Project Title

Swedes: Biology and Control of Cabbage Root Fly

Project number: FV 66a

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Location of project: Commercial farms in England (Crediton, Devon; Owston Ferry, South Yorkshire) and Scotland (Cocksburnspath, Lothian).

Project Coordinators: Mr A Ewan, Mr M Holmes, Mr J Jemmett

Project timeline: Commenced April 1997, completion due 30 March 2001.

Keywords: Swedes, cabbage root fly, Birlane 24, chlorfenvinphos.

The results and conclusions in this report are based on a series of experiments and surveys. The conditions under which the work was carried out and the results have been reported with detail and accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results especially if they are used as the basis for commercial product recommendations.

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1. PRACTICAL SECTION FOR GROWERS

Objectives and background

Current practice for the control of cabbage root fly in culinary swedes does not provide reliable control of the pest. Current commercial and legal pressures on the industry increase the risk that even the most effective available products may have a limited future. The objectives of the current work, which began in 1997, are to investigate the potential to improve the timing of treatments and to evaluate the efficacy of alternative insecticides. This report summarises the results of the third year of study.

Under current supervised control strategies, egg counts and the HDC/HRI model are used to time insecticide treatments. These tools give an indication of the duration of pest activity during each generation. However, they do not identify whether there is a critical risk period during each generation when the crop must be protected to avoid significant levels of pest damage. Currently approved insecticides are often not persistent enough to protect the crop for the duration of second generation activity. Therefore the definition of a critical risk period would enable the period of protection to be identified more accurately and the most effective control measures could be applied when they would provide the greatest benefit.

Results from field work in 1998 suggest that the rate of development of damage to swede bulbs was not uniform throughout the season. A relatively rapid increase in damage occurred two to three weeks after eggs were detected. Pot experimentation confirmed that Yaltox (carbofuran) was the most effective product against cabbage root fly. Foliar treatments were poor probably because the foliage intercepted a large proportion of the spray. Therefore in 1999 it was decided to undertake experiments to investigate further timing of insecticidal control measures and the efficiency with which these treatments reached their target.

Work on the timing of insecticide sprays concentrated on attempting to prevent the initial rapid rise in root damage to see how this would influence damage levels later in the autumn. In a separate experiment the relative efficacy of applying sprays over the swede bulb or over the foliage was compared. In summary, work in 1999 concentrated on answering two questions.

- Will control of early second generation larvae prevent or reduce late season damage?

- Is a directed spray over the swede bulb more effective than a foliar treatment in reducing cabbage root fly damage?

Birlane 24 (chlorfenvinphos) was chosen as an experimental tool primarily because of HDC funded work at HRI Stockbridge House aimed at gaining a specific off-label Approval (SOLA) for this product on swedes.

Summary of results to date

Controlling early season damage

This work was undertaken in Devon and South Yorkshire and generally egg numbers were low throughout the season. In Devon less than 0.2 eggs/plant/day were recorded throughout July and peak oviposition was between 2 and 9 September with 0.7 eggs/plant/day. This was a third generation of the pest. In South Yorkshire peak oviposition of second generation flies was between 9 and 15 July (1.0 eggs/plant/day) and of third generation flies between 26 August and 9 September (0.8 eggs/plant/day).

Overall control of cabbage root fly damage was poor. In South Yorkshire 40% of the root area of individual swedes was mined and 90% of swedes were attacked. In Devon less than 20% of root area was mined but at least 40% of roots were attacked. There was some evidence at the Devon site that four sprays applied at weekly intervals, beginning one week after the start of egg laying, was more effective than four treatments between weeks five to eight.

Comparing sprays directed at the bulb or over the foliage

This experiment was done in Berwickshire where egg laying was lower than in Devon or South Yorkshire. Peak oviposition was recorded between 5 and 12 July with 0.3 eggs/plant/day. Although there was no statistically significant difference between treatments there was a trend to find least root damage where sprays were directed over the bulb in comparison with over the foliage. However, at least 50% of roots were damaged in all treatments.

Action points for growers

The poor level of control of root damage with insecticide sprays means that only tentative conclusions can be drawn. It is likely that the damage levels in the trials were a reflection of the limited effectiveness of the insecticide used.

- **Timing of second generation treatments:** Limited evidence from Devon suggests that sprays applied a week after the detection of first cabbage root fly eggs can limit damage levels later in the season. This supports the existence of a critical risk period. However, further evaluation should be undertaken when foliar sprays that offer better control of cabbage root fly are available.

- **Directing sprays over the swede bulb:** Sprays over the bulb generally had a lower level of damage than where they were applied over the foliage. However, the poor performance of Birlane 24 means that at present results are still inconclusive. The use of irrigation or high water volumes may be an alternative means of ensuring that sprays reach their target area.

- **Pest pressure and root damage:** Results from all three sites confirm that the degree of pest pressure has a significant effect on root damage. In both Berwickshire and Devon fewer roots were damaged than in South Yorkshire where there were two clear peaks in pest activity. Siting crops as far as possible from a source of the pest could prove as effective in limiting root damage as existing chemical control options.

Practical and financial benefits from study

During 1996 roughly 75% of root brassica crops were treated with insecticides for cabbage root fly control. The majority of these treatments were timed according to egg counts and the HDC/HRI model. Nevertheless, devastating attacks were reported in many crops during the autumn. Second and third generation cabbage root fly control alone frequently costs the industry about £990,000 per year, but despite this investment, control is still unreliable. During 1995/96, 4.405 ha of swedes and turnips were planted, giving a potential total yield of 147,668 t. The average price throughout the year was £133.68/t, assuming an estimated 30% loss in overall value due to cabbage root fly damage, the total losses amount to approximately £5,922,077 (MAFF 1996, C Treble personal communication).

The development of a more effective control programme will reduce the estimated cost of crop damage, and improve the return on investments in pest control. If further work supports the narrowing of the critical risk period, the need for late sprays may also be reduced, allowing subsequent cost savings and environmental benefits.

2. SCIENCE SECTION

General introduction

Cabbage root fly continues to cause serious damage to culinary root brassica crops, and in many areas is the single greatest challenge facing producers. Current insecticide programmes rely on Yaltox (carbofuran) and Birlane 24 (chlorfenvinphos), and even the best control is often inadequate. The industry's reliance on these products carries increasing commercial risks. With the introduction of Integrated Crop Management Systems, major retailers are asking growers to use compounds with low persistence and greater selectivity wherever possible. Furthermore, the continual review of pesticide regulations means that products can be lost at short notice, either due to direct revocation of use, or as the results of a commercial decision to discontinue production. At present there is mounting pressure to reduce the use of organophosphorous insecticides in vegetable crops and the future for both chlorfenvinphos and carbofuran is unclear. The label Approvals for chlorfenvinphos as Birlane 24 or Sapecron 240 for control of second generation cabbage root fly in swedes lapsed on 31 August 1999. Following lobbying of the Ministry of Agriculture, an on-label approval was permitted for Birlane 24 until 31 March 2000, allowing HDC/HRI additional time to generate additional data as requested by PSD following assessment of a SOLA application. The SOLA application for Birlane 24 is currently being assessed by PSD. Bayer plc have confirmed that they will no longer support the retention of carbofuran as Yaltox. Carbosulfan will be available, now marketed by Bayer as Posse 10G. This compound is a precursor of carbofuran but has a 100 day harvest interval which could prevent its use in some white turnip crops which are harvested within this time period. In summary, the unreliability of existing chemical control strategies and uncertainty over the future of Birlane 24 (chlorfenvinphos) and Yaltox (carbofuran) has necessitated the search for more effective, alternative control programmes for the cabbage root fly in root brassicas.

The unreliability of existing control programmes is probably primarily due to the extended period during which the crop is exposed to egg laying flies. Fresh damage is often present at harvest suggesting that larvae arising from late second or third generation flies can cause significant damage, as well as those arising from early second generation activity. Egg counts and the HDC/HRI predictive cabbage root fly model usefully provide a 'risk window' for cabbage root fly activity. They can also provide an effective trigger for the initial second generation treatments. However, there is a need to establish the time of laying of second and third generation eggs which subsequently cause the most damage as larvae. Identification of this critical risk period was the primary objective of the first two years of this project with the aim of them being able to target insecticides against the most potentially damaging insects.

Results from the field work done in 1998 showed that in Devon and East Yorkshire damage by cabbage root fly larvae continued to increase throughout the season. In Scotland there was a slight decrease in damage levels from late September. However, the rate of increase in damage levels was not uniform throughout the season. In both Devon and in East Yorkshire there was a relatively rapid increase in damage levels two to three weeks after first eggs were detected. Pot experimentation confirmed that Yaltox (carbofuran) was the most effective product against cabbage root fly. Foliar treatments were poor, probably because a large proportion of sprays was intercepted by the swede foliage.

In the third year of the project (1999) it was intended to begin work on evaluating alternative programmes for cabbage root fly control. However, results from years one and two showed that before this could be done an improved understanding of how a number of factors influenced pest damage was necessary. These included the duration of second and third generation activity, insecticide application efficiency and timing. Therefore in year three it was decided to undertake experiments to investigate further the timing of control measures and application efficiency.

Work on timing control measures concentrated on attempting to prevent the initial rapid increase in damage levels, two to three weeks after the detection of first eggs, to see how this would affect late season attack. In a separate experiment the relative efficacy of applying insecticide sprays over the swede bulb or over the foliage was compared. Therefore in 1999 the project tested the following hypotheses:

- Control of early second generation larvae will prevent or reduce late season damage.
- A directed insecticide application over the swede bulb will control pest damage better than a treatment over the foliage.

In both experiments Birlane 24 was used as an experimental tool primarily because HDC-funded work was underway at HRI Stockbridge House to achieve a SOLA for this product on swedes.

An investigation of insecticide spray timing

Introduction

In a replicated small plot experiment the relative efficacy of two insecticide spray programmes in which treatments were applied 1-4 or 5-8 weeks after first eggs were laid were compared to determine their effect on cabbage root fly damage to the swede bulb. The work was undertaken at Crediton, Devon and Owston Ferry, South Yorkshire in commercial crops of swedes.

Materials and methods

Plots were set up on 9 July in Devon and South Yorkshire. The soil type at the Devon site was a typical brown earth and at the South Yorkshire site a loamy silt. The cultivar was Magres in both Devon and South Yorkshire.

Experimental treatments and layout

The experiment compared the following treatments.

1. Birlane 24 spray x 4 @ 7-10 day intervals to protect crops for four weeks immediately after first eggs were laid.
2. Birlane 24 spray x 4 @ 7-10 day intervals to protect crops from 5-8 weeks after first eggs were laid.
3. Untreated control.

There were 10 replicates of each treatment giving 30 plots in total arranged in a randomised complete block design. Plots one bed wide (assuming four rows in a 1.83 m bed) x 5 m long were marked out at the start of second generation egg laying. Plots were located at least 30 m into the field from a headland to maximise the chance of significant root fly attack. The experiment was surrounded by guard plots to isolate it from the farm crop.

Cabbage root fly egg sampling
A total of twenty plants in the untreated guard areas were marked for use for regular egg collection. Egg sampling began as soon as experiments had been marked out and was done weekly until first eggs were detected. Thereafter, assessments were made fortnightly. On each sampling occasion the soil immediately around the 20 marked plants was removed to a depth of 2 cm using a dessert spoon. This was then replaced by similar soil taken from between the rows of plants which did not contain cabbage root fly eggs.

The soil from each plant was bulked for egg extraction. This was done by washing the soil through a Fenwick can. The organic debris was collected in a fine sieve (350 microns) and washed onto a black filter paper. All hatched and unhatched eggs were then identified and counted.

Insecticide application
All insecticide treatments were applied with an Oxford Precision sprayer, calibrated to deliver 500 l/ha at medium spray quality. Birlane 24 was applied at 3.0 l/ha in 500 l water/ha through F110 flat fan nozzles.

Root sampling
Root samples were taken to assess the efficacy of insecticide treatments one week after the end of the first four sprays, one week after the end of the second four sprays and at harvest. Only the central two rows of roots were used to assess crop damage. The first two samples compared 40 roots/treatment with four roots taken from each of 10 replicate plots. The harvest sample consisted of 20 roots per plot or 200 roots per treatment. Harvest in Devon was on 11 November 1999 and in South Yorkshire on 29 October 1999.

Root damage was assessed the same way as in 1998. The percentage area of the bulb damaged by larvae was estimated to the nearest 10%. The growth stage of the root was then determined and its subterranean root area taken from the regression line of root area against growth stage. This relationship was best described by a 3rd order polynomial of the form $y = 0.934x^3 + 12.533x^2 - 7.14x$ where y = subterranean area, x = growth area, $R^2 = 0.9255$. Taking logarithms of both sides of this relationship produced a straight line which was used to define the average subterranean root area at each growth stage. Subterranean root area was multiplied by the percentage root area damaged to give the total damaged area of the bulb.

Approach to statistical analysis
The basis upon which statistical inferences were made was the analysis of variance. Where data sets did not conform to a normal distribution, transformation to $\log_{10}(x + 1)$ values was made. When root samples were taken one week after the first four Birlane 24 sprays had been applied to treatment one, treatment two, sprays applied 5-8 weeks after the start of egg laying, was considered as an extra untreated control. In this case a "t" test was used to compare treatment one with the untreated control.

Results

Cabbage root fly laying
In general, egg numbers were low in Devon and South Yorkshire. In Devon less than 0.2 eggs/plant/day were recorded throughout July and August (Figure 1). Peak oviposition was recorded in the sample taken on 9 September with 0.74 eggs/plant/day. This represented a third generation of the pest. Subsequently egg numbers declined rapidly.

In South Yorkshire peak oviposition by second generation flies was recorded between 9 and 15 July with 0.96 eggs/plant/day (Figure 2). This was the highest level of egg laying at all sites. There was evidence of a third generation of the pest during late August to early October. Peak egg numbers (0.77 eggs/plant/day) were found between 26 August and 9 September.

Root damage assessments
In Devon the percentage root area damaged differed significantly between treatments in samples taken after sprays had been applied between five and eight weeks after the start of egg laying ($P < 0.05$) and at harvest (Table 1, Figure 3). In both cases the pattern of damage between treatments was similar. Least damage was recorded where sprays had been applied one to four weeks after the start of egg laying and most in the untreated control. Damage levels in October were higher than in November. Root samples taken after the completion of sprays from one to four weeks after egg laying showed less damage in the sprayed than untreated plots but differences were not statistically significant.

Figure 1. Pattern of cabbage root fly egg laying (eggs/plant/day) at Crediton, Devon.

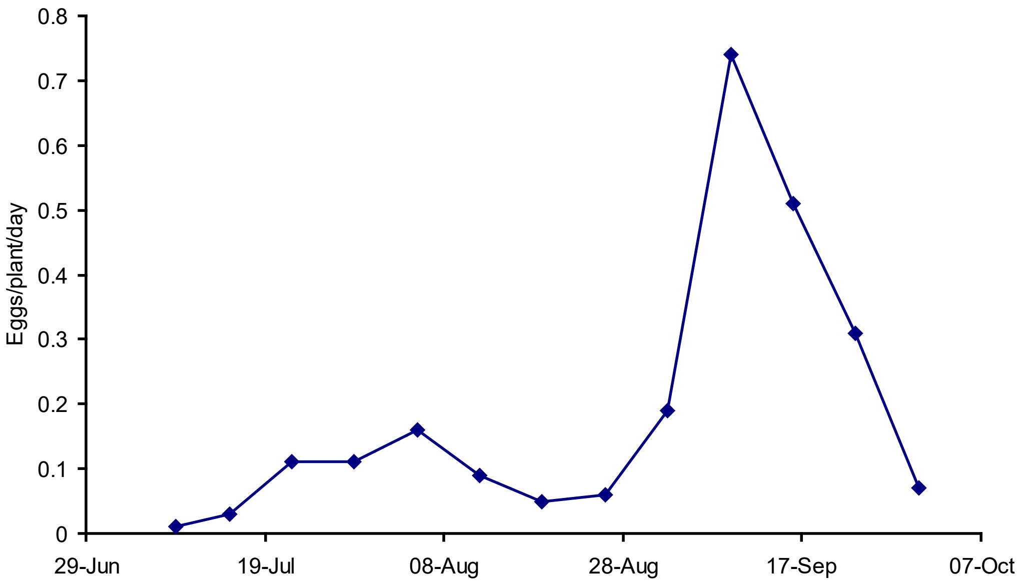


Figure 2. Pattern of cabbage root fly egg laying (eggs/plant/day) at Owston Ferry, South Yorkshire.

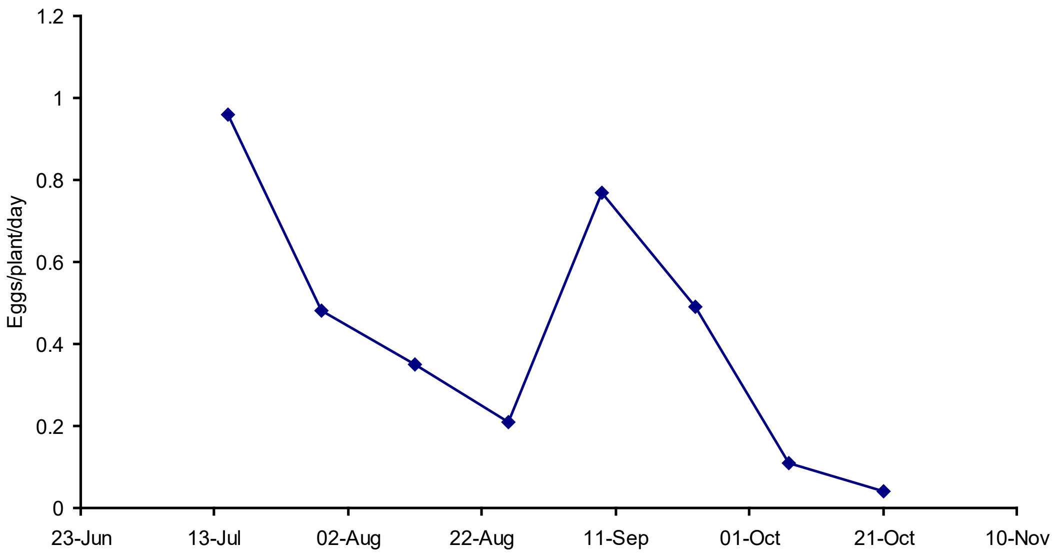


Figure 3. Mean percentage root area damaged by cabbage root fly at Crediton, Devon.

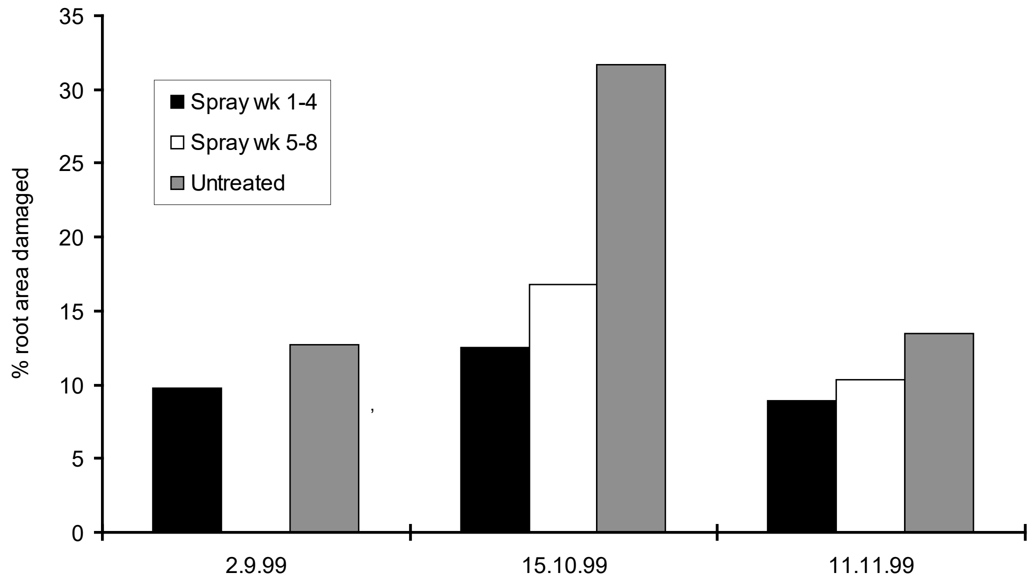


Figure 4. Mean percentage root area damaged by cabbage root fly at Owston Ferry, South Yorkshire.

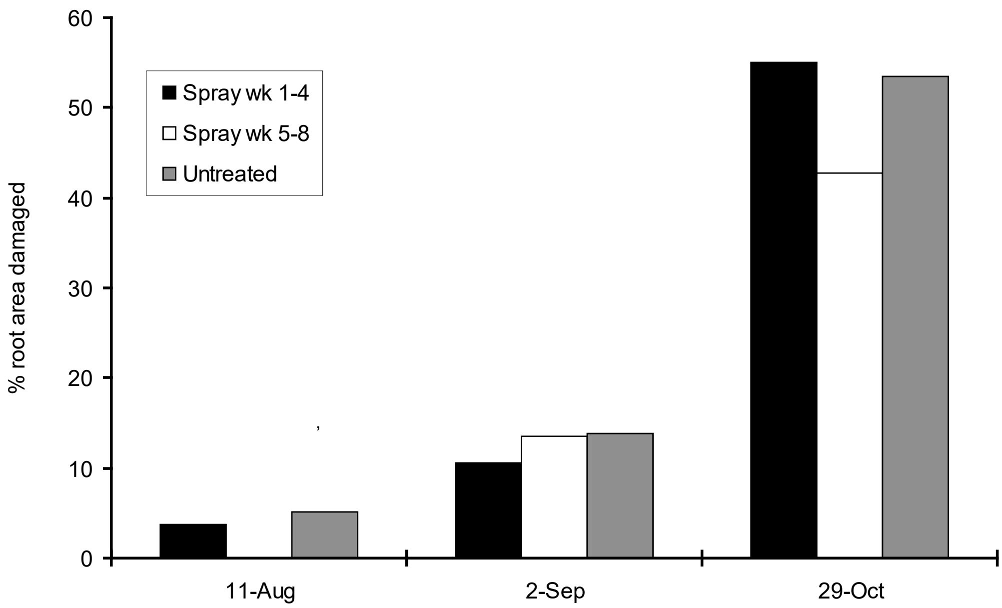


Table 1. The effect of timing of four spray programmes of Birlane 24 on percentage swede root area damaged by cabbage root fly larvae at Crediton, Devon and Owston Ferry, South Yorkshire, 1999 (SED = standard error of the difference between means; d.f. = error degrees of freedom).

		% root area damaged				
Site	Date	Sprays 1-4 weeks after start of egg laying	Sprays 5-8 weeks after start of egg laying	Untreated control	SED	d.f.
Crediton,	2/9/99	9.8	-	12.7	4.50	24
Devon	15/10/99	12.5	16.8	31.7	6.09	18
	11/11/99	8.9	10.2	13.4	1.79	18
Owston Ferry,	11/8/99	3.8	-	5.1	1.70	19
South Yorks	2/9/99	10.5	13.6	13.8	3.87	18
	29/10/99	55.0	42.7	53.5	5.17	18

The proportion of damaged plants at both the Devon and South Yorkshire sites is shown in Table 2. In Devon the proportion of damaged plants differed significantly between treatments in September ($P = 0.06$) and at harvest ($P < 0.05$). Most damaged plants were always found in the untreated control and least where sprays were applied one to four weeks after the start of egg laying. Up to two thirds of plants were attacked in the untreated control and this was reduced to 48% and 38% where sprays were applied five to eight or one to four weeks after the start of egg laying respectively.

Table 2. The effect of timing of four spray programmes of Birlane 24 on the percentage of swedes damaged by cabbage root fly larvae at Crediton, Devon and Owston Ferry, South Yorkshire, 1999 (SED = standard error of the difference between means; d.f. = error degrees of freedom).

		% of roots damaged				
Site	Date	Sprays 1-4 weeks after start of egg laying	Sprays 5-8 weeks after start of egg laying	Untreated control	SED	d.f.
Crediton, Devon	2/9/99	17.5	-	32.5	7.60	24
	15/10/99	37.5	47.5	65.0	13.03	18
	11/11/99	44.5	56.0	62.0	5.29	18
Owston Ferry,	11/8/99	40.0	-	53.7	8.50	19
South Yorks	2/9/99	55.0	65.0	47.5	12.41	18
	29/10/99	93.0	93.0	97.5	4.12	18

In South Yorkshire there was no consistent trend in the proportion of damaged plants between treatments (Table 2, Figure 4). In August and in October most damaged plants were recorded in the untreated control but in September this treatment had the lowest level of damage. Damage levels at harvest were also much higher in South Yorkshire than in Devon with at least 93% of swedes mined by cabbage root fly.

A comparison of insecticide sprays directed over the swede bulb or foliage

Introduction

A replicated small plot experiment was undertaken to compare the relative efficacy of a four spray programme of Birlane 24 directed over the swede bulb or foliage for control of damage due to cabbage root fly larvae. This work was undertaken at Cockburnspath, Berwickshire, Scotland.

Materials and methods

Plots were set up on 14 June 1999 in a commercial crop of swedes (cv. Laurentian). The soil type was a sandy loam.

Experimental treatments and layout

The experiment compared the following treatments.

1. Birlane 24 spray x 4 @ 7-10 day intervals applied over the top of the crop immediately after first eggs were laid.

2. Birlane 24 spray x 4 @ 7-10 day intervals, directed at the swede bulb, immediately after first eggs were laid.

3. Untreated control.

There were 10 replicate plots of each treatment as in Devon and South Yorkshire. Plot size and layout was also identical to those used at the English sites in the spray timing experiments.

Cabbage root fly egg sampling

The number of plants sampled and the procedure were the same as at the English sites.

Insecticide application

The same application equipment and rate of application of insecticide and water as at the English sites were used. However, where treatments were directed over the swede bulb the treated area was significantly less than for a whole plot. A lance with a single nozzle was used for the directed treatment and the volume of spray solution calculated to be equivalent to that applied over the top of the foliage. Assuming a row of swedes occupied a band approximately 15 cm wide x plot length (5 m) the total area treated was (0.15 x 5) x 4 rows = 3 m^2. This compared to an area of 9.2 m^2 for a plot of 1.83 x 5 m, so approximately one third of the volume of spray solution was needed for the directed spray compared with that over the foliage.

Figure 5. Pattern of cabbage root fly egg laying (eggs/plant/day) at Cocksburnspath, Scotland.

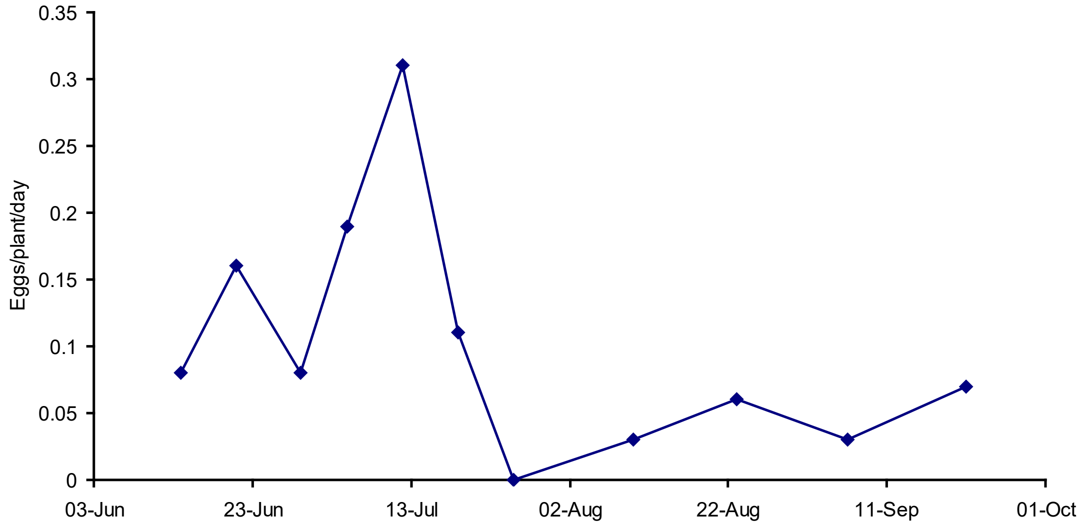
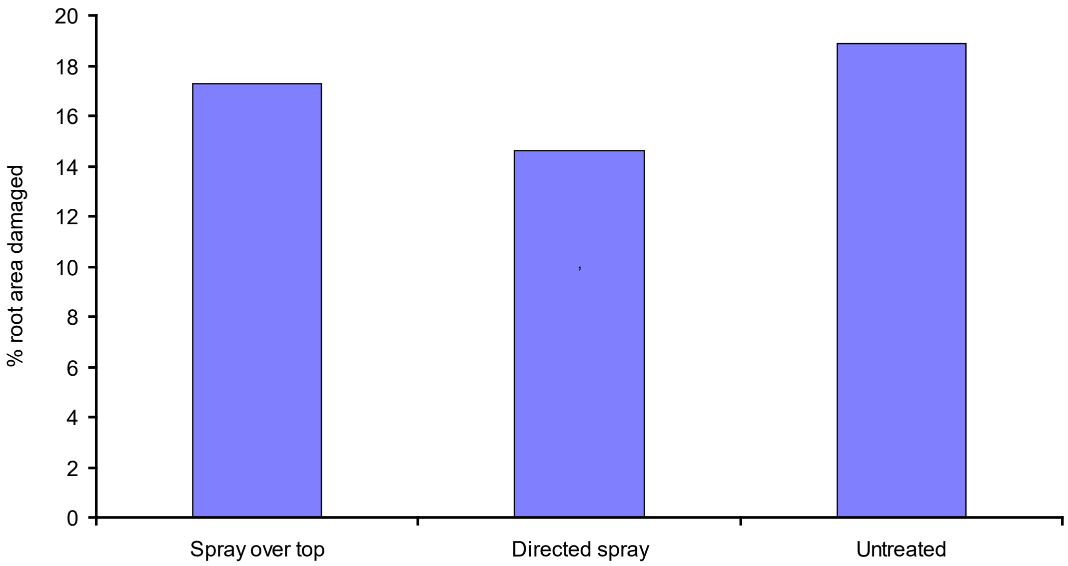


Figure 6. Percentage roots damaged at harvest at Cocksburnspath when treated with Birlane 24 either as a spray over the foliage or as a directed spray to the swede bulb.



Root sampling
A single root sample was taken comprising 20 roots per plot at harvest (21 September 1999). Root damage was assessed using the same method as at the English sites.

Approach to statistical analysis
The analysis of variance was used for statistical analysis as in the experiment on spray timing.

Results

Cabbage root fly egg laying
Levels of egg laying in Scotland were much lower than in either Devon or South Yorkshire (Figure 5). Peak oviposition was recorded between 5 and 12 July with 0.31 eggs/plant/day. Numbers then dropped dramatically and none were found between 19 and 6 July. Subsequently there was a slight increase in oviposition but egg numbers never exceeded 0.1/plant/day.

Root damage assessments
There was no significant difference between treatments in the area of bulb mined by cabbage root fly larvae at harvest (Table 3, Figure 6). However, there was a trend to find least damage where sprays were directed over the bulb in comparison with over the foliage or the untreated control. There was little difference in the proportion of roots attacked between treatments, at least half of the harvested swedes were damaged.

Table 3. The effect of a four spray programme of Birlane 24 directed over the swede bulb or foliage on the area and number of roots mined by cabbage root fly larvae at Cockburnspath, Berwickshire, 1999 (SED = standard error of the difference between means; d.f. = error degrees of freedom).

Damage assessment	Sprays directed over the bulb	Sprays directed over the foliage	Untreated control	SED (18 d.f.)
% root area attacked	14.6	17.3	18.9	2.49
% of roots attacked	52.1	54.5	54.0	3.37

Discussion & conclusions

In general control of cabbage root fly damage with four spray programmes of Birlane 24 was poor. Levels of pest damage were greatest in South Yorkshire where at least 40% of root area was mined and 90% of swedes attacked. In Devon and Berwickshire the degree of damage on individual bulbs was lower than in South Yorkshire (less than 20% area mined) but at least 40% of roots were damaged. The variable levels of damage between sites are probably a reflection of pest pressure, which was greater in South Yorkshire than in either Devon or Berwickshire.

There was some evidence in Devon to suggest that four sprays applied one to four weeks after the start of egg laying were more effective than delaying treatments until weeks five to eight. In South Yorkshire similar results were obtained in September and it is possible that damage levels could have been reduced even further had the first sprays been applied slightly earlier. However, at harvest sprays applied 5-8 weeks after the start of egg hatch produced the least damaged swedes. This was possibly because these sprays were applied between 5-28 August and would have left a significant residue on the crop before peak third generation activity, which occurred between 26 August and 9 September. In Berwickshire a directed spray over the bulb resulted in a lower area of root damage than a treatment applied over the foliage, although differences were not statistically significant.

Although levels of pest control were poor the use of timed programmes of sprays beginning shortly after first second generation eggs are laid or directed treatments over the bulb should not be discounted as a means of minimising crop damage. It is probable that results in these experiments reflect the limited efficacy of Birlane 24 against cabbage root fly. In the absence of any effective foliar sprays against the pest it is difficult to evaluate the efficacy of specifically timed or directed spray programmes. Limited evidence from this work suggest that further evaluation should be undertaken if and when new active ingredients become available.

In the meantime the lack of effective insecticides and/or the uncertain future of organophosphorus products, suggests that research should consider a range of alternative control measures which could be combined in an integrated strategy for control of the pest. Initially, this should include evaluation of the effect of irrigation on pest control both with and without novel insecticidal products. Covers have been shown to protect the crop from damage but a rigorous evaluation of the economics of this technique is required before further field experimentation.

Insecticides are likely to continue to be important in the control of cabbage root fly. However, concerns over their environmental impact suggests that any new actives will have less persistence than organophosphorus products and certainly insufficient to span the period of activity of the second and third generation of the pest. Therefore they should be considered only as a component of any integrated strategy.

In the long term, research should continue to develop integrated strategies for control of cabbage root fly. These will have a greater life expectancy and be more robust than a single component strategy, particularly any based on the use of insecticides alone.

Acknowledgements

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Thanks also to the ADAS site managers and to Dr R McKinlay of SAC for useful discussions during the preparation of these experiments and writing of the report.

Glossary

Critical risk period: the period during which a crop must be protected in order to avoid the most significant levels of pest damage.

Damage progression: the development of pest damage over time.

Foliar insecticide: an insecticide formulation usually applied as a liquid to the crop canopy, may or may not have soil activity.

Granular insecticide: an insecticide formulation which is applied as a solid to the crop, usually having soil activity in the case of non-systemic active ingredients, and root or foliar activity in the case of systemic active ingredients.

Pot trial: an experimental method using plants in pots treated with an insecticide product or control and exposed to non-dispersing life stages of the pest insect to test the efficacy of the product.