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The Effect of Wavelength on Take-Off in the Western Flower Thrips

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There are many problems associated with the investigation of the effect of light on thrips behaviour. Some techniques to overcome them are presented. Experiments on the effect of light on take-off showed that adult female *Frankliniella occidentalis* (Pergande) took off readily and at a similar rate under UVA (350–380 nm), human-visible white light (400–700 nm) and human-visible white light with UVA (350–700 nm). Thrips also took off in the dark, but the rate was significantly lower. Thus, light was not necessary for take-off and either UVA or human-visible white light or both could stimulate take-off.

Keywords: *Frankliniella occidentalis,* ultra-violet light, UVA, UV, flight.

The western flower thrips, *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) is an economically important insect pest of protected crops (Brødsgaard, 1989). It is difficult to control because of the loss of effective insecticide approvals and because of its tendency to hide within the recesses of the host plant.

Take-off rate is an indication of the tendency of thrips to fly as opposed to hiding or other activities. There are many factors that affect insect take-off, including temperature (Lewis, 1963), relative humidity (Haufe, 1963), light and physiological state (Haufe, 1962). Under natural conditions, several factors may act together to affect take-off (Johnson, 1969) and it is necessary to take these into consideration when testing the effects of a single factor such as light. Photoperiod, light intensity and wavelength are important factors within the glasshouse environment and they are manipulated to control crop development and aid in pest management (Machin, 1997; Bragg and Coutts, 2003). A better understanding of how light affects take-off in *F. occidentalis* may assist in predicting the effect of glasshouse lighting manipulation on a pest population and help to develop novel pest management techniques.

The effect of light intensity and wavelength on take-off in *F. occidentalis* has not been investigated although there has been research on take-off in other thrips species (Lewis, 1963). In common with most insect species, *F. occidentalis* is highly sensitive to UVA light (350–380 nm) (Matteson et al., 1992) and is sensitive to wavelengths from 350 nm to 650 nm with peak sensitivity at 365 nm (near ultra-violet light or UVA) and 540 nm (yellow) (Matteson et al., 1992; Walbank, 1996). The role of UVA light in insect flight is poorly understood, although it is considered to have a role in eliciting phototaxis in many

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species (Goldsmith, 1994). UVA has been demonstrated to have a function in orientation during flight in the locust (Wilson, 1978), in which the ocelli detect UVA. It is interesting to note that thrips larvae have no ocelli, whereas the winged adults do. There has been no work on the role of the ocelli in UV detection by *F. occidentalis.*

The horticultural industry is exploring the use of plastic films that absorb specific wavelengths in order to affect plant growth in protected crops. UVA-blocking plastic films also appear to affect insect pest populations. Plots covered with a plastic film that reduces or removes the UVA element from the incident solar radiation have a lower population density of *F. occidentalis* than under comparable plastics with standard light transmission (Antignus et al., 1996, 1998; Antignus, 2000; Costa et al., 2002). In choice experiments, 90–98% of *F. occidentalis* were trapped under standard UVA-transmitting plastic films when compared with UVA-blocking films (Costa and Robb, 1999), suggesting a preference for areas of human-white (human-visible, 400–700 nm) light with UVA compared to human-white light without UVA. The underlying behaviour has not yet been investigated. In all cases, *F. occidentalis* population density and flight behaviour were measured indirectly by counting thrips caught on coloured sticky traps. There is little indication of how flight or take-off is affected by the presence or absence of UVA light. UVA may, for example, act as an attractant or as a stimulant for take-off. In contrast *Frankliniella tritici* (Fitch), a closely related flower thrips, is not attracted to human-white sticky traps that reflect a relatively high intensity of UVA but is attracted to traps that reflect only a low intensity of UVA (Walker, 1974). This may have an adaptive significance for host finding behaviour since many flowers reflect little or no UVA light (Walker, 1974).

The effect of UVA on thrips behaviour is complex. Although more *F. occidentalis* are attracted to an area lit with human-white light with UVA than without UVA (Costa and Robb, 1999), fewer *F. occidentalis* are induced to land on human-white surfaces with reflected UVA compared to human-white surfaces without UVA (Walker, 1974). This investigation will test whether take-off in *F. occidentalis* under human-white light is affected by the presence or absence of UVA.

There are intrinsic problems associated with investigating the effect of light on insect behaviour. First of all is the difficulty of simulating daylight within a controlled environment. Most domestic lighting has a spectral composition that is dissimilar to sunlight. Another consideration is the UVA component of daylight, which, although invisible to the human eye, is a part of insect vision. Many past experiments on the effects of light have ignored the importance of UVA light (Shields, 1989). In measuring light intensity, it is necessary to use sensors and units of measurement that are relevant to insect vision rather than human vision (Menzel, 1979; Shields, 1989). Finally, a key aspect of investigating the effect of light is to measure a response in the absence of light. This poses the problem of how to see the insect behaviour in the dark.

The aims of this paper are to describe techniques developed to investigate the effect of light on thrips behaviour and to test the effect of UVA light (λ_{max}=350 nm) on take-off in *F. occidentalis.*

Materials and Methods

Rearing

A culture of *F. occidentalis* from commercial glasshouses in the UK was maintained on pot chrysanthemums (*Dendranthema grandiflora* Tzvelev) at 25±2 °C and L16: D8. The culture was lit by an array of standard fluorescent lights and housed within Perspex cages. Perspex does not transmit UVA (wavelengths less than 380 nm) so the thrips were reared in the absence of UVA, a point that is discussed later.

Bioassay

Mixed-age adult females were collected from the culture and placed individually in stoppered glass tubes (diam. 10 mm, height 37 mm) using an aspirator. These were kept under culture conditions of light and temperature until used. Trials were conducted in a constant temperature room maintained at 26±1 °C with an ambient relative humidity of 38–44%. The areas below and surrounding the experimental arenas were lined with matt black card and black plastic to prevent unwanted light reflection. Take-off was measured from an arena consisting of a circular glass coverslip (diam. 19 mm) rimmed with roughened petroleum jelly to discourage escapes by walking *(Fig. 1)*. The glass tubes previously loaded with one thrips were taken, two at a time, and chilled for 3 minutes in ice to immobilise the thrips inside. Each thrips was then placed carefully onto an arena and the time until take-off was recorded up to a maximum of 300 s. Dead, missing or escaped thrips were discounted. Both arenas were discounted if one thrips walked onto the neighbouring arena. The process was recorded using infra-red (IR) light-emitting diodes (LEDs) (1.5 V medium beam angle IR emitters with a peak emission of 850 nm) and a video camera fitted with an IR pass filter on a manual aperture lens. IR illumination allowed observation of the thrips in the dark by a TV monitor. The IR pass filter allowed the transmission of IR light to the camera but little transmission of other wavelengths, thus providing a consistent, sharp image on the TV monitor under all lighting conditions. In common with most insects, thrips are not sensitive to far red or IR light (Menzel, 1979;

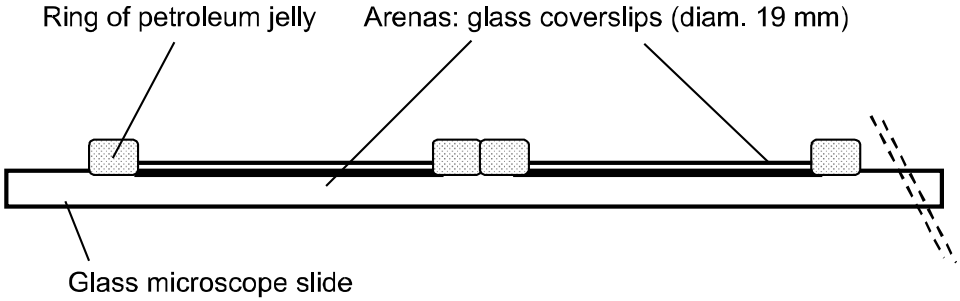

Fig. 1. Diagram of the arenas used for take-off experiments

Matteson et al., 1992; Walbank, 1996). For consistency, the IR LEDs were used during light as well as dark treatments.

Ten thrips were subjected to a given light treatment before changing the conditions. The sequence of treatments was assigned randomly. The experiment was replicated four times over four days and all trials were conducted between 8:00 h and 19:00 h during the light phase of the thrips culture.

Lighting

The arenas were illuminated from above with an array of fluorescent lights filtered and arranged to provide four experimental lighting conditions, combining human-white light (400–700 nm) and UVA (280–380 nm) light. The treatments were: simulated daylight (+visible +UVA), darkness (–visible –UVA), UVA light that included a low intensity of violet light (–visible +UVA), and human-white light without UVA (+visible –UVA) *(Table 1).* Simulated daylight was provided by four 60 cm full spectrum Sylvania "Activa 172" 18 W fluorescent tubes powered with 240 V AC using standard ballast with a flicker rate of 100 Hz. The tubes were positioned 26 cm above the bench and diffused using a Rosco 450 white diffusion paper. For human-white light without UVA, the same arrangement was used with an extra filter: a UVA absorbing plastic film (Sterilite HDF, XL Horticulture). UVA light was provided with one 60 cm Sylvania Blacklight Blue 18 W (λ_{max}=350 nm) fluorescent tube powered as described above. This was diffused and intensity reduced using a neutral density filter (Lee ND1). Switching off all lights provided dark conditions. Thrips were placed onto the arena with the aid of a dim red light (λ_{max}=676 nm).

Table 1

The light intensities of the four light treatments

Treatment	Visible light intensity (Wm^{-2})	UVA light intensity (Wm^{-2})
+visible +UVA	10.6–13.3	0.3
+visible –UVA	12.3	0
–visible +UVA	0	0.4
–visible –UVA	0	0

Light intensities were measured with a datalogger (Skye Instruments Ltd, Llandrindod Wells, UK) with two light sensors covering the spectral range of *F. occidentalis:* UVA sensor SKU 420 (280–380 nm, λ_{max} =347 nm) and an "Energy sensor" SKE 510 for the human-white range of the spectrum (400–700 nm).

Data analysis

Take-off times were compared using a Kruskal-Wallis test and multiple Mann-Whitney U-tests with *P*-values adjusted for multiple comparisons by Holm's procedure (Holm, 1979). The proportion of thrips that took off was compared between treatments with a chi-square test.

Results

There was a significant difference in the proportion of thrips that took off within 300 s between the treatments ($\chi^2_{(3)}$=39.14, P<0.001) *(Table 2)* with a much lower proportion taking off in the dark.

Table 2

The percentage of adult female *F. occidentalis* that took off under each light treatment where *n* is the number of thrips tested

Treatment	Percentage take-off	*n*
+visible +UVA	88	33
+visible –UVA	83	30
–visible +UVA	87	31
–visible –UVA	22	23

The median time to take-off was significantly different between the light treatments (Kruskal-Wallis, $H_{(3)}$=29.2, P<0.001) *(Fig. 2)* and thrips took longer to take-off in the dark. The median time to take-off was slightly longer with +Vis–UVA compared to –Vis+UVA or +Vis+UVA and there was a slight reduction in the proportion of thrips that took off. These differences, however, were not statistically significant *(Fig. 2).*

There was no significant difference between the median rates of take-off of thrips under +Vis+UVA compared to –Vis+UVA (Mann Whitney, W=1050.5, P = 0.77). *F. occidentalis* was, therefore, taking off as readily under UVA light alone as under human-white light with UVA.

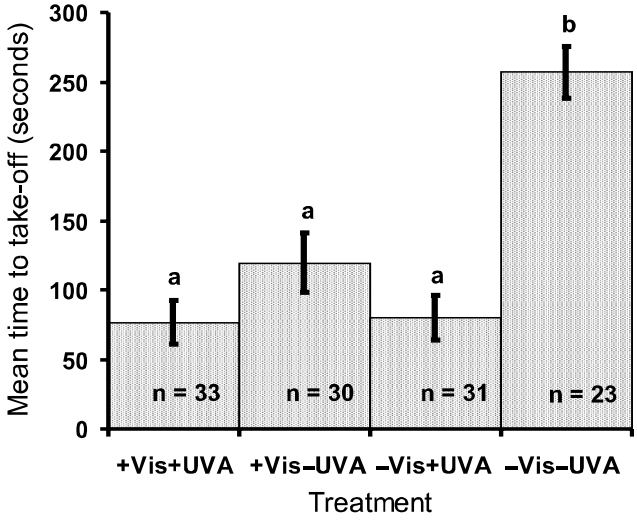

Fig. 2. Graph of the effect of light treatment on take-off in *F. occidentalis.*
Treatments are with and without human-visible light (Vis) and with and without near ultra-violet light (UVA). Bars show mean ± SEM. Bars with the same letters are not significantly different (P>0.05)

Discussion

Take-off is greatly reduced or absent in the dark even though the thrips are naturally active during the light phase when the experiments were carried out. *F. occidentalis,* therefore, is stimulated to take off by light. A low intensity of UVA elicits a take-off response similar to that from a higher intensity of human-white with UVA, since thrips took off readily when illuminated by UVA alone. This occurred even though the intensity of this wavelength was very low, only 0.4 Wm^{-2}, similar to the UVA intensity that would naturally be encountered in low daylight conditions in a glasshouse. A similar rate of take-off was stimulated with a human-white light with UVA with an intensity of 13.6 Wm^{-2} under the full spectrum lighting. Not only was UVA light a stimulant but also the human-visible spectrum (400–700 nm) was not necessary for take-off to occur.

There was no significant difference in the rate of take-off under human-white light without UVA (+visible –UVA) compared with the take-off rate under human-white light with UVA (+visible +UVA) or UVA alone (–visible +UVA). Although UVA will stimulate take-off, it is not essential for take-off to take place.

It appears that there is no significant difference in the rate of take-off under human-white light with or without UVA. This result cannot account for the fact that in a choice experiment, thrips show a preference for areas of human-white light with UVA compared with one without UVA as found under UVA-transmitting plastics (Costa and Robb, 1999). The preference by *F. occidentalis* for UVA-transmitting plastics may involve differences in the duration and direction of flight activity after take-off.

Costa and Robb (1999) also found that in no-choice trials there was no significant difference in the percentage of thrips caught in flight after being released at one end of a single tunnel covered with UVA-transmitting plastic film (human-white light with UVA) compared to those caught under UVA-blocking plastic film (human-white light without UVA). This suggests that the presence or absence of UVA in human-white light does not affect the ability of thrips to fly and is consistent with our results.

In *Aedes aegypti* (L.) (Diptera, Culicidae) the previous environmental conditions affect its readiness to take-off (Haufe, 1961, 1962). It is possible that a change in conditions is as important as the imposed experimental conditions themselves. The *F. occidentalis* used in these trials were cultured at a higher relative humidity than in the bioassay and in the absence of UVA light. It will be necessary to repeat these trials with *F. occidentalis* raised under human-white with UVA to test whether they respond in the same way as thrips raised without UVA.

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