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Efficacy of different light-emitting diodes (leds) attached to yellow sticky traps for whitefly *Trialeurodes vaporariorum* capture

Eficacia de diferentes diodos emisores de luz (LEDs) unidos a trampas adhesivas amarillas para la captura de la mosca blanca *Trialeurodes vaporariorum*

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RESUMEN

Teniendo en cuenta que algunos adultos de insectos muestran preferencia a ciertas longitudes de onda, se ha considerado este comportamiento para desarrollar herramientas de monitoreo y estrategias de control de insectos plaga. Como ejemplo de ello, las tarjetas adhesivas amarillas han sido ampliamente usadas para monitorear población de moscas blancas a campo como invernadero. Este estudio tuvo como objetivo evaluar la efectividad de trampas adhesivas amarillas provistas con luces emitidas por diodos (LEDs) para el trampeo de adultos moscas blancas *Trialeurodes vaporariorum* (Westwood) (Hemiptera: Aleyrodidae). Los ensayos se llevaron a cabo en la EEA INTA Concordia en condiciones de umbráculo, donde se ubicaron jaulas de cría con plantas de tabaco, *Solanum tabacum* (L.) y poroto, *Phaseolus vulgaris* L. desde Junio hasta Julio del 2013. Las trampas adhesivas amarillas tuvieron una superficie de 64cm^2 provistas con (LEDs) de diferentes longitudes de onda promedio (525 nm verde y 380 nm UV) y sin LED como testigo. Los ensayos mostraron que los adultos de mosca blanca fueron significativamente (p >0,05) más atraídos por las trampas equipadas con LED 525nm verde (134 ± 7,4 adultos/tarjeta) comparadas con trampas equipadas con LED 380 nm UV (105 ± 7,4 adultos/tarjeta) y trampas sin LED (85,17 ± 7,4 adultos/tarjeta). Estos resultados muestran que los adultos de *T. vaporariorum* son atraídos a trampas dotadas con LED verde, las cuales podrían tener un promisorio uso en invernadero como detección, monitoreo y control de mosca blanca.

Palabras clave: trampas, aleyrodidae, longitud de onda, tarjetas adhesivas amarillas.

ABSTRACT

Since adult insects respond to particular wavelengths, some investigations have proposed to use such behavior as a potential target for novel monitoring and pest control tools. Yellow sticky traps have been commonly used for monitoring whitefly populations in open-fields, as well as in greenhouses. However, the attractiveness depends on various factors such as the reflected intensity (brightness) and hues of yellow color (wavelength) of the trap surface, which is often influenced by environmental conditions and may sometimes affect whitefly capture. Therefore, the use of light-emitting diodes (LEDs) can be a significant complementary tool to strengthen the attractiveness and selectivity of these traps. This research was carried out to investigate the efficacy of LED-equipped yellow sticky traps in the capturing mechanism of adult whiteflies *Trialeurodes vaporariorum* (Westwood) (Hemiptera: Aleyrodidae). This study has taken place in a little glass greenhouse at the Argentine Agricultural Experiment Station (EEA) of the National Institute for Agricultural Technology (INTA) of Concordia, Province of Entre Rios (Argentina), where rearing insect cages were placed together with tobacco plants, *Solanum tabacum* L. and beans *Phaseolus vulgaris* L. from June to July, 2013. The yellow sticky traps covered an area of 64 cm^2 and were supplemented with LEDs of different wavelengths, namely, green LEDs (525 nm) and UV LEDs (380 nm), in addition to a control treatment without LEDs. The trials showed that *T. vaporariorum* adults on average preferred ($p>0.05$) traps equipped with green LEDs (525nm) (134 ± 7.4 adults/trap) compared to traps equipped with UV LEDs (105 ± 7.4 adults/trap) and traps without LEDs (85.17 ± 7.4 adults/trap). The results show that *T. vaporariorum* adults are attracted to yellow sticky traps attached to green LEDs, which could have a promising use in greenhouses for the identification, monitoring, and control of whiteflies.

Keywords: LED traps, Aleyrodidae, wavelength, yellow sticky trap.

INTRODUCTION

Horticultural activity in Argentina is well known for its wide geographical distribution and the variety of crops grown in the area. This is a fundamental socio-economic sector that provides daily food to the population living in this region, satisfying the domestic demand and contributing to the GDP (11,6% of the Agricultural GDP). This sector also provides employment to approximately 350,000 people, mainly family farmers, in a horticultural area of 600,000 hectares, resulting in an annual production of 10,500,000 tons (Colamarino *et al*., 2006). In the Province of Entre Ríos, the most important developed horticultural areas can be found in the cities of Federation, Paraná, Concordia, and Colón that represent 83% of the total horticultural areas within Entre Rios (CNA, 2002). About 550 farmers grow vegetables in these fields, covering a productive area of 1,300 hectares, out of which 80 are developed in greenhouses. The most important vegetables grown in this area include leafy vegetables (lettuces), fruits from vegetables (tomatoes, peppers), sweet potatoes, onions, and squashes. With reference to main greenhouse crops in the city of Chajarí, it has been observed that a large number of polyphagous arthropods affecting such crops leads to both direct and indirect damage, which creates a significant economic loss due to yield reduction within this quality.

Among these agricultural pests, certain types of whitefly, including the greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood) (Hemiptera: Aleyrodidae), are important pests that produce significant economic damages. Whitefly adults and nymphs on greenhouse commercial crops cause yield reduction due to water extraction, photosynthates, and amino acids in the plant (Mound and Halsey, 1978). Furthermore, whiteflies excrete a sticky honeydew that leads to the growth of sooty mold and can transmit plant viruses that belong to the family Geminiviridae as in the case of tomato plants (Polston *et al*., 1999).

Chemical control has traditionally been the main control treatment for *T. vaporariorum* in the Province of Entre Ríos. However, the application of chemical pesticides has not been completely effective to some extent because of the presence of serosity produced by the pest. The serosity avoids contact of the chemical with the different stages of nymphs and pupa, which remain immobile (Gerling, 1990). Additionally, frequent use of excessive chemical products has led adults and nymphs to develop resistance against pesticides, resulting in new outbreaks of the pest (Palumbo *et al*., 2001). Repeated applications of chemical products also lead to reducing the natural enemies of *T. vaporariorum* (González *et al*., 2004). However, despite the activity of natural enemies as the sole pest management strategy, this control method would not be sufficient to avoid crop loss in case of high infestation by *T. vaporariorum*. Thus, this situation has led to seek new efficient alternatives for whiteflies management. LEDs are emissions from solid-state material, semiconductor light sources, of small size, with particular properties, high mechanic stability, high reliability, long life time, and low cost (Schubert, 2003). LEDs have been used for some applications such as remote controls, numeric screens, state indicators, flat screens, optical communications, among others (Schubert and Yao, 2002). Few studies have been carried out to investigate how insects respond to LEDs. Based on the fact that yellow sticky traps (YST) are commonly used for monitoring changes in the population of aphids, leaf miners, and other pest insects (Qui and Ren, 2006; Gu *et al*., 2008), as well as whiteflies (Riley and Ciomper lik, 1997), greenhouse whiteflies have played a key role for the integrated pest management of particular pests (Kaas *et al*., 2005; Park *et al*., 2011). Considering that adults of *Bemisia tabaci* are attracted to green light in the wavelength range of 530nm, corresponding to the highest spectral reflectance of healthy green leaves, Chu *et al*. (2004) reported that the whitefly *T. vaporariorum* is attracted to two wavelength ranges between blue/ultraviolet 400-490 (migration) and yellow 500-600 (selection of host plant). The aim of this research was to determine the improvement of adult whitefly capture efficacy through the use of LEDs with two wavelengths attached to YST.

MATERIALS AND METHODS

The main virus-free whitefly *Trialeurodes vaporariorum* colony used for trials was collected at Villa Zorraquin, City of Concordia. This colony was maintained on tobacco plants *Nicotiana tabacum* L. (Solanacea) variety Virginia and beans *Phaseolus vulgaris* L. (Leguminosae) over the last three years without exposure to chemical pesticides, in cages covered with *voile* (80 cm x 80 cm x 80 cm) to avoid other insects. A portion of this colony was transferred to another four cages with tobacco and beans. These colonies were reared in individual cages in a little glass greenhouse with windows, equipped with air conditioning devices at a temperature ranging of 25 ± 5°C, relative humidity of 65 ± 10%, and a photoperiod (16: 8) (L: O) supplemented by 40 W fluorescent tube light bulbs.

Yellow Sticky Traps and LEDs. The research was carried out in a little glass greenhouse from June to July, 2013. The attractiveness of whiteflies was determined by using three types of traps, all of them with the same area of 64 cm^2: (1) a yellow sticky trap supplemented with green LEDs (530nm, 36.80 lumens, 90°C, NºXL503320UBGC525); (2) a yellow sticky trap supplemented with UV (380 nm, 36.80 lumens, 20°, NºXL503320UV380) (SHENZEN SEALAND OPTOELECTRONICS CO., LTD), each of them connected to a 220 ohm resistance and powered with a light source of 6V constant current (CC)/ 220V alternating current (AC); and (3) a yellow sticky trap without LEDs. The LEDs were attached to the yellow sticky traps through a LEDs holder fitted on the upper sticky part of the traps.

Capture of *Trialeurodes vaporariorum* adults. The study was designed as a randomized complete block design (RCBD) with four cages (80 x 80 x 80cm) that represented each unit (block). Within each cage, three traps (treatments) attached to a vertical wire support system on the top of 15 tobacco and beans plants infested with adult whiteflies (n ~1000) were randomly placed in a triangular arrangement at the same time. This trial was replicated six times on six different days. The number of adult whiteflies for each tramp was counted after a 24-hour exposure under a stereo magnifier (Figure 1). The average number of adults caught in each trap in each cage was analyzed using ANOVA. Further testing was made using Tukey's method with a significance level of 5% (Figure 2). All of the calculations were performed using InfoStat/Professional software, version 1.1, 2004.

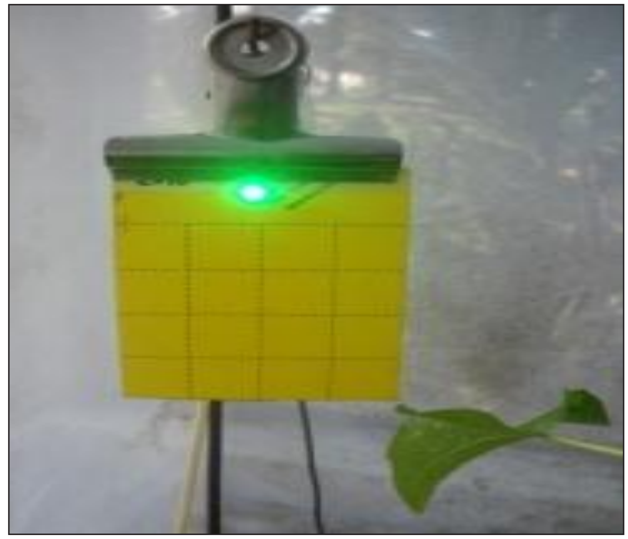

Figure 1. Green LEDs attached to yellow sticky trap.

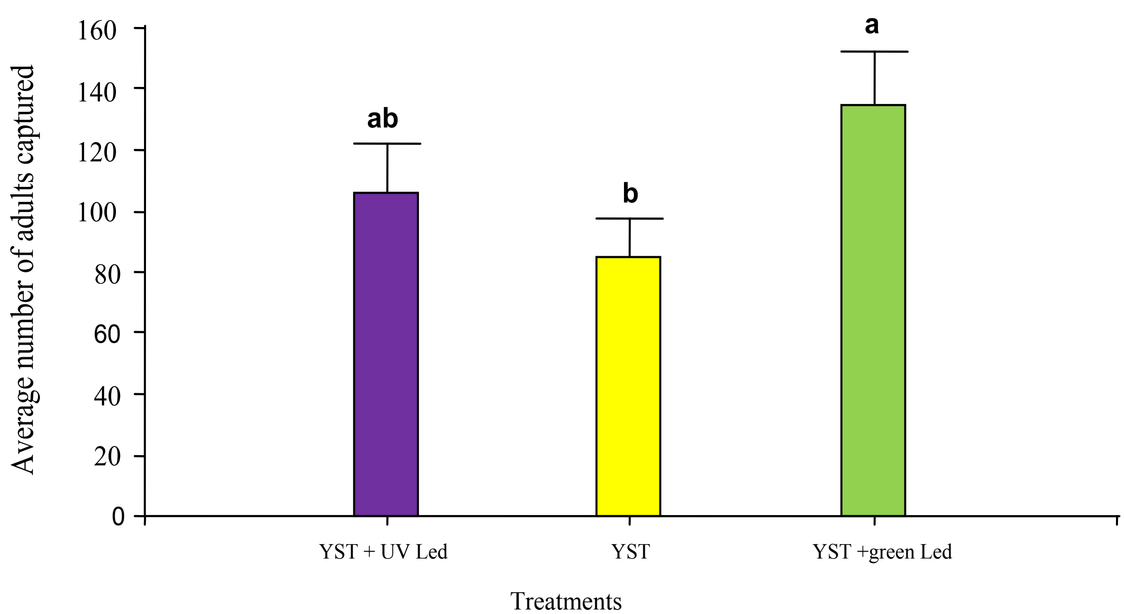

Figure 2. Average number of adult whiteflies *T. vaporariorum* caught in cages with LED traps (YST + green LEDs, YST + UV LEDs) and a yellow sticky trap without LED during eight weeks in the little greenhouse. Vertical bars represent standard errors. Different letters above bars indicate that the treatments are significantly different (p< 0,05).

RESULTS AND DISCUSSION

The results showed that in all of the cages where the trials were conducted during the trial period, the average number of adult whiteflies caught in these different treatments (YST + green LEDs /YST + UV LEDs / YST) presented significant differences ($F_{treatment}$ =11,44; df=2; P= 0,003). Consequently, a Tukey's test showed that the total average number of adults caught in YST with green LEDs was significantly higher compared to YST with UV LEDs and YST (Figure 2). In addition, at the end of the six trial dates, a total average of 134.96 ± 7.4 whiteflies/trap with green LEDs, compared to 105,79 ± 7,4 whiteflies/YST with UV LEDs and 85,17 ± 7.4 whiteflies /YST was observed.

DISCUSSION

The above results are supported by Mutwiwa *et al*., (2005), who reported that *T. vaporariorum* adults were more attracted to areas with a maximum refraction or transmittance in the green–yellow area (520-610nm) than to ultraviolet (360-380nm). Based on the different response of *T. vaporariorum* to the wavelength in the UV and yellow area, the results found by Coombe (1982) and Mellor *et al*., (1997) also showed the positive response of greenhouse adult whiteflies to green areas of visible spectrum (550 nm). However, Mound (1962) noted that, in the case of *T. vaporarioum*, there is a balance between the migration behavior influenced by the ultraviolet (UV) and their landing on yellow areas influenced by the sensitivity to yellow. Taking into consideration such balance, Coombe (1982) explained that *T. vaporariorum* adults fly toward a visual stimuli of 400 nm (Zenith lighting) rather than one of 550nm; however, during the flight this last visual stimuli was the most important signal for identification of the host and the subsequent landing on it. Moreover, Blackmer *et al*., (1995) showed that the migration flight of *B. tabaci* came to an end after their attraction to the visual stimuli of 550nm, the typical refraction wavelength of plants.

CONCLUSIONS

T. vaporariorum adults were attracted in greater number by the visual stimuli coming from the yellow sticky trap supplemented with green LEDs. These studies contribute to the design of methods for monitoring and identification of *T. vaporariorum* in order to provide information about the presence and evolution of the pest. This information is important to determine a better control strategy and timing for such control. This investigation line will continue to reduce and improve the effectiveness of chemical pesticides, with an aim to avoid conflict between the need to increase food production and protect the environment.

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