Project title:	Activity patterns in the western flower thrips and their manipulation to enhance control measures
Project number:	CP 10
Project leader:	Dr William D.J. Kirk
Report:	First annual report, 30 September 2002
Key worker:	Ann O'Leary
Location of project:	School of Life Sciences Keele University Staffs ST5 5BG Tel: 01782 583517
Project co-ordinator:	Mr Dave Abbott, SGP Ltd
Date project commenced:	1 October 2001
Date completion due :	30 September 2004
Key words:	western flower thrips, WFT, *Frankliniella occidentalis*, light intensity, visible light, ultra violet light, glasshouse, chrysanthemums, humidity

Contents

PRACTICAL SECTION FOR GROWERS

Commercial benefits of the project

Need to await project completion until the commercial benefits of the project can be realized.

Background

Frankliniella occidentalis (Pergande) (western flower thrips or WFT) has proved difficult to control on UK glasshouse salad crops and ornamentals since its introduction in 1986. Its small size and preference for remaining hidden within small recesses of the plant reduces the chance of contact with chemical pesticides or natural predators. It is resistant to many chemical insecticides and the withdrawal of an increasing number of pesticides adds to the necessity to find novel techniques to improve the effectiveness of IPM programmes against this crop pest. Much research has been undertaken to test the effectiveness of various biological control agents such as the predatory mite *Neoseiulus cucumeris* and predatory bugs such as *Orius* spp. within IPM programmes but little work has been carried out on the behaviour of the pest species itself. What research has been done has shown that:

- Western flower thrips adults are more active (see below) during daylight than at night
- This activity includes egg-laying (oviposition), walking, feeding and flying
- When inactive they move into recesses and crevices within the plant
- Their activity can be influenced by changes in their environment such as light

It is logical to suggest that the insect pest would be more vulnerable to control measures such as a high volume spray application of entomopathogenic fungus or the presence of natural predators when they are, for example, walking about out on the plant surface more actively, since they are more likely to come into contact with the control agents. Shipp and Zhang (1999) stated that an increase in air temperature from 21º – 23ºC to 26º – 28ºC within a glasshouse, resulted in an increase in mortality of western flower thrips from insecticide by 23 – 25%. Although the mechanism by which this increase in mortality came about has not yet been demonstrated, these results may illustrate how the efficacy of an insecticide could be enhanced through changes in the climate regime of a glasshouse. Increasing mortality per

application could then lead to a reduction of applications required for adequate control saving time and money.

Objectives of the project

The aims of this project are to investigate how the activity of western flower thrips is affected by changes in light intensity, daylength, and wavelengths of light. If, for example, flight or walking activity was increased by an increase of light intensity, then the use of supplementary lighting at the time of a spray application could increase the efficiency of that application.
This project is part of a three year PhD studentship at Keele University. The aim of the HDC is to fund PhD studentships through a new HDC Studentship Scheme in order to support the training of new research staff for the horticultural industry.
The experimental aims include:

- To record the daily patterns (i.e. changes over 24 hours) of walking and feeding by larvae and adults under glasshouse conditions.
- To record the daily patterns of oviposition and flight (trap catches) by adult females under glasshouse conditions.
- To quantify how lighting (brightness, photoperiod and wavelength) affect the daily patterns of walking and feeding by larvae and adults under constant temperature.
- To quantify how lighting (brightness, photoperiod and wavelength) affects the daily patterns of oviposition and take-off by adult females under constant temperature.
- To test whether manipulation of lighting (such as brightness or wavelength) affects activity in commercial-scale glasshouses.

Summary of results and conclusions

After the completion of the initial postgraduate training element of this studentship, experimental work has now commenced in earnest. Most of the target experiments are in progress and much has been learnt in terms of implementation and technique.

Environmental monitoring

In order to quantify the effect of light on western flower thrips activity, it was first necessary to attempt to quantify the light to which the insect is subjected. A series of measurements were taken and recorded automatically using environmental sensors and a data-logger. Research was needed to find the best way of doing this and the most appropriate equipment to use. Light intensity was measured as watts per square metre (Wm^{-2}) under the following conditions (a) natural daylight measured on the roof of a building to avoid shadows from objects, (b) within the laboratory under experimental conditions and (c) inside a glasshouse. Two wavelength bands were measured for comparison; visible light (400 – 700nm) and UVA light (315 – 380nm).

Not surprisingly, it was found that the light intensity within the laboratory was much lower than natural daylight outdoors and than that found within the glasshouse with UV light levels being negligible in comparison. This must be taken into consideration when comparing the results of experiments carried out under glasshouse and laboratory conditions. Supplementary lighting, including a UV source, may be used in further laboratory experimental work.

Egg-laying or oviposition activity

In a series of tests to investigate the effect of adult female thrips density on rate of egg production, it was found that fewer eggs were laid as density increased. This result was particularly important in determining the number of adult females to place in each experimental tube. Since the total number of eggs produced was actually reduced as the number of adults per tube increased, there was no advantage in placing more than one thrips per tube.

This relationship between the density of adults in a closed space and the rate of egg production may also have some relevance to the population dynamics of the insect in a more natural situation.

Anticipated practical and financial benefits

The research could lead in the short term to simple and cost-effective ways of enhancing control measures for thrips in protected ornamental and edible crops. The research will improve our understanding of the activity of thrips and this has many potential benefits.

For example:

- We could predict the effect on thrips populations on changes in glasshouse lighting regimes.
- Improved understanding of the frequency of thrips encounters with predators could help in the development of biological control programs.
- Improved understanding of the movement of thrips could help in the efficacy of microbial pesticides.

SCIENCE SECTION

1 Introduction

1.1 Background to the project

Since its spread around the world in the 1980s, the western flower thrips (*Frankliniella occidentalis* (Pergande)) has become one of the most important insect pests of many edible and ornamental crops (Brødsgaard, 1989; Robb *et al.*, 1995; Bennison *et al.*, 1999b). It has caused substantial economic losses through direct physical damage to crops and by spreading plant viruses (Ullman *et al.*, 1997). The control of western flower thrips is not easy as it is resistant to chemical pesticides (Robb, 1989; Helyer & Brobyn, 1992) and its preference for remaining hidden within recesses in the plant host reduces the chance of contact with chemical pesticides. Integrated pest management has been used in glasshouse crops since the 1980s (Wardlow *et al.*, 1992) but the success of biological control of western flower thrips on ornamentals has been variable (Bennison *et al.*, 1999a). A better understanding of the behaviour of western flower thrips could be used to enhance the effectiveness of current management techniques. For example, if the manipulation of glasshouse conditions increased thrips activity, this would increase contact with chemical or biological control agents.

Thrips in the suborder Terebrantia such as the western flower thrips, have six stages in the life cycle. After hatching from the egg, these stages consist of larva I, larva II, propupa, pupa and adult (fig 2.1). Both larval stages are fully active, feeding stages which must eat enough for development through the pupal stages (Lewis, 1973). Being active they may at times occupy similar niches to the adults (Moritz, 1997). Both the larvae and the adults of pest thrips cause crop damage and are the subjects of this study. The propupa and pupa neither eat nor excrete and are inactive. They tend to remain hidden, often in the soil, while extensive internal development of organs and musculature takes place (Moritz, 1997). Both male and female adults are winged in the western flower thrips, which may account for their dispersal between neighbouring crops.

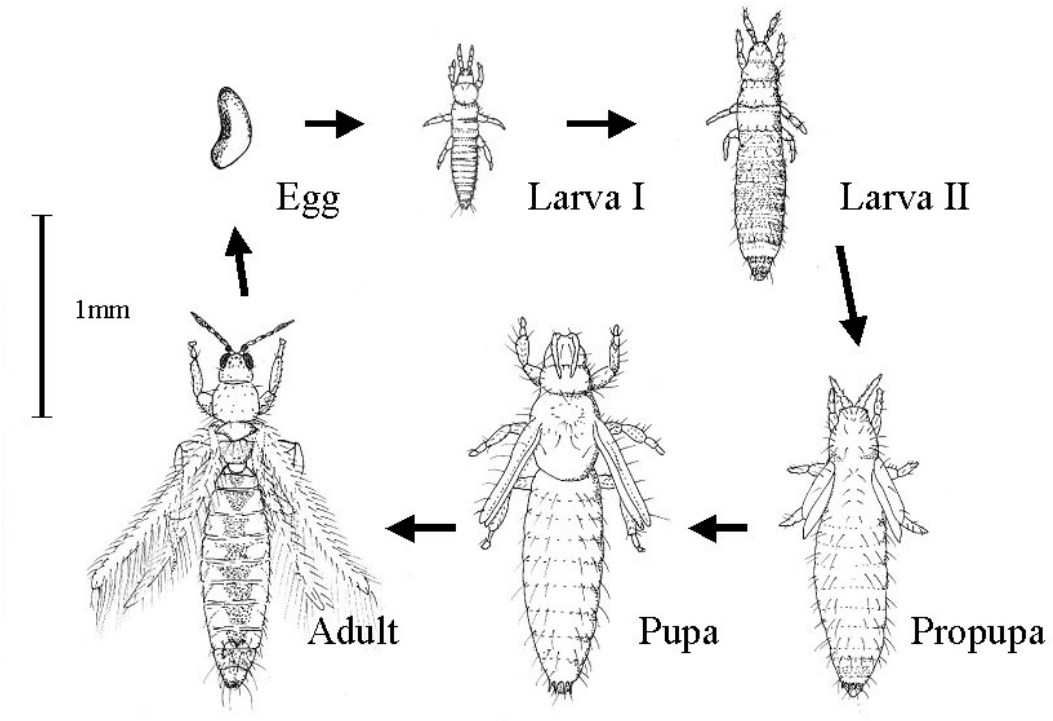

Fig 1.1 The life cycle of the western flower thrips (after Kirk, 1996)

Very little is known about the patterns of behaviour in western flower thrips or the environmental factors that control their behaviour. A review of the work published has been presented in an unpublished literature review (O'Leary, 2002). In summary, adult western flower thrips display a diel periodicity generally being more active during daylight hours than in the dark. This has been observed during several types of activity pattern including oviposition (de Kogel, 1997; Kirk *et al.*, 1999; Kiers *et al.*, 2000); walking (Cho *et al.*, 2000) and flight (Mateus *et al.*, 1996). Environmental factors that have been shown to affect these patterns of behaviour include photoperiod (Brødsgaard, 1994) and temperature (Shipp & Zhang, 1999). Small changes in the glasshouse environment can enhance the efficacy of integrated pest management (IPM) either by affecting the biological control agents, or by affecting the pest species directly. The western flower thrips, in common with other thrips, has the habit of crawling into narrow, enclosed spaces within the host plant structure and effectively hides from predators and chemical pesticides. Any environmental influence that increases walking and flight activity would increase contact with predators and chemicals and therefore increase mortality. Under glasshouse conditions, an increase of air temperature from 21-23° to 26-28° results in an increase in flight activity of western flower thrips and a corresponding increase in mortality from insecticide by 23-25% (Shipp & Zhang, 1999). By investigating the effects of light on activity patterns in western flower thrips, it may be possible to produce similar results by artificially increasing light intensity. Alternatively, it

may be possible to reduce oviposition with changes in the photoperiod. The potential results of this project are relevant to practical applications in the pest management of a serious pest of protected crops.

1.2 Project aims

The aims of this project were agreed in advance with the Horticultural Development Council, which is funding the three year studentship. The aim of the HDC is to fund PhD studentships through a new HDC Studentship Scheme in order to support the training of new research staff for the horticultural industry. They include those aims related to the completion of a post-graduate doctorate degree at Keele University such as the satisfactory completion of the Keele post-graduate training course and production of a written review of the background literature to the project. The experimental aims are detailed below.

Overall aim

The aims are to understand the factors that influence the activity patterns of the western flower thrips and to exploit this knowledge to suggest means of enhancing control measures in glasshouses.

Specific objectives

1. To record the daily patterns (i.e. changes over 24 hours) of walking and feeding by larvae and adults under glasshouse conditions.
2. To record the daily patterns of oviposition and flight (trap catches) by adult females under glasshouse conditions
3. To quantify how lighting (brightness, photoperiod and wavelength) affect the daily patterns of walking and feeding by larvae and adults under constant temperature.
4. To quantify how lighting (brightness, photoperiod and wavelength) affects the daily patterns of oviposition and take-off by adult females under constant temperature.
5. To test whether manipulation of lighting (such as brightness or wavelength, using information gained from 3-4) affects activity in commercial-scale glasshouses.

Experiments to quantify the effects of external factors on thrips behaviour need to be conducted under controlled conditions in the laboratory. In order to be sure that the results obtained are applicable to the glasshouse environment, however, behavioural observations must also be made under the variable conditions typical of a commercial glasshouse.

2 Materials and methods

2.1 Environmental monitoring

2.1.1 Introduction

So that the conditions of light, temperature and humidity can be quantified and controlled, they were monitored using environmental sensors and dataloggers. Thrips are known to be affected by temperature and relative humidity and are sensitive to light in the wavelength range of 350 to 650nm (Vernon & Gillespie, 1990). As well as using temperature and relative humidity sensors, it is also necessary to monitor UVA (315 – 380nm) as well as 'visible' light (400 – 700nm). Two systems were used:

1. Grant Squirrel datalogger with 16 temperature sensor channels
2. Skye Datahog 2 with 4 sensor channels to monitor temperature, relative humidity, UVA and visible light intensities.

The sensors and dataloggers were used to record these environmental factors during experiments run under constant temperature and under glasshouse conditions. In this way, constant temperature could be confirmed and the relative light intensities found under laboratory conditions could be compared with those found within a glasshouse. Measurements were taken the near the experiment to show general ambient conditions as well as within the apparatus itself to record the microclimate inside. They were also used to gather data on the ambient conditions of natural light intensity, temperature and relative humidity over a period of time.

Fig 2.1 Skye datalogger with sensors

2.1.2 Measurement of ambient environmental conditions

As discussed in section 5 of the literature review produced for this project (O'Leary, 2002), the intensity of light within a glasshouse is mostly determined by the intensity of the natural light. In order to obtain a record of typical environmental conditions at Keele over a year, the Skye datalogger and sensors were placed on the roof of the biology department for eight days each month to record daily fluctuations in visible and UV light intensities, temperature and relative humidity. Readings were taken automatically every five minutes and the data for seven full days from midnight to midnight was averaged to produce charts showing the mean daily fluctuation in environmental conditions. These typical figures for light intensity were obtained in the open air. They can be converted to light intensity within any glasshouse if the transmission properties are known.

2.1.3 Transmission of light through glass

The quality of light inside a glasshouse varies with the construction of the glasshouse and the condition of the construction materials although as a general guide, the transmission of light through glass, polycarbonate or plastic varies from between 50 and 70% (Langton & Fuller, 2001). In order to investigate the transmission of light into a glasshouse, spot readings were taken of visible and UV light directly and through a sheet of glasshouse glass at different times of day and different light intensities. Since glass is the most popular material used for glasshouses, this material was used in the experiment initially but other materials such as plastics will be tested as they become available.

Readings were taken from early morning to early afternoon over a range of light intensities, with each pair of readings, direct and transmitted, being taken in quick succession. Although ideally, to measure the transmission of natural light through the glass, the readings should have been taken simultaneously, in practice, with a very clear sky or with complete cloud cover the light intensity remained constant in the 1 to 2 seconds which lapsed between comparable readings.

2.2 Western flower thrips culture

A culture of western flower thrips has been maintained for around six years at Keele University. The insects are reared on a susceptible variety of chrysanthemum (*Dendanthema grandiflora* (Tzvelev) Yellow Princess Anne), which is cultivated in the university glasshouses. Five separate culture cages each contain 4 pot plants standing in dishes so that they can be watered from the base to avoid over-saturation of the pot soil. The pots stand on a thick base of vermiculite, which can act as a pupation site along with the pot soil and the structure of the plants themselves. Care is taken to keep the vermiculite dry and free from plant debris to reduce the chance of infestation by mites, collembolans or other organisms. Each cage is ventilated with screens and a small fan extractor since thrips will drown in small droplets of condensation (fig 2.2).

Fig 2.2 A culture cage in which western flower thrips are reared in a mixed age population

The cages are maintained at 25°C under a lighting regime of L:D 18:6 with the lights switching on at 0300 GMT and off at 2100 GMT. Illumination is provided solely by a bank of four 1500mm, 65W fluorescent tubes.
Thrips can be removed from the culture at any time for experimental use although the population has a mixed age structure.

2.3 Effects of thrips density on oviposition

An investigation into the effects of light on oviposition in western flower thrips involves placing thrips into a small cage and allowing them to lay their eggs onto a membrane. Before conducting such trials, it was necessary to determine the optimum number of thrips per cage. Although a greater number of thrips per cage would provide a higher number of replicates, any density-dependent effect on oviposition may reduce the overall oviposition rate.

Adult female western flower thrips of mixed ages were collected from the laboratory culture and placed in varying densities into oviposition tubes for a period of 48h to determine the effect of density on the number of eggs laid through a Parafilm M® membrane. The density of thrips and number of replicates of each density were as follows:

Number of thrips per tube	1	2	4	8	16
Number of tubes per trial	16	8	4	2	1

Table 2.1 Range of densities of western flower thrips used

Replication was such that each treatment had the same number of thrips. The experiment was repeated 4 times. Polythene tubes were prepared as shown in figure 2.3.

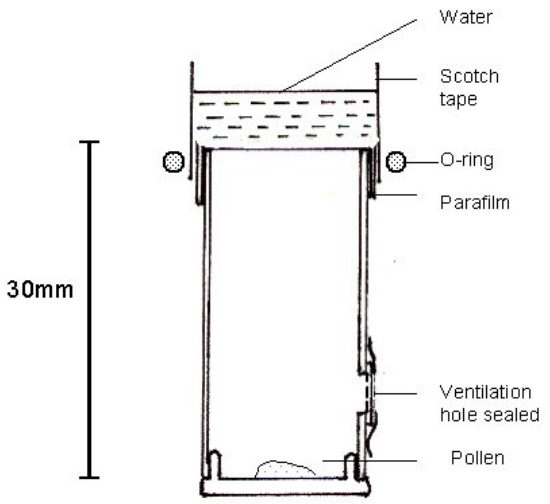

Fig 2.3 Construction of an oviposition tube

A food supply in the form of pine pollen (*Pinus sylvestris*) was supplied at the base of the tube.

Female thrips were placed in each tube through the ventilation hole, using a mini-pooter, and then each hole was sealed using Scotch® tape and Kimberley Clarke tissue. This prevented escapes but allowed sufficient ventilation to maintain adequate humidity within the tube. Due to the possibility of contamination of the tubes with semiochemicals, fresh tubes were prepared for each trial.

Each batch of 31 tubes was placed in a rack positioned inside a glass tank containing a layer, 1.5cm deep of saturated potassium tartrate solution. This solution served to maintain a constant relative humidity within the tank of 75% (Winston & Bates, 1960) when allowed to equilibrate with a glass lid fitted tightly over the top. Once in position inside the humidity tank, each of the tubes had 1ml of distilled water pipetted into the reservoirs over the membrane. The humidity tank was positioned within a constant temperature room at 25°C under a light regime of 18:6 light to dark, the same conditions under which the thrips had been reared.

Once set up, the oviposition tubes were left for one hour before being individually removed and examined under a dissecting microscope to count the number of eggs laid. This process was then repeated after 24h and 48h. Any eggs laid in the first hour were disregarded to take account of any possible effects of disturbance.

2.4 Observation of the diel pattern of oviposition under constant and glasshouse conditions

The equipment used to conduct these trials was designed and constructed by a former Keele PhD student, Mark Whittaker. He used the equipment successfully to record a diel activity pattern of oviposition in western flower thrips (M.S.Whittaker, pers. comm. 2001). In principle, it is similar to that used in the previous experiment in that adult female thrips are placed into small tubes with an oviposition membrane at the top. In this experiment, however, the pattern of egg laying over a period of 72h is to be recorded. Instead of counting the total number of eggs laid after periods of 24h, eggs are counted every hour. For this to be possible, the tubes are mounted on a carousel, which rotates, positioning each tube under a video-microscope once every three minutes. The eggs are illuminated with IR, which is invisible to the thrips, so can be used through the light and dark periods. This is recorded using a time-lapse videocassette recorder (VCR) and the eggs counted using the recording, for every hour. In this way the mean oviposition rate at each hour throughout a 24h period, can be charted. Careful adjustment is necessary to be able to film the eggs reliably, because they are only 300 µm long.

Initially the experiment was carried out using laboratory reared female adults under constant temperature and relative humidity and a light regime of 18:6h light to dark. Arrangements are currently underway to repeat the experiment, using glasshouse reared western flower thrips within a commercial type glasshouse. Once the pattern has been confirmed, experiments can then be conducted using the same apparatus but subjecting the western flower thrips to different lighting conditions.

The arrangement of the equipment for this experiment is outlined in fig. 2.4.

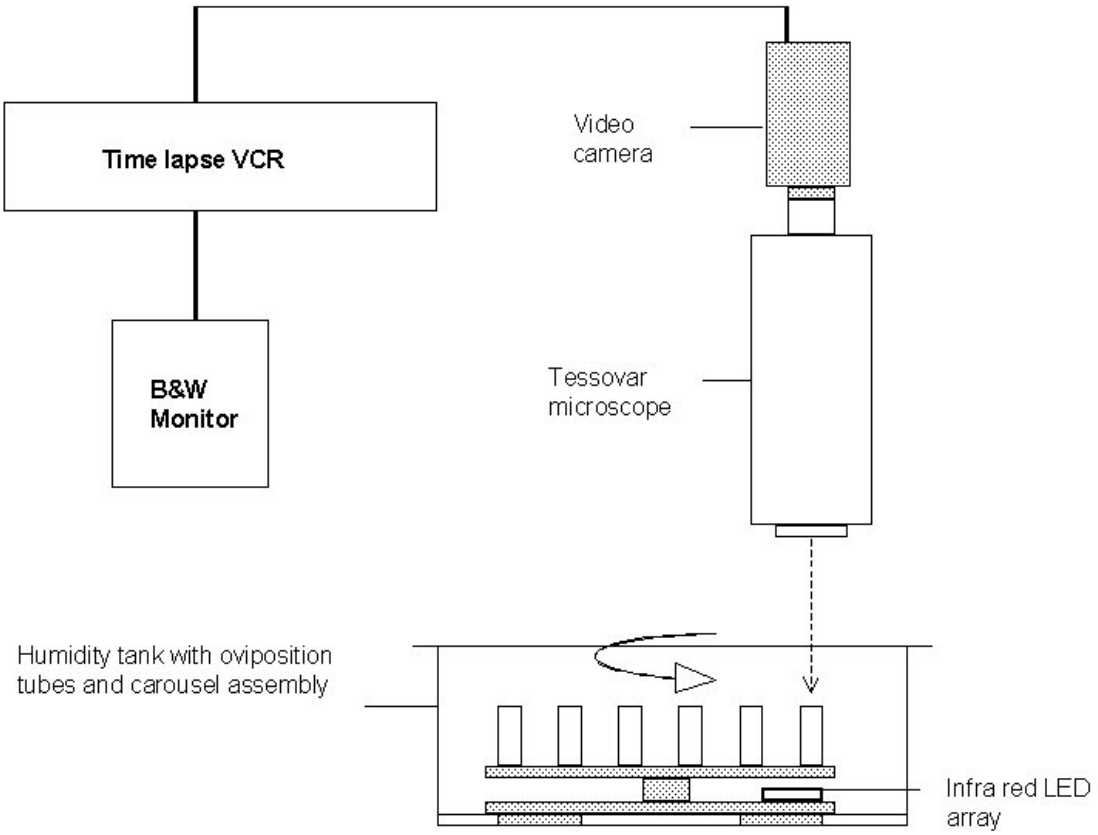

Fig 2.4 Diagram of the arrangement of equipment for time-lapse micro-videography of oviposition in western flower thrips.

Oviposition tubes are similar in construction to those described in section 2.2 with the following differences:

- tubes are made of perspex for precision fitting on the carousel
- they were cleaned using 10% Teepol® solution then re-used after each trial
- there was no base to the tubes but instead each tube was sealed onto a recess on the carousel plate using glycerol jelly
- the reservoir at the top of each tube was formed using a fitted brass collar, which did not curl like scotch tape, making it easier to view the eggs
- pollen was placed, as described in section 2.2, onto the recesses of the carousel plate which acted as the base to each tube.

Using the results from the previous experiment on the effects of density on oviposition, one mixed age, adult, female western flower thrips was placed into each oviposition tube through the base of the tube.

The video camera was fitted with and an infra-red (IR) filter to allow only IR light into the camera. The oviposition tubes were illuminated from below with an array of 20, IR LED's. Western flower thrips are not sensitive to infra-red light and therefore the oviposition membranes could be recorded in the presence or absence of visible light without interrupting the lighting regime.

Fig 2.5 Photograph of oviposition humidity tank assembly with Tessovar microscope, video camera and monitor

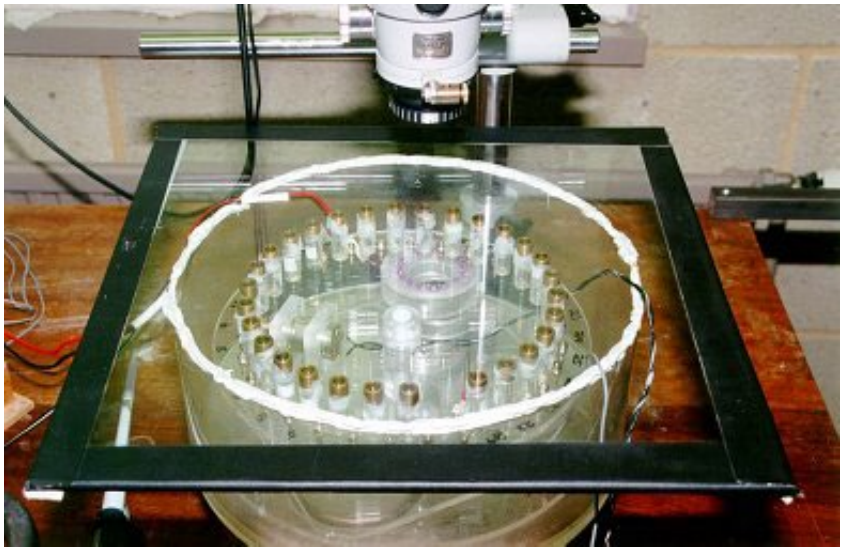

Fig 2.6 Close up of humidity tank showing carousel with oviposition tubes and IR array

2.5 Effect of light on take-off in adult female western flower thrips

Take-off, as an element of insect flight, is an important aspect of thrips behaviour since thrips in active flight may be more susceptible to certain control measures such as fumigant insecticide spray e.g. Dichlorvos. Studies have shown that light intensity and temperature are important factors in determining take-off and subsequent flight in some thrips species (Lewis, 1963). In this series of experiments, adult, female western flower thrips are placed in small closed tubes for a short period of time to settle. The tubes are then opened and left for a few minutes. The number of thrips remaining can then be counted to determine the percentage take-off of thrips under given conditions. The trials are conducted under constant temperature (25°C) and under a variety of lighting conditions to determine how light intensity and wavelength may affect take-off.

The design needs to be such that it can be repeated many times under controlled conditions. The thrips are allowed to settle and are then exposed to ambient conditions without being able to hide.

A small number of western flower thrips were chilled and placed inside a gelatin capsule pierced at each end with entomological pins and mounted vertically into Plastazote®. After a settling time of three minutes, the top of the capsule was removed and mounted upside down next to its base. Any thrips that had crawled into the top part of the capsule were therefore included in the count data when the remaining thrips were counted after two minutes. Four capsules were prepared at the same time and the whole treatment was then repeated a number of times to provide sufficient replicates for statistically valid results.

Initially four light intensities at the same wavelength will be used to investigate the effect of light intensity on take-off. Using filters, it should then be possible to investigate the effect of wavelength at a constant intensity. The thrips will be illuminated with IR light throughout the trials so that counts can be made in the dark with the use of the IR sensitive video camera. The experimental arrangement is illustrated in figure 2.7.

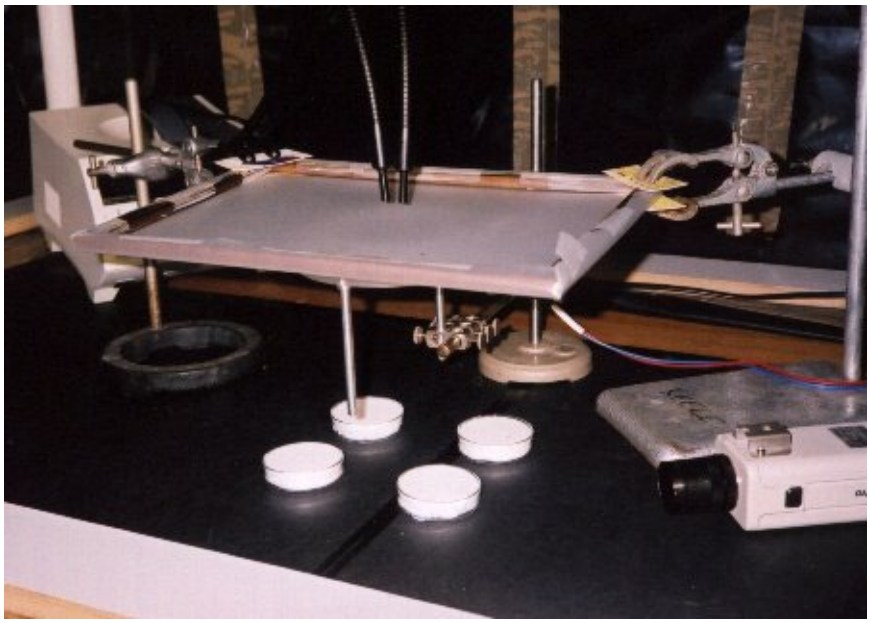

Fig. 2.7 Photograph of the experimental arrangement for investigation of the effect of light on takeoff.

Fig.2.8 Close-up photograph of a capsule used in takeoff bioassays.

2.6 Recording walking and feeding patterns under controlled and glasshouse conditions

The experimental apparatus for this procedure has been designed and successfully used by Mark Whittaker to investigate walking activity patterns in western flower thrips. As with the investigation into the diel pattern of oviposition, the experiment relies on IR videography of thrips within small cages. In this investigation, the thrips are placed individually into cone shaped arenas and videoed from below (the widest end of the arenas) so that with the given depth of field of the camera, each thrips will always be in focus on the recording. The video image is passed directly to a PC with which the movement of each thrips is automatically tracked and analysed using the software Ethovision®. By having different regions within each arena including a feeding membrane and a refuge, the percentage time spent inactive, walking, feeding (i.e. remaining on the feeding membrane) or within the refuge can be determined.

In the first instance, the apparatus is to be used to record activity of laboratory reared thrips under controlled conditions to gain familiarity with the techniques involved. It is then to be used to record activity of glasshouse reared thrips under natural glasshouse conditions. There are certain technical problems to be overcome under natural light conditions. This is because the maintenance of constant illumination within the video image necessary for Ethovision to function is difficult under the extreme range of light intensity found within the glasshouse despite the use of an IR filter. It may mean that the analysis of activity will have to be completed manually.

At the time of writing, this experiment is still in the design stage.

3 Results and discussion

3.1 Introduction

Of the experimental work planned for the first year of this studentship, results have been obtained from the environmental monitoring and from preliminary work to investigate the effect of thrips density within the oviposition tubes on oviposition rate.
Work is in progress on the recording of the oviposition activity pattern under glasshouse conditions and the effects of light on take-off but as yet, no data have been collected.

3.2 Environmental monitoring

Figures were obtained for the months of April through to July for visible light intensity, UV light intensity (appendix 1), temperature and relative humidity. As an example, the light intensity figures are shown for June 2002 in figs 3.1 and 3.2.

Similar recordings made in the laboratory, next to the experimental equipment during an experiment, produced very different results (fig 3.3 and 3.4).

The most notable observation to be made is the difference in scale of light intensity of natural light, even in April, as compared with the light provided by the fluorescent tube array within the laboratory. Visible light intensity during the light phase within the constant temperature room is between only 5 – 7 Wm^{-2} (fig 3.3) with a UV intensity of between 0.9 – 0.14 Wm-2 (fig 3.4). Natural visible light, however, when measured directly, reaches a maximum intensity of over 500 Wm^{-2} between 1200 and 1400 GMT (fig 3.1) with a UV peak of over 30 Wm^{-2} (fig 3.2). In addition to the difference in scale, the changeover from dark to light and vice versa is very gradual under natural light and sharply distinct in the laboratory. It is worth noting, however, that thrips are often within flowers or underneath leaves where the light levels may be much closer to those in the laboratory.
Glass absorbs UV light and it will therefore be necessary to confirm the intensity of UV light inside the humidity tank. This emphasises the importance of measuring the ‘microclimate’ of the western flower thrips inside the experimental containers as well as the ‘macroclimate’ in the surrounding area of the laboratory or glasshouse. This is also relevant to the ‘microclimate’ of the individual thrips, which are often found within recesses in the plant where the light levels will be much lower.

Since there is such a large discrepancy between the absolute light intensities of the laboratory and glasshouse, it is important that the experiments are repeated under natural glasshouse conditions to test whether the diel activity patterns observed under one set of conditions are also present under the other. It is possible that a threshold of light intensity is important in triggering behaviour patterns in which case the maximum light intensity may be less important or irrelevant. This can be investigated in the laboratory. As a threshold effect may be affected by prior conditions, it also necessary to consider the rearing conditions of the experimental thrips whether lab reared or 'wild'.

3.3 Transmission of light through glass

The results from this investigation can be used to predict the proportion of incident visible solar radiation, which would be transmitted into a glasshouse. There was a straight-line relationship between direct light intensity, for both visible and UV wavelengths, and transmitted light intensity (figs 3.5 and 3.6). Around 80% of visible light was transmitted through glass 3mm thick. The glass absorbed a greater percentage of UV light than the visible light as might be expected but a high proportion of UV was still transmitted (about 66%). Although the intensity is low, there could still be a sufficient UV light inside a glasshouse to have an effect on thrips behaviour. The effect of UV light on thrips behaviour has been studied by experimentally reducing UV within glasshouses with UV-absorbing plastics (Antignus *et al.*, 1996; Costa & Robb, 1999; Costa *et al.*, 2002). Evidence suggests that UV light has some effect on thrips activity but with such a low UV intensity produced by the laboratory lighting array, this effect may not be apparent. It may be necessary to supply supplemental UV light in order to more closely simulate glasshouse conditions.

3.4 Effects of western flower thrips density on oviposition

This experiment was repeated six times but in two of the replicates, there were high escape rates from the tubes. It was decided that any trial with a greater than 50% escape rate within any one treatment should be excluded from the analysis since the number of eggs laid in these tubes may not be comparable with the other results. Trials numbered 102 and 105 had escape rates of 81% and 62% from the 16 thrips tubes and were thus rejected. From the remaining trials it was found that the rate of oviposition decreased as the density of thrips within a cage

increased (fig 3.7). A regression analysis of the data shows that the reduction in oviposition as density increases is highly significant ($p<0.001$).

Observation of the western flower thrips within the oviposition tube would suggest that the decrease in egg laying rate may be due to physical disturbance between individual adults. The walking activity of thrips at high densities appeared to be higher than at lower densities. Each time they made physical contact with each other, they each moved away. This could disrupt egg-laying behaviour at higher densities where the average number of contacts between individuals would be higher. This is supported by Bryan and Smith (1956) in their observation that the female western flower thrips requires a period of relative inactivity before ovipostion takes place. These results were used in planning the next investigation.

Figure 3.8 shows how the total number of eggs laid by the thrips decreases sharply with increasing thrips density and not just the rate of oviposition per thrips. These results are significant for further experimental work on oviposition. Since fewer eggs are produced at higher thrips densities, there is no advantage in using more than one thrips per cage and handling is easier when only one thrips is used.

Finally, to show that this decrease in egg laying is not due to an increase in thrips mortality or escapes, the mean number of thrips left alive at the end of each trial was plotted against thrips density (fig 3.9). For completeness, all six trial results were included.
Although there appears to be a slight decrease in survival with increasing thrips density, regression analysis shows that this trend is not significant ($p>0.05$).

3.5 Observation of the diel pattern of oviposition under constant and glasshouse conditions

This experiment has been run under constant temperature and under glasshouse conditions and at the time of writing, the video data is under analysis.

The arrangement of the experimental apparatus within the glasshouse is shown in figure 3.12. Glycerol jelly was used to seal the oviposition tubes onto the carousel plate. This melted in the fairly high temperatures reached within the glasshouse and all the thrips drowned in the liquid. An alternative method of sealing the tubes may have to be found.

The environmental conditions of visible light intensity, UV light intensity, temperature and relative humidity were monitored throughout the trial. Graph plots of the data (appendix 3) show that the conditions vary widely through a 24h period. Visible and UV light intensity do not reach the maximum levels found outside in July (appendix 1) as might be expected due to the loss of light intensity during transmission through the roof and walls of the glasshouse. Both visible and UV light intensities measured inside the glasshouse were intermediate between those typically measured outside and those produced in the controlled environment of the laboratory. Temperature fluctuations were very high with a peak of around 45ºC after the air vents were closed. Although western flower thrips are known to survive these temperature fluctuations, such a high maximum temperature may not represent normal conditions in UK commercial glasshouses and will have to be avoided in future trials.

3.6 Effect of light on take-off in adult female western flower thrips

At the time of writing, initial trials are underway to establish the best protocol for this experiment.

4 Conclusions

At this stage, experimental work is underway and although much of the preliminary work has been completed and practical techniques developed, the main lines of enquiry are still in progress.

Much data has been collected on the environmental conditions to which western flower thrips are subjected. The glass of the glasshouse walls and roof was found to absorb visible light as predicted (Langton & Fuller, 2001, D Abbott, pers. comm. 2001). What is not normally monitored within the horticultural industry, however, is the level of ultraviolet light transmitted into the glasshouse. Although the glass absorbs a percentage of UV light, the greater percentage is transmitted and may have some influence on the behaviour of western flower thrips. The effect of UV light on thrips activity is to be investigated under controlled conditions.

Within the closed conditions of an oviposition tube, the fecundity of adult female western flower thrips exhibits an over-compensating density dependent response. This conclusion is

useful for the planning of further oviposition experiments but further experimental work is required before wider conclusions can be made.

5 Glossary

Term used	Definition
Fecundity	The number of eggs or seeds or generally offspring in the first stage of the life cycle, produced by an individual. *
Oviposition	The process of egg laying, in this case by an insect using an ovipositor – a piercing, tube - like organ at the tip of the abdomen.

Definitions provided by:

* Begon, M., Harper, J L. and Townsend, C R. (1996). Ecology – Individuals, populations and communities (3rd edition) Blackwell Science, Oxford

6 References

Antignus, Y., Mor, N., Joseph, R.B., Lapidot, M. & Cohen, S. (1996) Ultraviolet-absorbing plastic sheets protect crops from insect pests and from virus diseases vectored by insects. *Environmental Entomology* 25, 919-924.

Bennison, J.A., Pow, E.M., Wadhams, L.J., Maulden, K.A., Wardlow, L.R. & Buxton, J.H. (1999a) Improving biological control of western flower thrips, *Frankliniella occidentalis*, on greenhouse ornamentals. In: *Proceedings: Sixth International Symposium on Thysanoptera, Akdeniz University, Antalya, Turkey, 27 April-1 May, 1998*. Edited by: G. Vierbergen & I. Tunç. akdeniz University, Antalya. pp 19-24.

Bennison, J.A., Pow, E.M., Wadhams, L.J., Maulden, K.A., Wardlow, L.R. & Buxton, J.H. (1999b) Improving biological control of western flower thrips, *Frankliniella occidentalis*, on greenhouse ornamentals. *Proceedings of the 6th International Symposium on Thysanoptera, Turkey* 1998, 19-24.

Brødsgaard, H.F. (1989) *Frankliniella occidentalis* (Thysanoptera: Thripidae) - a new pest in Danish glasshouses. A review. *Danish Journal of Plant and Soil Science* 93, 83-91.

Brødsgaard, H.F. (1994) Effect of photoperiod on the bionomics of *Frankliniella occidentalis* (Pergande) (Thysanoptera, Thripidae). *Journal of Applied Entomology* 117, 498-507.

Bryan, D.E. & Smith, R.F. (1956) The *Frankliniella occidentalis* (Pergande) complex in California (Thysanoptera: Thripidae). *University of California Publications in Entomology* 10, 359-410.

Cho, K.J., Walgenbach, J.F. & Kennedy, G.G. (2000) Daily and temporal occurrence of *Frankliniella* spp. (Thysanoptera: Thripidae) on tomato. *Applied Entomology and Zoology* 35, 207-214.

Costa, H.S. & Robb, K.L. (1999) Effects of ultraviolet-absorbing greenhouse plastic films on flight behavior of *Bemisia argentifolii* (Homoptera: Aleyrodidae) and *Frankliniella occidentalis* (Thysanoptera: Thripidae). *Journal of Economic Entomology* 92, 557-562.

Costa, H.S., Robb, K.L. & Wilen, C.A. (2002) Field trials measuring the effects of ultraviolet-absorbing greenhouse plastic films on insect populations. *Journal of Economic Entomology* 95, 113-120.

de Kogel, W.J. (1997) *Host plant resistance to western flower thrips: variable plants and insects*. Ph.D. thesis, University of Amsterdam.

Helyer, N.L. & Brobyn, P.J. (1992) Chemical control of western flower thrips (*Frankliniella occidentalis* Pergande). *Annals of Applied Biology* 121, 219-231.

Kiers, E., de Kogel, W.J., Balkema-Boomstra, A. & Mollema, C. (2000) Flower visitation and oviposition behaviour of *Frankliniella occidentalis* (Thysanoptera: Thripidae) on cucumber plants. *Journal of Applied Entomology* 124, 27-32.

Kirk, W.D.J. (1996) *Thrips. Naturalists' Handbooks 25*. Richmond Publishing Co. Ltd., Slough.

Kirk, W.D.J., MacDonald, K.M., Whittaker, M.S., Hamilton, J.G.C. & Jacobson, R. (1999) The oviposition behaviour of the western flower thrips, *Frankliniella occidentalis* (Pergande). In: *Proceedings: Sixth International Symposium on Thysanoptera, Akdeniz University, Antalya, Turkey, 27 April-1 May, 1998*. Edited by: G. Vierbergen & I. Tunç. Akdeniz University, Antalya. pp 69-75.

Langton, A. & Fuller, D. (2001) *Supplementary lighting of pot chrysanthemums: A grower guide*. Horticultural Development Council, Kent.

Lewis, T. (1963) The effect of weather on emergence and take-off of overwintering *Limothrips cerealium* Haliday (Thysanoptera). *Annals of Applied Biology* 51, 489-502.

Lewis, T. (1973) *Thrips. Their biology, ecology and economic importance*. Academic Press, London.

Mateus, C., Araújo, J. & Mexia, A. (1996) Daily flight periodicity of *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae). *Folia Entomologica Hungarica* 57 Suppl., 97-102.

Moritz, G. (1997) Structure, growth and development. In: *Thrips as crop pests*. Edited by: T. Lewis. CAB International, Wallingford, UK. pp 15-63.

O'Leary, A.T. (2002) *Literature Review - Activity patterns in the western flower thrips and their manipulation to enhance control measures*. Keele University, Keele.

Robb, K.L. (1989) *Analysis of* Frankliniella occidentalis *(Pergande) as a pest of floricultural crops in California greenhouses*. Ph.D. thesis, University of California Riverside.

Robb, K.L., Newman, J., Virzi, J.K. & Parrella, M.P. (1995) Insecticide resistance in western flower thrips. In: *Thrips biology and management*. Edited by: B.L. Parker, M. Skinner & T. Lewis. Plenum Press, New York. pp 341-346.

Shipp, J.L. & Zhang, Y. (1999) Using greenhouse microclimate to improve the efficacy of insecticide application for *Frankliniella occidentalis* (Thysanoptera: Thripidae). *Journal of Economic Entomology* 92, 201-206.

Ullman, D.E., Sherwood, J.L. & German, T.L. (1997) Thrips as vectors of plant pathogens. In: *Thrips as crop pests*. Edited by: T. Lewis. CAB International, Wallingford. pp 539-565.

Vernon, R.S. & Gillespie, D.R. (1990) Spectral responsiveness of *Frankliniella occidentalis* (Thysanoptera: Thripidae) determined by trap catches in greenhouses. *Environmental Entomology* 19, 1229-1241.

Wardlow, L.R., Brough, W. & Need, C. (1992) Integrated pest management in protected ornamentals in England. *Bulletin OEPP (European and Mediterranean Plant Protection Organization)* 22, 493-498.

Winston, P.W. & Bates, D.H. (1960) Saturated solutions for the control of humidity in biological research. *Ecology* 41, 232-237.

