4869	3235	3600	3817
Untreated	2632	4049	3505	2749	3234
F-val	1.42				1.85
P-val	0.232				0.164
SED	707.3				286.7
LSD	1411.4				611.1
df	67.9				15

Table 7.9 The effect of spray only (irrespective of variety or seed treatment) on Swift moth control

Programme	**Number damaged roots/m row**	
	Square root	**Back Trans**
HDCI 003 + Hallmark	0.695	0.483
HDCI 003	0.331	0.109
HDCI 005 + Hallmark	0.882	0.779
HDCI 005	0.695	0.483
Hallmark	0.530	0.281
Untreated	0.677	0.458
F-val	0.91	
P-val	0.502	
SED	0.2769	
LSD	0.5902	
df	15	

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Discussion

All of the spray programmes tested offered some degree of carrot fly control. The standard Hallmark programme was only partially effective and somewhat less effective than has previously been observed in trials at Wellesbourne. This may well be a function of year-to-year differences in pest pressure but other factors such as insect resistance cannot be ruled out.

The HDCI 003b programmes were the most effective tested and were equally effective with, or without, Hallmark and more effective than both HDCI 005 programmes and the Hallmark programme.

Experiment 8 - Novel insecticide treatments to control aphids in carrot

Materials and methods

The experiment was done within the field known as Long Meadow West at Warwick HRI, Wellesbourne. The trial was laid out as a complete Trojan Square. The field plots were 5 m x 1 bed (1.83 m each) in size and plots were separated by 1 m along beds. In total there were 8 treatments including one seed treatment and there were 4 replicates of each treatment. The seed (cv Laguna) was drilled on 16 April 2010 at a spacing of 100 seeds/m within rows and 0.35 m between rows. The arrival of willow-carrot aphid was monitored in a nearby plot. Numbers were allowed to increase for about 1 week then the spray treatments were applied on 25 May. All sprays were applied using a knapsack sprayer fitted with 02F110 nozzles in a water volume of 300l/ha. The treatments are listed in Table 8.1.

Table 8.1 Treatments used in trial on willow-carrot aphid

Code	Product	Application method	a.i.	Rate (product/ha)
1	Movento	Spray	Spirotetramat	480 ml
2	Biscaya	Spray	Thiacloprid	400 ml
3	HDCI 003b	Spray		1000 ml
4	Aphox	Spray	Pirimicarb	280 g
5	Plenum	Spray	Pymetrozine	400 g
6	HDCI 005	Spray		175 ml
7	Untreated			
8	HDCI 006	Seed treatment		0.035 + 0.012 mg/a.i./seed

<u>Assessments</u>

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A 0.5 m length of row was marked in one of the middle two rows in each plot and the numbers of winged and wingless aphids were recorded. Counts were made pre-spray on 24 May and on 4 occasions post-spray (28 May, 3 June, 10 June and 17 June). A visual assessment of phytotoxic effects was also made on 3 June.

Roots were harvested from treatments 3, 6, 7 and 8 on two occasions (14 July and 26 November). On both dates the roots were taken from 0.5 m in each of the middle two rows in each plot, washed and assessed for carrot fly damage. Data were collected on the numbers of roots and the total weight of the roots per metre length of row, as well as classifying the roots into categories according to the extent of carrot fly damage. The damage categories were 0%, <5%, 5-10%, 10-25%, 25-50% and >50% of the surface area affected by carrot fly. These equate to damage scores of 0, 1, 2, 3, 4 and 5 respectively. The Root Damage Index (RDI) was calculated as the number of roots in each category multiplied by the category value and divided by the total number of roots in each sample.

Results

Statistical analysis

All analyses were performed using analysis of variance (ANOVA). Interpretations were made using the treatment means together with standard errors of the difference (SED) and least significance difference (LSD) values. Where appropriate, transformations of the data were used to ensure homogeneity of variance between treatments. The trial was designed as a Trojan square with 4 rows and 8 columns and within this the treatments assessed for carrot fly damage were embedded in a Latin square design.

Phytotoxicity

There were no visible phytotoxic effects, so no data were collected.

Willow-carrot aphid

Numbers of winged and wingless aphids on each assessment date were analysed after a square root transformation and the results are presented in Table 8.2 and Figure 8.1 for winged aphids and Table 8.3 and Figure 8.2 for wingless aphids.

There were no significant differences in numbers of winged aphids between treatments before spraying. Three days after spraying, plots treated with Aphox, Biscaya, HDCI 003b and HDCI 006 all had significantly fewer winged aphids than the untreated plots. Thereafter numbers began to decline on all plots and there were no significant differences between treatments. By 17 June, winged aphids had virtually disappeared.

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The pre-spray count of wingless aphids indicated that the seed treatment (HDCI 006) had significantly fewer aphids than all other plots. After spraying, all treatments except HDCI 005 had significantly fewer wingless aphids than the untreated control, but there were no differences between the effective treatments. Subsequent assessments indicated that numbers of wingless aphid on untreated plots peaked on 10 June then started to decline, but were still present in large numbers when assessments were ceased on 17 June. On 3 June, all treatments had significantly fewer wingless aphids than the untreated plots. HDCI 003b, Movento and HDCI 006 also had significantly fewer aphids than HDCI 005 and Plenum while Aphox had significantly fewer aphids than HDCI 005 only. Similarly, on 10 June all treatments still had significantly fewer wingless aphids than the untreated plots. HDCI 006 also had significantly fewer aphids than Plenum and HDCI 005. HDCI 003b, Aphox, Biscaya and Movento had significantly fewer aphids than HDCI 005. This pattern was repeated on the final assessment date (17 June) with all treatments having significantly fewer aphids than the untreated control and HDCI 006 also having significantly fewer aphids than Plenum and HDCI 005. There were no other significant differences.

Table 8.2 Carrot – The mean numbers of winged willow-carrot aphid in 0.5m of row

Treatment	24 May		28 May		3 June		10 June		17 June	
	Square root	Back Trans	Square root	Back Trans	Square root	Back Trans	Square root	Back Trans	Square root	Back Trans
Movento	5.34	28.5	3.96	15.7	3.07	9.4	0.60	0.36	0.25	0.06
Biscaya	5.24	27.5	2.56	6.6	3.90	15.2	0.60	0.36	0.00	0.00
HDCI 003b	4.42	19.5	2.82	8.0	3.39	11.5	1.14	1.30	0.00	0.00
Aphox	4.32	18.7	3.14	9.9	3.07	9.4	0.25	0.06	0.00	0.00
Plenum	3.97	15.8	3.98	15.8	3.25	10.6	0.50	0.25	0.00	0.00
HDCI 005	4.73	22.4	3.95	15.6	3.51	12.3	0.43	0.18	0.00	0.00
Untreated	4.99	24.9	4.48	20.1	2.74	7.5	0.68	0.46	0.25	0.06
HDCI 006	5.50	30.3	2.86	8.2	3.46	12.0	0.25	0.06	0.00	0.00
F-val	1.31		5.58		0.58		0.66		0.96	
P-val	0.301		0.002		0.760		0.704		0.485	
SED	0.671		0.422		0.648		0.496		0.167	
LSD	1.410		0.887		1.360		1.043		0.350	
df	18		18		18		18		18	

Table 8.3 Carrot – The mean numbers of wingless willow-carrot aphid in 0.5m of row

Treatment	24 May	28 May	3 June	10 June	17 June

	Square root	Back Trans	Square root	Back Trans	Square root	Back Trans	Square root	Back Trans	Square root	Back Trans
Movento	4.87	23.7	0.50	0.25	0.25	0.06	1.62	2.62	0.43	0.18
Biscaya	3.38	11.4	0.00	0.00	3.38	11.4	2.12	4.49	1.42	2.01
HDCI 003b	2.61	6.8	0.00	0.00	0.60	0.36	1.22	1.49	0.35	0.12
Aphox	3.98	15.8	0.50	0.25	1.00	1.00	1.87	3.50	0.91	0.83
Plenum	3.56	12.7	0.87	0.76	2.36	5.57	2.82	7.95	2.16	4.67
HDCI 005	3.60	13.0	1.74	3.03	3.07	9.42	4.72	22.3	1.97	3.88
Untreated	4.87	23.7	2.65	7.02	5.47	29.9	9.77	95.5	6.54	42.8
HDCI 006	0.25	0.1	0.00	0.00	0.60	0.36	0.00	0.00	0.00	0.00
F-val	6.45		7.77		10.64		20.41			
P-val	<0.001		<0.001		<0.001		<0.001			
SED	0.823		0.486		0.788		0.953			
LSD	1.729		1.021		1.656		2.002			
df	18		18		18		18			

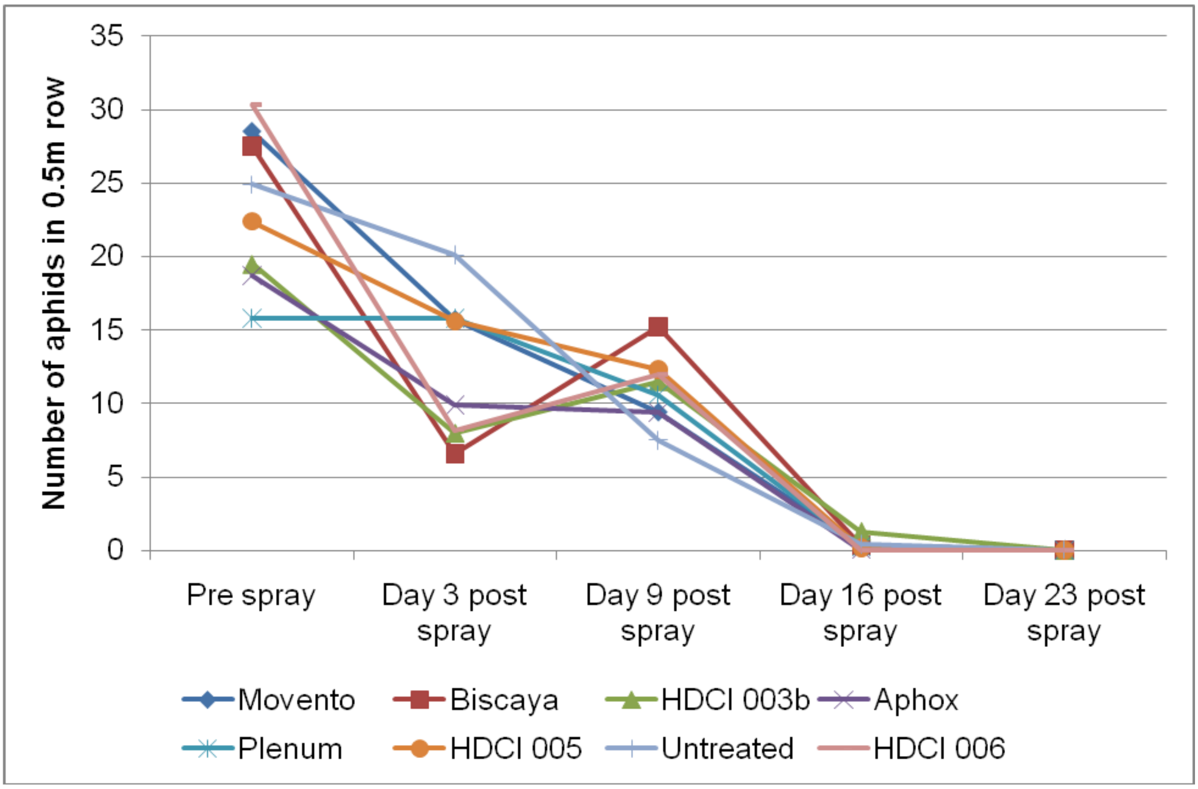

Figure 8.1 Carrot – The mean numbers of winged willow-carrot aphid in 0.5m of row

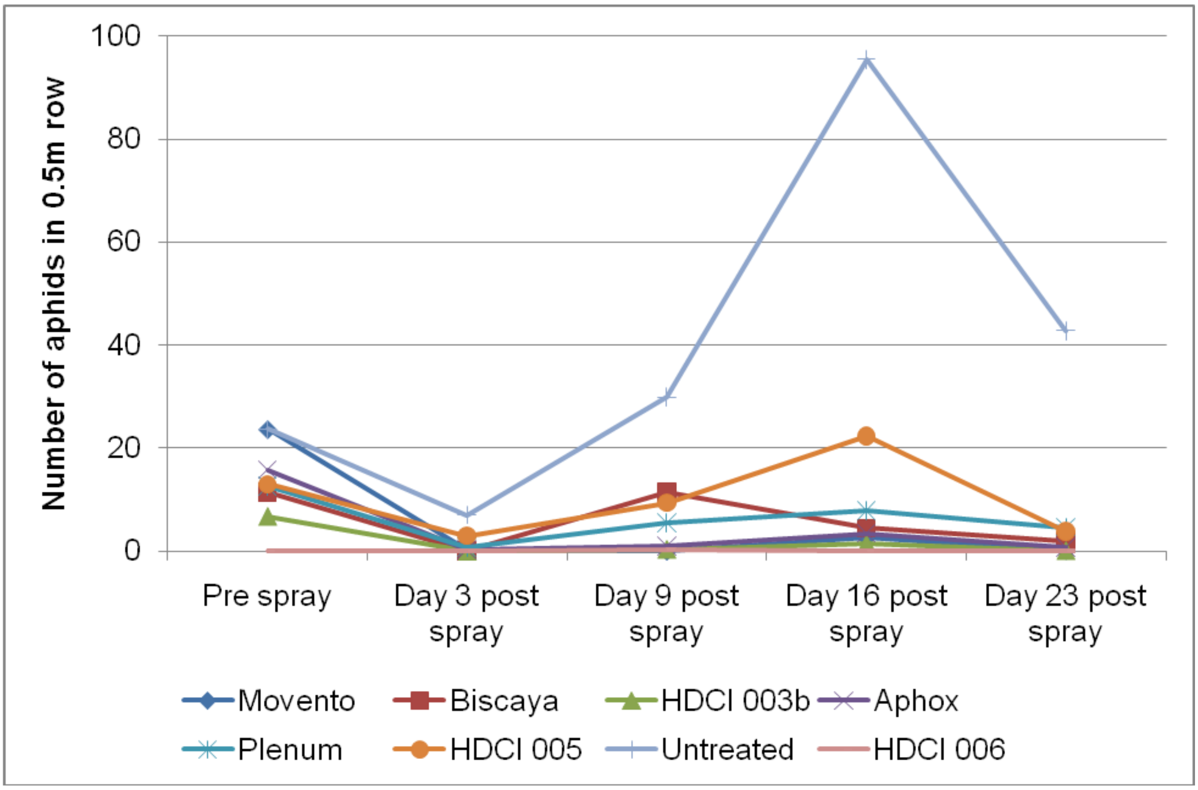

Figure 8.2 Carrot – The mean numbers of wingless willow-carrot aphid in 0.5m of row

Carrot fly

14 July 2010

The RDI, percentage numbers of undamaged roots after Angular transformation and total root weight were analysed. Levels of damage were very low and the treatment factor was not significant at the 5% level for either assessment of damage. There were, however, significant differences in weight. Both HDCI 003b and HDCI 006 gave larger weights than HDCI 005 and the untreated control. The results are displayed in Table 8.4 and Figure 8.3 (weight).

Table 8.4 The effect of sprays on first generation carrot fly control

Programme	**RDI**	**Weight of sample (g)**	**% undamaged roots Angular**	**Back Trans**
HDCI 003b	0.092	1093	75.3	93.6
HDCI 005	0.088	746	74.9	93.3
HDCI 006	0.058	942	78.4	95.9
Untreated	0.154	744	69.6	87.9
F-val	1.16	4.87	0.91	
P-val	0.400	0.048	0.490	
SED	0.0527	108.4	5.37	
LSD	0.1289	265.2	13.14	
df	6	6	6	

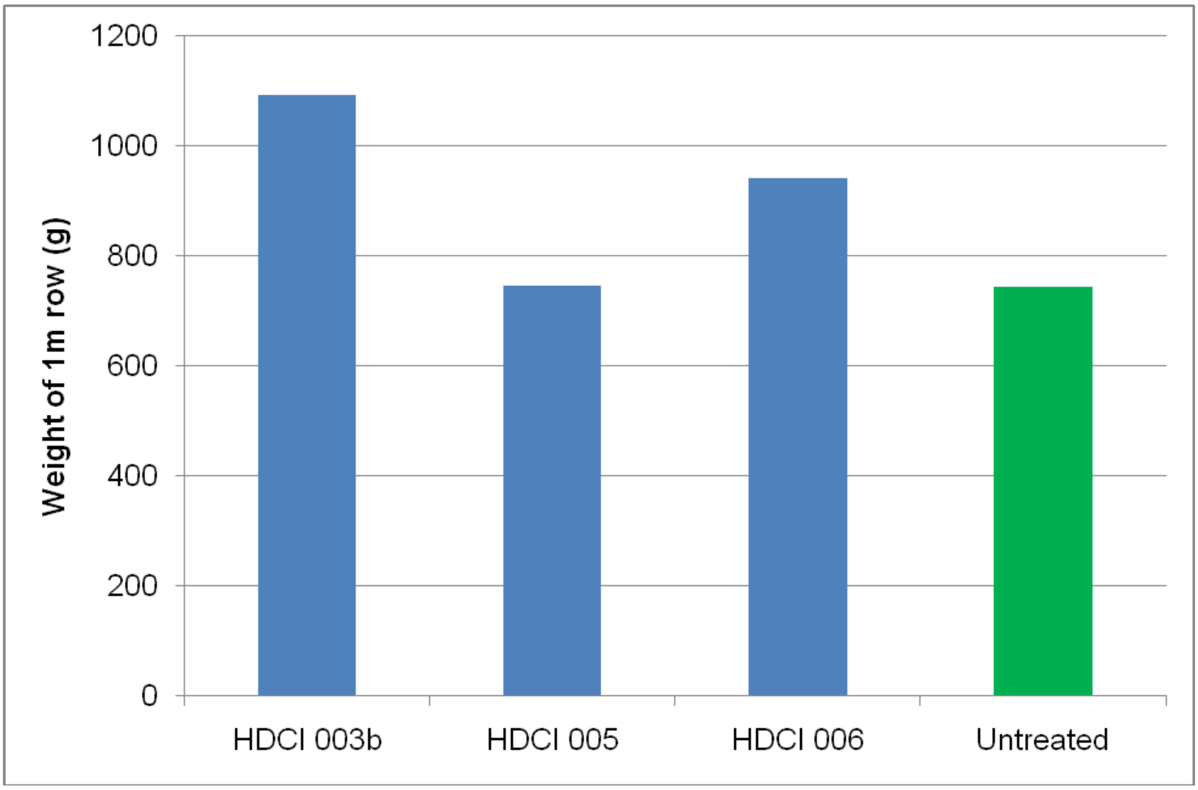

Figure 8.3 The weight of 1m row of carrot roots after first generation carrot fly attack

26 November 2010

The RDI, percentage numbers of undamaged roots after Angular transformation and total weight were analysed. Levels of damage had increased considerably since the first assessment and for all the analyses the treatment factor was significant at the 5% level. The results are displayed in Table 8.5 and Figure 8.4 (RDI).

When considering either RDI or percentage undamaged roots, HDCI 003b reduced damage compared with both of the other treatments and the control. HDCI 003b also increased yield compared with both HDCI 005 and the control.

Table 8.5 The effect of sprays on first generation carrot fly control

Programme	**RDI**	**Weight of sample (g)**	**% undamaged roots**	
			Angular	**Back Trans**
HDCI 003b	1.58	4904	32.2	28.3
HDCI 005	2.34	3653	20.1	11.8
HDCI 006	3.05	4701	9.2	2.6
Untreated	3.01	4170	13.5	5.5
F-val	6.48	7.11	8.93	
P-val	0.026	0.021	0.012	
SED	0.383	298.1	4.73	
LSD	0.937	729.3	11.58	
df	6	6	6	

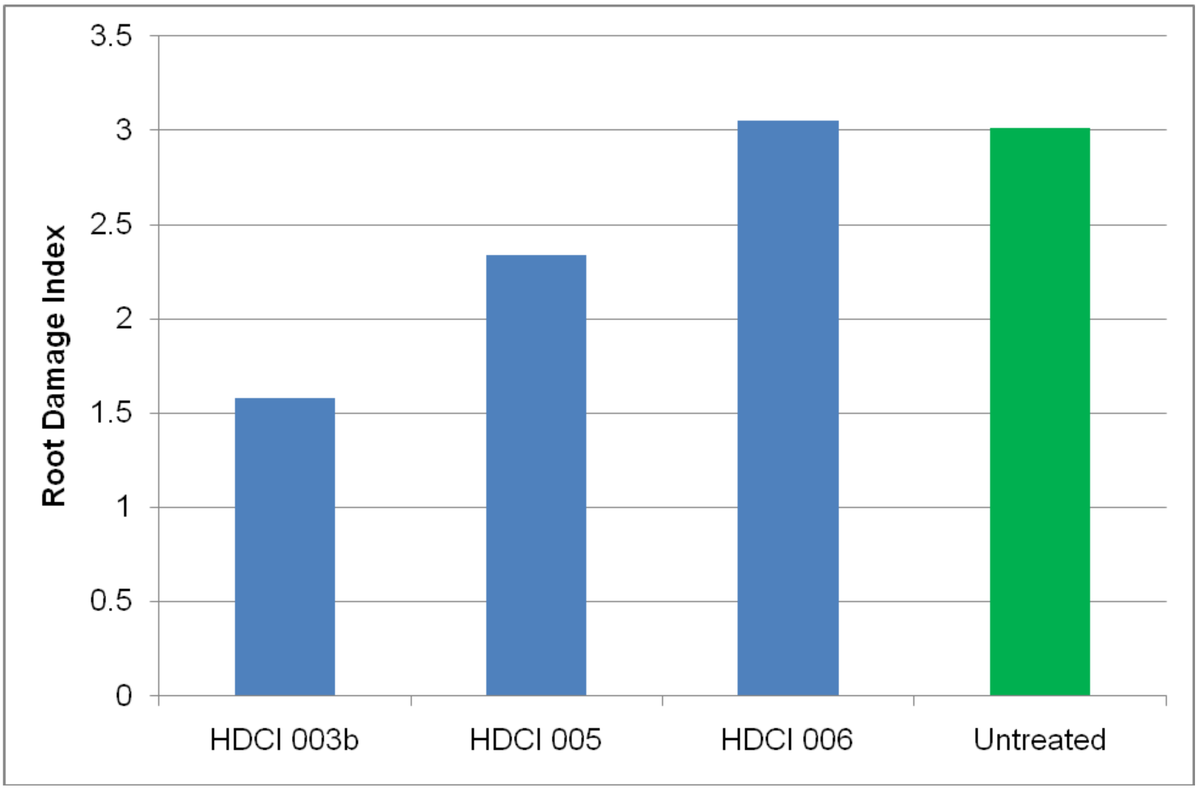

Figure 8.4 The RDI of carrot roots after second generation carrot fly damage

Discussion

Numbers of wingless aphids were quite high, peaking at nearly 200 aphids per metre in the control plots. The seed treatment (HDCI 006) had significantly fewer aphids than all other plots before spraying and remained virtually aphid-free throughout the assessment period. Three days after spraying, all treatments except HDCI 005 had significantly fewer wingless aphids than the untreated control, but there were no discernable differences between the effective treatments. On 3 June (10 days after spraying) all spray treatments had significantly fewer wingless aphids than the untreated plots. Similarly, on 10 June (17 days after spraying) all treatments still had significantly fewer wingless aphids than the untreated plots and this pattern was repeated on the final assessment date (17 June). All of the spray treatments were similarly effective and persistent, except HDCI 005 which was less effective. The persistence may be as a result of continued insecticidal activity, but the nature of willow-carrot invasion, which occurs over a short period, may mean that once the plants are cleared of aphids, no new ones arrive to take their place.

Limited second generation carrot fly control was also observed with HDCI 003b. This is very surprising considering only 1 spray was applied on 25 May – over 1 month before egg laying commenced

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Conclusions

Leafy brassicas

- Cabbage root fly control was difficult to assess due to relatively low levels of damage observed in the root area but there was direct evidence of control with HDCI 003b and Steward drenches. Also increases in foliage weight mid-season (HDCI 003b) could be attributed partly to cabbage root fly control.
- Several sowing-time treatments (Gaucho - Sanokote®®, HDCI 006 - Dead seed, HDCI 003a - ‘Phytodrip’ and HDCI 003a - Drench) showed effective control of aphids
- Five treatments gave good aphid control (Plenum, HDCI 003b, Movento, Biscaya and HDCI 005).
- Flea beetle damage was reduced by HDCI 003a (pre-planting) and HDCI 006 (sowing-time)
- Whitefly infestations were reduced by the sowing-time treatments HDCI 006 - Dead seed and Sanokote® - Gaucho and by the sprays HDCI 003b and Movento.
- Caterpillar numbers were reduced by HDCI 003a (pre-planting) and HDCI 003b, HDCI 005, Steward, Biscaya and Movento sprays. HDCI 003a, HDCI 003b and HDCI 005 remained active for several weeks
- Leaf miners were controlled by HDCI 003a (pre-planting)
- Several pre-planting treatments increased plant size mid-season (HDCI 003a, Steward, HDCI 006 and Sanokote® – Gaucho).
- HDCI 003a increased cauliflower curd weight at harvest
- The most effective overall treatment appeared to be HDCI 003. When applied as either a pre-planting drench or as a foliar spray, it controlled aphids, whitefly and caterpillars. The drench treatment also increased foliage and cauliflower curd weight and controlled flea beetle and leaf miners
- The biological treatments tested were largely ineffective

Carrot

- Spray programmes of HDCI 003b were equally effective with, or without, Hallmark, and were more effective than the standard Hallmark programme and programmes with HDCI 005.
- HDCI 006 (seed treatment) provided excellent control of willow-carrot aphid for the duration of the infestation. Single sprays of Biscaya, HDCI 003b, Plenum, Movento and Aphox were as effective and HDCI 005 also gave reasonable control.

- The single HDCI 003b spray applied to control aphids (pre-second carrot fly generation emergence) gave partial control of second generation carrot fly.
- Small numbers of swift moth caterpillars and feeding damage were observed in the roots at harvest. No treatment effects were seen.

<u>Leek</u>

- HDCI 006 (seed treatment) reduced levels of damage in the early part of the season.
- Mesurol was the most effective spray tested. HDCI 003b, Tracer, Dursban WG and Dynamec gave some control
- The biological treatments tested were largely ineffective

<u>Lettuce</u>

- HDCI 003 was effective when applied at sowing but not as a spray.
- Movento and Aphox sprays were also effective
- The biological treatment tested were largely ineffective

Technology Transfer

April 2011 Article for HDC News

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APPENDIX

Weather records Warwick HRI, Wellesbourne

DATE	TEMP_MAX	TEMP_MIN	RAINFALL
01/04/2010	7.9	1.1	5.4
02/04/2010	9.7	3.9	4.2
03/04/2010	10.4	3.8	11.6
04/04/2010	11.5	3.2	0.1
05/04/2010	13.2	3	0
06/04/2010	15.6	6.2	0.4
07/04/2010	12.8	6.9	0
08/04/2010	17.2	0.2	0
09/04/2010	18.1	0.2	0
10/04/2010	17.9	3.1	0
11/04/2010	16.9	5.8	0
12/04/2010	12.5	6	0
13/04/2010	14	3.7	0
14/04/2010	14.5	5.6	0
15/04/2010	11	4	0
16/04/2010	13.6	1.3	0
17/04/2010	18	-1.1	0
18/04/2010	17.7	0.1	0
19/04/2010	15.6	6.1	0
20/04/2010	13.8	0.7	0
21/04/2010	12.2	-0.1	0
22/04/2010	14.9	-1.4	0
23/04/2010	17.5	0.9	0
24/04/2010	20.6	1.7	1.4
25/04/2010	17.8	9.3	0
26/04/2010	18.7	7.8	0
27/04/2010	20.1	2.5	0
28/04/2010	20.1	8.5	0
29/04/2010	16.2	10.2	3.1
30/04/2010	15.2	5.3	4.4

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01/05/2010	15.1	7.6	28
02/05/2010	15.2	6.5	0
03/05/2010	11	5.1	2.3
04/05/2010	13.9	-0.5	0
05/05/2010	16	7.5	0.5
06/05/2010	12.9	8.9	0
07/05/2010	13.5	6.4	0.1
08/05/2010	9.3	6.4	1.2
09/05/2010	14	6.1	0
10/05/2010	12.1	-0.3	0
11/05/2010	11.3	5.1	0
12/05/2010	11.5	2	0
13/05/2010	13.5	-1	0.1
14/05/2010	13.9	5	0
15/05/2010	17.4	3.1	0
16/05/2010	17.9	2.6	0
17/05/2010	18	3.1	0
18/05/2010	19.4	1.9	0
19/05/2010	19.2	8.2	0
20/05/2010	23.3	13.9	0
21/05/2010	24.9	10.1	0
22/05/2010	24.2	8.5	0
23/05/2010	27.2	8.1	0
24/05/2010	26.5	9.5	0
25/05/2010	22.5	10.3	0
26/05/2010	18.9	7.9	8.2
27/05/2010	17	5.7	0
28/05/2010	18.2	6.5	1
29/05/2010	16.5	8	4.7
30/05/2010	16.1	11.4	0
31/05/2010		7.1	0
01/06/2010	18.8		8
02/06/2010	20.2	7.9	0
03/06/2010	22.4	7	0
04/06/2010	25.4	8	0
05/06/2010	24.8	12.4	0

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06/06/2010	22.8	14.6	1
07/06/2010	19.1	11.1	10.2
08/06/2010	19.4	11.8	2.3
09/06/2010	18.9	13.1	4.2
10/06/2010	16	13.1	0
11/06/2010	19.3	10.9	0
12/06/2010	19.9	10.5	0
13/06/2010	20.7	8.6	1.5
14/06/2010	16.9	11.6	0
15/06/2010	17.3	4.6	0
16/06/2010	20.2	5.3	0
17/06/2010	21.7	3.5	0
18/06/2010	20.1	7.8	2.5
19/06/2010	15.6	6.2	0
20/06/2010	20.2	5.2	0
21/06/2010	24.5	9	0
22/06/2010	25.5	11.5	0
23/06/2010	24.7	8.9	0
24/06/2010	25	11.6	0
25/06/2010	24.4	8.4	0
26/06/2010	27.9	12.1	0
27/06/2010	27.5	12.8	0
28/06/2010	26.5	10.5	2.4
29/06/2010	26.9	14.3	0
30/06/2010	25.4	11.8	0
01/07/2010	26.4	13.5	0
02/07/2010	23.9	14.9	0
03/07/2010	24	9.9	0
04/07/2010	23.7	8.7	0
05/07/2010		11.2	0
06/07/2010	23.5	8.4	0
07/07/2010	24.3	8.1	0
08/07/2010	24.3	14.5	0
09/07/2010	21.6	10.6	0
10/07/2010	27.5	14.8	0
11/07/2010	27.4	14.9	0

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12/07/2010	19.5	14.8	0
13/07/2010	19.9	13	3.6
14/07/2010	22.1	14.4	6
15/07/2010	21.6	14.5	3
16/07/2010	21.8	11.5	2.9
17/07/2010	20.5	12.2	0
18/07/2010	25	11.3	0
19/07/2010	27.6	14.6	0.5
20/07/2010	26.6	15.1	0.4
21/07/2010	24	13.4	0
22/07/2010	21.5	11.8	0.4
23/07/2010	20	13.1	0
24/07/2010	21.2	11.3	0
25/07/2010	25.4	14.2	0
26/07/2010	23.4	16.5	1.8
27/07/2010	24.5	14.4	0
28/07/2010	21.4	9.3	0
29/07/2010	21	13.2	0
30/07/2010	21.3	7.5	1.8
31/07/2010	21.6	15.2	0
01/08/2010	21.5	13.8	0
02/08/2010	22.2	11.6	0
03/08/2010	24.2	6.6	1.1
04/08/2010	19.6	12.6	0.5
05/08/2010	20.1	7.5	0
06/08/2010	21.3	7.6	0
07/08/2010	23.5	14.7	4.4
08/08/2010	23.3	12.8	0
09/08/2010	23.7	10.2	6.7
10/08/2010	20.3	13	0
11/08/2010	22.7	7.6	0
12/08/2010	18.1	11.3	2.6
13/08/2010	17.2	10.7	4.2
14/08/2010	18.6	11.4	11.1
15/08/2010	23.3	12	0
16/08/2010	23.9	10.9	0

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17/08/2010	25	13	4.8
18/08/2010	21.4	8.1	1
19/08/2010	21.5	8.5	13.7
20/08/2010	22	13.9	3.1
21/08/2010	25	10.5	1.8
22/08/2010	23.7	13.6	18.7
23/08/2010	18.5	13.8	12.8
24/08/2010	20	9.6	0
25/08/2010	16.2	9.4	33.3
26/08/2010	14.6	11.7	3.2
27/08/2010	17.5	10.9	0
28/08/2010	19.5	13.5	2.1
29/08/2010	17.6	12.6	3.2
30/08/2010	17.8	12.1	0
31/08/2010	21	4.9	0
01/09/2010	21.5	6	0
02/09/2010	20.4	13.8	0
03/09/2010	21.1	12.1	0
04/09/2010	21.7	12.7	0
05/09/2010	21.2	13	1
06/09/2010	20.5	16.7	11.8
07/09/2010	19.7	14.6	0.9
08/09/2010	20.2	12.3	0
09/09/2010	20.9	16	3.2
10/09/2010	21.1	16	1.5
11/09/2010	22.1	14.4	0.4
12/09/2010	18.7	8.1	0
13/09/2010	18.3	8.9	0
14/09/2010	20.2	15.7	4.6
15/09/2010	16.2	8.3	0.1
16/09/2010	17.4	8.7	0
17/09/2010	13.8	5.2	0
18/09/2010	16.7	3.8	0.2
19/09/2010	18.3	11.1	0.1
20/09/2010	21.6	13.4	0
21/09/2010	22.3	6.9	0

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22/09/2010	21.1	9.2	1.7
23/09/2010	19.6	13.9	0.2
24/09/2010	12.5	11.5	0
25/09/2010	14	1.7	0
26/09/2010	13.9	1.9	0.6
27/09/2010	14	1.7	0.6
28/09/2010	16.8	11.9	3.3
29/09/2010	16	13.2	3.2
30/09/2010	16.5	4	1.5
01/10/2010	15.5	11.2	10.3
02/10/2010	16.6	6.5	11.6
03/10/2010	16.4	8.8	1.3
04/10/2010	18.4	7.8	0.1
05/10/2010	18.9	10.2	5.2
06/10/2010	17	11.9	0.4
07/10/2010	17.8	8.4	0.6
08/10/2010	19.6	13.1	0
09/10/2010	15.7	13.7	0
10/10/2010	19.7	12.6	0
11/10/2010	16.4	10.5	0
12/10/2010	12.7	8.5	0
13/10/2010	12	7.8	0
14/10/2010	10.2	3	0
15/10/2010	12.6	8.3	1.2
16/10/2010	12.9	4.1	0
17/10/2010	13	-1.2	0
18/10/2010	14.1	5.3	3.3
19/10/2010	12.8	5.5	6.9
20/10/2010	8.9	0.5	0
21/10/2010	12.5	-1.7	0
22/10/2010	14.2	3.8	7.3
23/10/2010	12.1	7	1.8
24/10/2010	10.5	0.6	1.6
25/10/2010	10.2	-1.3	0.6
26/10/2010	14.7	1.2	5.9
27/10/2010	15.9	8.2	0.1

28/10/2010	15.1	9.8	0
29/10/2010	14.7	12.1	0
30/10/2010	14.2	6.8	0
31/10/2010	11.3	8.5	0.7
01/11/2010	13.8	7.8	0
02/11/2010	14.7	9.8	0.4
03/11/2010	15.7	9.3	0
04/11/2010	17	11.7	0.4
05/11/2010	15	14	10.5
06/11/2010	14.8	8.1	1.7
07/11/2010	14.9	3.4	6.6
08/11/2010	6.9	2.6	3.9
09/11/2010	9.4	4.1	0.2
10/11/2010	11.4	1	3.1
11/11/2010	14.4	-1.1	2
12/11/2010	12.2	5.9	2
13/11/2010	10.8	6.7	1.1
14/11/2010	6.5	0.6	0.1
15/11/2010	11.1	-2.1	0
16/11/2010	8.3	-1.7	0
17/11/2010	7.1	-0.2	0.1
18/11/2010	10	3	0.7
19/11/2010	11.7	-0.2	0
20/11/2010	6.7		0
21/11/2010	6.6		0
22/11/2010	7.6		0
23/11/2010	7.2	2.9	0
24/11/2010	5	-2.5	0
25/11/2010	2.5	-2.2	0
26/11/2010	4	-4.7	0
27/11/2010	3.3	-5.2	0
28/11/2010	3.4	-10	0
29/11/2010	1	-2.6	1.4
30/11/2010	1.4	-2.9	0