HDC Project Report

Project no. FV 159

Control of Cabbage Root Fly on Outdoor Radish

By

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AUTHENTICATION

I declare that this work has been done under my supervision according to the procedures described herein and that this report represents a true and accurate record of the results obtained.

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RELEVANCE TO GROWERS AND PRACTICAL APPLICATION

Project objectives

To investigate methods of controlling cabbage root fly on outdoor radish by:

1. Testing the efficacy of new candidate insecticides, and new methods of applying established insecticides.
2. Investigating the efficacy of supplementary, short persistence insecticides timed to coincide with peak risk periods of cabbage root fly activity as indicated by the HDC-funded cabbage root fly forecast.
3. Investigating the patterns of adult activity, egg laying, and development of root fly damage in the radish crop.

Key results

The main findings were:

1. Existing on- and off-label treatments for cabbage root fly control on radish were generally not effective, even when pest attack was low.
2. The best alternative to current control recommendations would be the use of a chlorpyrifos seed treatment (e.g. 'Gigant'). Other seed treatments were either not effective (e.g. tefluthrin) or phytotoxic (e.g. chlorfenvinphos).
3. Post-emergence spray treatments timed to coincide with the main 'risk period' (crop emergence to 7 days before harvest) did not improve the level of control given by standard treatments applied at drilling.
4. Egg-laying could occur at any time from crop emergence onwards, but tended to peak close to harvest. The pattern of adult fly activity also influenced the pattern of egg-laying. Larvae hatching from eggs laid within 7 to 10 days of harvest did not appear to contribute to crop damage.

Opportunity for application

1. Chlorpyrifos seed treatment on outdoor radish is not currently Approved and cannot be legally used commercially at present unless treated seed is imported from outside the UK. A Specific Off-label Approval (SOLA) application for chlorpyrifos to be applied to radish seed is currently being made with the support of HDC.
2. The finding that the use of post-emergence spray treatments does not generally enhance the level of control means that growers should only use this approach where experience on their own crops suggests that such treatments are beneficial. Growers not currently using post-emergence sprays have little justification to start doing so.

Summary

Project scope and objectives

Cabbage root fly grubs attack the marketable part of the crop - the roots - causing unsightly mines. Grubs can also tunnel inside apparently undamaged roots. Damage levels can vary considerably on different sowings through the season, but even a relatively low level of attack makes it difficult and expensive to grade out the damaged roots.

The currently available chemical control options for cabbage root fly on radish are limited. Only one active ingredient, chlorfenvinphos (as Birlane 24 or Sapecron 240 EC) has a label recommendation for cabbage root fly control on radish. While this treatment is adequate when pest pressure is low, control during peaks of cabbage root fly activity is often poor. Other insecticides which can be used under Specific Off-Label Approvals (SOLA's) are chlorpyrifos (as Dursban 4) and trichlorfon (as Dipterex). Although commonly used, the efficacy of these treatments has never been tested experimentally. Experience suggests that their effectiveness is probably limited.

This project was started in 1993 to investigate possible new approaches to the control of cabbage root fly on radish.

The aims of the project were three-fold:

1. To investigate the use of seed treatments as an alternative to the standard chlorfenvinphos pre-drilling treatment.
2. To assess the efficacy of the existing SOLA treatments.
3. To investigate the relationship between the pattern of cabbage root fly egg-laying on the radish crop and the subsequent appearance of damage.

Summary of results

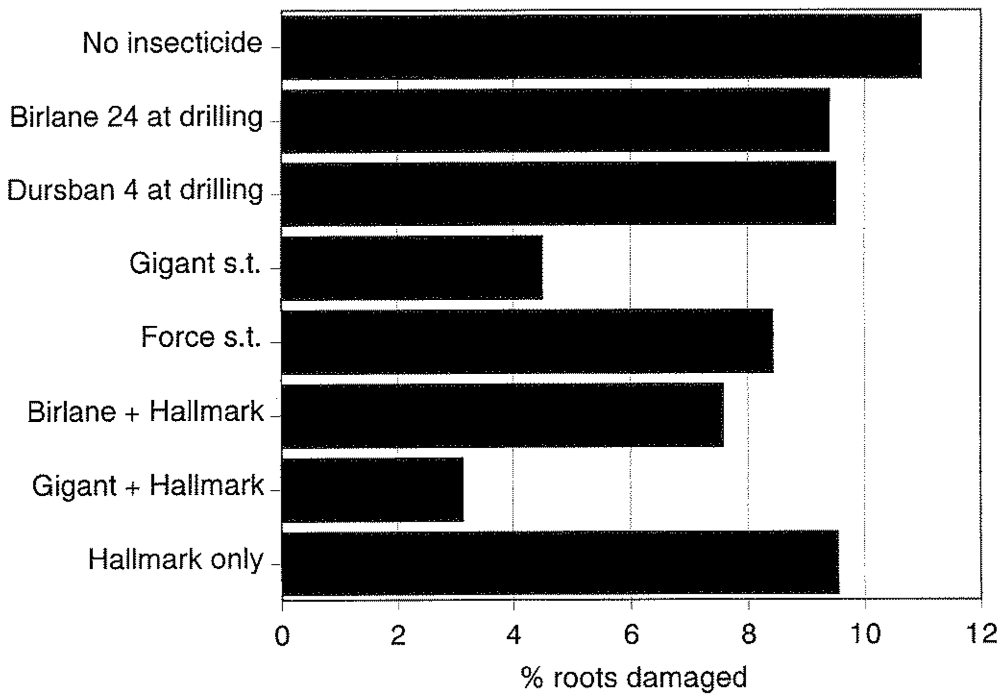
Between 1993 and 1995, ten trials were done, five on mineral soils in Kent (two in 1993, two in 1994 and one in 1995), and five were done on organic soils (one in Lancashire in 1994, two in Lancashire in 1995, and two in Norfolk in 1995). The trials were as close to commercial reality as possible. All the work was done on farms which grow radish regularly, trials were grown alongside commercial radish crops, all seed (cv. Marabelle) was drilled using the farms' own equipment, and all inputs other than insecticides were as per farm practice. A range of different treatments were used, including all the existing on and off-label treatments, plus film-coated seed treatments including Force (tefluthrin) and Gigant (chlorpyrifos). Post-drilling supplementary spray treatments (i.e. in *addition* to a standard Birlane 24 treatment at drilling) were also tried in each year. These were modified from year to year in the light of the previous year's results.

Alongside each trial, a complementary experiment aimed at identifying the relationship between the pattern of egg-laying and the appearance of damage on the crop was also done. The aim of this was to help identify a 'risk window' in which post-emergence spray treatments could be best applied.

The level of cabbage root fly attack which occurred on most of the trials was disappointingly low. Nonetheless, where useful results were obtained, the pattern of

treatment effects was very consistent from site to site (Figure A). This was that the existing on and off-label treatments gave very little (none in most trials) control of root fly damage. Of the seed treatments, only chlorpyrifos (Gigant) gave consistent significant reductions in damage. However, even with this treatment, only partial control of damage was achieved, and this tended to be proportionately less as the overall pest pressure increased. The use of post-emergence spray treatments to control adults (either in addition to a drilling treatment or on their own) did not improve the level of control. Note that the worst damage occurred on organic soil sites - insufficient attacks occurred at the mineral soil sites to thoroughly test the treatments.

Figure A. Effect of different treatments on the percentage of roots damaged by cabbage root fly (average of 3 organic soil sites).



The work on the relationship between egg-laying and subsequent damage showed that egg-laying started at crop emergence and tended to peak in the week before harvest, although the level of adult activity also influenced the pattern of egg-laying. The interval between egg-laying and the appearance of damage averaged about 7 to 10 days, indicating that larvae hatching from eggs laid within a week of harvest do not cause damage to the crop.

Action points for growers

- Continue to use existing options (Birlane or Dursban applied at drilling) for cabbage root fly control for the time being. These will sometimes still give some degree of control.
- In the event that chlorpyrifos seed treatment becomes available (see below), this should be used in preference to existing treatments.
- There is little point in applying post-emergence sprays to control adults unless you have good evidence that these are having some effect in your situation. Hallmark

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is *not* Approved on radish in any case. Where post-emergence treatments (e.g. Dipterex) are used, there is no point in applying a treatment within 7 days of harvest.

Practical and financial anticipated benefits

1. At present, Gigant seed treatment cannot legally be used by commercial radish growers unless seed is treated outside the UK and then imported. HDC is coordinating efforts to apply for a SOLA which would effectively be a 'change of use' for chlorpyrifos, allowing it to be used as a seed treatment. If this happens, then Gigant-treated seed will quickly become available to radish growers, who can then start to realise the economic benefits of improved control. The likely cost of the seed treatment on radish is unknown, but it would probably be competitive with existing treatments. The current cost of Gigant on other brassicas is around £40/ha, comparing favourably with a Birlane application costing *c.* £70/ha.
2. Growers using post-emergence spray treatments can save the cost of these treatments as they are not effective in most situations. Growers who do not currently use these treatments do not need to start now.
3. If chlorpyrifos seed treatment does become available, the overall amount of insecticide applied to the radish crop will be substantially reduced, and thus its use will be in line with the spirit of most integrated crop management protocols.

EXPERIMENTAL SECTION

Introduction

As a root brassica, radish is particularly prone to quality-reducing attacks by cabbage root fly. Larvae feed on the developing roots causing unsightly mines, and can sometimes also burrow into the root. As the root is the harvested part of the plant, such damage can result in an unacceptably high percentage of the crop becoming unmarketable.

The chemical control options for cabbage root fly currently available to radish growers are limited. Only one active ingredient, chlorfenvinphos (as Birlane 24 and Sapecron 240 EC) has a label recommendation for cabbage root fly control on radish, and the efficacy of off-label approvals such as the use of chlorpyrifos (as Dursban 4) and trichlorfon (as Dipterex 80, usually used as a post-emergence treatment to supplement an insecticide applied at drilling) has never been tested experimentally. While these treatments are adequate when pest pressure is low, control during peaks of cabbage root fly activity is often poor due to higher pest pressure. Regular use of chlorfenvinphos on ground repeatedly cropped with radish may also lead to problems with enhanced degradation, although this has not yet been confirmed in the field in the UK.

With increasing consumer concern over pesticide residues, there is a need to ensure that any insecticides applied to food crops are applied as effectively and as sparingly as possible consistent with effective control. Such an approach, if successful, also reduces costs to growers. This work investigates different approaches to the chemical control of cabbage root fly control through the use of seed treatments and the possibility of using the HDC-funded cabbage root fly forecast as a tool for rationalising the use of supplementary insecticide treatments. To achieve a greater understanding of the pattern of cabbage root fly attack on a radish crop, observations on cabbage root fly activity in relation to the timing of damage are also necessary.

Objectives

1. Test the efficacy of new candidate insecticides, and new methods of applying established insecticides.
2. Investigate the efficacy of supplementary, short persistence insecticides timed to coincide with peak risk periods of cabbage root fly activity as indicated by the HDC-funded cabbage root fly forecast.
3. Investigate the patterns of adult activity, egg laying, and development of root fly damage in the radish crop.

Materials and methods

Experiment site location

The experiments were carried out under conditions as close to commercial reality as possible. All the work was done on farms which grow radish regularly (on both mineral and organic soils). Experiments were done in or alongside commercial radish crops, all seed was drilled using the farms' own equipment (see Appendix 1), and all inputs other than insecticides were as per farm practice. As far as possible all experiments were timed to coincide with peaks of cabbage root fly activity as indicated by the HDC cabbage root fly forecast. Experimental site locations, drilling and harvest dates are given in Table 1.

Table 1. Experiment site locations, soil type, harvest and drilling dates.

Expt. no.	Location	Year	Soil type	Drilled	Harvested
1	Kent	1993	Mineral	28 June	22 July
2	Kent	1993	Mineral	19 August	16 September
3	Kent	1994	Mineral	12 July	3 August
4	Kent	1994	Mineral	24 August	26 September
5	Lancashire	1994	Organic	26 July	23 August
6	Kent	1995	Mineral	5 July	27 July
7	Lancashire	1995	Organic	12 May	15 June
8	Lancashire	1995	Organic	19 July	15 August
9	Norfolk	1995	Organic	15 May	15 June
10	Norfolk	1995	Organic	12 July	9 August

Insecticide treatments

The insecticide treatments used in each year are shown in Table 2. All seed (cv. Marabelle in all trials) was supplied by Nickersons Seeds Ltd. Film-coated seed treatments were done by Seedcote Systems Ltd. Untreated seeds received a 'blank' (no insecticide) seed coating.

The post-drilling spray treatments (Table 2) were intended to be applied as programmes of applications made at about 5 day intervals. The principle was to test the use of the HDC cabbage root fly forecast to identify the critical 'window' during which such post-emergence spray treatments were likely to be most effective. The forecast can predict the development rate of cabbage root fly eggs and larvae. These data were used in conjunction with an estimated harvest date to generate a 'last significant egg-lay date' for the experimental crops. After this date, there was no point in applying insecticides to control newly-hatching larvae, as they would not start to cause damage before the crop was harvested. The 'last effective egg-lay date' for each experiment was calculated from the HDC cabbage root fly forecast once sowing and anticipated harvest dates were known. This was approximately seven days before harvest in each case. In 1993, the timing of the end of three programmes of Dipterex sprays was varied in relation to the calculated last-effective egg-lay date to aid in the validation of this approach. In 1994 and 1995, the work concentrated on the efficacy of post-emergence spray programmes. Final applications were always made as close as possible to the last effective egg lay date (see Appendix 2 for application dates).

Experimental design & analysis

Each experiment was a randomised complete block design with each treatment replicated five times. Untreated plots were replicated twice. Plot size was six m by one bed (five m by one bed in Lancashire in 1994). Results were analysed by analysis of variance. Andersen-Darling tests indicated that all raw data sets were not normally distributed, and so appropriate transformations (usually square-root transformation) were applied to the data prior to analysis of variance. Differences between means were tested using Duncan's multiple range test.

Table 2. Insecticide treatments used in experiments in Lancashire in 1994 and 1995 (a.i. = active ingredient; s.t. = seed treatment; * = rate for single application; **Y** = treatment used, n = treatment not used).

Treatment	**a.i.**	**g a.i. ha^{-1}** (spray treatments)	**g a.i. 100,000 seeds^{-1}** (seed treatments)	**Experiment** 1993 1	1993 2	1994 3	1994 4	1994 5	1995 6	1995 7	1995 8	1995 9	1995 10
'Drilling' treatments													
No insecticide	-	-	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Birlane 24 at drilling	chlorfenvinphos	2352	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Dursban 4 at drilling	chlorpyrifos	960	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Gigant seed treatment.	chlorpyrifos	-	9.8										
Birlane seed treatment	chlorfenvinphos	-	9.8	Y	Y	n	n	n	n	n	n	n	n
Force seed treatment	tefluthrin	-	9.8	Y	Y	n	n	n	n	n	n	n	n
Force seed treatment	tefluthrin	-	40.0	n	n	Y	Y	Y	Y	Y	Y	Y	Y
'Drilling' +													
post-emergence treatments													
Birlane + Dipterex (early)*	chlorfenvinphos + trichlorfon	2352 + 400*	-	Y	Y	n	n	n	n	n	n	n	n
Birlane + Dipterex (late)*	chlorfenvinphos + trichlorfon	2352 + 400*		Y	Y	n	n	n	n	n	n	n	n
Birlane + Dipterex (normal)*	chlorfenvinphos + trichlorfon	2352 + 400*		Y	Y	Y	Y	Y	n	n	n	n	n
Birlane + Hallmark (normal)*	chlorfenvinphos + λ-cyhalothrin	2352 + 7.5*	-	n	n	Y	Y	Y	Y	Y	Y	Y	Y
Gigant + Hallmark (normal)*	chlorpyrifos + λ-cyhalothrin	s. t. + 7.5*	9.8	n	n	n	n	n	Y	Y	Y	Y	Y
Hallmark (normal)*[+]	λ-cyhalothrin	7.5*	-	n	n	n	n	n	Y	Y	Y	Y	Y

*'**Early**' = last application made approximately 4 days *before* 'last effective egg lay-date'.
'**Late**' = last application made approximately 4 days *after* 'last effective egg lay-date'.
'**Normal**' = last application made *on* 'last effective egg lay-date'.

[+] Hallmark applied post-emergence only

Root damage assessments

At harvest, a sample of roots (200/plot in 1993 and 1994, 150/plot in 1995) were harvested from the centre rows of each plot; the last 0.5 m of row at the end of each plot were *not* used for sampling. The tops were trimmed off and the roots washed prior to assessment. The root surface was examined for cabbage root fly mines and scored as either damaged or undamaged. Each root was then cut open to record the incidence of internal damage.

Pattern of adult fly activity, egg-laying and damage development

Adult fly activity was monitored in each experiment using yellow water traps. Traps were placed on the ground in the middle of each of three beds spaced evenly through the experiment area. At drilling, each trap was half-filled with clean water and a drop of Teepol (or washing-up liquid) added to reduce surface tension. At five day intervals from drilling until harvest, the trap contents were collected and returned to the laboratory for identification. The trap was re-filled with clean water and Teepol after each collection.

To determine the pattern of egg-laying and subsequent damage development, a 20 m section of untreated bed was divided into five or six plots (depending on the expected experiment duration) at drilling. All plots except one were covered with 10 g/m^2 non-woven fleece. Five days after drilling, three 30 cm length of row were dug up (removing plants and soil to five cm depth in a band three cm wide centred on the plant row) from each of the five plots, minimising the uncovered time as much as possible during the sampling. The samples from each plot were bagged separately (the three 30 cm samples were bulked for each plot), and returned to the laboratory for extraction of cabbage root fly eggs. After each egg-sampling, a further plot (four m of bed) was uncovered. This process was repeated at five day intervals until harvest. Eggs were extracted from the soil by flotation in the laboratory and identified. Thirty five of the plants retained from the egg-sampling (see above) were assessed for the presence or absence of cabbage root fly damage.

Results

1993 work

Insecticide efficacy

Experiment 1 (June sowing). Despite being drilled at the time of the forecast start of second generation cabbage root fly activity, no cabbage root fly damage was recorded in this trial at harvest. However, the Birlane WP (chlorfenvinphos) film-coat treated seed was found to be phytotoxic, causing severe crop stunting. This effect was quantified at harvest by assessing the total fresh weight of 200 roots from each plot (Figure 1). Significant differences were found between treatments (F (variance ratio) = 11.78, 24 d.f., $p<0.001$) with the mean fresh weight of 200 plants grown with Birlane WP seed treatment reduced by 54% compared with untreated plants (Figure 1).

Experiment 2 (August sowing). A moderate cabbage root fly attack developed on this trial. At harvest, an average of 7.8% of roots in untreated plots were found to have cabbage root fly damage (Figure 2, all categories of damage pooled). Cabbage root fly damage was numerically lower on plots treated with insecticide compared with untreated plots, but analysis of variance indicated that there were no significant differences between treatments ($F = 0.58$, 24 d.f., $p = 0.782$). The Birlane WP seed-treatment was again found to be phytotoxic, though fresh weights for each treatment were not recorded for this trial. The use of the supplementary Dipterex 80 applications did not improve the level of control.

Cabbage root fly activity

Adult monitoring. No adult flies were caught in the traps during Experiment 1 (June sowing), and only one female fly was caught (on 8 September) during Experiment 2 (August sowing), indicating low levels of fly activity during both trials.

Pattern of egg-laying and root damage. Few eggs were recovered from the sequentially uncovered plots during Experiment 1; meaningful conclusions could not be drawn from these results. Significant egg-laying did occur on Experiment 2. Plots which were uncovered at the time of crop emergence (24 August) were found to contain low numbers of cabbage root fly eggs by 29 August, indicating that egg-laying had started almost immediately, although eggs were not found in the 'no cover' plot until 8 September. This probably reflects the low level of adult cabbage root fly activity. However, virtually all plots uncovered by 3 September were found to contain eggs by 8 September, some two weeks after crop emergence. The highest number of eggs was found on the last sampling date (16 September), the day of crop harvest.

Averaging the number of unhatched eggs found in those plots uncovered prior to each sampling date and relating these to the proportion of roots showing damage on each sampling occasion (Figure 3) gave the best picture of the pattern of egg-laying and damage (unhatched eggs gave an indication of the number of new eggs laid between each sampling occasion; hatched eggs may have been present on earlier sampling occasions). Egg-laying started at a relatively low level soon after emergence and remained at low levels until the crop was close to harvest, when a large increase in unhatched eggs was recorded (see 16 September sample date, Figure 3). No damage

Figure 1. Total harvest fresh weight (g) of 200 radish roots from different treatments in Experiment 1.

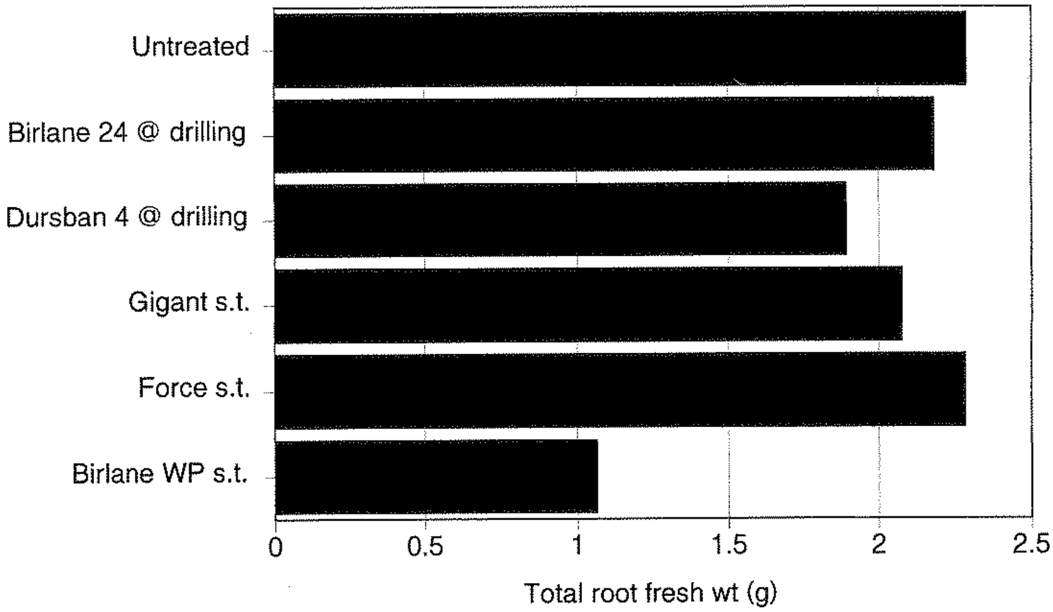
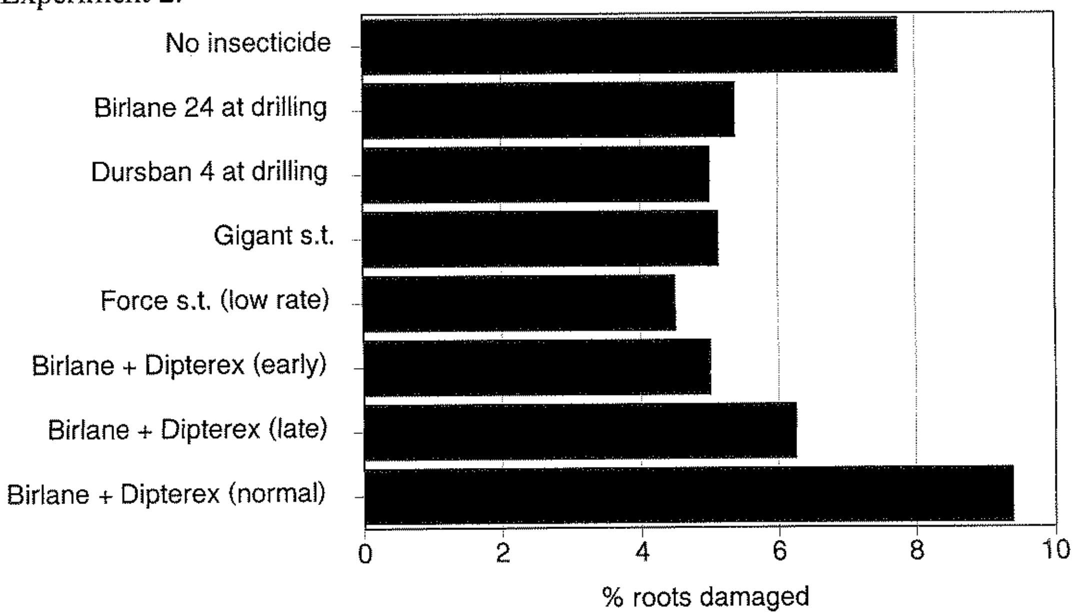
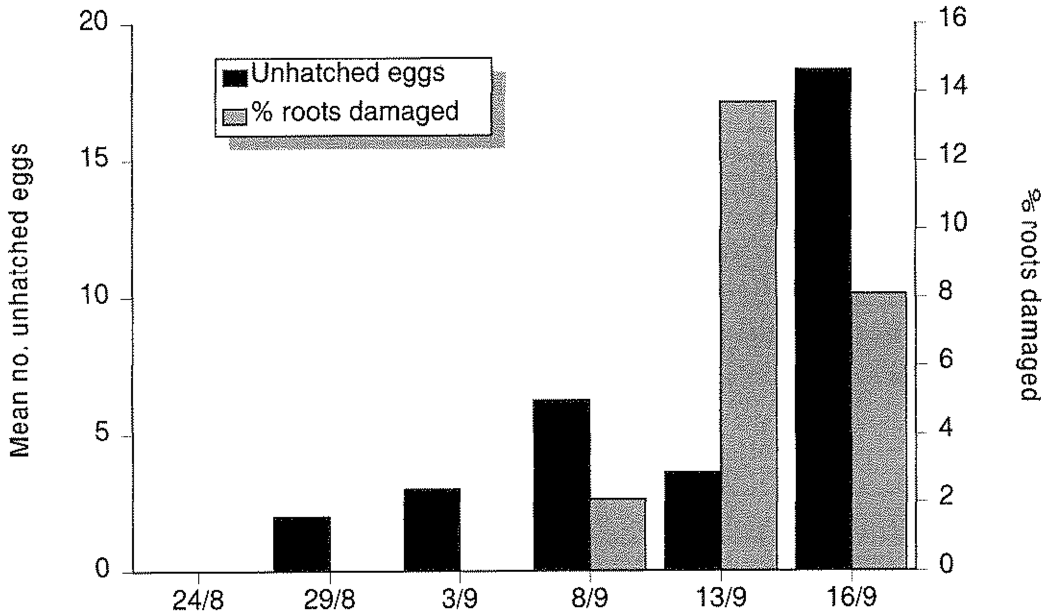


Figure 2. Percentage of radish roots attacked by cabbage root fly at harvest on Experiment 2.



was recorded from any plot until 8 September (20 days after drilling and two weeks after emergence). The majority of damage occurred in the 14 day period immediately prior to harvest (between 3 September and 16 September, Figure 3), even in those plots which had been uncovered for the majority of the duration of the trial. In plots uncovered on or after 29 August, it took at least six to 10 days for damage to appear subsequently in those plots. Hence no damage was recorded from the plot uncovered on 13 September, three days before harvest.

Figure 3. Experiment 2, Kent 1993: pattern of cabbage root fly egg-laying and the percentage of roots damaged.



1994 work

Insecticide efficacy

Experiment 3 (Kent, July sowing). Despite being drilled at the time of the forecast start of second generation cabbage root fly activity, only a very low level of cabbage root fly damage was recorded in this trial at harvest (Figure 4). However, the highest level of damage was recorded on untreated plots and damage was consistently lower on all treated plots. Analysis of variance indicated that differences between individual treatments were almost significant ($F = 2.43$, 29 d.f., $p = 0.051$). Analysing pooled data from all treated plots in comparison to untreated controls did indicate that overall, treatment had significantly reduced the level of damage ($F = 15.0$, 34 d.f., $p < 0.001$). The overall mean percentage root damage on untreated plots was 1.04%, and 0.08% on all treated plots.

Experiment 4 (Kent, August sowing). Very little damage occurred on this experiment (Table 3) and no meaningful conclusions could be drawn from the data.

Figure 4. Percentage root damage on treated and untreated plots from Experiment 3.

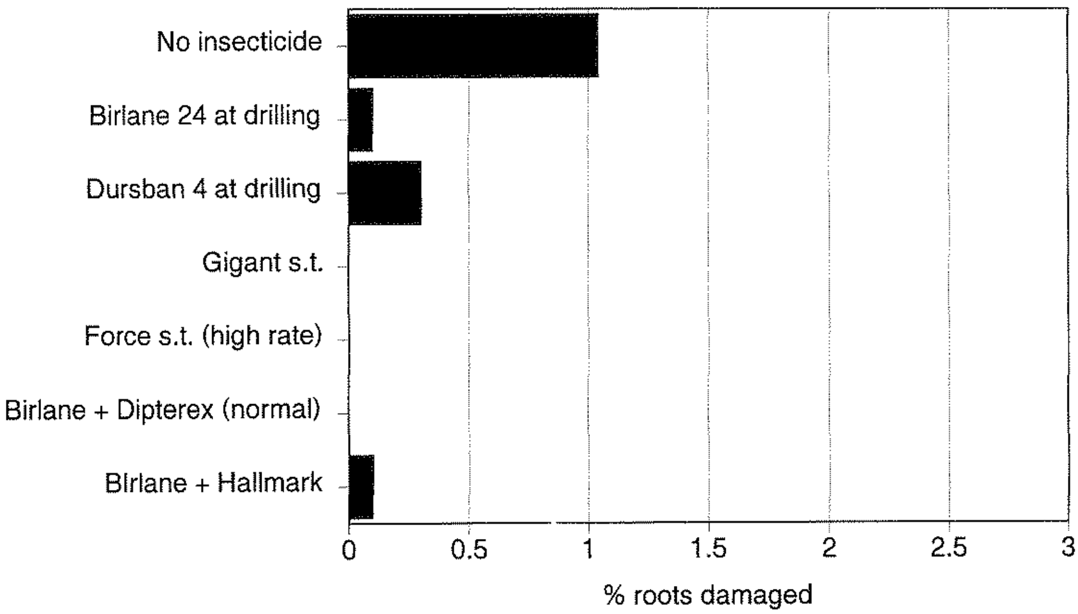
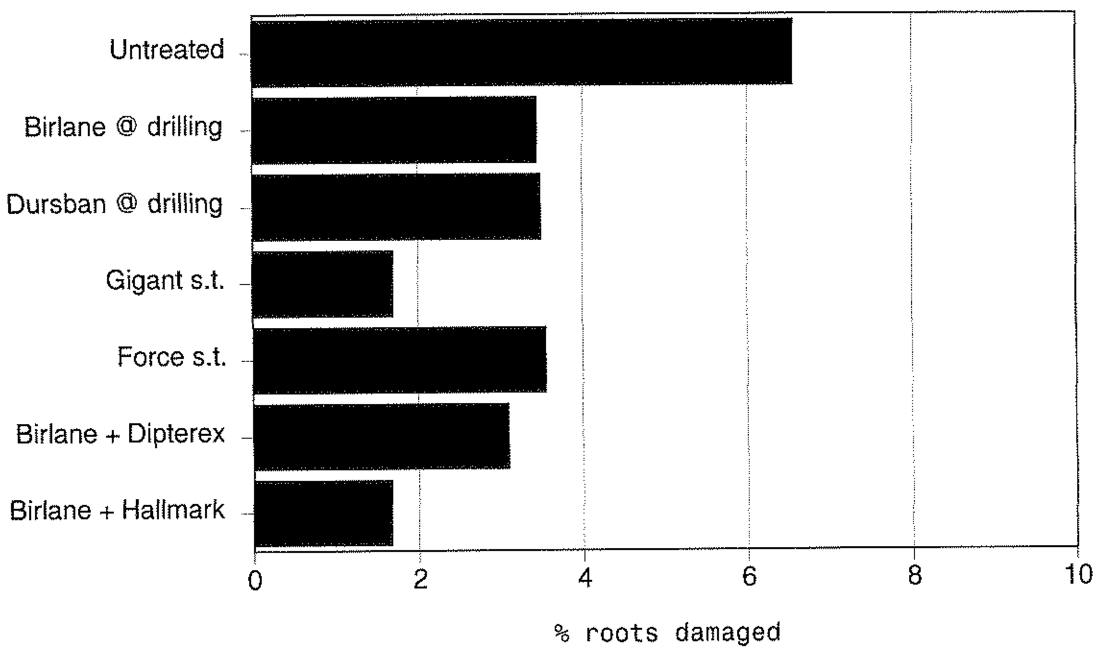


Figure 5. Percentage root damage on treated and untreated plots from Experiment 5.



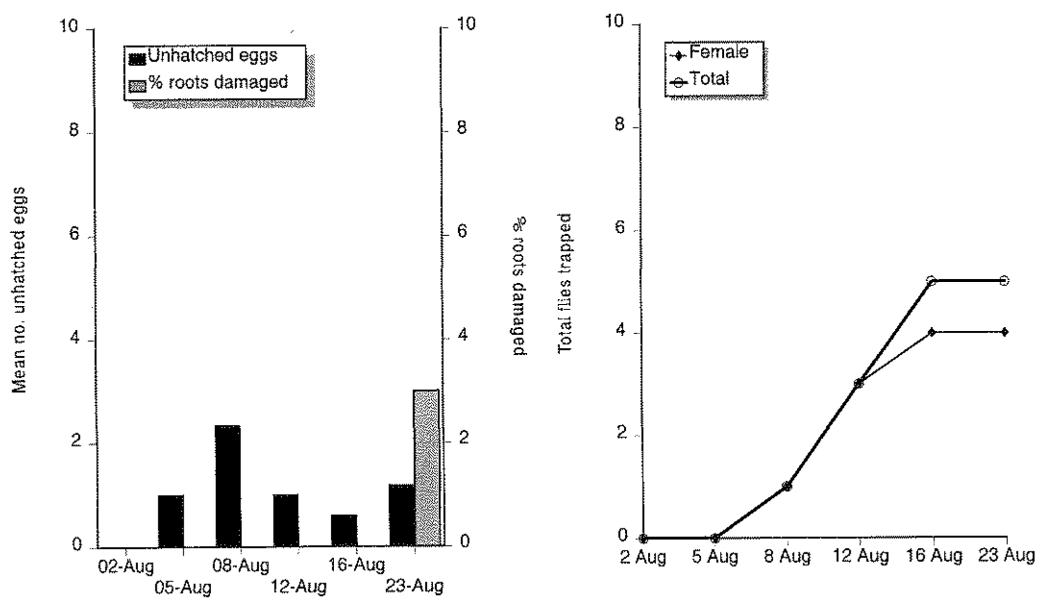
Experiment 5 (Lancashire, July sowing). A moderate cabbage root fly attack occurred on this experiment, resulting in damage to 6.6% of untreated radishes (Figure 5). Analysis of variance indicated that differences between individual treatments were significant (F = 20.56, 29 d.f., p <0.001). Pre-drilling applications of soil-acting insecticides (i.e. Birlane and Dursban) and Force seed treatment significantly reduced damage to *c.* 50% of untreated levels. Gigant seed treatment gave significantly better control than these (Appendix 3), reducing damage by *c.* 75%. The use of Dipterex supplementary treatments did not improve the overall level of control beyond that given by the application of Birlane at drilling. However, the use of Birlane applied at drilling with Hallmark supplementary treatments gave significantly better control than the Birlane treatment alone.

Cabbage root fly activity

Adult monitoring. No adult flies were caught in the traps during Experiment 3 (Kent, July sowing), and only one female fly was caught (on 5 September) during Experiment 4 (Kent, August sowing), indicating low levels of fly activity during both of these trials. The results of the adult monitoring for Experiment 5 (Lancashire, July sowing) are shown in Figure 6. No flies were caught during the first 10 days of the trial, but thereafter flies were caught during each subsequent trapping period. Female flies usually contained mature or maturing eggs.

Figure 6. Experiment 5, Lancashire 1994: a) pattern of cabbage root fly egg-laying and the percentage of roots damaged; b) numbers of cabbage root flies caught in water-traps.

a) b)



Pattern of egg-laying and root damage. No eggs were recovered from the sequentially uncovered plots during Experiment 3 and only the occasional egg was found in similar plots during Experiment 4. However, significant egg-laying did occur in Experiment 5 (Figure 6). Plots which were uncovered at the time of crop emergence (2 August) were found to contain low numbers of cabbage root fly eggs by 5 August, indicating that egg-laying had started almost immediately after crop emergence. Unhatched eggs were in fact found in all uncovered plots at the first sampling occasion after cover removal. Damage was not recorded on any plots before the assessment made at harvest.

1995 work

Insecticide efficacy

Experiment 6 (Kent, July sowing). Virtually no cabbage root fly damage occurred on this experiment (Appendix 3).

Experiment 7 (Lancashire, May sowing). There was a moderate cabbage root fly attack on this experiment, with 9.1% of roots damaged on untreated plots at harvest. Analysis of variance indicated that differences between individual treatments were significant ($F = 6.71$, 33 d.f., $p < 0.001$). Although all treatments gave a numeric reduction in the percentage of roots damaged (Figure 7), only those treatments which included Gigant seed treatment significantly reduced damaged (Appendix 3). The average damage reduction given by Gigant seed treatment was 78%. There was no added control benefit from any of the Hallmark post-emergence treatments.

Experiment 8 (Lancashire, July sowing). The level of cabbage root fly attack on this experiment was the highest recorded during this project, with 18.6% of roots damaged on untreated plots (Figure 8). Analysis of variance indicated that differences between treatments were significant ($F = 5.21$, 32 d.f., $p < 0.001$). As with the previous experiment, only those treatments which included Gigant seed treatment significantly reduced damage (Appendix 3). The average damage reduction given by Gigant seed treatment was 49%, considerably lower than in Experiment 7. Post-emergence applications of Hallmark did not improve the level of control given by Birlane 24 or Gigant seed treatment.

Experiment 9 (Norfolk, May sowing). Cabbage root fly damage was virtually absent on this experiment (Appendix 3).

Experiment 10 (Norfolk, July sowing). The level of attack on this experiment was very low (3.3% of roots attacked on untreated plots). Although analysis of variance indicated no significant differences between treatments ($F = 2.06$, 32 d.f., $p = 0.077$), Gigant seed treatments gave the lowest level of damage in numeric terms (Figure 9), thus following the trend of the results from the other experiments.

Figure 7. Percentage root damage on treated and untreated plots from Experiment 7.

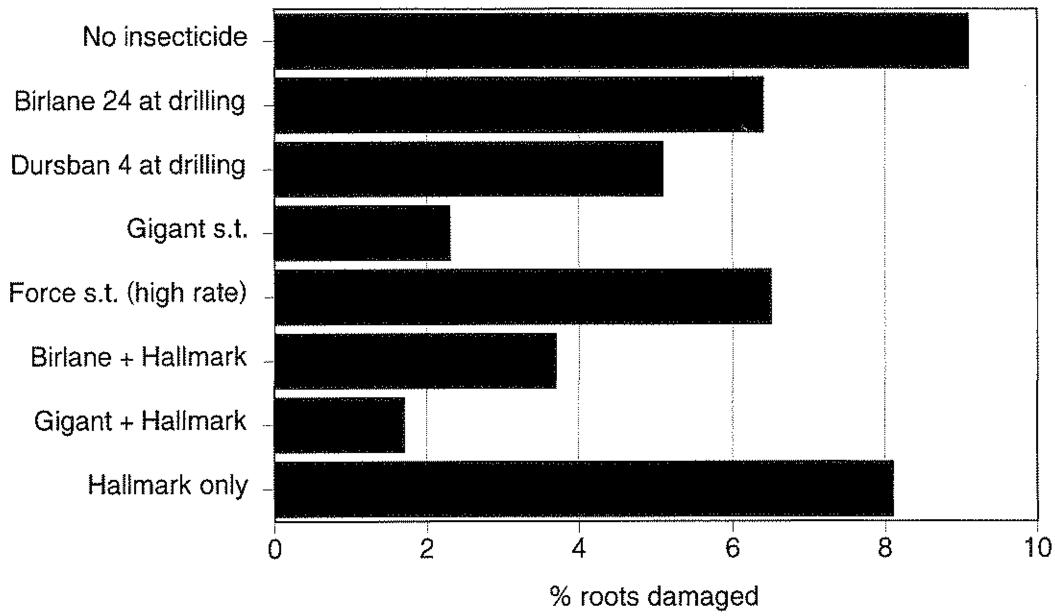


Figure 8. Percentage root damage on treated and untreated plots from Experiment 8.

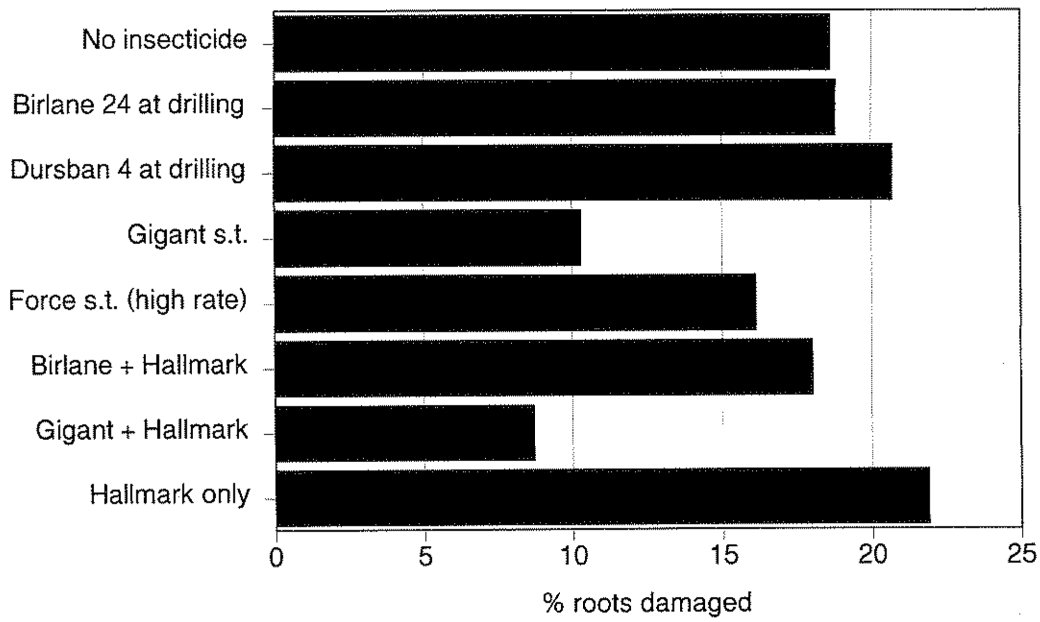
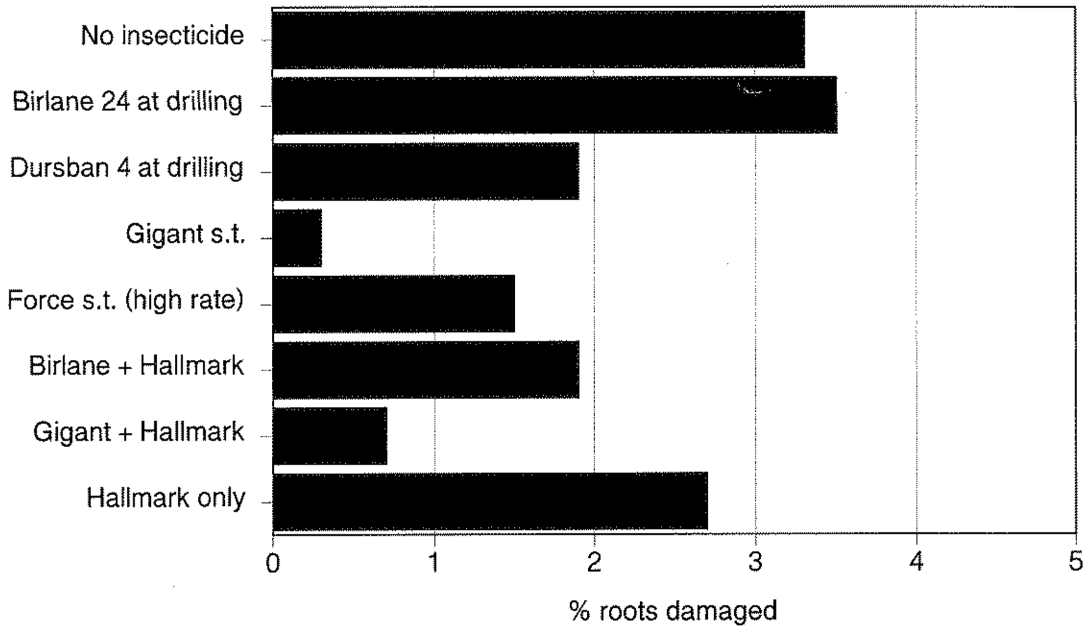


Figure 9. Percentage root damage on treated and untreated plots from Experiment 10.



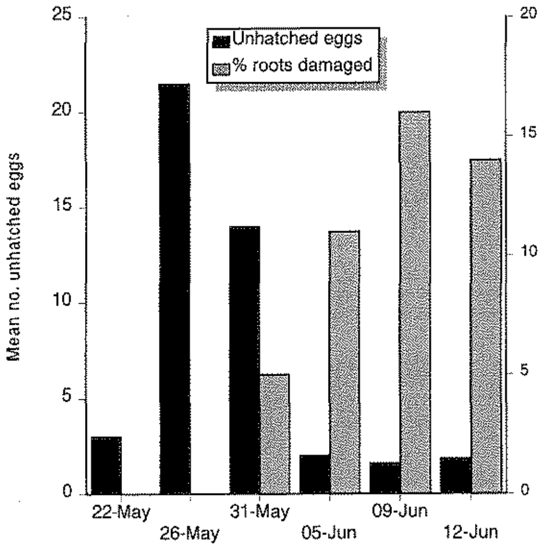
Cabbage root fly activity

Adult monitoring. Only five flies in total were trapped at the Kent site (Experiment 6), and thus identifying any pattern of activity was not possible. During Experiment 7 (Lancashire, May sowing), fly numbers were high during the first 2 weeks after drilling (Figure 10), but thereafter activity declined rapidly, possibly reflecting the end of first generation. The level of fly activity on the second Lancashire sowing (Experiment 8) was lower but relatively constant throughout the duration of the experiment (Figure 11). On the first Norfolk sowing (Experiment 9) fly numbers again peaked in the first 10 days after drilling (Figure 12) before falling away to low levels. On the second Norfolk sowing, two distinct peaks of fly activity were observed, one shortly after drilling, and the second close to harvest (Figure 13).

Pattern of egg-laying and root damage. In Experiment 7, egg-laying peaked during the first 14 days after drilling, coinciding with the early peak of adult activity (Figure 10). In Experiment 8, adult activity was more constant through the life of the crop, and the egg-laying peak occurred during the week before harvest (Figure 11). In both these experiments, cabbage root fly damage became most apparent in the last seven to 10 days before harvest (Figures 10 and 11). At the Norfolk sites (experiments 9 and 10), egg-laying was much lower despite the presence of adults (most flies caught during Experiment 9 were males). Root damage again tended to appear in the last 7 to 10 days before harvest (Figures 12 and 13); the level of damage on Experiment 10 was considerably higher than might have been expected given the low numbers of eggs found. At the Kent site (Experiment 6) egg-laying was negligible and <2% of roots showed cabbage root fly damage at harvest.

Figure 10. Experiment 7, Lancashire 1995: a) pattern of cabbage root fly egg-laying and the percentage of roots damaged; b) numbers of cabbage root flies caught in water-traps.

a)



b)

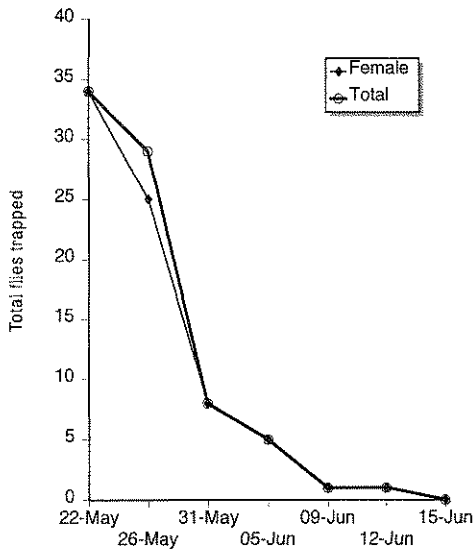
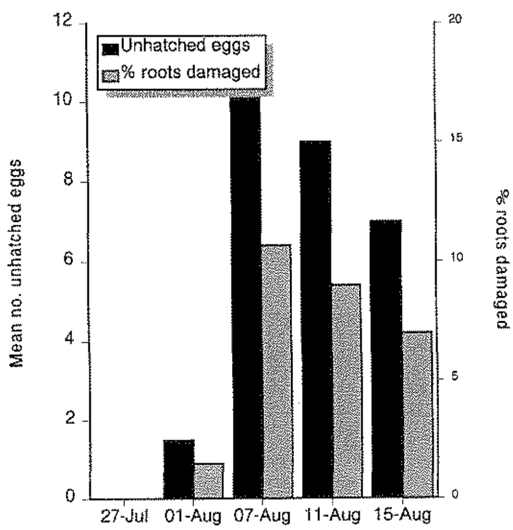


Figure 11. Experiment 8, Lancashire 1995: a) pattern of cabbage root fly egg-laying and the percentage of roots damaged; b) numbers of cabbage root flies caught in water-traps.

a)



b)

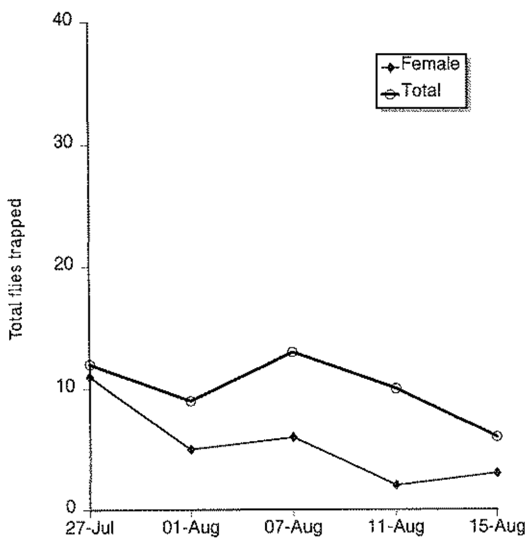


Figure 12. Experiment 9, Norfolk 1995: a) pattern of cabbage root fly egg-laying and the percentage of roots damaged; b) numbers of cabbage root flies caught in water-traps.

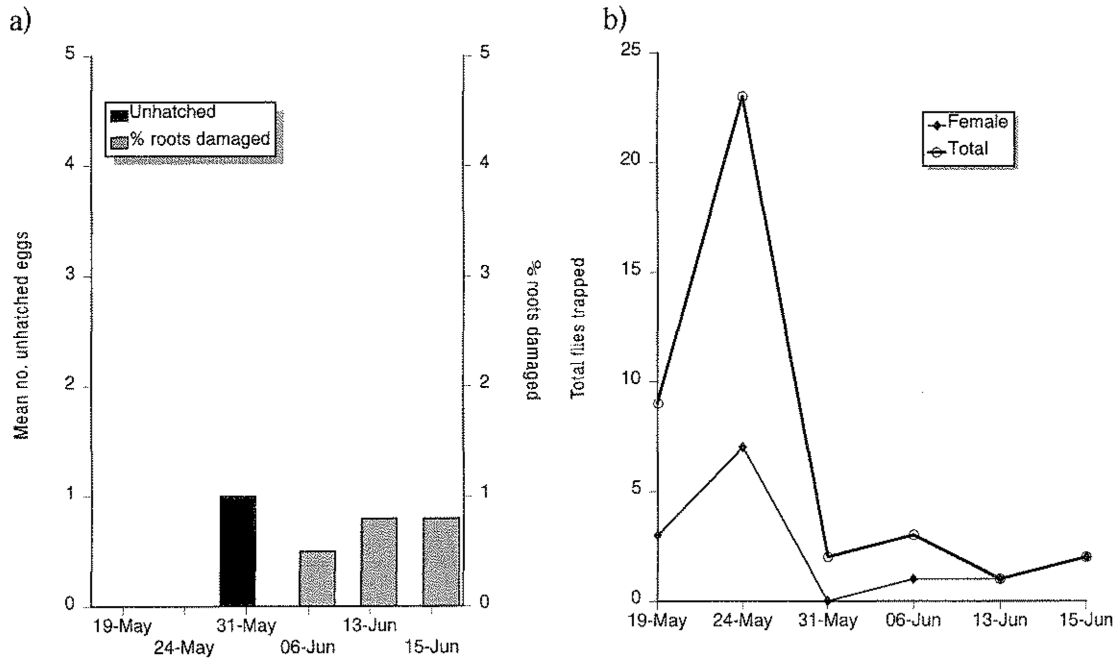
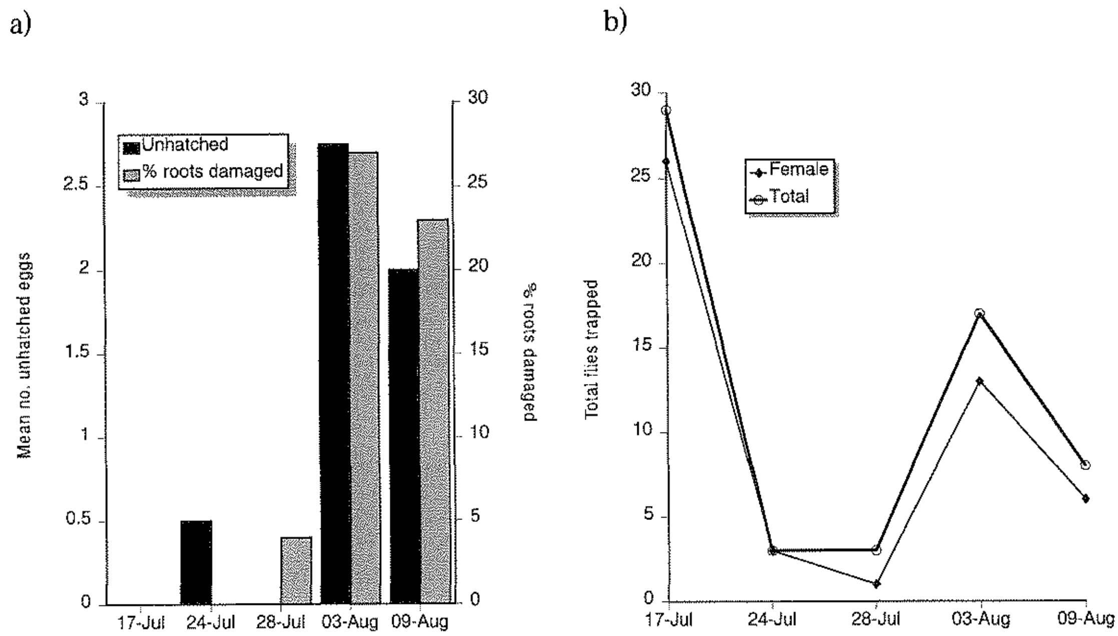


Figure 13. Experiment 10, Norfolk 1995: a) pattern of cabbage root fly egg-laying and the percentage of roots damaged; b) numbers of cabbage root flies caught in water-traps.



Discussion

Insecticide efficacy

Overall, the levels of cabbage root fly damage encountered during this project were lower than expected. This meant that good results were only obtained from a limited number of trials, principally those in Lancashire, but consistent differences between treatments were found. The level of control given by the existing label and off-label recommendations (Birlane 24 and Dursban 4 applied at drilling) was generally poor, with statistically significant reductions in damage being recorded only at a site with a low overall level of damage (Experiment 5, Appendix 3). Of the two seed treatments, Force also gave inconsistent reductions in damage. The Gigant seed treatment gave the most consistent level of control, whether used alone or in combination with supplementary post-emergence sprays, and thus could be considered a better alternative to the existing recommendations. However, it was noticeable that the level of control given by Gigant was never 100%, and its overall efficacy tended to decline as the pest pressure increased. Thus the level of control given Gigant is unlikely to be sufficient when high levels of cabbage root fly attack occur.

An important proviso to these results is that low pest attacks occurred on all the experiments done in Kent. These were the only sites where crops were grown on mineral soils. Soil-applied insecticides such as Birlane 24 and Dursban tend to perform badly where organic matter levels are high, so it is possible that control on mineral soils by such treatments could be better than that suggested by the results from this project. However, in the one Kent experiment where measurable damage levels occurred (Experiment 2, 1993), none of the treatments significantly reduced damage.

The post-emergence spray programmes did not generally improve the level of control given by the soil-applied treatments or the seed treatments. The only exception was in the 1994 experiment where a λ-cyhalothrin programme following chlorfenvinphos treatment at drilling improved significantly the level of control. However, the results from the 1995 experiments showed clearly that a λ-cyhalothrin programme on its own did not reduce damage. These results suggest that the use of post-emergence treatments aimed at controlling adult flies are unlikely to be cost-effective in the majority of cases.

Pattern of egg-laying and damage

In general, the pattern of egg-laying and damage was that egg-laying could occur at any time from crop emergence onwards, but that damage only started to become apparent within about 7 to 10 days of harvest. Previous work has shown that the attractiveness of radish to egg-laying cabbage root flies varies with plant age (Doane and Chapman, 1962; Ellis *et al.*, 1979). These studies suggested that there is a peak of egg-laying during the time the hypocotyl is swelling (i.e. as the radish bulb approaches marketable size). The results obtained during this project tended to support this finding, provided cabbage root fly activity was constant throughout the life of the crop (e.g. Figure 1). However, this general pattern may be masked by large changes in fly activity. For example in Experiment 7, cabbage root fly activity declined dramatically during the course of the experiment, and mirrored closely the intensity of egg-laying (Figure 10).

In most experiments, the period between first recorded eggs and the first appearance of damage was usually in the range of 7 to 10 days. Although there were occasions when eggs and damage appeared at the same time, this is probably due to low numbers of eggs not being detected in the crop at an earlier sampling date. Based on these results, a 'last-effective egg-lay date' of about 7 days before harvest was used to time the end of the supplementary spray programmes in the insecticide efficacy experiments, although this estimate was also backed up by the use of a cabbage root fly simulation model (Collier *et al.*, 1991). However, as supplementary spray treatments are rarely effective (see above), it is likely that information on last effective egg-lay dates could best be used to time the removal of crop covers, such as non-woven fleece or nets, which can be used to enhance crop earliness and/or to prevent pest damage.

Conclusions

1. Existing on- and off-label treatments for cabbage root fly control on radish were generally not effective, even when pest attack was low.
2. The best alternative to current control recommendations would be the use of a chlorpyrifos seed treatment (e.g. 'Gigant'). Other seed treatments were either not effective (e.g. tefluthrin) or phytotoxic (e.g. chlorfenvinphos). Chlorpyrifos seed treatment on outdoor radish is not currently Approved and cannot be legally used commercially at present unless treated seed is imported from outside the UK. A Specific Off-label Approval (SOLA) application for chlorpyrifos to be applied to radish seed is currently being made with the support of HDC. The Pesticide Safety Directorate (PSD) are currently considering this request. Residue data may not be limiting, but further information on operator exposure and ecotoxicology (particularly the risk to small mammals and birds) has been requested. Provided these concerns can be met, there is a fair chance of the SOLA being Approved. However, this will not happen in time for the 1996 season.
3. Post-emergence spray treatments timed to coincide with the main 'risk period' (crop emergence to 7 days before harvest) did not improve the level of control given by standard treatments applied at drilling.
4. Egg-laying could occur at any time from crop emergence onwards, but tended to peak close to harvest. The pattern of adult fly activity also influenced the pattern of egg-laying. Larvae hatching from eggs laid within 7 to 10 days of harvest did not appear to contribute to crop damage.
5. Given that the control given by chlorpyrifos is not fully effective, there is still a need to examine possible alternatives. These might include the use of nets (e.g. Agronet), which have been shown to be effective in Holland. These are expensive but can be re-used with care.

Acknowledgments

I am very grateful for the assistance of the participating growers (Tony Green, J J Barkers, Farningham, Kent; Neil Taylor, Boundary Meanygate, Tarleton, Lancashire; Bill Watkins, Feltwell, Norfolk) who not only provided sites for the work but also gave some of their own time and equipment for drilling the trials. The assistance of Hugh Poths (Nickersons Seeds) and Nick Bolton (Seedcote Systems Ltd.), who respectively provided seed and seed treatment facilities free of charge, was also essential. Chris Wallwork (Willmot Pertwee) acted as Project Coordinator and provided many valuable suggestions. Rosemary Collier (HRI Kirton) provided cabbage root fly forecast information. Additional financial support was also given by Zeneca Crop Protection Ltd. Last but not least, the efforts of ADAS colleagues (particularly Geoff Thorpe, Iain Ordidge, Alison Shearan and Jackie Town) at Wye, Wolverhampton and Arthur Rickwood are fully appreciated for dealing efficiently with a complex work schedule.

References

Collier, R. H., Finch, S. & Phelps, K. (1991). A simulation model for forecasting the timing of attacks of *Delia radicum* on cruciferous crops. *EPPO Bulletin* **21**: 419-424.

Doane, J. F. & Chapman, R. K. (1962). Oviposition preference of the cabbage maggot, *Hylemya brassicae* (Bouché). *Journal of Economic Entomology* **55**: 137-138.

Ellis, P. R., Hardman, J. A., Crisp, P. & Johnson, A. G. (1979). The influence of age on resistance of radish to cabbage root fly egg-laying. *Annals of Applied Biology* **93**:125-131

Appendices

Appendix 1. Detailed results and statistical analyses from all trials showing the effect of treatment on the mean % of roots with either internal or external damage. S.E.D. values (standard error of the difference between means) are for transformed data (see page 6), but mean values presented in table are back-transformed from the results of the data analysis, and do not correspond exactly to raw mean values used in Figures 2, 4, 5, 7, 8 and 9. d.f. = error degrees of freedom. Means followed by the same letter in any one column are not significantly different at $p = 0.05$, Duncan's multiple range test.

		1993		1994			1995				
Code	Treatment	1 (Kent)	2 (Kent)	3 (Kent)	4 (Kent)	5 (Lancs)	6 (Kent)	7 (Lancs)	8 (Lancs)	9 (Norfolk)	10 (Norfolk)
A	No insecticide	0	7.2 a	1.0 a	0.1 a	6.5 a	0.7 a	8.8 a	17.7 a	0.2 a	2.4 a
B	Birlane 24 at drilling	0	5.2 a	0.1 a	0.4 a	3.3 b	1.1 a	6.3 ab	18.6 a	0.4 a	3.1 a
C	Dursban 4 at drilling	0	4.6 a	0.3 a	0.0 a	3.4 b	1.9 a	4.9 ab	20.2 a	0.4 a	1.7 a
D	Gigant s.t.	0	5.0 a	0.0 a	0.0 a	1.6 c	0.7 a	1.6 c	10.3 bc	0 a	0.4 a
E	Force s.t. (low rate)	0	4.3 a								
F	Force s.t. (high rate)	0		0.0 a	0.0 a	3.5 b	0.1 a	6.0 ab	15.8 ab	0.1 a	1.5 a
G	Birlane s.t.	0	3.4 a								
H	Birlane + Dipterex (early)	0	4.9 a								
I	Birlane + Dipterex (late)	0	8.2 a								
J	Birlane + Dipterex (normal)	0	4.5 a	0.0 a	0.4 a	3.0 b					
K	Birlane + Hallmark			0.1 a	0.0 a	1.6 c	1.2 a	3.3 bc	17.8 a	0 a	1.6 a
L	Gigant + Hallmark						0 a	1.4 c	8.0 c	0 a	0.6 a
M	Hallmark only						1.1 a	7.5 ab	21.2 a	0.1 a	1.7 a
	S.E.D.	n/a	*0.58*	*0.23*	n/a	*0.16*	n/a	*0.40*	*0.39*	n/a	*0.36*
	d. f.	n/a	24	29	n/a	29	n/a	33	32	n/a	32

Appendix 2. Spray-dates for post-emergence applications i.e. excluding treatments at drilling and seed treatments (see Appendix 1 for treatment code explanations).

Site	Year	Treatment code	Application dates
1	1993	H	28 June, 2 July, 7 July
		I	28 June, 2 July, 16 July
		J	28 June, 2 July, 12 July
2	1993	H	19 Aug, 29 Aug, 3 Sept
		I	19 Aug, 29 Aug, 13 Sept
		J	19 Aug, 29 Aug, 8 Sept
3	1994	J, K	18 July, 22 July, 27 July
4	1994	J, K	24 Aug, 9 Sept, 14 Sept
5	1994	J, K	8 Aug, 12 Aug, 16 Aug
6	1995	K, L, M	10 July, 14 July, 19 July
7	1995	K, L M	22 May, 26 May, 31 May, 5 June, 9 June, 12 June
8	1995	K, L M	27 July, 1 Aug, 7 Aug, 11 Aug
9	1995	K, L M	24 May, 30 May, 5 June, 13 June
10	1995	K, L M	20 July, 24 July, 28 July, 3 Aug

CONTRACT

(see over)

*See amendment sheet (attached) dated 14/6/94

Contract between ADAS (hereinafter called the "Contractor") and the Horticultural Development Council (hereinafter called the "Council") for research/development project.

1. **TITLE OF PROJECT**

Contract No: FV159
Contract date: 13.8.93

OUTDOOR RADISH: DEVELOPMENT OF NEW PROGRAMMES FOR CABBAGE ROOT FLY CONTROL

2. **BACKGROUND AND COMMERCIAL OBJECTIVE**

As a root brassica, radish is particularly prone to quality-reducing attacks by cabbage root fly. The chemical control options currently available to growers are limited, and while these treatments may be adequate when pest pressure is low, mid-season control in particular is often poor due to higher pest pressure. Even early-season crops can be damaged in the north-west England. In addition, repeated use of the the only fully Approved treatment (chlorfenvinphos liquid) on ground repeatedly cropped with radish may ultimately lead to problems with enhanced degradation. There is therefore a need to investigate different approaches to cabbage root fly control, and in particular to examine the possibility of using the HDC cabbage root fly forecast as a tool in rationalising the use of supplementary insecticide treatments. The work should lead to more effective cabbage root fly control in strategies, with more targeted and possibly reduced insecticide use, resulting in consistently higher quality radish crops.

3. ~~**BACKGROUND AND COMMERCIAL OBJECTIVE**~~ POTENTIAL FINANCIAL BENEFIT T INDUSTRY

A working average yield for radish is 5000 boxes (of 12 bunches)/ha worth say £2.00/box. Cabbage root fly attacks can easily reduce marketable yield by 10% even with insecticide treatment, and in extreme cases can write-off the crop. Thus the minimum yield loss for 1 ha of crop is worth in the order of £1000 ha. A pre-drilling chlorfenvinphos application costs c. £70/ha and is therefore expensive for a treatment which may not be fully effective.

If the seed treatments tested in this trial are found to be effective, the likely cost of chemical treatment will be halved to around £40/ha (the current cost of Gigant seed treatment on other brassicas), a saving of £30/ha. Better targeting of any supplementary sprays will also lead to reduced costs. If the new treatments reduce the damage level to e.g. 5%, then on the basis of the figures quoted above, growers will save a further £500/ha, giving a conservative total of £530 ha.

4. **SCIENTIFIC/TECHNICAL TARGET OF THE WORK**

1. Test the efficacy of new candidate insecticides and new methods of applying established insecticides. The

main emphasis is on the testing of seed treatments.

2. Test the efficacy of supplementary, short persistence insecticides timed to coincide with peak risk periods of cabbage root fly activity as indicated by the HDC-funded cabbage root fly forecasting model.

3. Determine the patterns of adult activity, egg laying, and development of root fly damage in the radish crop to aid in the interpretation of trial results and treatment timings.

5. CLOSELY RELATED WORK - COMPLETED OR IN PROGRESS

There is no work currently being undertaken specifically on cabbage root fly control on radish. However, this work will draw on recent HDC-funded work which developed the cabbage root fly prediction model. Work carried out at HRI Wellesbourne (then NVRS) in the 1970's on the influence of crop age on resistance of radish to cabbage root fly egg-laying underpins this work to a certain extent; part of the current project is aimed at assessing the practical implications of the Wellesbourne work.

6. DESCRIPTION OF THE WORK

Year 1

This work will concentrate on:

1. Assessing the efficacy of existing and candidate insecticides.
2. Initial investigation of possibility of timing supplementary treatments using the HDC cabbage root fly forecast.
3. Obtaining biological data on the pattern of egg-laying, adult activity, and timing of the appearance of larval damage in the crop. This will provide essential information for interpreting the results of the treatments timed using the HDC forecast.

Year 2

1. Confirming the efficacy of candidate insecticides identified in year 1, extending the trials work onto organic soil sites, probably in the NW England.
2. More detailed investigation of supplementary treatment timing using HDC forecast. It may be necessary to do this work in large plots.
3. Confirmatory work on biological information as in (3) above.

Year 3

Further confirmatory work if considered necessary by the annual project review.

Trials location

Year 1

Trial 1. S England, mineral soil, drilled mid-June (high risk drilling).

Trial 2. S England, mineral soil, drilled early August (lower risk drilling).

Year 2

Trial 1 & 2. As year 1.

Trial 3 & 4. As trials 1 and 2 but carried out on organic soil site in N W England.

Proposed treatments for chemical efficacy and investigation of treatment timing using HDC cabbage root fly forecast (year 1, to be modified as required in years 2 and 3).

1. Untreated
2. Birlane 24 (chlorfenvinphos) @ 9.8 litres/ha in 500 litres water/ha pre-drilling (standard).
3. Dursban 4 (chlorpyrifos) @ 2 litres/ha in 600 litres water/ha pre-drilling (off-label).
4. Gigant (chlorpyrifos) treated seed (to be supplied by Nickersons).
5. Force (tefluthrin) film-coat treated seed (to be supplied by Seedcote Systems).
6. Birlane LST (chlorfenvinphos) film-coat treated seed (to be supplied by Seedcote Systems).

Treatments 7 to 9 test the principle of using the HDC cabbage root fly model to identify the critical time to apply supplementary treatments. The model can predict the development rate of cabbage root fly eggs and larvae. This data will be used in conjunction with an estimated harvest date to generate a 'last significant egg-lay date' for any particular crop. After this date, there is no point in applying insecticides to control newly-hatching larvae, as they will not start to cause damage before the crop is harvested. The supplementary spray treatments (see below) will be directed at controlling larvae which hatch *before* this date. In the situation where the trial crop coincides with the start of a cabbage root fly generation, one of the supplementary spray treatments will be timed to coincide with the forecast 10% egg-hatch date, provided this is not after the latest spray date indicated for that treatment.

7. As in (2) above, plus Dipterex (trichlorphon) sprays applied at about 5 day intervals @ 0.5 kg/ha in 500 litres water/ha, the first spray to be applied 3 days after crop emergence, final spray to **coincide** with latest significant egg-lay date as indicated using the HDC cabbage root fly model.

8. As in (2) above, plus Dipterex (trichlorphon) sprays applied at about 5 day intervals @ 0.5 kg/ha in 500 litres water/ha, the first spray to be applied 3 days after crop emergence, final spray to be applied no later than 4 days **before** the latest significant egg-lay date as indicated using the HDC cabbage root fly model.

9. As in (2) above, plus Dipterex (trichlorphon) sprays applied at about 5 day intervals @ 0.5 kg/ha in 500 litres water/ha, the first spray to be applied 3 days after crop emergence, final spray to be applied not before 4 days **after** the latest significant egg-lay date as indicated using the HDC cabbage root fly model.

Design

Randomised block design with each treatment replicated 4 times. Plot size approximately 6 metres by 2 metres depending on growing system. An extra untreated discard area (at least 30 metres by 2 metres) should be included for sampling during the life of the crop (see below).

Assessments

1. At harvest, a sample of 200 roots/plot should be assessed for cabbage root fly damage.

Biological work

Work on the relationship between cabbage root fly activity and timing of damage in the trial crops will be carried out. This is required for the interpretation of results from the insecticides trial, and to help validate assumptions made about the 'last effective egg-lay date' generated by the cabbage root fly forecast.

1. Adult cabbage root fly activity will be monitored using water traps throughout the life of the crop. Egg-laying should also be monitored in the untreated discard area by sampling a set length of row (plants and soil to be removed) approximately every 5 days.

2. The validity of the assumptions behind the 'last effective egg-lay date' will be checked by the following method: At drilling, all but 6 metres of the untreated discard area is covered with non-woven fleece, thus excluding all cabbage root fly. Every 5 days, 5 metres of the sampling area is uncovered. On each occasion, a sample of plants is removed from the covered and each uncovered area and assessed for root fly damage. The data so obtained will indicate, to within 5 dyas, the latest date of egg-lay beyond which crop damage caused by newly-hatching larvae does not occur.

Dependence on outside resources/consequences of success

The majority of the work will be undertaken by ADAS staff, though close co-operation with growers hosting the trials will be required as farm equipment will be needed to drill the trials.

If the seed treatments are shown to be successful, there will be a need to apply for off-label Approval as it is unlikely that manufacturer's will support a label Approval application. Residue data will be needed in support of an off-label application.

Stages of progress

1. Field trials successfully drilled, treated, harvested and assessed (2 trials in year 1, up to 4 trials each in years 2 and 3).

2. Biological assessments satisfactorily completed in years 1 to 3.

3. Annual reports completed and submitted to HDC by agreed deadlines.

4. Final report submitted to HDC by agreed deadline.

7. COMMENCEMENT DATE, DURATION & REPORTING DATES

Start date: 1 June 1993.
Duration: up to 3 years (subject to annual review); 7 months p.a.
Annual reports: due by 31 December 1993 (year 1) and 31 December 1994 (year 2).
Final report (if third year): Due by 31 December 1995, otherwise 31 December 1994.

8. STAFF RESPONSIBILITIES

Project Leader: Dr W E Parker, ADAS

Other staff: trials work in southern England to be carried out by ADAS R & D Team based at Wye (Team Leader, M Marks); trials in N W England to be carried out by ADAS R & D Team based at Wolverhampton (Team Leader R Cranfield, but work managed by Dr W Parker).

Project Co-ordinator: Mr C Wallwork, Willmot Pertwee.

9. LOCATION

General trials location as in 6 above; southern England trials will be carried out at J J Barkers, Southfleet, Kent. In year 2, trials on organic soils will be carried out on radish growers' farms in N W England in addition to the southern England trials.

Contract No: FV/159

TERMS AND CONDITIONS

The Council's standard terms and conditions of contract shall apply.

Signed for the Contractor(s)

Signature..

Position Head of Hortic Progs Pershore Centre

Date 25/8/93

Signed for the Contractor(s)

Signature..

Position..

Date..

Signed for the Council

Signature..

Position CHIEF EXECUTIVE

Date 13.8.93

48

Contract between ADAS (hereinafter called the "Contractor") and the Horticultural Development Council (hereinafter called the "Council") for research/development project.

1. TITLE OF PROJECT

Contract No: FV159
(Modified contract due to aborted work during 1994)
Contract date: 1.3.95

OUTDOOR RADISH: DEVELOPMENT OF NEW PROGRAMMES FOR CABBAGE ROOT FLY CONTROL

2. BACKGROUND AND COMMERCIAL OBJECTIVE

As for FV159

3. POTENTIAL FINANCIAL BENEFIT TO THE INDUSTRY

As for FV159

4. SCIENTIFIC/TECHNICAL TARGET OF THE WORK

As for FV159

5. CLOSELY RELATED WORK - COMPLETED OR IN PROGRESS

As for FV159

6. DESCRIPTION OF THE WORK

As for FV159 except that the timing of the trials will be changed as follows:

<u>Trials location</u>

Year 1

Trial 1. S England, mineral soil, drilled mid-June (high risk drilling).

Trial 2. S England, mineral soil, drilled early August (lower risk drilling).

Year 2

Trial 1 & 2. As year 1.

Trial 3. As trial 1, but carried out on organic soil site in N W England.

Year 3

Trials 1 & 2. As year 2.

Trials 3 & 4. NW England, organic soil, May drillings (high risk).

Trial 5. NW England, organic soil mid-July drillings (lower risk).

Treatments and assessments:

Year 1 - as for FV159.

Years 2 & 3 (nb. the data from the year 2 treatments will be reviewed at the end of 1994 and the treatments will be modified in year 3).

A. Untreated

B. Untreated

C. Birlane 24 (chlorfenvinphos) @ 9.8 litres/ha applied in 500 litres water/ha pre-drilling.

D. Dursban 4 (chlorpyrifos) @ 2 litres/ha applied in 600 litres water/ha pre-drilling.

E. Chlorpyrifos film-coated treated seed (9.6 g a.i./100,000 seeds).

F. Force (tefluthrin) film-coated treated seed (40 g a.i./100,000 seeds).

G. As in (C) above, plus Dipterex (trichlorphon) sprays applied at about 5 day intervals @ 0.5 kg/ha in 500 litres water/ha, the first spray to be applied 3 days after crop emergence, final spray to coincide with latest significant egg-lay date as indicated using the HDC cabbage root fly model.

H. As in (C) above, plus Hallmark (λ-cyhalothrin) sprays applied at about 5 day intervals @ 150 mil/ha in 500 litres water/ha, the first spray to be applied 3 days after crop emergence, final spray to coincide with latest significant egg-lay date as indicated using the HDC cabbage root fly model.

The 'last effective egg-lay date' will be calculated from the HDC-funded cabbage root fly forecast (run by Rosemary Collier, HRI Kirton) once sowing and anticipated harvest dates are known.

<u>Design</u>

Randomised block design with each treatment replicated 5 times. Plot size 6 metres by 1 bed. An extra untreated discard area (at least 50 metres by 1 bed) should be included for samplying during the life of the crop.

Biological work

As for FV159: additional work.

At one site, observations on egg laying work will be made concurrently in untreated areas on three different drillings to confirm whether crop growth stage influences the level of egg-laying activity. This additional work is dependent on the grower concerned being prepared to leave appropriate untreated areas.

7. COMMENCEMENT DATE, DURATION & REPORTING DATES

As for FV 159.

8. STAFF RESPONSIBILITIES

As for FV159.

9. LOCATION

General trials location as in 6 above; southern England trials will be carried out at J J Barkers, Hill Farm, Farningham, Kent. In years 2 & 3, trials on organic soils will be carried out on the land of Mr N Taylor, Hundred End, Boundary Meanygate, Hesketh Bank, Preston in addition to the southern England trials.

Contract No: FV159-MOD

TERMS AND CONDITIONS

The Council's standard terms and conditions of contract shall apply.

Signed for the Contractor(s)

Signature........M.C. Heath............

Position...ADAS...ACCOUNT...MANAGER

Date............30/3/95................

Signed for the Contractor(s)

Signature...

Position..

Date..

Signed for the Council

Signature..

Position CHIEF EXECUTIVE

Date 3.3.95