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Authors: Li, Chun-Xiao, Smith, Michael L., Fulcher, Ali, Kaufman, Phillip E., Zhao, Tong-Yan, et al.

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Field evaluation of three new mosquito light traps against two standard light traps to collect mosquitoes (Diptera: Culicidae) and non-target insects in northeast Florida

Chun-Xiao Li[1,3], Michael L. Smith[2], Ali Fulcher[2], Phillip E. Kaufman[1], Tong-Yan Zhao[3], and Rui-De Xue[2,]*

Abstract

Five light traps including 2 standard traps (New Jersey light trap and CDC light trap) and 3 new light traps (UV light trap, black light trap, and yellow fluorescent light trap) were evaluated for the collection of mosquitoes and non-target insects in northeast Florida from Sep to Oct 2013. In the evaluation of light traps without a chemical lure, the black light and CDC light traps collected large numbers of mosquitoes, and the ratios of mosquitoes to non-target insects were 1:7.5 and 1:8.9, respectively. In the evaluation of the 5 light traps, each baited either with octenol or with BG-Lure, the black light and CDC light traps collected larger numbers of mosquitoes than the other 3 types of traps. The ratios of mosquitoes to non-target insects were 1:2.8 and 1:6.7 for black light traps baited with octenol and BG-Lure, respectively, and 1:1.5 and 1:5.2 for CDC traps baited with octenol and BG-Lure, respectively. The results indicated that the black light trap was the best of the new traps evaluated based on its mosquito capture capabilities, while collecting the least non-target insects. Use of black light traps will benefit mosquito population surveillance by increasing the capture of insects of medical and veterinary importance.

Key Words: Culicidae; mosquitoes; light traps; attractants; non-target insects; surveillance

Resumen

Se evaluaron cinco trampas de luz, incluyendo 2 trampas de tipo estándar (trampa Nueva Jersey y trampa de luz CDC) y 3 nuevas trampas de luz (trampa de luz ultravioleta, trampa de luz negra, trampa de luz amarillo fluorescente) para recolectar los mosquitos y los insectos no objetivo en el noreste de la Florida de septiembre a octubre del 2013. En la evaluación de las trampas de luz sin un señuelo químico, la trampa de luz negra y la trampa de luz CDC recolectaron un gran cantidad de mosquitos, y la proporción de los mosquitos y los insectos no objetivo fueron de 1: 7.5 y 1: 8.9, respectivamente. En la evaluación de las 5 trampas de luz, cada una cebada ya sea con octenol o con el señuelo BG, la trampa de luz negra y trampa de luz CDC recolectaron un mayor número de mosquitos que las otras 3 trampas. La proporción de los mosquitos y los insectos no objetivo fueron de 1: 2.8 y 1: 6.7 para las trampas de luz negra cebadas con octenol, y 1: 1.5 y 1: 5.2 para las trampas de luz negra cebadas con el señuelo BG. Los resultados indicaron que la trampa de luz negra es la mejor de las nuevas trampas evaluadas en base a sus capacidad de capturar mosquitos, mientras que recolectaron el menos número de los insectos no objetivo. La utilización de trampas de luz negra beneficiará la vigilancia de poblaciones de mosquitos al incrementar la captura de insectos de importancia médica y veterinaria.

Palabras Clave: Culicidae; mosquitos; trampas de luz; atrayentes; insectos no objetivo; vigilancia

Mosquito traps play a vital role in monitoring mosquito populations and mosquito-borne diseases (Kline 2006). Through surveillance programs, mosquito trap efficacy has been used as justification for implementation and intervention of control measures. The New Jersey light trap, developed in the 1920s, became the "gold standard" trap used in mosquito surveillance (Reinert 1989). Since the invention of the New Jersey light trap, many mosquito traps have been developed and tested for mosquito surveillance (Moore et al 2001; Ritchie et al. 2008). Currently, the most popular of the developed traps, the CDC light trap, incorporates light and a secondary mosquito attractant, such as CO_2, to increase the number of mosquitoes captured (Newhouse et al. 1966). To enhance mosquito collection numbers, other secondary mosquito attractants, such as octenol (Takken & Kline 1989) or BG-Lure, have been used. Although there are many publications comparing the use of CDC light traps and other types of traps (Kline 2006), the literature focus is solely on the number of mosquitoes and mosquito species captured rather than on the non-target insects recovered in traps. Although the ability of a trap to capture mosquitoes is obviously critical, it is also important to consider capturing the smallest possible numbers of non-target insects.

Barrier spraying of vegetation with insecticides or attractive toxic sugar baits (ATSB) recently has been adapted for the operational con-

[1]Entomology and Nematology Department, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, Florida, USA
[2]Anastasia Mosquito Control District, 500 Old Beach Road, St. Augustine, Florida, USA
[3]Institute of Microbiology and Epidemiology, Fengtai, Beijing, People's Republic of China
*Corresponding author; e-mail: xueamcd@gmail.com

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trol of adult mosquitoes in golf courses, parks, and schools (Qualls et al. 2012, 2013, 2014; Xue et al. 2013). Concern about the impact of broadcast applications of insecticides to vegetation that is used by a great diversity of non-target organisms has gained the attention of scientists and residents. CDC light traps have been used to demonstrate barrier spray effectiveness. However, one might ask: Which light traps without secondary attractants are most suitable for collecting target mosquitoes without collecting many non-target insects?

The purpose of the present study was to evaluate the performance of 5 light traps including 3 new mosquito light traps with and without attractants (octenol and BG-Lure) to capture great numbers of target mosquitoes and small numbers of non-target insects such as butterflies, moths, beetles, and flies.

Materials and Methods

This study was conducted from 1 Sep to 30 Oct 2013 in the residential and agricultural farmland of Elkton in St. John County, northeast Florida. The performance of 5 light traps fitted with and without 1 of 2 attractants was evaluated. The traps were (1) CDC light trap (John W. Hock Company, Gainesville, Florida), (2) New Jersey light trap (John W. Hock Company, Gainesville, Florida), (3) black light mosquito trap (a small "U"-shaped light bar with a light wavelength of 365 nm and with the sucking fan in the bottom of the trap; PestNetChina Co., Ltd, Shanghai, China), (4) yellow fluorescent light trap (a large circular fluorescent light bar around a large yellow light bulb in the center with a yellow light wavelength of 570 nm, with the sucking fan under the light bulb; PestNetChina Co., Ltd, Shanghai, China), and (5) UV light trap (model: MSTRS-Talent; UV light bar with a dimension of 190 mm L ´ 63 mm W ´ 32 mm H and a light wavelength of 325 nm) modified from the CDC light trap and supplied by J. W. Zhu (Iowa State University, Ames, Iowa). The 2 attractants were octenol (BioSensory, Willimantic, Connecticut) and BG-Lure (BioGents, Regensburg, Germany). Trap performance was evaluated first without a secondary attractant, and then with the secondary attracts, octenol or BG-Lure, individually incorporated into the traps.

Each light trap was suspended 1.5 m above the ground. Traps were positioned linearly at a single location with a minimum distance of 20 m between trap sites. To eliminate site effects, traps were rotated between each site each day for 5 d, creating a 5 ´ 5 Latin Square design, providing 5 trap periods per trap model and 25 trap periods per experiment. This design was repeated for another 5 d period with the inclusion of octenol and BG-Lure, tested separately. Insects were removed from the traps every 24 h and stored in a -20 °C freezer before being identified and counted. Mosquitoes were identified to species, whereas non-target insects were identified to order and confirmed by staff at the Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Gainesville, Florida.

Collection data were log(n+1) transformed, and the numbers of mosquitoes and non-target insects collected were subjected to Latin Square Analysis of Variance (Snedecor & Cochran 1989). The model effects were trap type and sampling site. A significance *F*-test ($P < 0.05$) for a model effect was followed by a Least Significant Difference (LSD) post-hoc test to separate trap collection means. The mean numbers of mosquitoes and non-target insects collected by 5 different traps were subjected to Fisher's *t*-test (SAS Institute 2001). The ratios of total number of mosquitoes captured to total number of non-target insects captured were used to compare the efficacy of 5 light traps against targeted mosquitoes and non-target insects.

Results

NUMBERS OF MOSQUITOES CAPTURED

Twenty-five trap periods (5 traps operated over 5 d) yielded 261 mosquitoes without the use of attractant, and 677 or 290 mosquitoes with the addition of either octenol or BG-Lure, respectively. Mosquito species captured included *Anopheles crucians* Wiedemann*, Aedes atlanticus* Dyar and Knab*, An. quadrimaculatus* Say*, Coquillettidia perturbans* Walker*, Culiseta melanura* Coquillett*, Culex erraticus* Dyar and Knab*, Cx. nigripalpus* Theobald*, Psorophora columbiae* Dyar and Knab*,* and *Uranotaenia sapphirina* Osten Sacken regardless of attractant. *Anopheles crucians* was the dominant species and comprised 81.0% of mosquitoes captured.

There were significant differences in the mean numbers of mosquitoes caught between traps without attractant ($F = 15.13$, df = 4, $P < 0.01$), with octenol ($F = 14.51$, df = 4, $P < 0.01$), and with BG-Lure ($F = 32.52$, df = 4, $P < 0.0001$). The relative ranking of the different trap types with respect to numbers of mosquitoes captured was, in descending order regardless of attractants: black light trap, CDC light trap, yellow fluorescent light trap, UV light trap, and New Jersey light trap (Table 1).

Capture of Non-target Arthropods

In total, 7,401 non-target insects were captured without the use of an attractant, 6,640 with octenol, and 6,682 with BG-Lure. Non-target insects included Lepidoptera, Coleoptera, Diptera (excluding mosquitoes), Hemiptera, Hymenoptera, Thysanoptera, Neuroptera, Blattaria, Odonata, and Araneae (spiders). Diptera (33%, excluding mosquitoes), Lepidoptera (24%), Coleoptera (17%), and Hemiptera (16%) were the dominant non-target insects captured. There were significant differences in the mean numbers of non-target insects caught between traps without any attractants ($F = 12.61$, df = 4, $P < 0.01$), with octenol ($F = 20.50$, df = 4, $P < 0.0001$), and with BG-Lure ($F = 23.50$, df = 4, $P < 0.0001$). The ranking with respect to numbers of non-target insects captured in the absence of an attractant was, in descending order: yellow fluorescent light trap, black light trap, New Jersey light trap, CDC light trap, and UV light trap (Table 2). The yellow fluorescent light trap captured significantly more non-target insects than the other 4 trap types when used with either octenol or BG-Lure (Table 2).

In the evaluation of the 5 light traps without the secondary attractant, the black light trap and the CDC light trap captured the greatest

Table 1. Mean numbers (± SD) of all mosquitoes captured by 5 different types of light traps with or without attractants in northeast Florida.

Methods	Yellow light trap	Black light trap	New Jersey light trap	UV light trap	CDC light trap
Traps only	8.6 ± 3.4 b	27.4 ± 14.0 a	0.8 ± 0.3 c	3.6 ± 3.4 c	11.8 ± 8.0 b
Traps plus octenol	10.0 ± 7.4 c	74.4 ± 55.0 a	3.0 ± 2.7 c	3.2 ± 3.0 c	44.8 ± 34.0 b
Traps plus BG-Lure	9.0 ± 2.7 c	30.2 ± 16.9 a	0.6 ± 0.7 d	3.0 ± 2.1 d	15.2 ± 14.9 b

Anopheles crucians comprised 81% of all species of mosquitoes captured by the 5 types of light traps. Means followed by different letters within a row are significantly different ($P \leq 0.05$).

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Table 2. Mean numbers (± SD) of non-target insects captured by 5 different types of light traps with or without mosquito attractants in northeast Florida.

Method	Taxa	Yellow light trap	Black light trap	New Jersey light trap	UV light trap	CDC light trap
Traps only	Lepidoptera	102.2 ± 47.6	72.0 ± 42.2	20.0 ± 12.0	13.0 ± 6.1	9.6 ± 4.7
	Coleoptera	164.2 ± 153.1	21.4 ± 20.5	2.8 ± 1.6	7.8 ± 6.6	2.4 ± 1.1
	Diptera[a]	262.8 ± 156.3	111.0 ± 87.0	80.2 ± 47.4	248.8 ± 100.8	90.2 ± 45.4
	Hemiptera	187.0 ± 81.2	0.8 ± 1.3	2.6 ± 1.5	0.2 ± 0.4	2.6 ± 2.3
	Hymenoptera	0.6 ± 0.9	0.0 ± 0.0	0.2 ± 0.4	0.0 ± 0.0	0.0 ± 0.0
	Araneae[b]	1.6 ± 2.6	1.0 ± 0.7	0.6 ± 0.9	0.2 ± 0.4	0.0 ± 0.0
	Thysanoptera	73.0 ± 68.1	0.2 ± 0.4	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
	Neuroptera	0.4 ± 0.9	0.2 ± 0.4	0.2 ± 0.4	0.0 ± 0.0	0.0 ± 0.0
	Blattaria	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.4	0.0 ± 0.0
	Total[c]	791.8 ± 241.8 a	206.6 ± 67.6 b	106.8 ± 52.9 c	270.2 ± 112.5 b	104.8 ± 41.8 c
Traps plus octenol	Lepidoptera	262.4 ± 133.6	90.8 ± 76.8	16.2 ± 16.2	0.8 ± 1.0	20.2 ± 15.0
	Coleoptera	279.8 ± 363.8	31.2 ± 20.1	11.2 ± 4.0	0.0 ± 0.0	4.2 ± 2.4
	Diptera[a]	110.2 ± 30.6	77.2 ± 46.2	38.0 ± 20.1	59.0 ± 25.1	28.8 ± 14.5
	Hemiptera	152.4 ± 108.2	3.4 ± 3.1	17.4 ± 15.2	0.0 ± 0.0	13.8 ± 12.9
	Hymenoptera	3.2 ± 2.9	0.4 ± 0.6	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
	Araneae[b]	0.4 ± 0.6	0.4 ± 0.6	0.2 ± 0.5	0.0 ± 0.0	0.2 ± 0.5
	Thysanoptera	62.2 ± 52.4	0.4 ± 0.6	0.2 ± 0.5	0.0 ± 0.0	0.2 ± 0.5
	Neuroptera	37.4 ± 23.4	5.0 ± 3.7	2.0 ± 2.2	0.0 ± 0.0	0.2 ± 0.5
	Blattaria	0.2 ± 0.5	0.2 ± 0.5	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
	Odonata	1.2 ± 1.3	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
	Total[c]	909.8 ± 673.1 a	205.6 ± 94.4 b	85.4 ± 59.5 c	59.6 ± 34.6 c	67.6 ± 28.1 c
Traps plus BG-Lure	Lepidoptera	282.2 ± 54.4	108.0 ± 43.7	14.2 ± 9.7	1.0 ± 1.4	28.8 ± 16.5
	Coleoptera	163.8 ± 84.7	11.4 ± 4.4	6.4 ± 6.4	0.0 ± 0.0	3.2 ± 2.4
	Diptera[a]	157.8 ± 74.2	78.4 ± 54.6	12.4 ± 11.7	48.0 ± 36.2	28.0 ± 14.9
	Hemiptera	218.4 ± 140.6	1.8 ± 1.5	8.0 ± 6.7	0.5 ± 0.6	18.8 ± 17.3
	Hymenoptera	3.2 ± 4.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.5
	Araneae[b]	0.0 ± 0.0	0.2 ± 0.5	0.2 ± 0.5	0.0 ± 0.0	0.2 ± 0.5
	Thysanoptera	54.2 ± 42.6	0.0 ± 0.0	0.2 ± 0.5	0.0 ± 0.0	0.2 ± 0.5
	Neuroptera	80.0 ± 61.7	2.2 ± 1.7	3.0 ± 2.8	0.0 ± 0.0	0.0 ± 0.0
	Blattaria	0.8 ± 1.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
	Odonata	0.2 ± 0.5	0.2 ± 0.5	0.4 ± 0.6	0.0 ± 0.0	0.0 ± 0.0
	Total[c]	960.6 ± 326.5 a	202.4 ± 89.5 b	44.8 ± 33.0 c	49.6 ± 27.1 c	79.0 ± 43.5 c

[a]Excluding mosquitoes.
[b]Spiders.
[c]Means followed by different letters within a row are significantly different ($P \leq 0.05$).

numbers of mosquitoes while having the lowest ratios of mosquitoes captured to non-targets captured (1:7.5 and 1:8.9, respectively). With the addition of the secondary attractant (octenol or BG-Lure), the CDC light trap and the black light trap outperformed the 3 other trap types tested at both the number of mosquitoes captured and the ratio of mosquitoes to non-targets per trap (1:2.8 for black light trap baited with octenol and 1:6.7 for black light trap baited with BG-Lure; 1:1.5 for CDC trap baited with octenol and 1:5.2 for CDC trap baited with BG-Lure (Table 3).

Discussion

The CDC light trap is the most widely used mosquito monitoring tool in the world (Kline 2006). Our results showed that the CDC light

Table 3. The ratio of total number of mosquitoes to total number of non-target insects captured by each type of light trap with or without mosquito attractants in northeast Florida.

Method	Insects	Yellow light trap	Black light trap	New Jersey light trap	UV light trap	CDC light trap
Traps only	No. of mosquitoes	43	137	4	18	59
	No. of non-target	3,959	1,033	534	1,351	524
	Mosquito/non-target	1:92.1	1:7.5	1:133.5	1:75.1	1:8.9
Traps plus octenol	No. of mosquitoes	50	372	15	16	224
	No. of non-targets	4,549	1,028	427	298	338
	Mosquito/non-target	1:91.0	1:2.8	1:28.5	1:18.6	1:1.5
Traps plus BG-Lure	No. of mosquitoes	45	151	3	15	76
	No. of non-target	4,803	1,012	224	248	395
	Mosquito/non-target	1:106.7	1:6.7	1:74.7	1:16.5	1:5.2

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trap and the black light trap without any attractant captured many common mosquito species in northeast Florida. Compared with these 2 trap designs, the other 3 trap types (yellow fluorescent light, UV light, and New Jersey light traps) captured smaller numbers of mosquitoes.

Neither secondary attractant increased the numbers of non-target insects captured, which indicates that neither octenol nor BG-Lure is attractive to these insects. The best performing traps were the black light and CDC light traps, which both caught the most mosquitoes and had the lowest ratios (< 1:10) of mosquitoes to non-target insects. In contrast, the yellow fluorescent light trap had a low mosquito catch and a high mosquito to non-target ratio of 1:92. Most insects captured in the yellow fluorescent light trap were non-target insects.

The use of octenol improved the attractiveness of traps to mosquitoes in previous reports (Rubio-Palis 1996; Takken & Kline 1989), but the addition of octenol or BG-Lure did not significantly increase the catches in our trials. This difference in the performance of these 2 lures probably reflects the species composition of the local mosquito community, primarily *An. crucians*. BG-Lure was mainly developed to target *Aedes albopictus* Skuse and *Ae. aegypti* L.

Although there has been a vast amount of research on the ability of different types of light traps to capture mosquitoes (Moore et al. 2001; Cooper et al. 2004; Ritchie et al. 2008), there has been very little published on the propensity of different traps to capture non-target insects. Finding a relatively small number of mosquito specimens among a vast number of captured non-target insects is time consuming. To be useful, a mosquito trap must not only capture mosquitoes but also minimize the number of non-target insects captured.

Our results showed that the yellow fluorescent light trap was the most attractive to non-target insects, compared with 4 other types of light traps that captured 3- to 10-fold fewer numbers of Lepidoptera (butterflies, moths, etc.), Coleoptera (beetles), and Diptera (except mosquitoes, included love bugs, house flies, midges, etc.).

It is documented in the literature that different insect taxa are attracted to different wavelengths of light (Allan et al. 1989; Allan 1994). For example, Lepidoptera and Coleoptera tend to prefer wavelengths of 360 to 380 nm, 430 to 460 nm, 480 to 520 nm, and 580 to 620 nm, which correspond to UV, purple, blue, and yellow light sources, respectively. In contrast, members of the Diptera, including mosquitoes, tend not to be attracted to yellow light of wavelengths > 580 nm. These taxon-specific preferences may explain why yellow fluorescent light traps captured so many moths and beetles but relatively few mosquitoes.

The New Jersey light trap is the oldest of the effective mosquito traps (Reinert 1989). However, in the present study, this trap type captured a small number of mosquitoes compared with the other trap types tested. The UV light trap also captured a few mosquitoes, but the yellow fluorescent light trap captured a high number of non-target insects. The results support the findings of Yee (2013), where the color of the trap (yellow) influenced and increased the trap capture of agricultural pest insects, such as fruit flies, moths, and beetles.

In summary, the standard CDC light trap and the new black light trap were the most effective at collecting mosquitoes of medical and veterinary importance, while reducing the collection of non-target insects. The new black light trap could be used as an additional tool for surveillance of mosquito populations and effective evaluation of adult mosquito control measures.

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