HORTICULTURE RESEARCH INTERNATIONAL

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FINAL REPORT

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Protected lettuce:
Control of sciarid and shore flies

October 1997

Commercial - In Confidence

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

Authentication

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

Signature RJacobson

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Background and objectives

During the summer of 1994, HRI was asked by the Lettuce Technology Group to investigate problems caused by small black flies on lettuce plants at harvest. The flies were often present in large numbers and it was feared that they could become trapped under plastic wrappings leading to the rejection of whole batches of produce. HRI's preliminary investigation showed the insects to be shore flies (*Scatella stagnalis*) which were breeding on algae growing in wet areas of the greenhouse.

The overall objective of the project was to develop a practical and sustainable strategy for the control of shore flies in protected lettuce crops without increasing insecticide usage.

Summary of results

Relevant aspects of the life cycle and behaviour of *S. stagnalis* were investigated to improve our understanding of the insect and to identify potential weak links for exploitation in control strategies. These studies required the development of culturing techniques for both the flies and their algal food.

S. stagnalis development was shown to be temperature dependant. Although adult flies survived and laid eggs below 10°C, less than 2% of the immature insects completed their development. This indicates that a carefully timed insecticidal treatment in the late autumn, when the development of the immature stages of the pest has been arrested, could remove the risk of lettuce contamination by adult flies until temperatures rise again in late winter/early spring.

The populations of *S. stagnalis* recorded on plants in commercial crops were roughly in proportion to the moisture content of the soil surface and the growth of algae. Soil surface wetness was affected both by watering strategy and soil moisture retention. The sandier soils drained freely, so that water infiltrated quickly after irrigation and the surface remained quite dry. Water infiltration on the heavier sandy clay loams was moderate so the surface remained wet much longer allowing algae to grow and shore flies to breed. There were relatively wet patches in all greenhouses regardless of the general water retention characteristics of the soil type; for example,

1. on the narrow compacted paths in the crop beds
2. on the non-cropped strips at the ends of houses
3. at the wall/floor angles where moisture collects from condensation on the glass/plastic.

Small scale experiments showed that an insecticide, Darlingtons Diazinon Granules, could provide a short term solution to the *S. stagnalis* problem. However, this would require the generation of data to support an Off-Label Approval which was beyond the scope of this project and has not been pursued elsewhere. The insect growth regulator, teflubenzuron (Nemolt), also provided promising results in small scale experiments and was taken forward to crop scale evaluation but did not provide control at acceptable application rates.

While an effective insecticide may provide an immediate solution to the shore fly problem, it is unlikely to be acceptable in the longer term because lettuce growers are under pressure to reduce their overall insecticide usage. Several biological control agents, including entomopathogenic nematodes and predatory mites, were therefore evaluated but none provided acceptable control of the pest.

The most sensible approach to controlling *S. stagnalis* was considered to be the elimination of their algal food source. This principle was first demonstrated with relatively high application rates of the dithiocarbamate fungicide, thiram (Thianosan DG), which prevented growth of algae and development of shore flies. Unfortunately, the product was ineffective at commercially acceptable rates.

In many situations, growth of algae can be reduced by careful and even watering to avoid the development of damp patches in the crop. However, additional action is required in the insect's primary breeding sites; the access paths within lettuce beds and the periphery of the crop. A number of potentially useful algaecides were screened by laboratory bioassay and the most promising were taken forward to crop scale experiments. The most successful treatment was quinoclamine (Mogeton) applied to the non-cropped areas of the greenhouse at the rate of 140 g per 10 litres water per 100 m^2. This reduced numbers of adult *S. stagnalis* by 50% compared to untreated controls. It is anticipated that applications of an effective algaecide to sequential crops would gradually reduce the overall shore fly population so that the necessity for treatments would decline.

A method of removing adult flies by suction was evaluated. Variations of this technique could may make a useful contribution to the overall control of *S. stagnalis* and should be further evaluated.

In parallel to these studies, Elaine Wright (HRI, Wellesbourne) has worked with two species of parasitic wasps which are both effective parasitoids of *S. stagnalis*. These parasitoids may have a role in an integrated approach to shore fly control in protected lettuce but only if growers are able to move to a full IPM programme which eliminates the need to apply broad spectrum insecticides against other pests such as aphids and caterpillars.

Action points

Insecticidal applications against *S. stagnalis* in protected lettuce could be minimised by the adoption of an integrated strategy based on the following procedures.

1. Water should be applied evenly and in minimal quantity to avoid the development of permanently damp patches of soil within the crop.

2. When the soil temperature is above 10°C, growth of algae in non-crop areas should be prevented by application of an effective algaecide such as quinoclamine (Mogeton). Applications may have to be repeated several times within each crop.

3. If there are significant numbers of adult flies when the mean daily soil temperature falls below 10°C in the late Autumn, a single spray of a broad spectrum insecticide should be applied to kill adults.

4. It should not be necessary to apply insecticides or algaecides while the mean daily soil temperature remains below 10°C.

Precise control programmes must be tailored to suit individual nurseries due to differences in growth of algae and development of *S. stagnalis* on different soil types.

Recommendation for further work

1. It is recommended that control programmes based on the above strategy are designed for three nurseries with different soil types and monitored at each through one annual cycle of crops.

2. Pest control measures based on the physical removal of insects by suction should be further evaluated.

3. The principles developed within this project should be used to design and evaluate *S. stagnalis* control strategies for other crops; in particular, protected celery, bedding plants, herbs and pot plants.

4. The use of parasitic wasps against shore flies should be evaluated if growers move towards a full IPM programme which eliminates the need to apply broad spectrum insecticides against other pests.

Practical and financial benefits from study

An effective strategy for the control of *S. stagnalis,* based on minimal use of insecticides, will avoid rejection of produce and help to satisfy demands by the UK's leading food retailers for reduction of pesticide usage in protected lettuce crops.

The acquisition of knowledge will also be beneficial to celery, bedding plant, herb and pot plant growers.

EXPERIMENTAL SECTION

INTRODUCTION

In 1994, the Lettuce Technology Group asked HRI to investigate problems caused by small black flies, thought to be sciarids, which were often present on lettuce plants at harvest. It was feared that these flies would become trapped under plastic wrappings and lead to the rejection of whole batches of produce. A preliminary study indicated that the insects were in fact shore flies and a project was set up to find a sustainable control strategy.

Shore flies belong to a large family of insects known as the ephydrids. They have a worldwide distribution with broad ecological tolerances including saline marshes, thermal springs, moist grassland and rocky substrates along streams and lakes. The larvae of the majority of species, feed on algae and detritus, but some are scavengers and a few are predators.

Although the knowledge of ephydrids is expanding steadily, there is still much to be done to understand fully this large and complex family of insects which has been described as being "in the full flower of its evolution" and is likely to become more important economically.

Within temperate regions the species encountered most commonly in greenhouses is *Scatella stagnalis*. The larvae are believed to feed primarily on green algae and thrive in this environment regardless of crop type and growing media. There is no evidence to suggest that larvae damage plants directly but they may contribute to the development of root disease as vectors of *Pythium spp.*

SUMMARY OF WORK COMPLETED BEFORE THIS REPORTING PERIOD.

1. Surveys - Autumn 1994 and Summer 1995

As a first step in the development of a sustainable solution, HRI surveyed growers of protected lettuce who had suffered varying degrees of difficulty with this pest. The aim was to gain a better understanding of the overall problem before identifying and evaluating potential control measures.

Grower participants were questioned regarding their use of pesticides and their watering/feeding regimes. At the same time, notes were made of soil type, soil moisture, growth of algae and the degree of insect infestation. Samples of algae and insects were collected for culture and identification.

The growers all watered and fed through overhead irrigation lines according to their previous experience of the chosen lettuce cultivars. The frequency of application and quantity of water applied varied between sites but was within acceptable parameters and all produced good marketable crops.

Although the troublesome insects had previously been described as sciarids, this survey confirmed that they were shore flies and all specimens collected for identification were *Scatella stagnalis*.

As anticipated, the populations of shore flies recorded on the plants were roughly in proportion to the moisture content of the soil surface and the amount of growth of algae. This ranged from less than one fly per 20 plants at the driest site to over 10 flies per plant at the wettest site with even larger numbers found locally.

Soil surface wetness was clearly affected by watering strategy and soil moisture retention. The sandier soils drained freely, so that water infiltrated quickly after irrigation and the surface remained quite dry. Water infiltration on the heavier sandy clay loams was moderate, so the surface remained wet much longer allowing algae to grow and shore flies to breed.

There were relatively wet patches in all greenhouses regardless of the general water retention characteristics of the soil type; for example,

1. on the narrow compacted paths in the crop beds
2. on the non-cropped strips at the ends of houses
3. at the wall/floor angles where moisture collects from condensation on the glass/plastic.

These areas always had more growth of algae and proved to be the main breeding sites of the flies.

2. Culturing algae and shore flies

Before more detailed experimentation could begin it was necessary to develop reliable culturing techniques for both algae and *S. stagnalis*. A relatively simple system which served both purposes was designed and extensively tested. It also formed the basis of bioassays used to test the efficacy of chemical and biological control measures against both algae and flies, and for studies of the insects life cycle.

3. Biology of *S. stagnalis*

The life cycle and behaviour of *S. stagnalis* was poorly understood and it was important to improve this knowledge so that weak links could be identified and exploited in the control strategy.

The life cycle was initially studied at 21°C as this information was critical to the development of the culturing system. At this temperature, females laid up to 30 eggs per day on the surface of the growing media. The eggs, which hatched after 4 days, were particularly vulnerable to predation and prone to desiccation. The larvae sought moist conditions and fed on algae on the surface of the growing media for 8 days before pupating in the same area. The whole cycle, from egg to adult, was completed in 10 to 14 days.

The studies then focused on aspects of biology and behaviour which were relevant to the performance of *S. stagnalis* in lettuce crops, with particular emphasis on survival during the colder months of the year.

The longevity of adult flies at 5, 10 and 21°C was found to be 51, 19 and 16 days respectively. Eggs were laid at 10°C but not at 5°C, showing that the egg laying threshold was between these two temperatures. Adults transferred from 5°C to 21°C after 21 days began laying eggs immediately.

The duration of the life cycle from egg to adult was measured at four temperatures; 5, 10, 15 and 21°C. No development occurred at 5°C and only 2% of immature *S. stagnalis* progressed to adult within 58 days at 10°C. The life cycle was completed in 28 days at 15°C, more than twice as long as at 21°C.

Both eggs and pupae were stored for up to 5 weeks at 5°C and 10°C and their development subsequently measured at 21°C. No eggs survived at 5°C and only 2% survived at 10°C. All the pupae survived the exposure to cool conditions.

The results of this series of experiments indicated that *S. stagnalis* survive the coldest months of the year as adults or pupae. A single carefully timed insecticidal treatment in the late autumn, when the development of the immature stages of the pest has been arrested, could therefore kill adult flies and remove the risk of lettuce contamination until temperatures rise in late winter or early spring.

4. Identification of algae

The samples of algae collected from lettuce crops at Stockbridge House and commercial nurseries consisted almost entirely of green algae (Chlorophyta). The species, which were identified by Prof. Leedale (Leeds University), could be divided into two categories:

1. Simple unbranched filamentous algae dominated by *Hormidium* and *Ulothrix*.

2. Unicellular algae with a predominance of *Chlorella* and *Chlamydomonas*.

All of these species provided adequate nutrition for *S. stagnalis* although they performed better on the filamentous types.

The filamentous algae, which tended to be more tolerant to fluctuations in moisture levels, were more common in the soil, while the unicellular algae were more successful in the artificial cultures. Care was taken to ensure that any measures developed subsequently to control algae were effective against all the species commonly encountered.

5. Control Measures directed at *S. stagnalis*

5.1. Insecticides

Foliar sprays and space treatments of insecticides have only a temporary impact on populations of adult shore flies because they do not reach the larval development sites. Soil treatments are more effective but there are no products Approved for protected lettuce in the UK which are both effective against *S. stagnalis* and have adequate persistence in the soil.

5.1.1. Diazinon

One of the original objectives of the project was to identify an insecticide which could provide a short term solution to the shore fly problem pending the development of a more sustainable control strategy. A list of potentially useful insecticides was compiled, of which Darlingtons Diazinon Granules appeared to be most promising. Diazinon (as Basudin 5G) had been used against soil pests in protected lettuce in the past and Darlingtons Diazinon Granules had an existing Approval for mushrooms which could have formed the basis for an Off-Label Approval for lettuce.

In small scale experiments at Stockbridge House, Darlingtons Diazinon Granules were applied to the surface of the growing medium at rates equivalent to 11.2 and 22.4 kg per hectare. This prevented the development of the first generation of shore flies at both rates although control began to break down after 22 days.

At the HDC Project Review Meeting in March 1997, the panel decided not to pursue an Off-Label Approval.

5.1.2. Teflubenzuron (Nemolt)

Teflubenzuron is an insect growth regulator which disrupts moulting by inhibiting chitin synthesis and thus prevents susceptible immature insects completing their development to adults.

The efficacy of direct applications of teflubenzuron to eggs and larvae of *S. stagnalis* was determined by bioassay. The product was also evaluated as an application to the surface of growth media prior to releasing adult flies. In both cases, eggs did not hatch and 99% of larvae failed to complete their development to adult flies.

On the basis of these results, teflubenzuron was included in a crop scale experiment.

5.2. Biological control of *S. stagnalis*

The efficacy against *S. stagnalis* of the entomopathogenic nematode, *Steinernema feltiae*, and the predatory mite, *Hypoaspis miles*, were evaluated in small scale experiments.

5.2.1. *Steinernema feltiae* (Nemasys).

Preliminary experiments in Petri dishes showed that *S. feltiae* would invade and kill *S. stagnalis* larvae and produce hundreds of progeny within each dead insect. However, the progeny did not appear to be released into the growing medium in their infective stage. Larger scale bioassays, in which *S. feltiae* were applied to *S. stagnalis* cultures at rates recommended for the control of sciarid flies, did not significantly reduce numbers of flies compared to untreated controls.

5.2.2. *Hypoaspis spp.*

Preliminary experiments in Petri dishes demonstrated that two species, *Hypoaspis miles* and *H. aculeifer*, would feed on the larvae of *S. stagnalis*. However, in larger scale bioassays, neither species reduced the numbers of insects to less than untreated controls.

5. Control measures directed at algae

While an effective insecticide may provide an immediate solution to the shore fly problem, it is unlikely to be acceptable in the longer term because lettuce growers are under pressure to reduce their overall insecticide usage. A more sensible strategy was considered to be the elimination of the pests algae food source.

Growers can reduce growth of algae and shore fly development by minimising overhead watering and feeding but there is little margin for error and this practice could lead to crop damage. Furthermore, the surface of heavier soils would still remain moist long enough for some *S. stagnalis* egg and larval development.

The application of products which prevent or suppress growth of algae was considered to be the next best approach. Preliminary studies with relatively high application rates of a fungicide with known algaecidal properties, thiram (Thianosan DG), demonstrated that prevention of growth of algae would also prevent the development of *S. stagnalis*. However, Approved application rates of thiram did not provide adequate control of algae and another, more effective, product was sought.

Many potentially useful products, including traditional algaecides, fungicides and some biological products, were screened using a simple laboratory-based bioassay. Benzalkonium chloride (Fargro Algaecide) and quinoclamine (Mogeton) stood out as the most promising options and they were taken forward to crop scale evaluation.

Mogeton is described as an algaecide, fungicide and herbicide. A phytotoxicity study was therefore completed before the crop scale evaluation. Mogeton was applied to lettuce beds at rates up to 140 gm per 10 litres water per 100 m^2 before and after planting the cultivar Titania. No acute phytotoxicity was observed when the product was applied to the soil surface the day before planting. However, some leaf scorch was noted when the product was sprayed over the plants at the highest application rate. Post-planting treatments must therefore be restricted to non-cropped areas.

FIRST CROP SCALE EXPERIMENT

Title

To evaluate the efficacy against algae and *S. stagnalis* of seven control strategies based on applications of various combinations of two algaecides and an insect growth regulator.

Introduction

Small scale laboratory-based bioassays had demonstrated that two algaecides (Fargro Algaecide and Mogeton) and an insect growth regulator (Nemolt) had potential for the control of *S. stagnalis* populations in protected lettuce crops. This crop scale experiment evaluated the efficacy of seven control strategies based on applications of various combinations of the three products .

Materials and Methods

Site:

Glasshouse F23, HRI, Stockbridge House.

Crop production details:

Crop:	Lettuce, cultivar Rachel
Planting date:	4 October 1996
Date harvested:	20 November 1996

Watering: Water was applied evenly through overhead irrigation lines. The quantity of water applied and frequency of application were determined by inspection of the soil surface.

Crop protection products used:

Pre-planting

Favour (2ml/litre water) to blocks.

Basilex (2kg/150litres water/1000m^2)

Post-planting

week 1 - Rovral (50g/100 litres water/300m^2)
plus Aliette (100g/50 litres water/300m^2)

week 2 - Aliette (100g/50 litres water/300m^2)

week 3 - Rovral (50g/100 litres water/300m^2)
plus Aliette (100g/50 litres water/300m^2)

week 4 - Aliette (100g/50 litres water/300m^2)

week 5 - Aliette (100g/50 litres water/300m^2)

Algae:

Algae was cultured in a constant environment room (21 ± 2°C, 16L:8D). On the 24 September 1996 and 2 October 1996, cultured material was diluted and applied evenly along the paths within the lettuce beds which formed the experimental plots . The paths were then covered with transparent plastic to prevent drying and to aid establishment of algae.

Shore flies:

S. stagnalis were reared in a constant environment room (21 ± 2°C, 16L:8D). Twenty adult flies were released in each experimental plot on 8 October 1996, followed by ten adult flies on each of the 9, 11 and 16 October 1996.

Experimental products, rates of application and area sprayed:

1. Nemolt applied to paths in growing beds at the rate equivalent to 35 ml per 50

litres water per 100 m^2.

2. Mogeton applied to whole growing beds before planting at the rate equivalent to 140 g per 10 litres water per 100 m^2.

3. Fargro Algaecide applied to whole growing beds before planting at the rate equivalent to 50 ml per 5 litres water per 100 m^2.

Treatments:

Treatment Reference	Product:			
	Mogeton 3 Oct 1996	Fargro Algaecide 3 Oct 1996	Nemolt 16 Oct 1996	Nemolt 31 Oct 1996
A				
B				✓
C	✓			
D	✓			✓
E		✓		
F		✓		✓
G			✓	
H			✓	✓

Application of experimental products:

All products were applied with a fully calibrated Oxford Precision Sprayer.

Assessments:

Growth of algae: Growth of algae on paths within each plot was assessed on 14 November 1996. This was recorded as the proportion of ground covered.

S. stagnalis numbers: The numbers of adult *S. stagnalis* caught on four sticky traps per plot were recorded on 14 and 18 November 1996.

Experimental Design and Analysis:

This was a split plot experiment with four replicates and main plots divided for the two level factor. Each sub-plot measured 11.9 m^2 (approx. 3.2 m x 3.8 m). Data were analyzed by analysis of variance (ANOVA) and LSD.

Results

The growth of algae recorded on the paths within the plots of each treatment on 14 November 1996 are shown in Table 1. There was significantly less algae recorded in the plots treated with Mogeton than any of the other treatments.

The mean numbers of *S. stagnalis* recorded per plot in each treatment over both assessment dates are shown in Table 2. There were significantly fewer flies in the plots treated with Mogeton (Treatments C and D) than in the untreated controls or the plots treated with Fargro Algaecide (Treatments E and F)($P < 0.05$)*. Single applications of Nemolt, sprayed either 12 days (Treatment G) or 27 days (Treatment B) after planting, did not reduce fly numbers compared to untreated controls. However, the combination of these applications, with sprays on both dates (Treatment H), did reduce fly numbers significantly compared to untreated plots ($P < 0.05$)*.

* $P < 0.05$ - the probability of this result occurring by chance is equal to or less than 1 in 20.

Discussion

The most successful *S. stagnalis* control strategy was the application of Mogeton to the whole growing bed one day before planting the lettuces. This reduced the growth of algae, thus offering fewer opportunities for *S. stagnalis* feeding and oviposition. The numbers of adult flies in the Mogeton treated plots was reduced to 32% of the numbers recorded in untreated plots. There was no benefit in combining this treatment with an application of Nemolt to the path within the crop bed 27 days after planting.

Two sprays of Nemolt, 12 and 27 days after planting, reduced the number of adult flies to 50% of the number recorded in untreated plots.

Fargro Algaecide, used alone or in combination with a single application of Nemolt, did not significantly reduce growth of algae or shore fly development compared to the untreated plots.

Although the plots were relatively large (approx. 3.2 m x 3.8 m), there appeared to be some migration of shore flies between them in the latter stages of the experiment. This may have resulted in artificially high counts in the plots with least algae, ie Treatments C and D.

The results of this study indicated that applications of either Mogeton or Nemolt could form the basis of a strategy for the control of *S. stagnalis* in protected lettuce. However, further experimentation was required to fine tune the control measures before firm recommendations could be made to growers.

Table 1. Growth of algae on paths within experimental plots on 14 November 1996.

Treatment reference	Products applied	Proportion of ground covered by algae.
A	-	0.71
B	Nemolt (31 Oct)	0.66
C	Mogeton	0.08
D	Mogeton + Nemolt (31 Oct)	0.07
E	Fargro Algaecide	0.71
F	Fargro Alg. + Nemolt (31 Oct)	0.61
G	Nemolt (16 Oct)	0.81
H	Nemolt (16 Oct) + Nemolt (31 Oct)	0.71
LSD^1		0.21
LSD^2		0.19

The LSD is the least (minimum) difference, when comparing any two figures, that is required for those figures to be statistically different.

LSD^1 should be used for comparisons between means of subplots from the same main plot (eg A v B, C v D, E v F or G v H)

LSD^2 should be used for all other comparisons.

Table 2. Mean numbers of *S. stagnalis* recorded per plot in each treatment on 14 and 18 November 1996.

Treatment reference	Products applied	Mean number of flies
A	-	452
B	Nemolt (31 Oct)	346
C	Mogeton	147
D	Mogeton + Nemolt (31 Oct)	170
E	Fargro Algaecide	443
F	Fargro Alg. + Nemolt (31 Oct)	399
G	Nemolt (16 Oct)	342
H	Nemolt (16 Oct) + Nemolt (31 Oct)	224
LSD ^{1}		191
LSD ^{2}		221

The LSD is the least (minimum) difference, when comparing any two figures, that is required for those figures to be statistically different.

LSD^1 should be used for comparisons between means of subplots from the same main plot (eg A v B, C v D, E v F or G v H)

LSD^2 should be used for all other comparisons.

SUMMARY OF SMALL SCALE STUDIES IN PREPARATION FOR THE SECOND CROP SCALE EXPERIMENT

At the HDC Project Review meeting on 3 March 1997, it was agreed that the project should be extended to include a second crop scale experiment. However, the design of the experiment would depend on the outcome of small scale studies to clarify certain aspects of the use of Mogeton, Nemolt and Thiram in protected lettuce crops.

1. Use of Mogeton

1.1. Legality

Although Mogeton is not Approved for application to protected lettuce crops, the label does include application to "non-crop areas and surfaces". The Project Leader contacted the Pesticide Safety Directorate (PSD) in March 1997 to determine whether the access paths within the lettuce beds and the spaces around the periphery of the crop could be considered to be non-crop areas. PSD confirmed, in writing, that both were non-crop areas and that it was acceptable to treat them with Mogeton during cropping.

1.2. Cost

The cost of Mogeton applied at the rate of 140 gm per 10 litres water per 100 m^2 to the entire soil surface in a lettuce crop is over £500 per hectare, which is prohibitively expensive. However, an application to the main *S. stagnalis* breeding sites, that is the paths within lettuce beds and the non-crop area around the periphery of the crop, is £75 per hectare, which is acceptable.

2. Use of Nemolt

There is no Approval for the use of Nemolt against *S. stagnalis* in protected lettuce crops. The nearest recommendation was for the application of a compost drench to control sciarid flies in ornamental crops; the application rate detailed in the product information sheet was

500 ml per 1000 litres of water but the volume required per unit area was not clear. The rate chosen for the first crop scale experiment was equivalent to 3.5 litres product per hectare. The suppliers of Nemolt advised subsequently that the application rate should be limited to 2 litres product per hectare and this lower application rate was evaluated in May 1997. Nemolt was applied twice, two and three weeks after planting lettuces, but did not give adequate control of *S. stagnalis* and therefore was not included in the second crop scale experiment.

3. Use of Thiram

Thiram was originally tested against algae at a relatively high rate equivalent to 14.9 kg product per hectare (recommended rate as a fungicide being 4 kg per hectare) and this provided total control. The Project Review Panel requested that it be re-evaluated to determine the lowest effective rate against algae.

Rates equivalent to 5.97 and 11.9 kg product per hectare were tested by bioassay. The lowest rate did not prevent growth of algae while the higher rate provided partial control. This indicated that the critical dose was between 11.9 and 14.9 kg per hectare. This was too high to be acceptable in commercial crops and the product was not therefore included in crop scale evaluations.

SECOND CROP SCALE EXPERIMENT

Title

To evaluate the efficacy against *S. stagnalis* of three control strategies based on applications of Mogeton and physical removal of adult flies.

Introduction

The first crop scale experiment (Autumn 1996) had demonstrated that Mogeton treatments to the soil surface would reduce growth of algae and the subsequent development of *S. stagnalis*. However, treatments to the whole soil surface were considered to be unacceptable because they were prohibitively expensive. This experiment was designed to determine the efficacy against *S. stagnalis* of Mogeton applied to non-cropped areas compared to applications to the whole soil surface.

A number of growers had expressed interest in the physical removal of shore flies from lettuce plants by suction. Similar techniques have been utilised against other pests in Californian strawberry crops and Danish ornamental crops. It was agreed that this should be included in the experiment to determine whether the technique had further potential within an integrated control strategy.

Materials and Methods

<u>Site:</u>

Glasshouse F15, HRI, Stockbridge House.

Crop production details:

Crop:	Lettuce, cultivar Flandria
Planting date:	23 July 1997
Harvest date:	26 August 1997
Watering:	Water was applied evenly through overhead irrigation lines. The quantity of water applied and frequency of application were determined by inspection of the soil surface.
Crop protection products used:	Pre-planting Basilex (2kg/150litres water/1000m^2) Post-planting week 1 - Aliette (100g/50 litres water/300m^2)

Experimental products, rates of application and area sprayed:

1. Mogeton applied to whole growing beds before planting at the rate equivalent to 140 g per 10 litres water per 100 m^2.

2. Mogeton applied to paths within growing beds at the rate equivalent to 140 g per 10 litres water per 100 m^2.

3. Adult *S. stagnalis* removed from plants by suction using a Dietrich Vacuum Insect Net.

Treatments:

Treatment Reference	Control measure:		
	Mogeton to growing bed on 22 July 1997	Mogeton to paths on 22 July, 6 and 13 August 1997	Flies removed by suction on 13 and 21 August 1997
A			
B	✓	✓	
C		✓	
D		✓	✓

Application of experimental products:

All Mogeton sprays were applied with a fully calibrated Oxford Precision Sprayer.

Assessments:

The numbers of *S. stagnalis* adults caught on seven sticky traps per plot were recorded on 22 August 1997.

Experimental Design and Analysis:

This was a randomised complete block experiment with four replicates. Each plot measured 35.3 m^2 (approx. 2.94 m x 12.0 m). Data were analyzed by analysis of variance (ANOVA) of the square root transformed treatment means and LSD.

Results

The mean numbers of *S. stagnalis* recorded per plot in each treatment are shown in Table 3. There were significantly fewer flies in the three treatments which received Mogeton (Treatments B, C and D) than in the untreated control (Treatment A) ($P < 0.05$)*. However, there were no significant differences between Treatments B, C and D.

Discussion

Where Mogeton applications were restricted to the paths within lettuce beds, the numbers of *S. stagnalis* caught on traps were reduced to 50% of the untreated controls. The additional pre-planting treatment of Mogeton to the whole bed did not significantly improve the control of *S. stagnalis*.

The application of this algaecide to non-cropped areas in lettuce crops could make a considerable contribution to the overall control of *S. stagnalis*.

Mogeton applications to paths plus the physical removal of adult flies by suction reduced shore fly numbers to 32% of untreated controls. Although this indicates that the physical removal of flies increased overall control, the improvement was not statistically significant. It is possible that this technique could be modified to provide better results and it should be further evaluated.

* $P < 0.05$ - the probability of this result occurring by chance is equal to or less than 1 in 20.

Table 3. Mean numbers of shore flies recorded per plot in each treatment on 22 August 1997

Treatment reference	Control measures	Mean number of *S. stagnalis* per plot	Square root mean transformation
A	untreated	181	12.72
B	Mogeton pre-planting to whole bed and to paths post-planting	78	8.24
C	Mogeton to paths post-planting	90	9.43
D	Mogeton to paths post-planting and physical removal by suction	58	7.42
	LSD		2.31

The LSD is the least (minimum) difference, when comparing any two figures, that is required for those figures to be statistically different.

CONCLUSIONS

The preliminary surveys of commercial crops confirmed that it was the shore fly, *Scatella stagnalis*, that was causing marketing difficulties for lettuce growers. The size of the *S. scatella* populations were roughly in proportion to moisture content of the soil surface and growth of algae. Soil surface wetness was influenced by both watering strategy and soil moisture retention; the heavier the soils, the greater the moisture retention resulting in more algae and larger *S. stagnalis* populations.

These studies have improved the general understanding of the biology of *S. stagnalis* and in particular the insects behaviour in protected lettuce crops. Both adults and larvae feed on green algae growing on the surface of moist soil. The breeding sites are predominantly:

1. the narrow compacted paths in the crop beds
2. the non-cropped strips at the ends of houses
3. the wall/floor angles where moisture collects from condensation on the glass/plastic.

S. stagnalis development is temperature dependant and limited below 10°C. Although adult flies may survive and lay eggs below 10°C, less than 2% of the immature insects complete their development. This indicates that a single carefully timed insecticidal treatment in the late autumn, when the development of the immature stages of the pest has been arrested, could remove the risk of lettuce contamination by adult flies until temperatures rise again in late winter/early spring.

During warmer months, foliar sprays and space treatments of insecticides have only a temporary impact on *S. stagnalis* populations because they do not reach the larval development sites. However, in small scale experiments, diazinon granules (Darlingtons Diazinon Granules), applied to the surface of the growing medium at rates equivalent to 11.2 kg per hectare, were shown to kill *S. stagnalis* larvae and prevent development from eggs for up to 22 days. The Project Review Panel decided that it was not appropriate to pursue an Off-Label Approval for this product due to the pressure being placed on lettuce growers to reduce insecticide usage.

A more specific insecticide, teflubenzuron (Nemolt), was shown to have potential for the control of *S. stagnalis*. Two applications at 3.5 litres per hectare, significantly reduced *S. stagnalis* numbers but this rate was higher than the maximum suggested by the product's distributors. Nemolt does not have Approval for use in lettuce crops.

Two commercially available biological control products, *Steinernema feltiae* and *Hypoaspis miles*, were evaluated for the control of *S. stagnalis* but did not provide acceptable control in this situation. In parallel to these studies, Elaine Wright (HRI, Wellesbourne) has worked with two species of parasitic wasps which are both effective parasitoids of *S. stagnalis*. These parasitoids may have a role in an integrated approach to shore fly control in protected lettuce but only if growers are able to move to a full IPM programme which eliminates the need to apply broad spectrum insecticides against other pests such as aphids and caterpillars.

The most successful control strategies involved removal of *S. stagnalis* algae food material. In many situations, growth of algae could be reduced by careful and even watering to avoid the development of permanent damp patches. However, additional action is required in the insects primary breeding sites; ie the access paths within lettuce beds and the periphery of the crop. The algaecide, Mogeton, applied to these non-crop areas in the greenhouse, at the rate of 140 g per 10 litres water per 100 m^2, reduced numbers of *S. stagnalis* by 50% compared to untreated controls. It is anticipated that applications of an effective algaecide to sequential crops would gradually reduce the overall shore fly population so that the necessity for treatments would decline.

The removal of adult flies by suction may make a useful contribution to the overall control of *S. stagnalis* but this must be further evaluated.

Insecticidal applications against *S. stagnalis* in protected lettuce could be minimised by the adoption of integrated strategies based on the following procedures. However, precise control programmes will have to be tailored to suit individual nurseries because of variations in soil types.

1. Water should be applied evenly and in minimal quantity to avoid the development of permanently damp patches of soil within the crop.

2. When the soil temperature is above 10°C, growth of algae in non-crop areas should be prevented by application of an effective algaecide such as quinoclamine (Mogeton). Applications may have to be repeated several times within each crop.

3. If there are significant numbers of adult flies when the mean daily soil temperature falls below 10°C in the late Autumn, a single spray of a broad spectrum insecticide should be applied to kill adults.

4. It should not be necessary to apply insecticides or algaecides while the mean daily soil temperature remains below 10°C.

Recommendation for further work

1. It is recommended that control programmes based on the above strategy are designed for three nurseries with different soil types and monitored at each through one annual cycle of crops.

2. Pest control measures based on the physical removal of insects by suction should be further evaluated.

3. The principles developed within this project should be used to design and evaluate *S. stagnalis* control strategies for other crops, eg protected celery & bedding plants.

4. The use of parasitic wasps against shore flies should be evaluated if growers move towards a full IPM programme which eliminates the need to apply broad spectrum insecticides against other pests.

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