Title:	Radish: evaluation of non OP insecticides for controlling cabbage root fly
Final Report:	1998-99
Project Number:	FV 159a
Project Leader:	S Finch
Location of Project:	HRI Wellesbourne Warwickshire CV35 9EF
Project Co-ordinator:	Mr Peter Knight
Date commenced:	1 April 1998
Date completed:	31 July 1999 (Original deadline extended to cover period of peak fly activity in 1999 season)
Keywords:	Radish, cabbage root fly, Admire (imidacloprid), fipronil, Force ST (tefluthrin), Hallmark (lambda-cyhalothrin), Yaltox (carbofuran), carbamate insecticides, pyrethroid insecticides, film-coated seed.

CONTENTS OF REPORT

Page

PRACTICAL SECTION FOR GROWERS

SCOPE AND OBJECTIVES

The cabbage root fly (*Delia radicum*) is the most serious pest of brassica and radish crops in the United Kingdom. Since 1963, the larvae of this pest have been controlled by granular and spray formulations of mainly organophosphorus (OP) insecticides. The current UK anticholinesterase review, which covers organophosphorus and Carbama compounds, and the impending second round of the EU review which will include all OPs and Carbama are likely to have an impact on the future use of these products in horticulture. The USA are also reviewing the use of Ops at present. These reviews are likely to impose additional costs on the manufacturers for preparation of registration dossiers and generation of additional data. Manufacturers may decide sales are insufficient to warrant such expenditure and products will be lost, especially on minor horticultural crops. Growers therefore need viable alterations for CRF control.

Radish growers rely on ###. Dursban (chlorpyriphos) and Birlane 24 (chlorfenvinphos), Dipterex (trichlorphon) for control of CRF and leaf miners.

The overall commercial objective is to achieve acceptable levels of cabbage root fly control in both outdoor and indoor radish crops without having to rely on OP-insecticides.

SUMMARY

During 1998 work was done to answer the following four questions:-

1. How frequently do Hallmark (lambda-cyhalothrin) sprays have to be applied?

2. Do flies affected by Hallmark jettison their eggs before dying?

3. What is the optimum insecticide loading for the insecticides Yaltox, Force, Hallmark and fipronil when applied as film coatings to radish seed ? (Glasshouse experiment.)

4. How effective are Yaltox, Force, Hallmark and fipronil when applied as film coatings? (Field experiment.)

As Hallmark (lambda-cyhalothrin) appeared to have little effect in controlling the adult flies, additional tests were done from May through July 1999 in commercial fields (Experiment 5) to assess the relative effectiveness of seed film-coated with fipronil.

RESULTS

Sprays of pyrethroid insecticides applied to radish foliage

- ♦ Pyrethroid insecticides kill only the fly adults as the active ingredient is inactivated as soon as it comes into contact with soil.

- Hallmark (lambda-cyhalothrin) sprays applied at the recommended rate (15g a.i./ha) do not kill adults of the cabbage root fly.
- Hallmark sprayed at 100 x the recommended rate kills only between 45-60% of the test flies.
- Hallmark sprays should not be included in any programme aimed at controlling the cabbage root fly.

- ▪ Contest/Fastac (alpha-cypermethrin) could be included in future screening trials for an insecticide to kill fly adults.

"New" insecticides applied as film-coatings to radish seed

- ♦ These kill only the fly larvae in the soil.

Admire (imidacloprid)

- Was not even effective when applied at the rate of 101g a.i./100,000 seeds, that is the equivalent of 1919g/ha.
- The current limit for this insecticide has been set at 125g a.i./ha.
- Should not be included in any seed treatment aimed at controlling the cabbage root fly.

Force ST(tefluthrin)

- Was not effective when tested at four doses from 10-70g a.i./100,000 seeds.
- At each of the four doses tested, Force ST killed only about one-third of the test insects.
- Should not be included in any seed treatment aimed at controlling the cabbage root fly.

Fipronil

- In glasshouse trials at HRI Wellesbourne, radish seed film-coated with fipronil gave effective control when applied at 24g a.i./100,000 seeds. This was equivalent to about 450 g a.i./ha.
- The current limit for this insecticide has been set at 400g a.i./ha.
- In glasshouse trials at HRI Wellesbourne, radish seed film-coated commercially with fipronil gave effective control when applied at 6g a.i./100,000 seeds. This was equivalent to 112g a.i./ha, well below the 400g limit set by Rhône-Poulenc.
- In commercial crops, fipronil applied at the rate of 5g a.i./100,000 seeds gave only moderate control, primarily because the seed was film-coated at HRI Wellesbourne rather than commercially by Nickerson Zwann.
- To be effective at low doses, it is not the amount of fipronil that is present that is important but the way it is applied to the seed coat.

- The method used to apply this insecticide as a film coating - that is, the FORMULATION - is ALL IMPORTANT if this insecticide is to be effective at low dose rates.

Sprays of OP/carbamate insecticides applied to the soil

- These kill on the fly larvae in the soil.

Organophosphorus compounds

- Every effort should be made to retain Dursban 4 (chlorpyriphos) and Birlane (chlorfenvinphos) for controlling larvae of the cabbage root fly.

Carbamate compounds

- Furadan, 350F, and Furadan, 480F, (both emulsifiable concentrates of carbofuran) are both freely-available to be used as spray treatments throughout Europe and North America.

  - If Furadan sprays were made available in the UK, they would enable growers to rotate OP and carbamate sprays instead, of having to rely solely on the OP compounds, which can cause difficulties in localities where the soil might be cropped more than once in a given season. The manufacturers have indicated that it is extremely unlikely that seed treatment formulations of carbofuran will be made available in UK.

Carbamate insecticide applied as a film-coating for radish seed

Carbofuran

- Under glasshouse conditions, this carbamate was highly effective when applied at 24g a.i./100,000 seeds, the equivalent of 450g a.i./ha.
- Under field conditions, 9g a.i.of Carbofuran applied/100,000 seeds was about 3 times as effective as 9g of fipronil (Wellesbourne application).
- Under field conditions 9g a.i. Carbofuran/100,000 seeds was about twice as effective as the 6g a.i. applied commercially to 100,000 seeds.
- If used in a film-coating 171g a.i./ha would be sufficient to control the cabbage root fly infestation in radish crops.
- Dose for dose, Carbofuran was as effective as fipronil in the glasshouse trial and more effective in the field trial.

  - Every effort should be made to introduce Furadan, as it would be effective both as a seed treatment and as a spray.

The manufacturers have indicated that it is extremely unlikely that seed treatment formulations of carbofuran will be made available in UK.

GENERAL

The question asked most frequently by growers is "How effective is the new treatment compared to the one it is intended to replace?" To be able to answer this question, it will be important to ensure in any future work that the existing treatment is used as the "positive control" so that its relative performance can be compared directly with that of the new treatments.

BENEFITS

Radish production in the UK is now in excess of 6,000 tonnes/year and has a current market value of approximately £7m. Even with OP-insecticides, total crop losses can occur if the insecticide treatments are not applied correctly. At present, growers rely almost exclusively on OP-insecticides for controlling infestations of the cabbage root fly. Without these insecticides, or comparable alternatives, all radish crops will be damaged heavily by the fly, and any crops drilled that coincide with the peaks of fly activity of the spring (May) and summer (July) fly generations will be destroyed before they can become established.

All brassica crops would benefit from extrapolation of this work. Brassica crops in the UK occupy about 55,000 ha of land each year and are worth currently about £250m per annum. At present, soil insecticides are applied to control the cabbage root fly on about 34,000 ha of crop at an annual cost of about £9m. About £8m of this money is spent on organophosphorus compounds. The alternative approved chemical available currently, the carbamate carbofuran (Yaltox), is prone to enhanced degradation in some soils, but could be an appropriate interim measure for some crops. The current work will use Yaltox as the positive standard and is being targeted primarily to look for alternative insecticides from within the new groups of chemicals now available.

The major benefit will be to find an insecticide that gives the required level of control without producing unacceptable residues in the harvested crop.

ADDITIONAL INFORMATION

The research work will concentrate on collecting the type of information needed to develop medium and long-term strategies for controlling the cabbage root fly in radish crops.

In an attempt to make the transition to using non-OP groups of insecticides as smooth as possible, experiments will be done to test whether killing the fly adults using pyrethroid insecticides gives comparable levels of control to those achieved by killing the fly larvae with organophosphorus insecticides. Attempts will be made also to find chemicals that can be effective against the fly larvae when applied as seed coatings. The extremely small amounts of insecticide applied using this technique are less likely to be criticized for contaminating the environment.

Neither control method is mutually exclusive and so it is likely that combinations of the two will prove to be more acceptable than relying solely on just one of the methods. It is unfortunate that there does not appear to be any new short-term strategy for controlling this pest on radish crops. One obvious approach would be to look for carbamate sprays that could be used directly to replace the organophosphorus sprays applied currently, as there would be few, if any, problems in implementing such a change. All the growers would have to do would be to apply the carbamate insecticide, using the methods and machinery they now use for applying the OP-insecticides.

Unfortunately, the only insecticides that could be applied in this way are Furadan 350F or Furadan 480F (both emulsifiable concentrates of carbofuran). Although such formulations are freely-available throughout Europe and North America, they are not available in the UK. The carbamates recommended for controlling the cabbage root fly in the UK are available only as granular formulations. Using such formulations in radish crops is not an acceptable option, as radish crops require only 21 days from drilling to harvest at the height of the season. Hence, when granular formulations are applied the insecticide residue left in the harvested crop are usually much too high. However, it might be possible to reduce the amount of insecticide used by incorporating less into the granules or by applying carbamates as film coatings.

ACTION POINTS FOR GROWERS

- Hallmark will not kill cabbage root fly (Hallmark is not currently approved on radish but a specific off label approval (SOLA) application has been made to PSD for control of stem weevil. Once approved, Hallmark must not be used for control of cabbage root fly)

- Fipronil appears to be a possible alternative insecticide for cabbage root fly control. It is not approved for use at present. HDC are in discussion with the manufacturers Rhône-Poulenc on how best to progress this use. Carbofuran also gave effective control but the manufacturers, Bayer plc, confirm that a seed treatment formulation will not be registered in the UK. Imidacloprid and tefluthrin did not give acceptable control of cabbage root fly control in radish.

Please note: Hallmark, fipronil, carbofuran, imidacloprid, tefluthrin are not approved for use on radish and their use is illegal.

SCIENCE SECTION

GENERAL INTRODUCTION

The UK anticholinesterase review, the second round of the EU review and the USA OP review have focussed attention on OP and carbamate insecticides. These reviews will have financial implications for manufacturers who may decide not to support active ingredients and/or certain uses. Minor horticultural uses are likely to be affected. New insecticides with different modes of action are required.

The five experiments described in this section should help growers to decide how best to approach what is fast becoming an extremely difficult problem, that of controlling the cabbage root fly in field crops of radish.

………………………………………………..

Experiment 1. To assess how frequently Hallmark (lambda-cyhalothrin) has to be re-applied to kill at least half of the flies present each day.

Introduction

Answers to this and the following question (Experiment 2) should help to resolve whether sprays of the pyrethroid Hallmark can be used to keep populations of the cabbage root fly at relatively low levels in crops of radish, until more permanent solutions are found.

Unlike the OP-compounds, pyrethroid insecticides do not kill the fly larvae in the soil but instead kill the fly adults that land on sprayed plant foliage. Hence, the pyrethroid insecticides cannot be considered as a direct replacement for the OP-insecticides, as the two chemical groups kill different stages in the life-cycle of the pest.

At present, excellent soil coverage with the OP-insecticides is achieved by spraying the recommended dose of insecticide onto the soil the day after the crop has been drilled. This approach is not suitable for sprays of pyrethroid insecticides, as most pyrethroids lose their effectiveness as soon as they reach the soil. As it is the residues of pyrethroid on the radish foliage that kills the adult flies, more than one application of lambda-cyhalothrin may be needed to ensure that there is enough pyrethroid present to kill sufficient flies throughout the growth of each crop. This is unlikely to produce any residue problems, as sprays of lambda-cyhalothrin are applied at 15g a.i./ha (Finch *et al.,*1998), compared to the 960g a.i./ha and 2,400g a.i./ha applied of the two OP-insecticides Dursban and Birlane, respectively. When applied at such low rates, pyrethroid insecticides are well below the limits that can be detected by residue analysis.

Materials and methods

On 17 November 1998, a large number of 10cm square pots were sown with radish, cv. Rudi. When the plants were about 10cm tall and possessed 4-5 true leaves, they were sprayed with Hallmark at the rate equivalent to 15g a.i./ha, the concentration known to be highly effective at controlling the carrot fly, *Psila rosae,* under field conditions. The nine 10cm square pots that made up the replicates for each test treatment had a total surface area equivalent to 0.09m^2. Hence, to achieve the required dosage, 0.027 ml of Hallmark was diluted with 20ml of water and sprayed onto the nine test pots of radish plants. The radish plants in each pot had been thinned earlier to 5 plants/pot, and so the amount of insecticide applied was equivalent to 0.027mg a.i./plant.

Immediately after the plants had been sprayed, they were placed into 15cm diameter x 30cm tall cylindrical cages made from plastic and whose bases were covered with damp sand. Standard fly food (Finch & Coaker, 1969) was supplied throughout the experiment.

Flies for these tests were taken directly from the HRI Wellesbourne culture (Finch & Coaker, 1969). On each day that foliage was tested, 20 flies were released into each of five test cages. The numbers of dead flies were counted one day later.

Test method

Fig.1. Schematic diagram of the method used to test the residual effect of Hallmark sprayed onto radish foliage.

Results and subsequent experiments

The results were totally unexpected, as even when the flies were released onto caged radish plants that had been sprayed less than one hour previously, the mean percentage mortality was the same (3±2.7) for both the plants sprayed with Hallmark and for the plants sprayed with water only.

Observations indicated that the flies rested for considerable periods on the underside of the cage lid, which was made from gauze mesh to ensure that the cages were ventilated adequately. To determine whether the insecticide was not effective simply because the flies rarely came into contact with it, milk filters were sprayed with a 15g a.i./ha rate of Hallmark and allowed to dry. The sprayed filters were then placed into the lids of the bioasssay cylinders (see Fig. 1).

Unfortunately, the milk filters either prevented adequate ventilation or had themselves been impregnated with some antibiotic chemical, as similar numbers of flies died in both the cylinders containing the Hallmark-sprayed and the water-sprayed (check treatment) milk filters. The results for the mean mortalities recorded in the Hallmark-sprayed/water-sprayed treatments were 18±3/22±6; 35±3/35±6; 43±4/37±7 and 65±3/52±7 when mortality was recorded 24,48,72 and 144 hours, respectively, after the spray was applied.

To determine if flies could be killed by higher doses of Hallmark, the original experiment was repeated on 24 November 1998 at a dose rate equivalent to 1500g a.i./ha. This was 100 times as high as the dose shown previously to be highly effective in the field against the carrot fly. The results of this three replicate trial are shown in Table 1.

Table 1. The effectiveness of residues of Hallmark, sprayed at the equivalent of 1500g a.i./ha, in controlling adults of the cabbage root fly.

Tested 1 hour after spray applied	**Number of flies dead after 24h exposure**	**Percentage mortality**	**Mean mortality**
Spray of Hallmark	11	44	
	13	52	45±4
	10	40	
Spray of water	4	16	
	0	0	7±5
	1	4	
Spray of Hallmark	12	48	
	18	72	60±7
	15	60	
Spray of water	1	4	
	0	0	3±1
	1	4	

Discussion

The results in Table 1 show that even at this extremely high dose for a pyrethroid insecticide, less than half (45±4%) of the flies were killed, even when the flies were released onto the plants immediately after spraying. The number of flies killed when they were subjected to spray residues on day 2 was slightly higher (60±7).

The advantage of using pyrethroid insecticides is that they are normally effective when applied at extremely low doses. However, this was not true when Hallmark was applied to control the adult stage of the cabbage root fly in the current experiments. The amounts of active ingredient (equivalent to 1500g a.i./ha) that had to be applied to give modest control (45-60% fly kill) was much higher than the 960g a.i./ha of Dursban 4 (OP-insecticide) that gives highly effective control of the fly larvae. Birlane 24, the other organophosphorus insecticide that can give 95% control, has to be applied at the rate of 2400g a.i./ha to be effective as a spray. Nevertheless, it is highly unlikely that raising the dose of Hallmark from 1500g to 2400g a.i./ha (that is less than doubling the previous highest dose) would increase pest mortality from 60% to 95%, as most of the new pyrethroids have relatively shallow slopes to their dose-mortality curves.

Finally, owing to the high potency of many of the new pyrethroid insecticides, such as Hallmark, even if a treatment that required 150g a.i./ha (10 times the amount effective against other pest species) was effective it would be unlikely to be registered.

Experiment 2. To investigate whether flies jettison their eggs before dying.

Results

As Hallmark (Experiment 1) failed to kill the test flies, this experiment is no longer relevant.

Discussion

Although sprays of Hallmark were not effective, it is still possible that one of the other available pyrethroids might kill adults of the cabbage root fly. The most obvious candidate to test next is alpha-cypermethrin, as this compound has a harvest interval of only 7 days and Cyanamid have claimed recently that their microtablet formulation (Contest) is about 7 times as effective as the emulsifiable concentrate formulation, known by the Tradename, Fastac.

Experiment 3: To assess what insecticide loading is required to give optimum control of fly larvae?

Introduction

Film-coating seems to be the insecticide formulation most likely to be accepted in the long term, as it involves placing only small amounts of insecticide into the soil at the position where it has maximum impact on the pest insect and least adverse impact on generalist beneficial insects. This approach, however, still has to be considered long-term, as even if one of the compounds proved highly effective, non of the products tested are approved for this use at present.

Materials and methods

Test method

Application of insecticide to radish seed

Fig.2. Diagram of the fluidized bed system used to film-coat seeds with insecticide.

a) Seed treatment

Batches of radish, cv. Favorella, seed (already treated with (iprodione) and (thiram)) were film-coated at HRI, Wellesbourne with fipronil (40% a.i. seed treatment formulation), imidacloprid (Admire 70% a.i. WG), tefluthrin (Force 20CS) or carbofuran (Furadan 33% a.i. LS). The insecticides were applied in a PVA sticker using 1g of sticker/100g of seed. A batch of seed, supplied by Hugh Poths of Nickerson Zwann, that had been treated commercially with fipronil, was also tested. After the various target dose of insecticide had been applied, the insecticide on the surface of samples from each batch of seed were extracted with solvent and analysed by High Pressure Liquid Chromatography to determine the dose actually achieved (Table 2). As the values applied are somewhat arbitrary, and cover a wide range of doses, there is little point in trying to match the target and the achieved doses. If such accuracy is required, it can be achieved by simply adding proportionally more insecticide to the spray chamber or by changing the balance of the input and the exhaust fans on the spray chamber (see Fig. 2). The important point is to know how much insecticide is on the seed rather than whether the actual application has achieved the target dose.

Table 2. The four target doses of each of the four test insecticides applied to radish seeds together with the doses actually achieved.

Treatment	Insecticide Active ingredient	Dose (g a.i./100,000 seeds)	
		Target Dose	Dose Achieved
1		12.5	11.3
2	Carbofuran	25	23.9
3	Carbofuran	50	47.2
4	Carbofuran	100	97.4
5	fipronil	12.5	12.3
6	fipronil	25	23.6
7	fipronil	50	42.6
8	fipronil	100	90.1
9	(commercial) fipronil	~6	5.7
10		12.5	17.4
11	Imidacloprid	25	29.8
12	Imidacloprid	50	54.9
13	Imidacloprid	100	100.7
14		12.5	9.8
15	Tefluthrin	25	23.6
16	Telfluthrin	50	43.0
17	Telfluthrin	100	69.6
18	Untreated		

b) Glasshouse experiment

On 30 June 1998, three hundred and sixty 15cm square plastic pots were filled with John Innes compost. The various batches of film-coated radish seed were sown three seeds per pot, with the seeds being spaced 3cm apart. Twenty replicate pots of each of the 18 treatments were prepared and randomised within 20 blocks in a glasshouse. The glasshouse was maintained at a temperature of 20ºC and the pots were watered three times each week. Seven days after the seedling radish had emerged from the soil, fifteen cabbage root fly eggs were washed into a groove made in the soil alongside each test plant. The eggs were washed around the middle plant in half of the pots, so that ten replicates of each insecticide loading were challenged with insects after 7 days. In the second half of the experiment, the eggs were washed onto the plants 14 days after the seedling radish had emerged from the soil.

On 17 August, all pots were washed out to recover any fly pupae and the amounts of cabbage root fly damage found on the radish roots were recorded. The numbers of pupae recovered from the pots containing the film-coated seed were compared with those from the pots with the untreated (insecticide-free) seed.

Test method

Fig.3. Schematic diagram of the method used to test the effectiveness of four insecticides applied to radish seed using the film-coating technique.

Results

The mean numbers of pupae recovered are shown in Table 3 and the percentage reduction in pupal numbers in Figure 4 (Fly eggs added 7 & 14 days after emergence of the radish seedlings). More insects survived to the pupal stage when the eggs were inoculated 14, rather than 7, days after seedling emergence. However, the numbers of pupae recovered from the untreated (insecticide-free) pots represented 39% and 55% of the numbers of eggs inoculated on days 7 and 14, respectively, indicating that overall survival was lower at the time of the first inoculation.

Table 3. Mean numbers of cabbage root fly pupae recovered from pots of radish seedlings inoculated with cabbage root fly eggs 7 and 14 days after seedling emergence.

Treatment Number	Insecticide Active ingredient	Dose (g a.i./100,000 seeds)	Mean number pupae/pot	
			7 days	14 days
1		11.3	0.2	2.0
2	Carbofuran	23.9	0	0.1
3		47.2	0	0.4
4		97.4	0	0.2
5	Fipronil	12.3	0.3	2.2
6		23.6	0	2.7
7		42.6	0.1	1.8
8		90.1	0.4	0.8
9	(commercial)	5.7	0.1	0.3
10		17.4	4.3	5.7
11	Imidacloprid	29.8	1.8	6.6
12		54.9	0.8	5.2
13		100.7	0.3	3.6
14		9.8	2	4.3
15	Tefluthrin	23.6	1.6	4.5
16		43.0	1.5	4.4
17		69.6	1.8	2.1
18	Untreated		5.8	8.3

Discussion

Carbofurangave 100% control at all except the lowest dose when challenged with fly eggs 7 days after the radish seedlings had emerged from the soil. Fipronil was generally as effective, though at the highest dose tested (90g a.i./100,000 seeds) it reduced pupal numbers by about 93% rather than 100%. This was not unexpected, as fipronil has a relatively shallow dose/mortality curve, and so the reduction recorded merely reflects the slight variation in control that can be obtained with this insecticide. Nevertheless, at the three lower doses tested, both Furadan and fipronil gave far superior control to either imidacloprid or tefluthrin. The difference is far more apparent in the data obtained (Fig. 4) when the fly eggs were inoculated only after 14 days.

Fig. 4. Percentage reduction in the numbers of cabbage root fly pupae covered when fly eggs were inoculated after 7 and 14 days onto potted radish treated with sixteen different insecticide treatments (4 insecticides x 4 doses).

The above data are not representative of the typical field situation, as the plants were seeded on 30 June and only harvested on 17 August, some 7 weeks later. This was done to allow those insects that survived sufficient time to complete their development and pupate, so that the numbers of insects that pupated could be used as an indication of the relative persistence of the four test insecticides. It is clear from Fig. 4. that the two intermediate doses of fipronil gave good control early in crop growth (day 7 inoculation) but had begun to lose their effectiveness by the day 14 inoculation. At the peak of the season, eggs laid on a radish crop after 14 days would have hatched into larvae by the time the crop was harvested (day 21). However, such larvae would still only be small first-instars and so their feeding damage would not be noticeable.

Experiment 4. To assess how effective the insecticides imidacloprid, fipronil, tefluthrin and carbofuran are when applied as film-coatings to radish seed and tested under field conditions.

Materials and methods

Batches of radish, cv Favorella, seed (coated with (iprodione) and (thiram)) were film-coated at HRI, Wellesbourne with fipronil (40% a.i. seed treatment formulation), Admire (70% a.i. WG), Force (20CS) or Furadan (33% a.i. LS). The insecticides were applied in a PVA sticker using 1g of sticker/100g of seed. A batch of seed that had been treated commercially with fipronil was also tested. After the various target dose of insecticide had been applied, the insecticide on the surface of samples from each batch of seed were extracted with solvent and analysed by High Pressure Liquid Chromatography to determine the dose that was actually achieved (Table 3).

Table 4. The two target doses of each of the four test insecticides applied to radish seed together with the eight doses actually achieved and a sample of seed film-coated commercially with fipronil.

Treatment	Insecticide	Dose (g a.i./100,000 seeds)	
		Target	Achieved
1		12.5	8.9
2	Carbofuran	25	15.7
3	Fipronil	12.5	8.9
4	Fipronil	25	15.7
5	(commercial)	?	5.7
6		12.5	10.1
7	Imidacloprid	25	20.6
8		12.5	8.4
9	Tefluthrin	25	14.9
10	Untreated	-	

Fig.5. Layout and randomization of field experiment for testing the effectiveness of four insecticides applied as film coatings to radish seed.

b) Field assessment

On 6 July 1998, the seeds were sown into prepared beds using a tractor mounted Stanhay Singulaire seed drill calibrated to sow at about 64 seeds/m of crop row. Four rows were drilled into each 1.83m bed at a row spacing of 46 cm. The treatments were randomised so that the experiment consisted of 9 randomised blocks of twelve 3m-long rows. Each block contained 9 treatments (rows 2-10) and three untreated rows (treatment 1), one included in each of the three treated beds (see diagram of plot layout/randomisation – Fig. 5.).

The mature radish were harvested (1.5 m/row) on 17 August. After washing to remove soil, the amounts of cabbage root fly damage found on the roots was recorded and the percentage of roots damaged in the various treatments were calculated.

Results

The percentages of radish roots that were damaged are shown in Table 5. The cabbage root fly infestation was heavy and as a result 72% of the untreated roots were damaged. The percentage damage on the insecticide-treated roots was compared with the percentage damage on the untreated roots using a t-test. Both doses of carbofuranreduced damage (P=0.05), as did the highest dose of imidacloprid and the fipronil treatment that had been applied commercially. Dose for dose, neither imidacloprid nor fipronil were as effective as carbofuran. The levels of damage in the plots drilled with the seed treated at HRI-Wellesbourne with the two doses of tefluthrin and the two doses of fipronil were as high as those recorded in the insecticide-free plots.

Table 5. The percentage of radish roots damaged by larvae of the cabbage root fly after radish seed had been film-coated with nine different insecticide treatments.

Treatment Number	Insecticide	Dose (g a.i./100,000 seeds)	% roots damaged
1		8.9	25
2	Carbofuran	15.7	20
3	Fipronil	8.9	68
4		15.7	68
5	(commercial)	5.7	53
6		10.1	62
7	Imidacloprid	20.6	54
8		8.4	70
9	Tefluthrin	14.9	68
10	Untreated	-	72

Discussion

In this field experiment, only carbofuran performed acceptably. Neither the seed treated commercially with fipronil nor that treated with the higher dose of imidacloprid, reduced crop damage to an economically-acceptable level. The failure of the seed treated with fipronil at HRI to control the pest under field conditions indicates that the insecticide could have been bound too strongly to the seed coat and therefore not been freely available to kill the cabbage root fly larvae. It is more likely, however, that we simply did not apply sufficient chemical, as 23.6g a.i./100,000 seeds were required to give effective control in the glasshouse trial whereas in the field we were constrained to apply only the equivalent of 8.9 and 15.7g a.i./100,000 seeds. In addition, the fly population at Wellesbourne is maintained artificially high so that it is easy to discriminate between chemicals even when the treatment effects are relatively small. Hence, fipronil may be capable of providing acceptable levels of control in commercial crops, where the levels of pest pressure are much lower than those generated at Wellesbourne. Further studies are required to confirm whether this is actually the case. An indication of what is likely to occur in commercial fields is described in Experiment 5.

Experiment 5. To assess how effective radish seed film-coated with fipronil is in controlling field populations of the cabbage root fly in commercial radish crops.

Materials and methods

Batches of the commercially grown radish variety, Rudi, were coated with fipronil at HRI Wellesbourne. The fipronil was applied at the rate of 5g a.i./100,000 seeds and was applied using PVA sticker at the rate of 5g/kg of seed. Batches of the treated seed were sent to Mr Bill Watkins at Feltwell, Norfolk and to Mr Peter Knight, of J.J. Barker Ltd, Farningham, Kent. The seeds were treated with this relatively low dose of fipronil to keep within the 400g a.i./ha that Bill Lankford of Rhône-Poulenc (personal communication) thought would be the upper limit permitted by Rhône-Poulenc.

Two trials were drilled by Bill Watkins on 3 and 14 May 1999 and harvested on 3 and 15 June 1999, respectively. These trials were situated alongside dykes about halfway along one side of two narrow 400m long fields. The fipronil-treated seed was drilled as three 30m-long adjacent beds. An area of untreated radish was available for sampling only at the time of the second drilling.

Three trials were drilled by Peter Knight on 5 May, 14 May and 1 July and harvested on 3 June, 7 June and 23 July, respectively. Two beds each about 20m long were drilled with fipronil-treated and untreated radish seed in the first two trials. These beds were drilled at positions toward the edges of radish crops in areas where fly damage had been serious in earlier years. The third trial in Kent was drilled in July to ensure that it coincided with the second fly generation, which has now become the most difficult to control. This trial consisted of two 20m-long beds of fipronil-treated seed, bordered on both sides by two untreated beds of radish. About 2m after the end of the outer untreated plot, the radish were subjected to the usual spray of Dursban 4. This area was where the plants for the "positive control" treatment were collected.

At harvest, samples of radish roots were collected from each plot and inspected to record accurately the amount of damage caused by the fly larvae. In the third trial done in Kent, the radish roots were also dissected carefully to record the numbers of living and dead fly larvae present in each sample.

Results

In the first four trials (two in Norfolk and two in Kent), root damage was assessed on about 400 radish roots/treatment. In the larger third trial done in Kent, the assessment was based on 1000 roots/treatment.

The values in parentheses (Table 6) for the second trial in Norfolk and the first trial in Kent represent the numbers of larvae found. They are in parentheses, as no records were taken of whether the larvae were alive or dead.

In all cases, the percentage of roots damaged was considerably lower on fipronil-treated plots than on the untreated plots. In the two instances where there were comparisons between the fipronil treatment and the Dursban 4 sprays, the fipronil treatment was also better.

Table 6. The amount of damage recorded on radish plants whose seed had been film-coated with fipronil and drilled within commercial radish crops.

Site/trial number	Date Drilled	Date harvested	Untreated (check) % damage	Dursban spray % damage	Fipronil film-coating % damage
NORFOLK					
1	3 May	3 June	-	0.7	0.4
2	14 May	15 June	6.0 (3)	0.0	3.0 (1)
KENT					
1	6 May	3 June	2.7 (0.7)	-	1.7 (0)
2	14 May	7 June	1.4	-	0.0
3	1 July	23 July	23.4	19.3	15.2
% of roots with larvae			3.9	7.1	1.2
% of larvae found alive			100	100	25

The high percentage damage on the Dursban treated rows at the time of the second fly generation (Kent – trial 3) was unexpected. It is possible that the roots collected for this sample were from an area that had not been sprayed with Dursban 4. Part of this bed had been left untreated alongside the fipronil-treated beds and so the area left unsprayed could have been longer than intended in the original plot layout.

Discussion

If the result from the Dursban 4 spray in the third trial in Kent is real, then it indicates that Dursban 4 sprays may not always be effective. It is well known that spraying insecticide onto the soil surface is the least effective way of applying soil-active insecticides. Unfortunately, with crops like radish which are drilled sequentially three times/week at certain times of year to maintain continuity of produce, crops cannot always be drilled under ideal conditions. Hence, some beds of radish may end up with the soil surface being granular rather than smooth. Applying a spray one or two days later to such soils, that in effect have much larger surface areas, could easily dilute the effect of the sprayed insecticide. Similarly, insecticides kill only a certain percentage of the fly population. Therefore, when the fly population is large more individuals survive to damage the crop.

Information is now required urgently to show how fly numbers change with time during the radish growing season and how this affects the relative effectiveness of the one spray of insecticide applied to each sequentially-drilled crops.

Whatever the reason for the variation in effectiveness of the post-drilling sprays, the results show clearly that the fipronil treatment does have a pronounced effect. If in the third trial in Kent only the percentage of roots with larvae are considered, then 1.2% of the plants had larvae in the fipronil treatment compared to 3.9% in the untreated plants, the equivalent of a 70% reduction in damage. In addition, three-quarters of the larvae in the fipronil samples were dead, indicating that insufficient fipronil was present to kill the larvae more or less immediately and so they had to feed for some time to acquire a lethal dose. Presumably, damage would have been lower and fewer larvae would have been found had more insecticide been included in the original film-coating treatment. It appears that fipronil is a good candidate chemical to include in future trials, provided the way it is formulated can be improved, and/or Rhône-Poulenc agree to increase the amount of their product that can be applied/ha.

GENERAL DISCUSSION

In the glasshouse trials, all treatments that resulted in 0 or 0.1 fly pupae being recovered per pot when the fly eggs were added seven days after seeding were considered to be highly effective.

Maximum levels of fly control were obtained when both carbofuran and fipronil were applied at the rate of 24g a.i./100,000 radish seeds. Only slightly less control (0.1 fly pupae test pot) was obtained from the fipronil treatment that was applied commercially. However, this treatment was applied at only 6g a.i./unit, or one-quarter of the earlier rate. Consequently, selecting the appropriate formulation is all-important if extremely low doses of fipronil are to be used.

Neither of the other two insecticides, imidacloprid nor tefluthrin, gave sufficient control to warrant any further tests of their efficacy against the cabbage root fly.

In an earlier study done for a commercial contract (Jukes & Finch, 1998), results from a log-dose trial done under field conditions indicated that a 90% reduction in the numbers of cabbage root fly larvae could be achieved by apply 301mg a.i./m of row of fipronil but only 118mg a.i./m of Birlane 24 (chlorfenvinphos). Consequently, when compared dose for dose, the OP-insecticide, Birlane 24, was more effective than fipronil.

If certain OP-insecticides can be retained for protecting crops from cabbage root fly larvae, then film-coating seed with chlorfenvinphos (Birlane) would appear to be a treatment worthy of further consideration. Its main advantage over the new compound fipronil is that it is applied at a lower dose but, more importantly, it is about three times as effective. Another insecticide that is equally effective and probably has an even stronger case for being retained is chlorpyrifos (Dursban 4), as this OP-insecticide is the commonest soil insecticide used on a world-wide basis and, as such, is likely to remain available commercially for some considerable time.

Finally, every effort possible should be made to introduce the carbamate carbofuran, as it is a highly effective chemical and is used as one of the routine treatments throughout Europe and North America. In addition, this insecticide is sold in a formulation that would enable it to be applied either to the radish seed as a film-coat or to be the soil as a post-drilling spray. Such a chemical would enable the insecticides applied to radish crops to be rotated, a strategy that is highly desirable in areas where the one chemical Dursban 4 has now been applied to sequentially-sown radish crops for a number of years.

ACKNOWLEDGEMENT

We thank the HDC for funding this work and Mr Bill Watkins, Feltwell, Norfolk and J. J. Barker's, Farningham, Kent for carrying out the trials with the fipronil film-coated seed within their commercial crops. We are especially grateful to the Project co-ordinator, Mr Peter Knight (J.J. Barker Ltd), for all of the information he made available to us during the course of this work and for the boundless enthusiasm and energy he showed throughout the project.

REFERENCES

Finch, S. & Coaker, T.H. (1969). A method for the continuous rearing of the cabbage root fly *Erioischia brassicae* (Bouché) and some observations on its biology. *Bulletin of Entomological Research* **58**, 619-627.

Finch, S., Collier, R.H. & Jukes, A. (1998). What a difference a spray makes. *Grower* **130(5)**, 20.

Jukes, A.A. & Finch, S. (1998). Assessing the relative merits of the insecticide fipronil for controlling the carrot fly and the cabbage root fly. *Confidential Technical Report*. 26pp.