Suitability of a UV Lamp for Trapping the Greenhouse Whitefly *Trialeurodes vaporariorum* Westwood (Hom: Aleyrodidae)

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ABSTRACT

Due to the increase in the demand for chemical free products and increasing pest resistance to chemicals, there is an urgent need to develop chemical free crop protection methods. Research was carried out to investigate the suitability of using a special UV lamp to trap the greenhouse whitefly *Trialeurodes vaporariorum* Westwood (Hom.: Aleyrodidae) in greenhouses located in the northern part of Germany. Four small tunnels were arranged in a cross-like pattern, with a black compartment in the centre. In the first experiment, the UV lamp was placed on one end above the tunnels such that the tunnels received different light intensities. For the second set of experiments, the UV lamp was positioned directly above the tunnels thereby generating equal UV intensities in all the tunnels. During each experiment, adult greenhouse whiteflies were released from the black compartment and allowed to fly into a tunnel of their choice, where they were recaptured using yellow sticky traps. Results show that significantly more whiteflies were recorded on yellow sticky traps inside the tunnels with more UV intensity. When the tunnels were illuminated with equal UV intensities, there was no significant difference in the number of whiteflies recorded in the tunnels. These results suggest that it is possible to develop a special lamp for trapping whiteflies in greenhouses.

Keywords: Development, UV trap, greenhouse whitefly, Trialeurodes vaporariorum

1. INTRODUCTION

Growing crops in greenhouses is faced by several challenges, among them, the infestation by pests and diseases. The rising demand by consumers for pest free products, the need to protect the environment, the rising cost of pesticides and the increase to acquired resistance to pesticides by several pests have rendered management practices that rely on pesticide applications both ineffective and inefficient. Hence there is a need to develop control strategies that ensure the production of high quality products while at the same time ensuring maximum consumer protection, environmental sustainability, and eliminate or slow down the build up of resistance by pests.

One of the most important pests in protected cultivation, especially in Europe, is the greenhouse whitefly *Trialeurodes vaporariorum* Westwood (Homoptera: Aleyrodidae) (Van Lenteren and Noldus, 1990). Whiteflies feed voraciously on the plant sap and in sufficient numbers, cause leaf drop and prohibit the maturing of fruits. They produce sticky honeydew which damages crops and serves as a substrate on which sooty mould (a black fungus) grow, thereby prohibiting normal respiration of leaves, reducing photosynthesis and rendering plant products unattractive. In addition to damage caused by direct feeding pressure, whiteflies transmit plant viruses such as the *Lettuce infectious yellow virus* (Fasulo, 2005).

Commercial biological control of *T. vaporariorum* through innudative releases of the parasitoid *Encarsia formosa* Gahan is used in most countries with an important greenhouse industry (Kassis and Michelakis, 1993; Van Lenteren, 2000, Van Lenteren et al., 1996). However, this may not achieve the level of efficacy needed by growers, particularly in case of virus transmission. Chemical control of *T. vaporariorum* is hindered by the rapid development of resistance (Dittrich and Ernst, 1990). Mature insects spread very fast among plants and cling on the underside of foliage making it difficult for contact pesticides to reach them. Immature stages on the other hand are not only small and difficult to detect but also tolerant to most insecticides. Although the use of physical methods such as anti-insect screens has been reported to protect crops from pest and viral infestation (Antignus et al., 1998), the screens reduce the ventilation efficiency of the greenhouse thereby raising temperature and relative humidity inside the greenhouse (Ajwang et al., 2002; Bell and Baker, 2000; Klose and Tantau, 2004; Teitel and Shklyar, 1998). Several researchers have reported that covering a greenhouse with UV absorbing plastic film reduces infestation of the crops by certain insect pests and the viruses they transmit (Antignus et al., 1996, 1997; Costa and Robb 1999; Costa et al., 2002; Mutwiwa et al., 2005).

Vision (colour, shape and size) and olfaction (host odour) are the primary cues used by insects to orient to their plant hosts, and sometimes the two types of cues complement each other. Insects often respond to a particular wavelength band with a different behaviour (Kirk, 1984; Menzel and Backhaus, 1991), and use colour contrasts to distinguish between a host and the surrounding environment (Antignus, 2000). This wavelength selective behaviour is highly dependent on intensity within each wavelength band, and involves different behaviours. Lloyd (1921) reported that *T. vaporariorum* was attracted in greater numbers to yellow sticky traps than to traps of other colours. Coombe (1981, 1982) observed that whiteflies took off more readily and walked faster under light with wavelength of 400 nm. In flight, they oriented towards 400 nm when simultaneously illuminated with equal quanta of 550 and 400 nm light. Mound (1962) reported that *B. tabaci* did not react to odour of the host plant but did react to two ranges of wavelengths, i.e. blue/ultraviolet (migration) and yellow (host plant selection). Affeldt et al. (1983) recorded maximum capture of *T. vaporariorum* on traps reflecting radiation with wavelength between 500-600 nm (yellow) and inhibition of landings under radiation with wavelength between 400-490 nm. Using an electroretinogram technique, Mellor et al. (1997) measured the spectral efficiency of *T. vaporariorum* and reported that primary peak efficiency occurred in the blue-green-yellow region, peak at 520 nm and a secondary peak in the UV region. Other species of insects have been shown to be dependent on UV light for orientation during flight and may use UV light reflectance patterns as cues in recognizing host plants and flower species (Kring 1969, Kirk 1984, Vaishampayan et al. 1975). Equipping the plastic insect traps with light emitting diodes (LED), has been reported to increase in their efficacy to trap certain greenhouse pests (Chu et al. 2003, Chen et al. 2004), while in some greenhouses, nocturnal insects are trapped by attracting them to lamps, where they are killed. However there is no lamp that specifically targets the control of *T. vaporariorum*. Hence the objective of this research was to investigate the suitability of using a UV lamp to trap the *T. vaporariorum* in greenhouses in northern Europe.

2. MATERIALS AND METHODS

2.1 UV Lamp and Plastic Films

The UV lamp used for the experiments was a 160 W fluorescent-tube-type (Sonepaar Deutschland, Hannover, Germany) measuring 1.778 m long, and 0.041 m in diameter. The spectral irradiance was measured in a light-tight room, using a LI-1800 portable spectroradiometer (LI-COR, Inc., Lincoln, Nebraska, USA). By placing the UV lamp horizontally 0.40 m above the cosine receptor of the spectroradiometer, the quantum flux density was calculated by integrating the spectral emission results from five measurements between the wavelengths 330 and 850 nm, at an interval of 5 nm. In addition the spectral transmissivity of the plastic film used to cover the tunnels was measured using a UV/VIS/NIR spectrophotometer (Perkin-Elmer Instruments, Norwalk, USA).

2.2 Rearing of Greenhouse Whiteflies

Greenhouse whiteflies, *T. vaporariorum* were mass reared on tobacco plants (*Nicotiana tabacum* L. (Solanaceae) cv. Xanthi) in insect proof cages (0.60 m long × 0.60 m wide × 0. 80 m high) at the Institute of Plant Diseases and Plant Protection (University of Hannover, Germany). New freshly growing tobacco plants were introduced into the cages every two week so as to sustain the whitefly culture. The cages were placed in a greenhouse whose temperature and relative humidity were maintained at 22 ± 2°C and 60 - 80%, respectively. Whiteflies were collected with a small aspirator and then transferred into a Petri dish (0.05 m diameter × 0.025 m deep) before release in the respective experiments.

2.3 Experimental Tunnels

Four small tunnels (1.0 m long × 0.5 m wide × 0.5 m high) were constructed and covered with a UV-transmitting plastic film (Hyplast Ltd. Hoogstaten, Belgium). The four tunnels were positioned in four locations (imitating the four arms of a cross). At the centre of this cross-like apparatus was a black box compartment constructed from timber in a way that made it light proof. In addition, the black compartment had a lining of black-white plastic film on the inside (black to keep the interior as dark as possible and white surface facing the outside to reflect any unwanted light. This black compartment had a tight fitting door (made from the same material) on the upper side and was connected to the four arms (tunnels) by small doors (0.15 wide × 0.15 m high) (Figure 1). The top of each tunnel had a door that was opened only when necessary e.g to clean the tunnels, collect or replace the sticky traps. Inside each tunnel, one yellow sticky card measuring 0.25 m long × 0.10 m wide, (Aeroxon GmbH, Waibligen, Germany), was positioned vertically 0.01 m above the ground at a distance of 0.50 m from the black compartment. The entire apparatus was placed in a greenhouse whose temperature and RH were maintained at 20 ± 2°C and 60-80%, respectively.

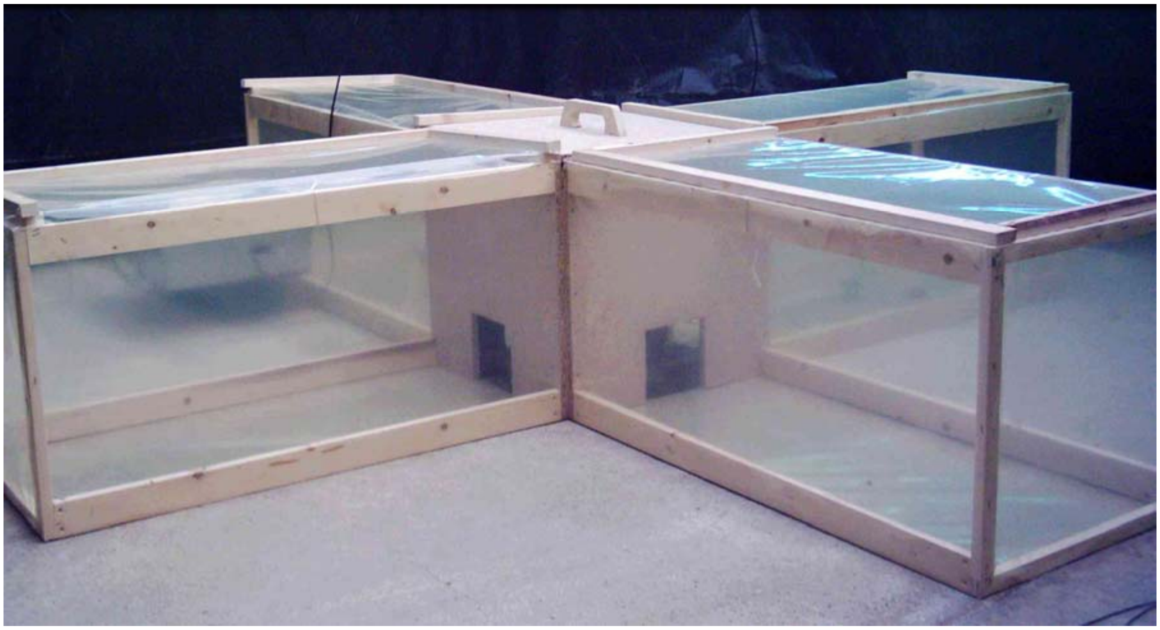

Figure 1. Photograph of the tunnels used for the greenhouse experiments using a UV lamp. All the four tunnels were covered with a UV-transmitting plastic film.

2.4 Methods

Two different types of experiments were performed using this set-up. In all experiments, 200 adult *T. vaporariorum* of unknown age and sex, were aspirated into the petridish stated above. The petridish was placed at the centre of the cross-like structure by slightly opening the door on the top (all other doors were closed) of the black compartment. The container carrying the insects was then opened to release them inside the black compartment and allow them to fly into a tunnel of their choice where they were recaptured using yellow sticky traps. Each experiment, conducted between December 2003 and March 2004, was initiated at 5.00 pm in the evening and lasted until 7.00 am the following morning. At the end of each experiment, the yellow sticky traps were removed (by opening the doors on top of the tunnels) and the whiteflies recaptured on it were counted and recorded. After counting, the recaptured whiteflies, the sticky traps were removed, all the doors of the cross-like apparatus were opened and the apparatus cleaned to ensure no whiteflies remained inside. In addition, before the start of each experiment, the tunnels were inspected to ensure that they were whitefly-free and new sticky traps were put in place. During each experiment the greenhouse was closed and all lights were switched off, except the UV lamp. In addition, light from adjacent buildings and any “wind blow” effects were blocked by a 2.5 m high plastic film “perimeter wall” created around the apparatus.

In the first set of experiments different UV intensities were generated in the various tunnels by positioning the UV lamp at a height of 0.40 m directly above the distal end of the southern tunnel. The central part of the lamp (approximately 0.5 m in length, i.e., the width of the tunnel) was positioned directly above the southern edge of the tunnel and the two ends, measuring approximately 0.639 m each, protruded from either side of the tunnel (Figure 2A). This ensured that the tunnel below (i.e., the southern) and the one furthest away from the lamp (i.e., the northern) received the highest and lowest UV intensities, respectively, while the two tunnels in the middle (i.e., the eastern and western) were exposed to equal UV intensities. For a replication, the lamp was positioned at the same height on the opposite side (north). A total of eight experiments were conducted i.e. four experiments with the lamp on the south and four on the north.

The second set of experiments acted as a control and involved the generation of equal UV intensities in all the four tunnels. This was achieved by positioning the same lamp at a height of 0.4 m directly above one of the diagonals of the black compartment. This was done such that slightly less than half of the lamp length (0.707 m) was positioned directly above and along one of the diagonals of the black compartment, thereby allowing two equal lamp portions (one on each end), measuring approximately 0.535 m in length, to protrude between the two tunnel junctions (i.e., southern-western and northern-eastern junctions) (Figure 2B). This experiment was repeated seven times.

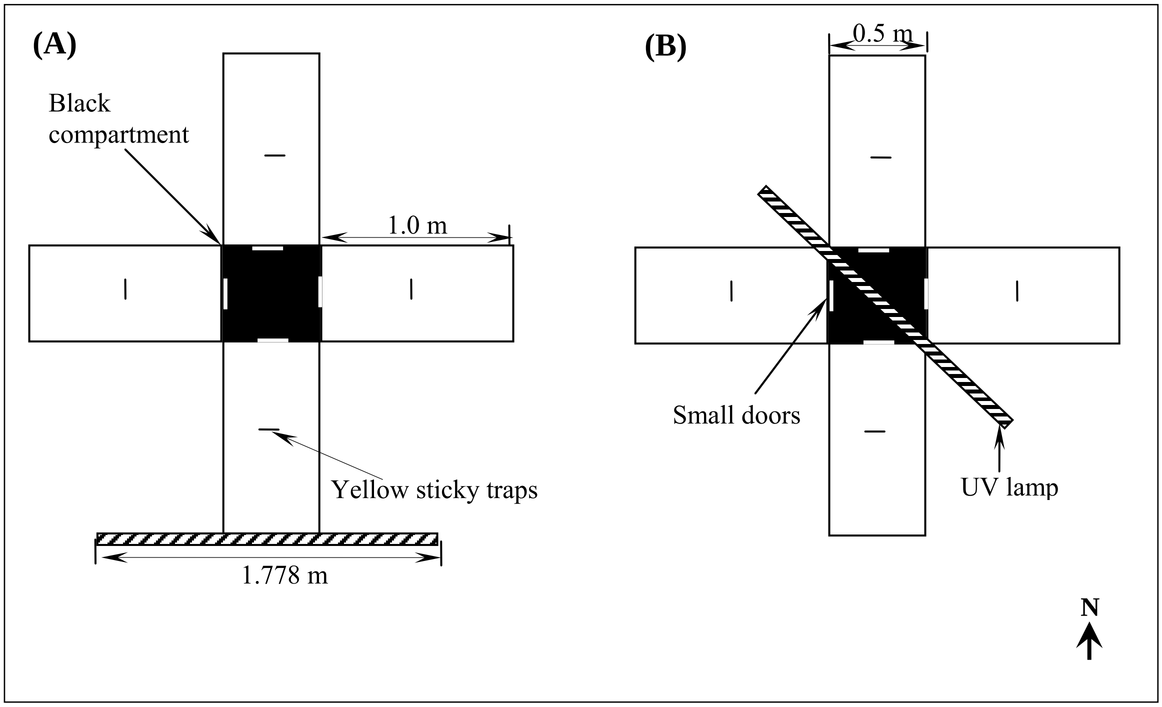

Figure 2. Experimental layout of the choice experiments conducted in the greenhouse with the UV lamp on the distal end of the southern tunnel (A) and positioned diagonally across the black compartment (B).

2.5 Statistical analysis

Data of experiments repeated over time were checked for homogeneity of variance using SAS statistical software (SAS, 2001) and only pooled when variance homogeneity could be assumed. The data were analysed using Chi-square test of association using the same software. When the null hypothesis was rejected, simultaneous confidence intervals for multinomial proportions were constructed based on Goodman's (1965) method using R statistical software (Cci, 2004). All analyses were performed at 5 % confidence level.

3. RESULTS

3.1 Spectral Properties of the Lamp and Plastic Film

The spectral emission of the UV lamp was as shown in figure 3. The large portion of the radiation emitted by the lamp was in the UV wavelength (89%), and some limited radiation in the photo synthetically active radiation (PAR) (11%) (also referred to as the visible radiation, VIS). The highest emission (0.37 W/(m^2/nm)) was recorded at 355 nm. Additionally, the lamp showed no emission in the near infra red (NIR) region. The spectral transmission of the plastic film used to cover the tunnels was 78, 86 and 88% in the UV, PAR and NIR, respectively.

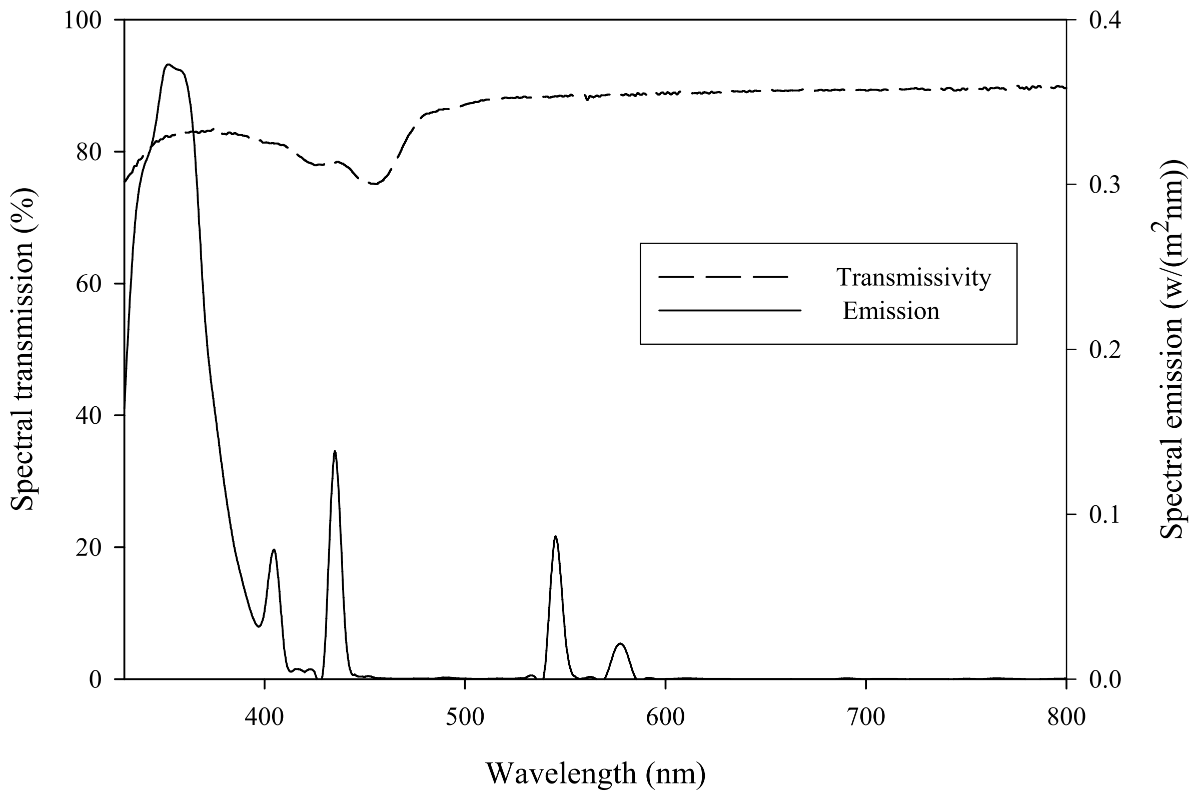

Figure 3. Spectral emission of the UV-lamp measured inside a light-tight room with a portable LI-1800 spectroradiometer and the spectral transmissivity of the UV-transmitting plastic film measured with Lambda 900 UV/VIS/NIR spectrophotometer (Perkin-Elmer Instruments, Norwalk, USA).

3.2 Distribution of Whiteflies

Experiments repeated over time were not significantly different from each other ($F = 1.38$; df = 6, 21; $P = 0.2699$) hence variance homogeneity could be assumed. Consequently data of experiments repeated over time were pooled and analysed together. When the UV lamp was positioned directly above the tunnels, assuring an equal distribution of UV intensity in all the tunnels, whiteflies were evenly distributed in all the tunnels. There were no significant differences in the number of whiteflies recaptured in the four different tunnels ($\chi^2 = 6.2606$; $P = 0.0996$) (Figure 4A). The tunnel in the west, north, east and south attracted 27.38, 25.85, 24.31 and 22.46% of the recaptured *T. vaporariorum*, respectively.

When the lamp was placed on one end of the cross-like apparatus, time did not have a significant effect ($F = 1.38$; df = 7, 24; $P = 0.2578$), hence data of experiments repeated over time were pooled and analysed together (variance homogeneity could be assumed). The number of whiteflies recaptured in the four tunnels differed significantly ($\chi^2 = 596.54$; $P < 0.0001$) (Figure 4B). The tunnel with the highest UV intensity (i.e. the tunnel nearest to the lamp) attracted the significantly highest number of whiteflies (approximately 70%), the tunnel with the lowest UV intensity (i.e., the tunnel farthest from the lamp) had the least (4.03%), while the tunnels on the east and west had similar proportions (10.83% and 11.68%, respectively) (Figure 4B).

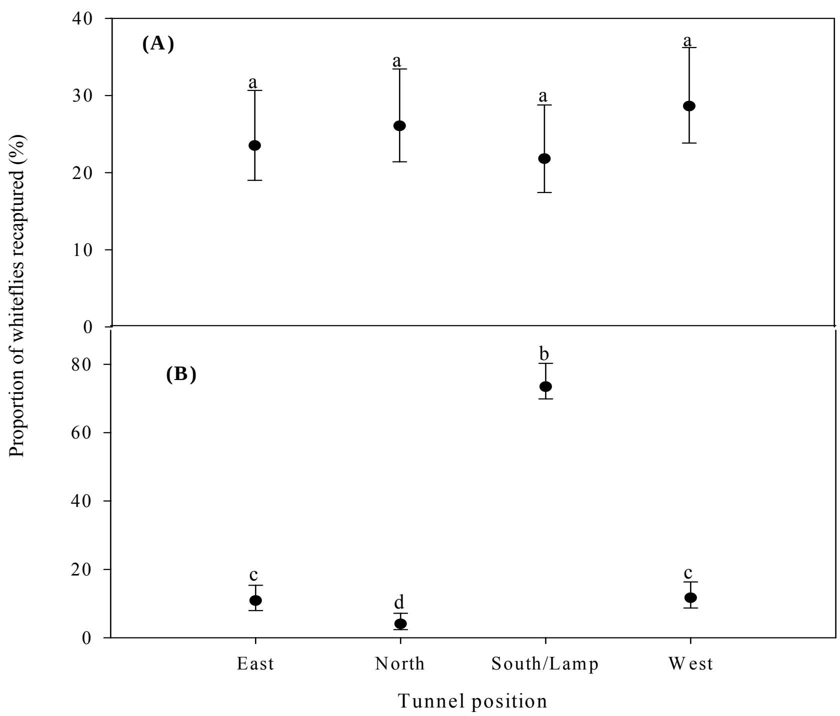

Figure 4. Proportion of recaptured *T. vaporariorum* (in mean % ± 95% confidence intervals) in plastic tunnels exposed to (A) equal UV intensities (i.e. the UV lamp placed overhead the four tunnels), and (B) different UV intensities (i.e. the UV lamp placed over one end of the four tunnels). Means followed by the same letter are not significantly different (χ^2–test, $P < 0.05$).

4. DISCUSSION

Due to the ineffectiveness and the increase in the cost of chemical control, the low threshold requirement, development of resistance against pesticides and the complexity of biological control strategies, it is important to develop alternative pest control measures to ensure the cultivation of pesticide free products and the development of environmentally friendly production techniques. The results show that whiteflies were attracted to tunnels with a higher UV intensity. When the UV lamp was positioned on one extreme end, resulting in different UV intensities inside the tunnels, the tunnel with the highest UV intensity attracted over 17 times more whiteflies than the UV-deficient tunnel. The results corroborate earlier findings of whitefly attraction to UV (Coombe, 1981; Mound, 1962). These results and the observations of Mellor et al. (1997), suggested that radiation with wavelength between 340 and 380 nm was important for *T. vaporariorum* hence developing a lamp that emits this radiation and combining it with yellow sticky traps (reflecting maximum radiation between 500 and 600 (Affeldt et al., 1983) may provide an alternative to chemical control of greenhouse whiteflies. The two types of radiation are complementary, and eliciting a balance between migratory behaviour induced by UV and a landing reaction controlled by sensitivity to yellow (Mound, 1962; Coombe, 1981; Moeller 2002). In our experiments, the two signals, UV for migration and yellow (on the sticky traps) for landing, were present inside all tunnels. Therefore only differences in UV intensity could have caused the differences in whitefly distribution. It is possible that the intensity of UV influenced the main parameters of the colour (from a biological perspective) namely; hue (the dominant wavelength remitted by the surface), colour saturation (purity of the hue), and brightness (light intensity), hence the yellow sticky traps in the tunnel with the highest UV intensity appeared more attractive to the insects. When the lamp was positioned at equal distances from the tunnels (i.e. overhead), there was no difference in these parameters and consequently, no differences in whitefly attraction were recorded, corroborating earlier findings on colour vision in *T. vaporariorum* (Mound, 1962; Vaishampayan et al., 1975; Affeldt et al., 1983). In addition, Antignus et al. (1996) studied whitefly behaviour under monochromatic UV light (254-366 nm) filtered through UV-absorbing and UV-transmitting plastic films and reported similar findings. Similar behavioural responses were observed by Kring (1969) studying the behaviour of the black bean aphid, *Aphis fabae* Scopoli, using a black light lamp with spectral emission similar to those of the lamp used in this study. According to Antignus (2000), the exact mechanism for the reduction in insect pest infestation in UV deficient environment is unknown but may be due to the interference with visual and or behavioural cues.

Results of this study demonstrate that using UV lamps may help in protecting greenhouse crops from infestation by *T. vaporariorum*, the most important whitefly species in European greenhouses. Since UV absorbing plastic films have already been found to offer some level of protection (Antignus et al., 1996; Mutwiwa et al., 2005), covering a greenhouse with these films will reduce the number of whiteflies migrating into the greenhouse, while the use of a UV emitting lamp incorporated with a mechanism to attract (e.g yellow coloured film) and kill whiteflies may provide a promising solution to their control. The possibility of combining light emitting diodes with insect traps has been shown to increase the efficacy of the traps without attracting large numbers of beneficial insects (Chu et al., 2003; Chen et al., 2004). Furthermore, Dyers and Chittka (2004) reported that the absence or presence of UV light did not influence the performance of bumblebees *Bombus terrestris* L. These results suggest that combining the use of yellow sticky traps with UV emitting lamps, covering the greenhouse with UV absorbing materials and the use of bio pesticides such as NeemAzal (Von Elling et al., 2000) may provide a good alternative to pesticide applications, without necessarily influencing the behaviour of beneficial insects. The possibility of developing a UV lamp to trap *T. vaporariorum* in greenhouses should be further studied, to come up with a suitable design that is easy to use.

5. ACKNOWLEDGEMENTS

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