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Source: Florida Entomologist, 104(2) : 148-150

Published By: Florida Entomological Society

URL: https://doi.org/10.1653/024.104.0215

Effect of UV-C irradiation on greenhouse whitefly, *Trialeurodes vaporariorum* (Hemiptera: Aleyrodidae)

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The greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood) (Hemiptera: Aleyrodidae), is a serious and ubiquitous pest of numerous crops and ornamentals grown in greenhouses as well as field-grown strawberry in yr-round production areas in California (Bi & Toscano 2007; Zalom et al. 2018). Pestiferous whitefly species affect crop quality and yield due to extensive phloem feeding, honeydew excretion resulting in sooty mold growth (Byrne & Bellows 1991), and reduced photosynthesis, as well as potential virus transmission (Navas-Castillo et al. 2011). To combat these problems, insecticide applications are applied frequently to vulnerable crops. However, insecticide resistance has been reported to various insecticide classes including pyrethroids, organophosphates (Wardlow et al. 1976; Wardlow 1985), insect growth regulators, and neonicotinoids (Gorman et al. 2007). Thus, alternative strategies are needed to manage *T. vaporariorum* effectively and reduce the likelihood of further development of resistance. Various management tactics have been evaluated for *T. vaporariorum* including application of biological control agents such as entomopathogenic fungi (Kim et al. 2013), predaceous coccinellids (Lucas et al. 2004), parasitoids (Greenberg et al. 2002), and use of trap cropping (Lee et al. 2009; Moreau & Isman 2012), whereas behavioral control strategies using semiochemicals, although promising, require further study (Schlaeger et al. 2018).

Another potential alternative management tactic is application of UV-C light. Despite the considerable benefits of post-harvest UV-C treatments on harvested fruits and vegetables in reducing decay, food-borne pathogens, and other bacterial microflora (Mercier et al. 1993; Stevens et al. 1997, 1998), they have not been used widely as a pre-harvest management tactic for pests and diseases because of damage inflicted on growing plants. However, short interval UV-C applications at low doses followed by a period of darkness has been shown to effectively manage twospotted spider mite, *Tetranychus urticae* Koch (Trombidiformes: Tetranychidae) on strawberry (Short et al. 2018). In this study, we used a similar UV-C application method against *T. vaporariorum* on tomato and determined its effect on numbers of adults, nymphs, and eggs (with both the adult and first instar crawlers being the only mobile life stages), as well as chlorophyll florescence activity.

Tomato transplants, variety 'Bonnie Better Bush,' purchased from Home Depot (Atlanta, Georgia, USA) were established in pots and maintained in a greenhouse at 20.0 ± 2.0 °C with daily watering and 1 fertilizer application (Miracle-Gro Water Soluble All Purpose Plant Food, Marysville, Ohio, USA). Prior to the experiment, plants were trimmed, and blooms and fruits were removed to ensure plants were of similar height of about 0.25 m and canopy density at the start of the experiment. Plants were infested by randomly positioning them among other tomato plants harboring *T. vaporariorum* populations for 1 wk. Following this period, the number of *T. vaporariorum* were counted (90 adults ± 58 Standard Error per plant) to ensure adequate *T. vaporariorum* adults were present, and each plant was transferred to a vented BugDorm™ cage (0.3m^2, Bioquip, Rancho Dominguez, California, USA).

Experiments were conducted in a walk-in phytotron as described in Short et al. (2018) from 21 Jun to 2 Aug 2018. BugDorm cages containing *T. vaporariorum*-infested tomato plants were transferred into the phytotron for 24 h of acclimation to promote further settling and potential oviposition prior to the start of the experiment. Following this period, the plants were removed from cages and pots were placed on shelves with 8 tomato plants comprising the unexposed treatment (the control) on 1 shelving unit and 8 plants in the UV-C treatment on a second shelving unit situated inside the UV-C irradiation apparatus. While the number of *T. vaporariorum* likely changed during transfer into and removal from BugDorm cages, all plants assigned to the treatment and control were infested with multiple life stages at the start of the trial. A black polyester felt curtain (JOANN Fabrics and Crafts, Hudson, Ohio, USA) was used to shield untreated plants from UV-C irradiation penetration (Short et al. 2018). The UV-C irradiation apparatus contained an array of 8 lights (GermAway UV 55W Mountable UVC Surface Sterilizer; CureUV, Delray Beach, Florida, USA) furnished with bulbs (TUV PL-L 55W; Phillips North America Corp., Andover, Massachusetts, USA) that had a peak emission of 254 nm and irradiation intensity of 0.237 W m^{-2}. Lights were positioned 30 cm from plants at a 30° angle to center allowing good light penetration into the upper and lower canopies of the plants. Treated plants received a 16-s application of UV-C nightly. A calibrated spectrometer (Model EPP2000, StellarNet Inc., Tampa, Florida, USA) was used to measure light intensity per 0.5 nm bandwidth from 200 to 800 nm at 0.5 nm increments. The total irradiation was 1.2 W m^{-2}, and was calculated from the integration of the area under light output from a 254 nm UV-C lamp at the distance of 30 cm, thus a 16-s exposure corresponded to an irradiance dose of 19.2 J m^{-2}. The phytotron temperature was maintained at 20 ± 3 °C and the plants were kept under natural photoperiod conditions. The position of plants on each shelving unit were re-randomized weekly. Each wk, a visual count of the number of adults present per plant was conducted. Additionally, 3 leaves at 3 canopy heights were removed from each plant, placed in Petri dishes and counts of nymphs and eggs were made using a Nikon SMZ-1500 (Mellville, New York, USA) dissecting micro-

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scope. At the conclusion of the experiment, 9 leaves were removed from each treatment plant (3 leaves per canopy height: low, mid, top) and analyzed with a chlorophyll fluorometer (MAXI-IMAGING-PAM, Heinz Walz GmbH, Effeltrich, Germany). The maximal PS II quantum yield (Fv/Fm) was recorded for each sample. Data were analyzed using unequal variance *T*-tests to compare both weekly and overall life stage counts for *T. vaporariorum*, and chlorophyll fluorescence readings on treated and control plants.

During the 6-wk study, the number of adults per plant ($t = -6.99$; df = 52.21; $P < 0.01$), and nymphs ($t = -4.45$; df = 70.92; $P = <0.01$), and eggs ($t = -4.14$; df = 61.56; $P < 0.01$) per leaf sample were significantly lower on tomato plants treated with nightly 16-s exposures to UV-C compared with untreated plants (Table 1). Additionally, the mean number of adults per plant, and nymphs and eggs per leaf sample per wk was significantly lower for all life stages during most wk (Fig. 1). Although we do not know the exact mechanism for these differences, i.e., direct mortality vs. changes in host acceptability, we believe that short-burst UV-C exposure does reduce survivorship because we saw decreases across all life stages. However, identifying the mode of action for this species as well as for *T. urticae* (Short et al. 2018) will be critical to the development of UV-C as a management tool. Whereas there are no available thresholds for *T. vaporariorum* on tomato, the threshold for sweetpotato whitefly (MEAM1), *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae), is 4 adults per leaf from a 30 healthy leaf sample (Zalom et al. 2011). Here, the average number of *T. vaporariorum* adults per plant on UV-C exposed tomato plants likely remained below 4 adults per leaf throughout the trial; the number of adults counted per plant was reduced from 31.6 adults at the start of the trial to 13.3 adults at the conclusion of the trial.

Poushand et al. (2017) found that a single exposure to UV-C light (wavelength = 254 nm, irradiation intensity not reported) applied for increasing lengths of time (0.5–12 min) to adults on green bean leaves positioned 70 to 90 cm away from a UV-C lamp resulted in increasing *T. vaporariorum* adult mortality over a 48-h period, with > 90% mortality after 12 min exposure. In our study, whole plants were positioned much closer to the UV-C apparatus (30 cm away), but irradiation lasted only 16-s per night (nightly dose of 19.2 J m^{-2}). Despite the much shorter irradiation times, we observed significant reductions in numbers of all life stages on UV-C treated plants indicating this treatment was directly affecting mortality of *T. vaporariorum*.

Indirect effects of the UV-C treatment on the host plant itself also could be important to practical application of this pest management approach. For example, UV-A and UV-B irradiation applied to eggplant for up to 90 min per d for 21 d resulted in reduced settling by *B. tabaci* adults on treated plants. The morphology of eggplant was significantly altered and detectable differences in some leaf chemistry measurements were present (Prieto-Ruiz et al. 2019). Here, we simply measured chlorophyll fluorescence activity (Maxwell & Johnson 2000) as a first step toward understanding indirect effects of UV-C exposure on tomato plants and observed no significant differences between UV-C treated and untreated plants ($t = 1.28$; df = 136.92; $P = 0.89$) at the conclusion of the experiment indicating that there was

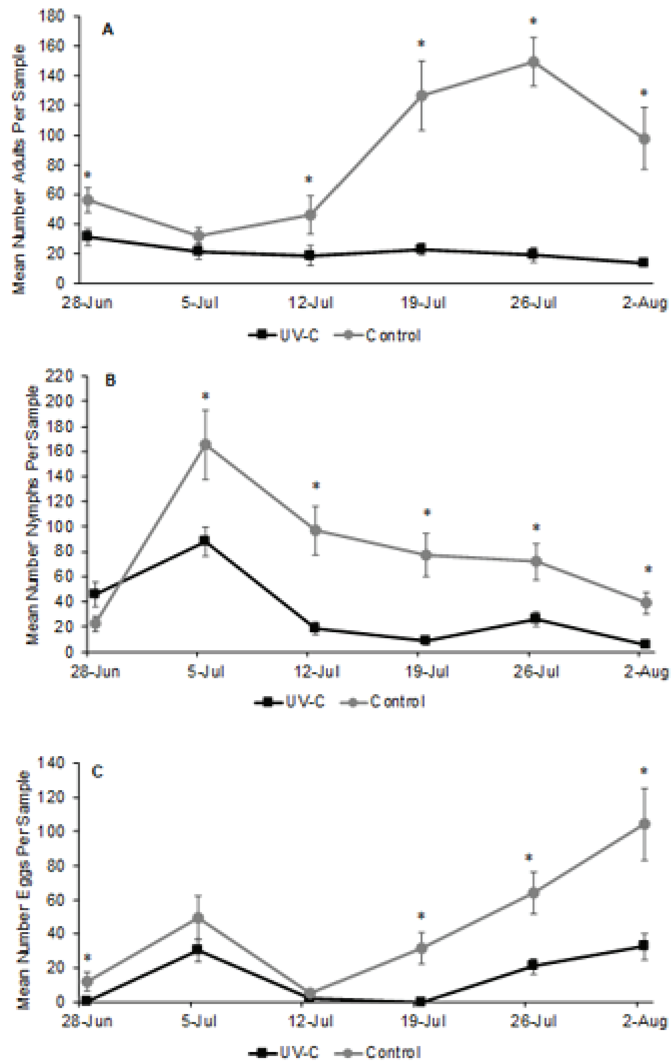

Fig. 1. Mean **± SE** number of *Trialeurodes vaporariorum* adults per plant (A), nymphs per 9-leaf sample (B), and eggs per 9-leaf sample (C) per wk from tomato plants treated nightly with a 16-s UV-C treatment or left untreated from 28 Jun to 2 Aug 2018. *Indicates a significant difference between treatment and control at $P < 0.05$).

no significant difference in photosynthetic activity. Both UV-C treated and untreated tomato plants bore fruit, although UV-C treated plants appeared somewhat darker with curled leaves at the conclusion of the trial, but they bore new leaves without this condition (Leskey et al., personal observation). In similar studies evaluating the use of UV-C irradiation against fungal pathogens on strawberry plants, no impact on strawberry plant growth, pollination, or phenolics content was detected (Janisiewicz et al. 2016a, b; Takeda et al. 2019; Sun et al. 2020).

Our results indicate that UV-C treatments offer promise for management of *T. vaporariorum* on tomato. UV-C treatments also could be effective in other vulnerable crops such as strawberry in California where this insect emerged as a serious pest in field plantings (Bi & Toscano 2007). Establishing mode of action, including effects on *T. vaporariorum* physiology using different methods of delivery and dosage, impacts on plant-mediated viral transmission by this species, as well as non-target impacts on crop plants; beneficial arthropods are the next step for developing management recommendations for using UV-C treatments for control of *T. vaporariorum* on vulnerable crops.

Table 1. Mean ± SE number of *Trialeurodes vaporariorum* present per wk on tomato plants treated nightly with a 16-s UV-C exposure or left untreated during a 6-wk trial.

Life stage per plant measurement	UV-C exposed	Untreated control
Adults per whole plant	21.33 ± 3.08*	84.73 ± 8.82
Nymphs per 9-leaf sample	31.50 ± 4.93*	78.81 ± 9.43
Eggs per 9-leaf sample	14.42 ± 2.69*	44.46 ± 6.74

*Indicates significantly different from the control at $P < 0.01$.

Mention of a concept, idea, trade name, or commercial product in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the US Department of Agriculture. The USDA is an equal opportunity employer. This work was funded, in part, by USDA-ARS Project 8080-21000-030-00-D.

Summary

Greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood) (Hemiptera: Aleyrodidae), is a serious pest of numerous crops grown in greenhouses and field-grown strawberry in yr-round production areas in California, USA. Problems with insecticide resistance have prompted the search for more sustainable methods for their management. Here, we applied UV-C light treatments nightly for 16 s (19.2 J m^{-2}) over a 6-wk period to tomatoes infested with *T. vaporariorum* and compared numbers of adults, nymphs, and eggs with those on untreated plants. All life stages of *T. vaporariorum* were significantly lower on tomatoes treated nightly with UV-C compared with unexposed plants. Additionally, there was no significant difference in chlorophyll fluorescence activity. Our results indicate that nightly UV-C treatments significantly reduce *T. vaporariorum* populations and offer a potential non-chemical method for their management on tomato.

Key Words: whitefly; IPM; greenhouse pest; tomato; insecticide resistance

Sumario

La mosca blanca del invernadero, *Trialeurodes vaporariorum* (Westwood) (Hemiptera: Aleyrodidae), es una plaga grave de numerosas plantas que se cultivan en invernaderos y de fresas cultivadas en el campo en áreas de producción durante todo el año en California, EE. UU. Los problemas de resistencia a los insecticidas han impulsado la búsqueda de métodos más sostenibles para su manejo. Aquí, aplicamos tratamientos de luz UV-C todas las noches durante 16 s (19.2 J m^{-2}) durante un período de 6 semanas a tomates infestados con *T. vaporariorum* y comparamos el número de adultos, ninfas y huevos con las plantas no tratadas. Todos los estadios de vida de *T. vaporariorum* fueron significativamente menores en los tomates tratados por la noche con UV-C en comparación con las plantas no expuestas. Además, no hubo diferencias significativas en la actividad de fluorescencia de la clorofila. Nuestros resultados indican que los tratamientos nocturnos con UV-C reducen significativamente las poblaciones de *T. vaporariorum* y ofrecen un método no químico potencial para su manejo del cultivo de tomate.

Palabras Clave: mosca blanca; MIP; plaga de invernadero; tomate; resistencia a insecticidas

References Cited

Bi JL, Toscano NC. 2007. Current status of the greenhouse whitefly, *Trialeurodes vaporariorum*, susceptibility to neonicotinoid and conventional insecticides on strawberries in southern California. Pest Management Science 63: 747–752.

Byrne DN, Bellows TS. 1991. Whitefly biology. Annual Review of Entomology 36: 431–457.

Gorman K, Devine G, Bennison J, Coussons P, Punchard N, Denholm I. 2007. Report of resistance to the neonicotinoid insecticide imidacloprid in *Trialeurodes vaporariorum* (Hemiptera: Aleyordidae). Pest Management Science 63: 555–558.

Greenberg SM, Jones WA, Liu T-X. 2002. Interactions among two species of *Eretmocerus* (Hymenoptera: Apheliniidae), two species of whiteflies (Homoptera: Aleyrodidae), and tomato. Environmental Entomology 31: 397–402.

Janisiewicz WJ, Takeda F, Glenn DM, Camp MJ, Jurick II W. 2016a. Dark period following UV-C treatment enhances killing of *Botrytis cinerea* conidia and controls gray mold of strawberries. Phytopathology 106: 386–394.

Janisiewicz WJ, Takeda F, Nichols B, Glenn DM, Jurick II WM, Camp MJ. 2016b. Use of low-dose UV-C irradiation to control powdery mildew caused by *Podosphaera aphanis* on strawberry plants. Canadian Journal of Plant Pathology 38: 430–439.

Kim JS, Je YH, Skinner M, Parker B. 2013. An oil-based formulation of *Isaria fumosorosea* blastospores for management of greenhouse whitefly *Trialeurodes vaporariorum* (Homoptera: Aleyrodidae). Pest Management Science 69: 576–581.

Lee D-H, Nyrop JP, Sanderson JP. 2009. Attraction of *Trialeurodes vaporariorum* and *Bemisia argentifollii* to eggplant and its potential as a trap crop for whitefly management on greenhouse poinsettia. Entomologia Experimentalis et Applicata 133: 105–116.

Lucas É, Labrecque C, Corderre E. 2004. *Dephastus catalinae* and *Coleomegilla maculata lengi* (Coleoptera: Coccinellidae) as biological control agents of the greenhouse whitefly, *Trialeurodes vaporariorum* (Homoptera: Aleyrodidae). Pest Management Science 60: 1073–1078.

Maxwell K, Johnson DN. 2000. Chlorophyll fluorescence—a practical guide. Journal of Experimental Botany 51: 659–668.

Mercier J, Arul J, Julien C. 1993. Effect of UV-C on phytoalexin accumulation and resistance to *Botrytis cinerea* in stored carrots. Journal of Phytopathology 139: 17–25.

Moreau TL, Isman MB. 2012. Combining reduced-risk products, trap crops and yellow sticky traps for greenhouse whitefly (*Trialeurodes vaporariorum*) management on sweet peppers (*Capsicum annum*). Crop Protection 34: 42–46.

Navas-Castillo J, Fialo-Olivé E, Sánchez-Campos S. 2011. Emerging virus diseases transmitted by whiteflies. Annual Review of Phytopathology 49: 219–248.

Poushand F, Aramideh S, Forouzan M. 2017. Effect of ultraviolet (UV-C) in different times and heights on adult stage of whitefly (*Trialeurodes vaporariorum*). Journal of Entomology and Zoology Studies 5: 864–868.

Prieto-Ruiz I, Garzo E, Moreno A, Dáder B, Medina P, Viñuela E, Fereres A. 2019. Supplementary UV radiation on eggplant indirectly deters *Bemisia tabaci* settlement without altering the predatory orientation of the biological control agents *Nesidiocoris tenuis* and *Sphaerophoria rueppellii*. Journal of Pest Science 92: 1057–1070.

Schlaeger S, Pickett JA, Birkett MA. 2018. Prospects for management of whitefly using semiochemicals, compared with related pests. Pest Management Science 74: 2405–2411.

Short BD, Janisiewicz W, Takeda F, Leskey TC. 2018. UV-C irradiation as a management tool for *Tetranychus urticae* on strawberries. Pest Management Science 74: 2419–2423.

Stevens C, Khan VA, Lu JY, Wilson CL, Pusey PL, Kabwe MK, Igwegbe ECK, Chaluz E, Droby S. 1998. The germicidal and hermetic effects of UV-C light on reducing brown rot and yeast microflora on peaches. Crop Protection 17: 75–84.

Stevens C, Khan VA, Lu JY, Wilson CL, Pusey PL, Kabwe MK, Mafalo Y, Liu J, Chaluz E, Droby S. 1997. Integration of ultraviolet (UV-C) light with yeast treatment for control of postharvest storage rots of fruits and vegetables. Biological Conservation 10: 98–103.

Sun J, Janisiewicz WJ, Takeda F, Evans BE, Jurick WM, Chen P, Zhang M, Yu LF. 2020. Effect of nighttime UV-C irradiation of strawberry plants on phenolics content of the fruit using targeted and non-targeted metabolomics analysis. Journal of Berry Research 10: 364–380.

Takeda F, Janisiewicz WJ, Smith BJ, Nichols B. 2019. A new approach for strawberry disease control. European Journal of Horticultural Science 84: 3–13.

Wardlow LR. 1985. Pyrethroid resistance in glasshouse whitefly (*Trialeurodes vaporariorum*, Westwood). Mededelingen van de Faculteit Landbouwwetenschappen, Rijksuniversiteit Gent 50: 164–165.

Wardlow LR, Ludlam AB, Bradley LF. 1976. Pesticide resistance in the glasshouse whitefly (*Trialeurodes vaporariorum* [Westwood]). Pesticide Science 7: 320–324.

Zalom FG, Bolda MP, Dara SK, Joseph SV. 2018. UC IPM Pest Management Guidelines: Strawberry. UC ANR Publication #3468. University of California-Davis, Davis, California, USA. https://www2.ipm.ucanr.edu/agriculture/strawberry/whiteflies/ (last accessed 15 Oct 2020).

Zalom FG, Trumble JT, Fouche CF, Summers G. 2011. UC IPM Pest Management Guidelines: Tomato. UC ANR Publication 3470. University of California-Davis, Davis, California, USA. http://www.ipm.ucdavis.edu/PMG/r783301211.html (last accessed 28 Oct 2020).