Project title:	**SWEDES: BIOLOGY AND CONTROL OF CABBAGE ROOT FLY**
Report:	**Annual report, January 1999, year 2 of 3**
Project number:	**FV 66a**
Project leader:	**Dr W E Parker** **ADAS** **Woodthorne** **Wolverhampton** **WV6 8TQ**
Key workers and roles:	
Somerset site manager:	**Mr S Tones: ADAS Starcross**
East Yorkshire site manager:	**Mr N Andrews: ADAS Wolverhampton**
Pot trials site manager: **(author of report)**	**Dr S A Ellis: ADAS High Mowthorpe**
Berwickshire site manager:	**Dr R G McKinlay: SAC Edinburgh**
Location:	**Devon, East Yorkshire, Berwickshire and ADAS High Mowthorpe**
Project co-ordinators:	**Mr A Ewan** **Mr M Holmes** **Mr J Jemmett**
Date commenced:	**19/05/97**
Date completed:	**31/03/00**
Keywords:	**Swedes, cabbage root fly, biology, control, insecticides**

©1998 Horticultural Development Council

CONTENTS

©1998 Horticultural Development Council

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 second year of study. In the final years of the project, the improved method for timing treatments will be used to evaluate the most promising new and traditional compounds under field conditions.

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. Identification of the critical risk period will be attempted by studying the progression of damage through the season.

In past HDC-funded work (Project FV 66), carbofuran and chlorfenvinphos were the most effective compounds available against cabbage root fly in swedes, but neither of them provided sufficiently reliable control. Pot trials will be used as a cost-effective method of screening a large number of compounds. Those insecticides which are the most effective will then be evaluated in field trials to develop a more reliable control strategy.

Summary of results to date

Please note - the approval status of insecticides mentioned in this report is listed in appendix 1.

Damage progression work

Results from the first year of work (1997) suggested that the majority of root damage occurred during the first seven weeks of second generation cabbage root fly activity. There was no increase in damage levels in terms of the percentage of root area attacked after the end of August despite continued moderate to high levels of egg laying. However, careful consideration of the data suggested that the use of percentage root area as an indicator of damage (assessed using a method devised in the 1950s and used as a standard tool by many projects since) may be misleading as it assumes that all swedes are of a similar size at harvest. This takes no account of the fact that roots were lifted over a four month period and substantially increased in size in that time. Therefore the apparent plateau in root damage after late August may

©1998 Horticultural Development Council

have been an effect of increasing root size, whereas in reality the absolute area of damage on swedes was increasing as root size increased. A new assessment technique which accounted for crop growth stage was developed and introduced for the 1998 work. In 1998, the area of damaged root was assessed and results showed that in Devon and East Yorkshire damage continued to increase throughout the season. In contrast, in Scotland from late September damage levels declined.

Egg numbers were generally low in 1998. In East Yorkshire first second generation eggs were laid between 15 and 21 July with peak oviposition between 21 July and 4 August. In Devon peak second generation egg lay occurred between 27 August and 8 September. A larger second peak occurred between 7 and 23 October, probably due to a third generation of the pest. Scotland recorded the highest peak of egg lay with 1.6 eggs/plant/day laid between 20 and 27 July.

Pot trials

During 1997, results suggested that only carbofuran had sufficient soil activity to give effective control of cabbage root fly larvae.

Work in 1998 compared the efficacy of chlorfenvinphos, fonofos, λ-cyhalothrin, carbofuran, chlorpyrifos and the coded products HDC 949A and HDC 685B. Swedes were grown in a silty clay loam soil collected from ADAS High Mowthorpe. Results confirmed the superiority of granular insecticides over foliar sprays. Carbofuran and HDC 949A were consistently the best treatments for controlling larvae and minimising root damage throughout the experiment

Action points for growers

Only tentative conclusions can be drawn from the first two years of this experiment. These will be confirmed and refined in later years of the project.

- **Timing of second generation treatments**: damage progression work suggests that there may be 14 days, or more, between the occurrence of the first second generation eggs and significant root damage. Therefore it may be possible to delay the application of second generation insecticides and so prolong their persistence later into the season. The time it takes eggs to hatch and larvae to develop to a size which cause significant root damage will be dependant on temperature and the HDC/HRI model can help to predict how long it is safe to wait before pesticides are applied. These conclusions are only preliminary and further work is necessary to validate this approach. In the meantime growers wishing to test the value of delaying second generation insecticides should do so only on a small area of crop.

- **Insecticide choice**: two years of pot experimentation have confirmed carbofuran as the most effective and persistent product for control of second generation cabbage root fly. A developmental granule trialed in 1998 also shows promise for the future.

©1998 Horticultural Development Council

Practical and financial benefits from study

During 1996 roughly 75% of root brassica crops were treated with insecticides for cabbage root fly control. A large proportion 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 147,668T. 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.

©1998 Horticultural Development Council

2. EXPERIMENTAL SECTION

A. 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 carbofuran and chlorfenvinphos, and even the best control is often inadequate. The industry's reliance on these compounds 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 result of a commercial decision to discontinue production. At present there is mounting pressure to reduce the use of organophosphorous insecticides in vegetable crops. Clearly, there is a need for more effective control programmes and the evaluation of alternative products.

Previous MAFF and HDC-funded work has contributed to the background of the present study. The most effective treatments have traditionally varied between regions. From 1986-89 ADAS and HRI Stockbridge House trials (Senior *et al.* 1992) showed carbofuran was often more effective than chlorfenvinphos, but in Devon, the opposite was true. HDC-funded work in 1991 and 1992 (Project FV 66) compared a range of strategies for the control of second generation cabbage root fly at commercial sites throughout Britain and evaluated the role of enhanced degradation (ED) of carbofuran. None of the insecticide programmes provided adequate control but those incorporating both chlorfenvinphos and carbofuran were better than either product on its own. Enhanced levels of carbofuran degradation were recorded at several sites but there was no correlation between levels of enhanced degradation and control. Improved control at some sites was shown to result from the use of cell-raised swedes treated with chlorpyrifos (as Dursban 4), but roots were often small and/or misshapen at harvest. Crop covers usually provided inadequate control, as the material was often torn by the wind and root weights were reduced.

The unreliability of existing control programmes is probably primarily due to the extended period during which the crop is exposed to egg-laying flies. Results from FV 66 showed that larvae and fresh damage were often present at harvest. This suggested that larvae arising from late second or third generation flies could cause significant damage, as well as those arising from early second generation activity. Thus while egg counts and the HDC/HRI predictive cabbage root fly model usefully provide a 'risk window', and an effective trigger for the initial second generation treatments, there is a need to establish the time of laying of second and third generation eggs which subsequently cause the most damage as larvae (the critical risk period). This is a primary objective of this project, and will enable chemical control to be targeted against the most potentially damaging insects. Once the critical risk period has been identified, new control programmes can be developed to protect the crop during this susceptible stage. The unreliability of existing insecticide recommendations means that alternative chemical strategies should be evaluated. Several new active ingredients, formulations and application methods are now available, and these require testing on the brassica root crop.

©1998 Horticultural Development Council

In summary, the objectives of the work done in the first two years of this project were:

1. To do damage progression experiments to identify the most damaging periods of cabbage root fly activity, and so identify when to concentrate the protection programme during the second and third generations.

2. To evaluate, using pot-based experiments, the efficacy of new active ingredients, formulations and applications techniques for controlling cabbage root fly damage on swedes.

In the final two years, the most effective products will be tested in the field with treatments timed to provide protection during the critical risk period identified from the damage progression work.

Please note: the approval status of insecticides mentioned in this report is listed in appendix 1.

B. PART I - DAMAGE ASSESSMENT WORK

Introduction

In replicated field plots sequential sampling techniques were used to deduce the most damaging period of cabbage root fly activity, and determine the optimal time for insecticide treatment, the critical risk period.

Materials and methods

Plots were set up in mid June in Berwickshire, early July in East Yorkshire, and mid July in Devon. All sites were sampled until late October/early November.

Layout

Before the start of second generation egg laying, plots four rows wide by 5 m long were marked out in four widely separated randomised blocks, each 30 m from the nearest headland.

Cabbage root fly egg sampling

Five plants in each block were labeled and sampled weekly for cabbage root fly eggs until the start of egg laying and fortnightly thereafter. On each occasion, soil was removed to a depth of 2 cm and a radius of 5 cm around each plant. The soil removed was replaced with silver sand or soil collected from a field not infested with cabbage root fly (e.g. a cereal field). The sample from each block was washed through a Fenwick can and the organic debris was extracted onto a fine sieve and washed onto a black filter paper. All hatched and unhatched cabbage root fly eggs were identified and counted.

Root sampling and damage assessment

©1998 Horticultural Development Council

Every two weeks, a sample of 20 roots was taken from each block (80 roots per treatment). The swedes were washed and the area damaged by cabbage root fly assessed. In 1997 a root damage index was calculated using a modified version of the technique described by King and Forbes (1954). However, this method was designed for use at harvest when most roots will, on average, be of a similar size. In this experiment swedes were sampled at two weekly periods from July until October so root area changed significantly as the crop matured. Consequently the plateauing of damage at the end of August noted in the 1997 experiment may have been a function of root expansion rather than any reduction in larval feeding. Therefore in 1998 an alternative root damage assessment was undertaken to take account of the increasing size of roots throughout the season.

During 1997 root growth stages were identified at the Scottish site and for each of these the subterranean root area, the area available for cabbage root fly attack, was determined. When subterranean root area was plotted against growth stage the resulting relationship was best described by a 3rd order polynomial of the form $y = - 0.934x^3 + 12.533x^2 - 7.14x$ (y - subterranean area, x = growth stage, $R^2 = 0.9255$). Taking the logarithm of both sides of this relationship produced a straight line which was then used to define the average subterranean root area at each growth stage.

Roots were assessed according to the percentage area with feeding damage. Percentages were estimated to the nearest 10%. The growth stage of the root was determined and its subterranean root area taken to equal the value from the regression line data (Appendix 2). This area was then multiplied by the percentage of root area with feeding damage to calculate the approximate area of root damaged.

Results and Discussion

Egg laying

Egg numbers were generally low in 1998. In Berwickshire first eggs were found on 10 July (Table 1). Oviposition then increased rapidly to reach a peak of 1.66 eggs/plant/day in the sample taken on 27 July. This was the highest level of egg laying recorded at all sites. Subsequently egg numbers decreased rapidly and none were recorded from 7 October onwards.

In Devon the first peak in oviposition was recorded from samples taken on 8 September (Table 2) with a second larger peak (0.73 eggs/plant/day) on 23 October, probably due to a third generation of the pest. By 5 November egg numbers were very low. In East Yorkshire (Table 3) the first second generation eggs were recorded between 15 and 21 July with peak oviposition of 0.56 eggs/plant/day between 21 July and 4 August. Egg laying then declined until 2 September after which a second smaller peak occurred between 2 and 15 September. Egg numbers then decreased at all subsequent sampling dates.

Damage progression

In Berwickshire the first root damage was recorded in samples taken on 27 July (Table 1, Figure 1). Levels of damage then continued to increase until 23 September,

©1998 Horticultural Development Council

with the most rapid change between 7 and 23 September. At the peak approximately 18 cm^2 of root was mined by cabbage root fly larvae. Subsequently damage levels declined.

In both Devon and East Yorkshire the area of root damage continued to increase throughout the experiment reaching a maximum of about 30 cm^2 at both sites (Tables 2 and 3, Figure 1). However the general progression of damage was slightly different at each site. In Devon there was a gradual increase to the peak. In East Yorkshire a rapid increase in root area damage between 4 and 21 August was followed by a less steep phase until 14 October, when the rate of root damage was again more rapid until 27 October.

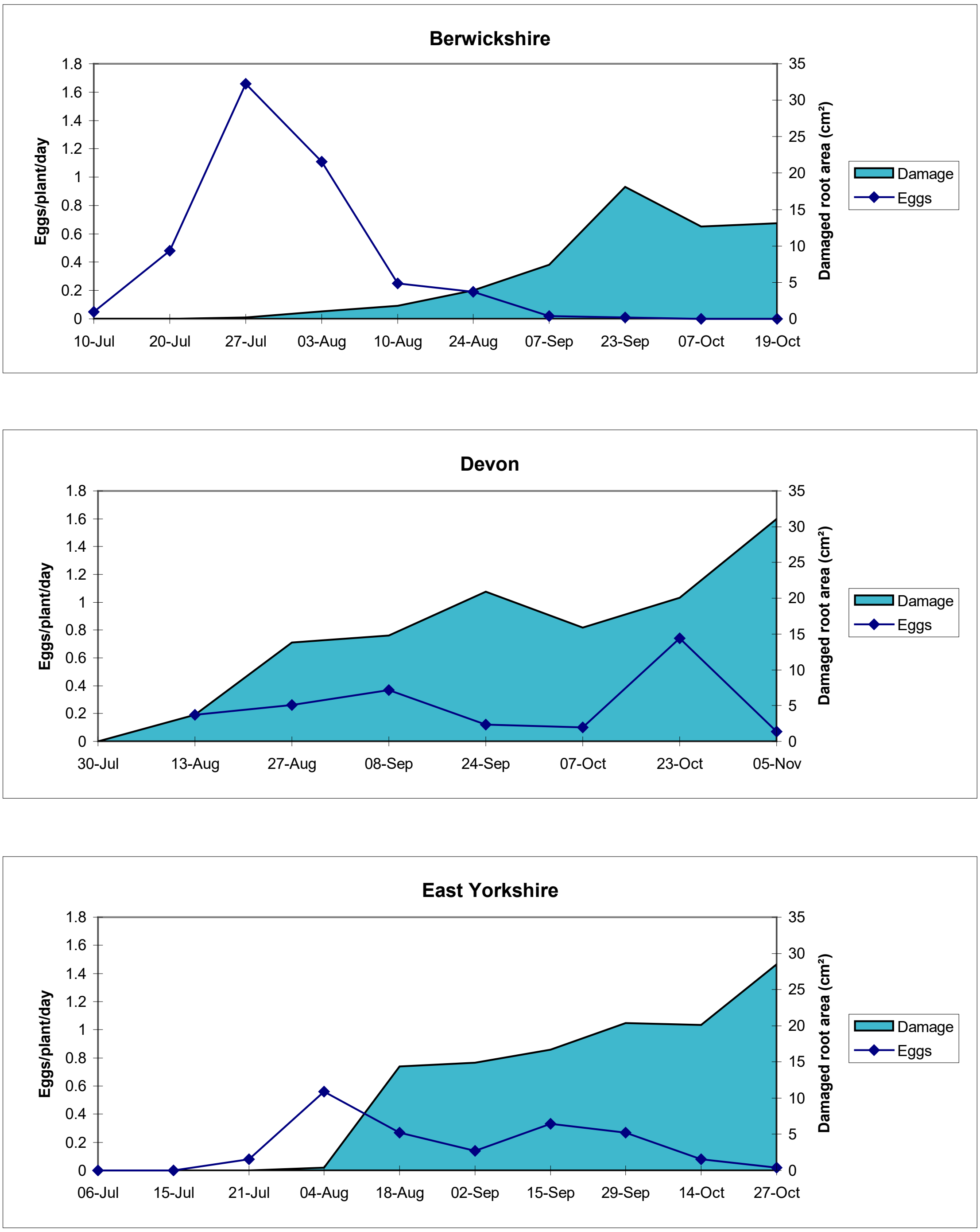
The timing of egg laying in relation to root damage (Figure 1) showed that in both Berwickshire and East Yorkshire there was an approximate 14 day interval between first eggs being laid and the first signs of crop damage.

Table 1. Cabbage root fly oviposition (numbers/plant/day) and damaged root area (%) at Berwickshire

Date	Number of eggs laid	Damaged root area
10 July	0.02	-
20 July	0.48	-
27 July	1.66	0.2
3 August	1.11	-
10 August	0.25	1.8
24 August	0.19	3.9
7 September	0.02	7.4
23 September	0.01	18.1
7 October	0	12.7
19 October	0	13.1

©1998 Horticultural Development Council

Figure 1. Cabbage root fly oviposition and damage progression in Berwickshire, Devon and East Yorkshire, 1998.



©1998 Horticultural Development Council

Table 2. Cabbage root fly oviposition (numbers/plant/day) and damaged root area (%) at Exminster, Devon

Date	Number of eggs laid	Damaged root area
30 July	-	0
13 August	0.19	3.7
27 August	0.26	13.8
8 September	0.37	14.8
24 September	0.12	20.9
7 October	0.10	15.9
23 October	0.74	20.1
5 November	0.07	31.1

Table 3. Cabbage root fly oviposition (numbers/plant/day) and damaged root area (%) at Rawcliffe, East Yorkshire

Date	Number of eggs laid	Damaged root area
6 July	0	0
15 July	0	0
21 July	0.08	0
4 August	0.56	0.4
18 August	0.27	14.4
2 September	0.14	14.9
15 September	0.33	16.7
29 September	0.27	20.4
14 October	0.08	20.1
27 October	0.02	28.5

©1998 Horticultural Development Council

Conclusions

In 1998 the progression of root damage varied between sites. At both English sites damage continued to increase throughout the experiment whereas in Scotland damage levels declined from late September onwards. Generally, these data contrast with the results from 1997 which suggest that damage levels remained relatively constant beyond the end of September. It is possible that this was an effect of the root damage index which failed to take account of the increasing size of swede bulbs throughout the season.

In both Berwickshire and East Yorkshire there were approximately 14 days between recording the first second generation eggs and significant root damage. Therefore it may be possible to delay the application of second generation insecticides so that they persist later into the season. The time it takes an egg to hatch and larvae to develop to a size which causes significant root damage is dependant on temperature. The HDC/HRI model can help to predict how long second generation pest insecticide programmes can be delayed without affecting root quality.

Also, although egg laying at the English sites continued throughout most of the experiment, it is unlikely that late laid eggs would have resulted in larvae which could significantly affect root damage. In Scotland egg laying have virtually stopped by 7 September and this could account for the reduction in root damage levels from 23 September. The thermal requirements for larval development discussed by Finch and Collier (1998) should help to determine the last eggs which will contribute to root damage.

In summary results from 1998 provide evidence of the existence of a critical risk period. Further work will identify this more precisely by taking into account the time between the start of second generation egg laying and the occurrence of crop damage. Also the threshold date will need to be determined after further oviposition is likely to affect significantly root damage.

©1998 Horticultural Development Council

PART II - POT TRIAL EXPERIMENTS

Introduction

The objective of this experiment was to identify, using pot trials, the most effective soil applied granules and spray treatments for control of cabbage root fly and their persistence.

Materials and methods

Swede seeds (cv Marion) were sown in soil in diameter plastic plant pots on 7 July 1998. A total of 200 pots were sown with three seeds per pot. Pots were then maintained in an insect-proofed glasshouse. Once seedlings had reached the three true leaf stage two were removed from each pot so that only one remained. In mid-July, at the start of second generation cabbage root fly egg laying, and when plants had reached the 4/5 leaf stage, a range of seven insecticide treatments were prepared and an untreated control. Batches of 25 plants were given one of the insecticide treatments. The complete treatment list is given in Table 4.

Table 4. Insecticide treatments

Code	Active ingredient	Product	Product rate/ha
P1	Untreated	-	-
Spray treatments			
P2	Chlorfenvinphos	Sapecron 240 ec (standard)	3 l/ha
P3	HDC 685B	-	4 l/ha
P4	Fonofos	Cudgel	3.18 l/ha
P5	λ Cyhalothrin	Hallmark	300 ml
Granule treatments			
P6	Carbofuran	Yaltox (standard)	27.5 kg/ha (0.18 g/plant)
P7	Chlorphyrifos	Suscon Indigo	50 kg/ha (0.33 g/plant)
P8	HDC 949A	-	26.7 kg/ha (0.18 g/plant)

Spray treatments were applied in 500 l/ha water equivalent using an Oxford Precision sprayer equipped with a 2 m boom and five 03F110 nozzles calibrated to operate at 2.0 bar pressure. Each batch of 25 plants was stood within an area of 5 x 2 m ($10m^2$). This entire area was then treated. With granular insecticide formulations individual pot doses of the product were weighed out in glass tubes. The chemical was then shaken around the base of the plant and incorporated just below the soil surface using a spatula. All treated plants and the untreated control were maintained in an insect-proof glasshouse.

©1998 Horticultural Development Council

On five occasions after insecticide treatment swede seedlings were inoculated with cabbage root fly eggs. The egg inoculation dates were:

A. Immediately post treatment
B. 1 week post treatment
C. 2 weeks post treatment
D. 3 weeks post treatment
E. 5 weeks post treatment

Cabbage root fly eggs were collected by taking soil samples from around the base of brassica plants using a dessert spoon. Eggs were extracted from the soil using a Fenwick can. In addition, a laboratory culture of the pest was also used to provide eggs. Adult flies were hatched from pupae and kept in a nylon mesh cage approximately 1 m long x 0.5 m wide x 0.5 m high. This was housed in a laboratory at a temperature of approximately 20°C with an 18 hour photoperiod. The flies were provided with water, 10% sucrose solution and marmite sprinkled with brewers yeast and soya flour. All were provided on a wad of absorbent cotton wool within a Petri dish. The water and sucrose were allowed to soak into the cotton wool whereas the marmite was smeared over its surface and the flour and yeast sprinkled onto this. Oviposition sites consisted of a piece of swede which had been cut using a scalpel blade to give a number of slits in its surface. These had proved to be very attractive for ovipositing flies in previous experiments. The swede was contained with a Petri dish on a piece of damp black filter paper. Black filter paper was used to ensure that any eggs laid under the swede were clearly visible.

On each inoculation date five replicates of each insecticide treatment were inoculated with cabbage root fly eggs. The aim was to inoculate each test plant with up to 30 eggs. The actual number of eggs inoculated was 13, 18, 12, 17 and 18 on each of inoculation dates A, B, C, D and E, respectively. Once plants had been inoculated they were returned to the glasshouse and arranged in a randomised block design. Each inoculation date was treated as a separate experiment.

Spare eggs from each inoculation date were maintained in a covered Petri dish on moist black filter paper at room temperature. These were observed daily and the number hatched recorded to determine egg viability. This continued until all eggs had hatched or there was no change in the number hatched on five consecutive days. This was not possible for all inoculation dates due to the low number of eggs available.

Approximately five weeks after egg inoculation the pots for each inoculation date were assessed for the presence of cabbage root fly larvae or pupae and their damage. This was done by immersing the soil from each pot within a 60-mesh sieve in saturated magnesium sulphate. The swedes were also washed clean of any soil with a high pressure hose to ensure that no larvae or pupae were trapped in the roots. Any larvae or pupae that floated to the surface were removed and counted. The plant from each pot was also assessed to determine the percentage root area damaged by the pest.

©1998 Horticultural Development Council

Statistical analysis

Data sets for both numbers of cabbage root fly larvae or pupae and root damage were subjected to statistical analysis. The basis upon which statistical inferences were made was the analysis of variance. Multiple comparison of treatments was done using Duncan's Multiple Range Test. These are interpreted with caution but are useful when considering the merits of any statistical inferences arising from the analysis of variance.

Results and Discussion

Egg viability

The results of egg viability testing are shown in Table 5. Viability ranged from 70-86%. In view of the numbers of eggs inoculated on each occasion this should have been sufficient to ensure that enough larvae emerged from eggs and were potentially available to attack the plants. At egg inoculation date B and D (1 and 3 weeks post treatment) there were too few eggs to undertake viability testing.

Table 5. Viability of eggs used to inoculate test plants immediately after insecticide treatment or up to five weeks subsequently

Egg inoculation date	Number of eggs tested	Number hatched	% viability	Source of eggs
A	42	36	86	Swinefleet, East Yorkshire
C	11	8	73	Swinefleet, East Yorkshire
E	20	14	70	Laboratory culture
Mean viability	-	-	76	-

Numbers of cabbage root fly larvae/pupae

The mean numbers of cabbage root fly larvae or pupae recovered from each treatment are given in Table 6. Numbers of larvae and pupae differed significantly between treatments on each egg inoculation date. ($P < 0.001$ for egg inoculations immediately after insecticide treatment and three and five weeks later, $P < 0.01$ for inoculation one week post treatment and $P < 0.05$ for inoculation two weeks post treatment). In general, carbofuran and HDC 949A gave the best control of cabbage root fly throughout the study. Chlorpyrifos was also very effective from two weeks after insecticide treatment. On average, HDC 685B was the best of the foliar insecticide sprays but these formulations gave poorer pest control than the granules. Duncan's Multiple Range Test indices are given to show differences between individual treatments.

©1998 Horticultural Development Council

Table 6. Mean numbers of cabbage root fly larvae and pupae

Treatment	Egg inoculation date				
	A	B	C	D	E
P1 Untreated	6.8 d	8.8 d	2.4 ab	5.0 bc	1.4 a
P2 Chlorfenvinphos	1.6 ab	3.8 abc	1.6 ab	7.8 c	5.8 c
P3 HDC 658B	2.6 bc	4.2 abcd	2.0 ab	3.2 ab	1.0 a
P4 Fonofos	4.6 c	5.4 bcd	1.8 ab	3.2 ab	3.8 b
P5 λ Cyhalothrin	8.0 d	6.8 cd	3.6 b	4.4 b	3.4 b
P6 Carbofuran	0 a	0 a	0 a	0 a	0.2 a
P7 Chlorpyrifos	4.4 c	4.0 abc	0.4 a	0.6 a	0.2 a
P8 HDC 949A	0.8 ab	1.2 ab	0 a	0 a	0 a
SED (28 DF)	0.95	2.13	1.13	1.58	0.91

a, b, c and d are Duncans Multiple Range Test indices, values followed by the same letter are not significantly different P < 0.05.

Root damage

Root damage differed significantly between treatments on all egg inoculation dates except one week after treatment (Table 7). Probability levels were P <0.001 immediately after treatment, and three and five weeks after treatment and P <0.05 two weeks after treatment. Throughout the experiment the lowest level of damage was recorded in pots treated with carbofuran or HDC 949A. Levels of damage in chlorpyrifos treated pots were also low from two weeks after treatment. HDC 685B was generally the most effective of the foliar sprays but these treatments were noticeably poorer than granular formulations. Duncan's Multiple Range test indices are again provided for separation of individual treatment means.

©1998 Horticultural Development Council

Table 7. Mean % damaged root

Treatment	Egg inoculation date				
	A	B	C	D	E
P1 Untreated	19.4 bc	11.8	5.4 ab	19.0 bc	12.2 b
P2 Chlorfenvinphos	4.2 a	11.4	6.0 ab	23.4 c	22.0 c
P3 HDC 685B	5.8 a	9.8	10.4 b	6.4 ab	3.0 a
P4 Fonofos	9.6 ab	11.4	7.4 ab	11.4 abc	19.0 bc
P5 λ Cyhalothrin	23.0 c	14.0	12.0 b	22.0 c	18.0 bc
P6 Carbofuran	0.4 a	0.2	0 a	1.2 a	1.4 a
P7 Chlorpyrifos	10.4 ab	8.2	0.4 a	3.0 a	0.8 a
P8 HDC 949A	2.0 a	2.8	1.2 a	0 a	0 a
SED (28 DF)	4.99	4.87	4.08	5.89	3.84

a, b and c are Duncan's Multiple Range test indices. Values followed by the same letter are not significantly different ($P < 0.05$).

Conclusions

Carbofuran and HDC 949A were consistently the best treatments at controlling larvae and minimising root damage throughout the experiment. These treatments were equally effective when eggs were inoculated either immediately or five weeks after insecticide application.

Chlorpyrifos as Suscon Indigo was also very effective from two weeks after insecticide application. This is a slow release formulation and it is possible that it took up to two weeks before sufficient active ingredient was available to control the pest.

As in 1997, control of cabbage root fly was better with granular applications than with foliar sprays. This is probably because a large proportion of the spray was intercepted by the foliage and eggs were inoculated around the base of the plant where there were probably low levels of insecticide. Chlorfenvinphos as Sapecron 240 EC generally gave poor control of cabbage root fly and it is possible that in the field this product has some deterrent effect on ovipositing flies. This may also be true of the other foliar sprays tested.

The experimental product HDC 949A was very promising and noticeably better than the formulation (Exp 60949A) trialed in 1997.

©1998 Horticultural Development Council

ACKNOWLEDGEMENTS

We extend our thanks to the Horticultural Development Council for funding this work, and to Messrs. A Ewan, M Holmes and J Jemmett for acting as Project co-ordinators.

The co-operation of the growers hosting these experiments is appreciated.

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.

APPENDIX 1

Active ingredient	Product name	Approval status
λ Cyhalothrin	Hallmark	none
Carbofuran	Yaltox (standard)	on label
Chlorfenvinphos	Sapecron 240 ec (standard)	withdrawn*
HDC 685B	-	none
HDC 949A	-	none
Fonofos	Cudgel	none (module drenches only)

Chemical names, product names and approval status on swedes for insecticides mentioned in this report, as confirmed by the Pesticides Safety Directorate 23 March 1998.

* The label recommendation for chlorfenvinphos as both Sapecron 240 ec and Birlane 24 has been withdrawn. A specific application for an off-label approval to replace this is in prepartion at HRI Stockbridge House under the HDC SOLA programme. However, a successful outcome to this application is not a foregone conclusion.

©1998 Horticultural Development Council

REFERENCES

Collier, R H and Finch, S (1988). Thermal requirements for cabbage root fly, *Delia radicum*, development. *Progress on Pest Management on Field Vegetables* (eds. Cavalloro, R and Pelerents, C). Rotando - D G XIII - Luxembourg no. EUR 10514. Balkema Rotterdam.

Finch, S and Collier, R H (1986). Forecasting the times of attack of the cabbage root fly (*Delia radicum*) on vegetable brassica crops. *Aspects of Applied Biology,* **12,** pp. 37-46.

HDC (1993). Cabbage root fly control in swedes/turnips: Project FV 66.

King and Forbes (1959). Control of Root Maggots in Rutabagas. *Journal of Economic Entomology,* **47** (4), pp. 607-615.

MAFF (1996). Basic Horticultural Statistics. MAFF Publications, London, pp.

Senior, D; Antill, D N; Emmett, B J; (1992). Evaluation of insecticides against cabbage root fly in cell-raised swedes. *Tests of Agrochemicals and Cultuvars No. 12, (Annals of Applied Biology* 120 Supplement), pp. 2-3.

©1998 Horticultural Development Council