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Laboratory and Field Performance of Five Cost-Effective Commercial Light Traps for Capturing Mosquitoes In China

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Research

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Abstract

Background

Mosquito traps for household use are popular because they are small, cost-effective, user friendly, and environmentally friendly. At present, there are many variations and specifications of mosquito traps intended for household use on the market. Their labels claim they are powerful, but research and evaluation of their claims is lacking.

Methods

This article tested the key parameters, the laboratory capture rate, and the greenhouse field capture rate of 5 popular mosquito traps intended for household use,and compared them with the BG-trap, used by professionals to monitor mosquitoes in the field.

Results

The study found that the wavelength of 395–400 nm had a better capture rate for *Culex quinquefasciatus*. In the laboratory experiment, the capture rate was between 34.7%-65.0%. The analysis showed that the total radiance, fan speed, and design of the air guide of the traps are important factors that affect the mosquito catch rate. Field tests in the greenhouse found that the 5 mosquito traps had low catch rates for *Aedes albopictus*. The average percentage of *Cx. quinquefasciatus*, *Ae. albopictus*, *Anopheles Sinensis*, and other flying insects captured every night was 51.76%, 25.29%, 14.12%, and 8.82%. There was no significant difference in the capture rate of *Ae. albopictus* by the 5 mosquito traps in the greenhouse, while the mosquito species captured during the same period by the human landing catch method were all *Ae. albopictus*, suggesting that the dominant species of mosquitoes in the greenhouse was *Ae. albopictus*. The comparison experiment of mosquito trap 5, with the highest capture rate in the laboratory simulation and greenhouse site, and the BG-trap in the morning, afternoon, and night showed that the capture rate of the BG-trap on *Ae. albopictus* and *Cx. quinquefasciatus* was higher than that of mosquito trap 5. Combined with the results of the human landing catch method during the same period, it showed that the BG-trap can more accurately reflect the composition of the mosquito community.

Conclusions

According to this study, it is suggested that the current 395–400 nm wavelength mosquito traps are not suitable for mosquito control measures in the domestic indoor environment where *Ae. albopictus* is the dominant species. The mosquito traps intended for household use can be improved by increasing the fan speed and optimizing the air guide. With a higher catch rate, the BG-trap is more suitable for mosquito monitoring than the UV-trap.

Introduction

Mosquito-borne diseases such as malaria, dengue fever, Chikungunya fever, and Zika are major threats to global health, especially dengue fever, which has increased 30-fold in the past 50 years(Huang, et al. 2019; Jelinek 2018; Lee, et al. 2018; Wilder-Smith, et al. 2019). Of the more than 50 mosquito-borne diseases known, vaccines are available only for epidemic encephalitis and yellow fever. The only way to curb other mosquito-borne diseases is mosquito control(Baldacchino, et al. 2015; de Thoisy, et al. 2020; Idoko, et al. 2020; Oliveira, et al. 2019; Trovato, et al. 2020). During mosquito season or a mosquito-borne disease epidemic, it is necessary not only to implement integrated mosquito control in the external environment, but also to control mosquitoes and prevent bites in residents' homes.

In malaria-endemic Africa, indoor control methods for the malaria vector *Anopheles* mosquitoes are mainly indoor residual spraying (IRS), which usually requires implementation by professional pest control personnel(Bouckenooghe, et al. 2019; Hamre, et al. 2020; Hien, et al. 2020; Kakilla, et al. 2020; Lees, et al. 2020). Mosquito incense and aerosols are traditional mosquito control methods in the home environment in dengue-endemic Southeast Asia and southern China. Due to the social attention to environmental protection and health concern, the number of families who have begun to adopt non-chemical mosquito control methods is increasing. One of these methods is the use of a mosquito trap.

Mosquito traps intended for household use are based on light mosquito trapping techniques for mosquito surveillance, such as the ultraviolet light trap for mosquito surveillance issued by the Centers for Disease Control and Prevention (CDC) (Holderman, et al. 2018; Li, et al. 2016; Silva, et al. 2019; Sriwichai, et al. 2015). Mosquito traps for household use are popular because they are small, cost-effective, user friendly, and environmentally friendly. The design principle of this kind of product is the same as that used by professionals. The light source used is an ordinary ultraviolet light or light-emitting diode (LED). The wavelength range of the ultraviolet light is 320 nm-400 nm, and a fan is set to form a guiding airflow, which draws the mosquitoes into the mosquito collection device, where they are trapped.

At present, there are many variations and specifications of mosquito traps intended for household use on the market. Their labels claim they are powerful, but research and evaluation of their claims is lacking. For that reason, we selected five popular mosquito traps costing 30 USD or less and evaluated their mosquito control performance in the home environment. We paid attention especially to how well they were made, and their mosquito capturing performance in the laboratory and in the field to provide valuable information for the control of mosquito-borne diseases by mosquito traps for household use.

Material And Methods

Description of the Five Light Traps and Quality Check

Source of mosquito trap

For this study, we purchased ultraviolet mosquito traps intended for household use from a well-known eCommerce store in China. We selected five of the most popular variations of mosquito traps with a price not exceeding 30 USD for research and evaluation. The product parameters are shown in Table 1.

Table 1
Parameters of five household mosquito traps used in the experiment

Product No.	Product Model	Power(W)	Power Supply	Net Weight(g)	Product Dimensions(mm)
Trap 1	DH-03S	5	DC5V	430	120*174
Trap 2	MY-100	5-0.5	DC5V-0.5A	370	137*225
Trap 3	KLY-188	5	220V/50HZ	200	120*215
Trap 4	N/A	5	DV 5V-1A	310	120*220
Trap 5	N/A	4	220v	500	170*340

Detection of radiation wavelength of mosquito traps

The radiation wavelength detection of the mosquito traps' UV light was conducted in the Mosquito Trap Quality Monitoring Laboratory of Zhongshan Protostar Optoelectronic Co., Ltd. The test method conformed to the inspection method for appliances with ultraviolet radiation lamps stipulated in Article 32 of the Chinese National Standard *Household and Similar Electrical Appliances—Safety—Particular Requirements for Insect Killers*(Institute, et al. 2008). The appliances were supplied with rated voltage and operated under normal working conditions. The test equipment used was the PMS-80 ultraviolet (UV)-visible (VIS)-near infrared (NIR) spectroscopy analysis system, which measures radiation at 1 m. The maximum radiation should be recorded when the measuring instrument is placed.

According to the specific operation process of the spectrometric testing instrument, the five variations of the mosquito traps were determined in order of number, and the data obtained after the test were analyzed. The total effective radiation was calculated by the following formula.

$$\mathrm{E} = \sum_{250nm}^{400nm} S_{\lambda} E_{\lambda} \Delta_{\lambda}$$

Where:

E——Effective Radiation;

S_λ——Relative Spectral Weight Factor;

E_λ——Spectral Irradiance(W/m^{2}nm)

Δ_λ——Bandwidth(nm)

When measuring spectral irradiance, the radiation required a stable light source. The effective radiation of each wavelength is calculated as the spectrum according to the ultraviolet (UV) of the spectral weight factor of different wavelengths. The total effective radiation (E) should not exceed 1 mW/m^2.

Ultraviolet mosquito trap air suction fan speed determination

The test was carried out following the stipulations of the Chinese National Standard *A. C. Fans and Regulators*(Institute, et al. 2018), and the test equipment used was the Hima-split anemometer AS8336. During the test, only the anemometer can be placed in front of the outlet of the fan. In the middle of the test, the tester can stay at the inlet side. The tester is only allowed to enter the fan outlet area when they need to control the speed and read the data. The tester should take minimum time to record the data and control the fan speed. The measurement begins about 20 mm from the air outlet side. For a more accurate result, the fan is sectioned into 4 quadrants (points). The anemometer is used to test the outgoing wind speed of each quadrant of the fan. Afterward, the value indicated by the anemometer is divided by the sampling time of the anemometer at that quadrant to measure the wind speed (m/s). The time used in measuring wind speed should not be less than 1 min.

Laboratory Test

Laboratory simulation field test experiment

A simulated field test was conducted in the Pesticide Evaluation Laboratory of Ningbo Yuying Vector Biocontrol Co., Ltd. in Zhejiang Province from May 25, 2020, to July 10, 2020. The test method followed the stipulations of the Chinese National Standard *Laboratory Efficacy Test Methods and Criterion of Public Health Equipment—Electronic Trap for Mosquitoes and Flies*(Prevention, et al. 2011). The glass test room was 3 m long, 3 m wide, and 3 m high, approximating a square room with a volume of 27 m^3. The test insect was *Cx. quinquefasciatus.* For the insecticide-sensitive strain of *Cx. quinquefasciatus* bred in this laboratory, female adult mosquitoes 3–5 days after emergence without blood suction were selected. The test conditions comprised temperature 26 °C ± 1 °C and relative humidity 65% ± 10%. The experiment started at 5 p.m. The mosquito trap to be tested was placed in the center of the test room and the light source was set 1.5 m away from the ground. Next, we released 100 mosquitoes into the test room, closed the doors and windows, and turned on the power supply to the mosquito trap after the test insects resumed their normal activities. At 8 a.m. on the second day, we cut off the power supply and wrapped the mosquito trap in a silk yarn cage to prevent the mosquitoes from escaping. Afterward, we extracted the mosquito trap's collection device to check the number of test mosquitoes captured to calculate the capture rate.

Capture rate = number of mosquitoes captured/number of mosquitoes released in the room × 100%

The test was repeated three times. The blank control was tested by turning on the fan, but not the light.

Field Test

The greenhouse field capture test was performed for the first time in November 2019 and for the second time in mid-July 2020. The site used for the field tests was the greenhouse of Guangxi Pastoral Biochemical Co., Ltd. in Nanning City, Guangxi Zhuang Autonomous Region. Geographically, the test site is 108.26° longitude, 22.86° latitude, and 77 m above sea level. It has a humid subtropical monsoon climate, with an annual average temperature of 20 °C -29 °C and annual average precipitation of 1304.2 mm. The greenhouse is 21 m long, 14 m wide, and 5 m high. The average daily temperature and humidity in the greenhouse are 30 °C and 80%, respectively. Corn, eggplants, rice, peppers, and other crops are planted all year round.

The test method followed the mosquito trap method and the human landing catch method stipulated in the China National Standard for *Vector Biodensity Monitoring Method—Mosquitoes* (Department of Analytical Microbiology 2009). In the mosquito trap method, we placed the mosquito traps in a sheltered area away from any interfering light source. The mosquito traps to be tested were placed more than 15 m apart, with plants between them to prevent light from any lamp from interfering with any other lamp. The light source of the mosquito trap was placed 1.5 m away from the ground. One hour before sunset, we turned on the mosquito traps to start the test. The power remained on until 1 hour after sunrise the next day. After turning off the lamp, we wrapped the mosquito traps with a silk yarn cage to prevent the captured mosquitoes from escaping. Then we counted and categorized the number and species of female mosquitoes captured. This test was carried out in two phases, each of which was repeated three times with the trap in a fixed position.

The human landing catch test was performed 30 minutes before the test of the mosquito traps. First, the monitors exposed one leg and remained stationary. Second, the species and number of mosquitoes that landed on the leg and were captured by the electric mosquito trap within 30 minutes were recorded. Lastly, the time, location, temperature, humidity, and wind speed at the beginning and end of the human landing catch test were recorded.

Comparative study of capture efficacy of the mosquito trap for household use and the BG-trap

The BG-trap (Biogents AG, Regensburg, Germany), used by professionals, is a foldable mosquito monitoring device, 36 cm in diameter and 40 cm in height. It's designed with a black tube in the middle of the plastic surface plate and a small fan under the tube connected to a removable mosquito collection device. Bait called BG-Sweetscent is placed in the container, which releases a mixture of lactic acid, ammonia, and hexanoic acid that mimics the odor on the surface of human skin to attract mosquitoes into the pipeline. Lastly, the fan airflow draws the attracted mosquitoes into the mosquito collection device. Unlike the five popular mosquito traps tested, it does not use a light to attract mosquitoes. It uses scent instead(Bhalala and Arias 2009; Ponlawat, et al. 2017).

Of the five mosquito traps, we selected the one with the highest capture rate for comparative testing with the BG-trap. The test was conducted in the same greenhouse as the previous experiment. Both mosquito control devices were placed on a shelf 1.5 m away from the ground. They were placed 15 m apart from each other. The tests were conducted three times per day. The testing periods for each day were as follows: 1) 9:00 A.M. to 11:00 A.M. 2) 2:00 P.M. to 4:00 P.M. 3) 6:00 P.M. to second day morning 8:00 A.M. After each test, the positions of the two mosquito traps were exchanged. Each mosquito control device was tested three times at each location and at each period.

Species Identification and Statistical Analysis

Morphological identification of mosquitoes captured, including mosquito species and genders, was performed using an anatomical microscope and the capture performance of the five mosquito traps was evaluated. All statistical analyses were performed using RStudio (Version 1.2.5001, 64bit) and R (version 3.4.1, 64bit) backends. In terms of statistical significance level, * means $P < 0.05$, ** means $P < 0.01$, *** means $P < 0.001$.

Results

Product Quality

The ultraviolet wavelengths of the five mosquito traps were measured by a PMS-80 ultraviolet (UV)-visible (VIS)-near infrared (NIR) spectroscopy analysis system. The results are shown in Table 2. According to the Chinese National Standard *Household and Similar Electrical Appliances—Safety—Particular Requirements for Insect Killers* (Institute, et al. 2008), mosquito traps exceeding 1 mW/m^2 total effective radiation exceed that which is allowed and are deemed unqualified. Therefore, mosquito trap 5 is judged to be unqualified, because its total effective radiation is 2.1980 mW/m^2, which exceeds the standard allowance. Whereas the remaining 4 traps are qualified.

Table 2
UV Wavelength Determination and Fan Speed Results of Five Household Mosquito Traps

Product No.	UV wavelength(nm)	Effective Radiation(mW/m^2)	Fan Speed(m/s)
Trap 1	400	0.1300	1.53
Trap 2	400	0.3902	1.32
Trap 3	395	0.0874	1.01
Trap 4	400	0.3029	1.15
Trap 5	395	2.1980	2.10

The fan speed test results of the suction fan of the traps are shown in Table 2. The average fan speed of mosquito trap 5 is 2.10 m/s, which is the highest among all the traps.

Laboratory Tests

The results of the mosquito capture rate test in the laboratory are shown in Table 3. The Shapiro-Wilk test was used to verify that the data were normally distributed. The results of variance analysis and the Tukey test showed that there were significant differences in the trapping rate of the five mosquito traps ($P < 0.001$). The capture rate of mosquito trap 5 and 1 exceeded 50%, which was significantly higher than that of the other three mosquito traps.

Table 3
Laboratory Test Capture Rate of Five Household Mosquito Traps

Product No.	Total release number	Re-capturing number	Capturing Rate (%)
Trap 1	300	179	59.7
Trap 2	300	136	45.3
Trap 3	300	121	40.3
Trap 4	300	104	34.7
Trap 5	300	195	65.0

Field Tests

In the first phase of the greenhouse field test, 170 specimens were collected from the five mosquito traps; 143 (84.12%) of the total specimens were female mosquitoes. The mosquito species captured most was the *Cx. quinquefasciatus*, 88 of which were captured, comprising 51.76% of the total number of mosquitoes captured. This was followed by *Ae. albopictus*, 43 of which were captured, comprising 25.29% of the total captured and *An. sinensis*, 24 of which were captured, comprising 14.12% of the total captured. The above three species of mosquito are the prevalent species in the urban environment of China, and thus, were the most captured mosquito species in our test (Table 4). The average number of mosquitoes captured per test round (30 min) was 2.33 + 0.82 by the human landing catch method, and all the captured mosquitoes were female *Ae. albopictus.*

Table 4
Comparison of five mosquito traps in field settings

mosquito	trap 1		trap 2		trap 3		trap 4		trap 5		Total	%
	Mean ± SE	N	Mean ± SE	N	Mean ± SE	N	Mean ± SE	N	Mean ± SE	N		
Ae. albopictus	1.00 ± 0.21	6	1.33 ± 0.33	8	1.17 ± 0.40	7	1.00 ± 0.37	6	2.67 ± 0.61	16	43	25.29
Cx. quinquefasciatus	4.83 ± 0.70	29	1.83 ± 0.31	11	1.50 ± 0.42	9	0.67 ± 0.21	4	5.83 ± 0.60	35	88	51.76
An. sinensis	0.84 ± 0.40	5	0.50 ± 0.22	3	0.33 ± 0.21	2	1.00 ± 0.36	6	1.33 ± 0.42	8	24	14.12
others	0.67 ± 0.33	4	0.33 ± 0.21	2	0.50 ± 0.22	3	0.17 ± 0.17	1	0.83 ± 0.40	5	15	8.82
Total number of individuals	44		24		21		17		64		170	
Total number of female	38		20		16		15		54		143	84.12

N = total number of individuals per trap; SE = Standard Error.

Table 5
Capture performance of BG vs UV trap in field settings

mosquito	**BG-trap**						**UVtrap**						**Total**	**%**
	morning		afternoon		evening		morning		afternoon		evening			
	Mean ± SE	N	Mean ± SE	N	Mean ± SE	N	Mean ± SE	N	Mean ± SE	N	Mean ± SE	N		
Ae. albopictus	4.83 ± 0.91	29	5.17 ± 0.75	31	37.67 ± 1.67	226	0.67 ± 0.33	4	0.17 ± 0.17	1	7.00 ± 1.15	42	333	72.87
Cx. quinquefasciatus	3.00 ± 1.18	18	2.00 ± 0.37	12	6.33 ± 0.82	38	0.17 ± 0.17	1	0.33 ± 0.21	2	3.33 ± 0.92	20	91	19.91
An. sinensis	1.17 ± 0.48	7	0.67 ± 0.33	4	2.83 ± 0.60	17	0.17 ± 0.17	1	0.17 ± 0.17	1	0.50 ± 0.34	3	33	7.22
Total number of individuals	382						75						457	
Total number of females	318						60						378	82.71

N = total number of individuals per trap; SE = Standard Error.

After the Shapiro-Wilk test was performed to confirm that the data were not a normal distribution, the Kruskal-Wallis test was performed. The results are shown in Fig. 1

The results showed that mosquito trap 5 caught the most *Ae. albopictus* on average every night(2.67 ± 0.61). However, there was no significant difference in the average number of mosquitoes captured per night among the five traps (P = 0.17). The results are shown in Fig. 1A.

The results of the number of *Cx. quinquefasciatus* captured showed that there were significant differences among the five mosquito traps (P < 0.001). The average number of mosquitoes captured per night of trap 5 was about 8.7 times that of trap 4 (P < 0.01), about 3.9 times that of trap 3 (P = 0.031), and about 7.2 times that of trap 1 (P = 0.0065). The results are shown in Fig. 1B.

In terms of the number of *An. sinensis* captured, only trap 5 captured more than 1 of this species, on average, and there was no significant difference among the five mosquito traps (P = 0.315). The results are shown in Fig. 1C.

The Kruskal-Wallis test result showed that there were significant differences among the five mosquito traps in the average total number of mosquitoes captured per night (P < 0.001). The average number of mosquito captured per night of trap 5 was about 3.7 times that of trap 4 (P < 0.001), about 3.0 times that of trap 3 (P < 0.01), about 2.66 times that of trap 2 (P = 0.023), and about 1.8 times that of trap 1 (P = 0.039). The mosquito capture performance of trap 5 was the best among the five traps, followed by trap 1. The results are shown in Fig. 1D.

In the first phase of the test in the greenhouse, the capture performance of trap 5 was the best. Thus, we decided to compare the performance of trap 5 with that of the BG-trap. We renamed trap 5 as UV-trap and compared it with the BG-trap in the greenhouse18 times. After the test, a total of 457 specimens were collected.

The second phase of the test was divided into three periods: morning, afternoon, and evening. A total of 457 mosquitoes were captured, 378 of which were female (82.7%). The largest ratio of mosquito species trapped was *Ae. albopictus*, of which 333 were captured, accounting for more than half of the total number (72.9%), followed by 91 *Cx. quinquefasciatus* (19.9%) and 33 *An. sinensis* (7.2%). Next, we analysed the conditions under which the mosquitoes were captured in different periods. The results are shown in Fig. 2. As for the result of the human landing catch method, the average number of captured mosquitoes per time (30 min) in the morning, afternoon, and evening were 1.67 ± 0.33, 1.83 ± 0.17, 3.00 ± 0.37, respectively. All the mosquitoes captured in the three periods were *Ae. albopictus*.

In the morning (Fig. 2A), the performance of the BG-trap in capturing *Ae. albopictus* and *Cx. quinquefasciatus* was significantly higher than that of the UV-trap. The number of *Ae. albopictus* captured by the BG-trap (4.83 ± 0.91) was 7.2 times higher than that of the UV-trap (0.67 ± 0.33) ($P < 0.01$). The number of *Cx. quinquefasciatus* captured by the BG-trap (3.00 ± 1.18) was 17.6 times higher than that of the UV-trap (0.17 ± 0.17) ($P < 0.05$).

In the afternoon (Fig. 2B), the performance of the BG-trap in capturing *Ae. albopictus* and *Cx. quinquefasciatus* was significantly higher than that of the UV-trap. The number of *Ae. albopictus* captured by the BG-trap (5.17 ± 0.75) was 30.4 times higher than that captured by the UV-trap (0.17 ± 0.17) ($P < 0.001$). The number of *Cx. quinquefasciatus* captured by the BG-trap (2.00 ± 0.37) was 6.1 times higher than that captured by the UV-trap (0.33 ± 0.21) ($P < 0.01$).

In the evening (Fig. 2C), the performance of the BG-trap in capturing the three species of mosquitoes was significantly higher than that of the UV-trap. The number of *Ae. albopictus* captured by the BG-trap (37.67 ± 1.67) was 5.2 times higher than that captured by the UV-trap (7.00 ± 1.15) ($P < 0.001$), while the number of *Cx. quinquefasciatus* captured by the BG-trap (6.33 ± 0.82) was 1.9 times higher than that captured by the UV-trap (3.33 ± 0.92) ($P < 0.05$). Lastly, the number of *An. sinensis* captured by the BG-trap (2.83 ± 0.60) was 5.7 times higher than that captured by the UV-trap (0.50 ± 0.34) ($P < 0.01$).

Further, we compared the total number of mosquitoes captured per hour in each period and obtained the result shown in Fig. 2D. The average number of mosquitoes captured per hour by the BG-trap (3.96 ± 1.03) was higher than that captured by the UV-trap (0.57 ± 0.54), and the difference was significant ($t = 12.381$, $df = 25.78$, $P < 0.001$).

Discussion

In this study, the ultraviolet light of all five household mosquito traps had a wavelength range of 390 nm-400 nm, which conformed to the standard ultraviolet light range. According to the Pearson correlation coefficient, the correlation coefficient between the ultraviolet light wavelength of the five mosquito traps and the mosquito capture rate in the laboratory was subtle ($P > 0.05$). Therefore, the ultraviolet light wavelength was not a significant factor influencing the difference in the mosquito traps' capture rate.

According to Pearson correlation coefficient analysis on the air suction efficiency of the mosquito traps, the fan speed and capture rate exhibited a linear relationship, which showed that fan speed might be a crucial factor influencing the mosquito capture performance of the traps ($P < 0.05$). Other researchers tested the effect of different fan speeds against the performance of the trap in capturing mosquitoes. The result showed that 1.7 m/s was the ideal suction rate to obtain a higher capture rate and lower damage to the captured mosquitoes' bodies(ZHANG Hong-xiang 2002). In our study, mosquito trap 5 had the highest capture rate with an air suction rate of 2 m/s. And the mosquitoes captured didn't show critical damage to their bodies. Therefore, we believe that whether it is a mosquito trap for household use or a mosquito monitoring trap, the mosquito capture performance can be enhanced by increasing the air suction rate.

Mosquito trap 5 and trap 1 had the highest mosquito capture rates during the laboratory field test. This may be due to their shape and structural design, which were different from the other three mosquito traps. Trap 5 and trap 1 have inclined upward-opening entries, which means they can capture mosquitoes from 360° around the top, whereas the entries of the other three traps are located at the middle, where the airflow into the entries is parallel and thus there is a smaller capture area. The capture area might be one factor influencing the mosquito capture rate.

In the first phase of the greenhouse field test, the largest ratio of one species of mosquito species captured by the five mosquito traps was 51.76% and the species captured was *Cx. quinquefasciatus*, while the main mosquito species captured by the human landing catch method was that of *Ae. albopictus*. However, *Ae. albopictus* was not the main species of mosquito captured by the five mosquito traps and did not reflect the mosquito species composition of the mosquito community in the field. This experiment shows that the ultraviolet trap with a wavelength of 390 nm-400 nm is inefficient in capturing *Ae. albopictus* and is not suitable for use as a light source for mosquito traps for household use in areas where *Ae. albopictus* is the dominant species, such as China. It has been reported that the capture rate of a light source with 520 nm wavelength had a higher capture rate of *Ae. albopictus*, which deserves further study(Costa-Neta, et al. 2017).

Mosquito trap 5 and trap 1 had a relatively high capture rate of mosquitoes, which was significantly higher than that of the other three traps. Further, the difference was particularly significant in the capturing of *Cx. quinquefasciatus*. The total effective radiation of mosquito trap 5 exceeded the standard quite a bit, and its air suction rate was also the largest, which may be the reason for its high capture rate. Mosquito trap 1 achieved high capture efficiency under the premise of product compliance and should be an excellent choice among the five mosquito traps for household use that we evaluated.

The published comparative test studies of the BG-trap and the UV-trap were conducted in the field, and this experiment evaluated both in the laboratory(Hoshi, et al. 2019; Ponlawat, et al. 2017). The experiment showed that in the greenhouse, the capture rate of Ae. albopictus and *Cx. quinquefasciatus* by the BG-trap (used by professionals) in the morning, afternoon, and evening was significantly higher than that by the UV-trap (mosquito trap 5). The capture rate of the BG-trap of *Ae. albopictus* was higher, which was corroborated by the human landing catch method and reflected the composition of the mosquito community more accurately. In the field of mosquito surveillance, the BG-trap is more objective and accurate than a lamp trap, and it can replace the human landing catch method.

There are few studies on the capture rate of mosquito traps for household use. This study tested the product parameters of five popular mosquito traps, the capture rate in the laboratory and the capture rate in a greenhouse, and obtained preliminary data, which provided research and development ideas for improving the performance of mosquito traps marketed for household use in China.

Declarations

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Author's contributions

Hong Jiang conceived and designed the experiments. Run Huang, Hongyun Song, Qian Fang, Junping Qian,Yaodan Zhang performed the experiments. Hong Jiang and Run Huang analyzed the data and wrote the paper. Hong Jiang and Run Huang critically revised the manuscript. All authors read and approved the final version of the submitted manuscript.

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Figures

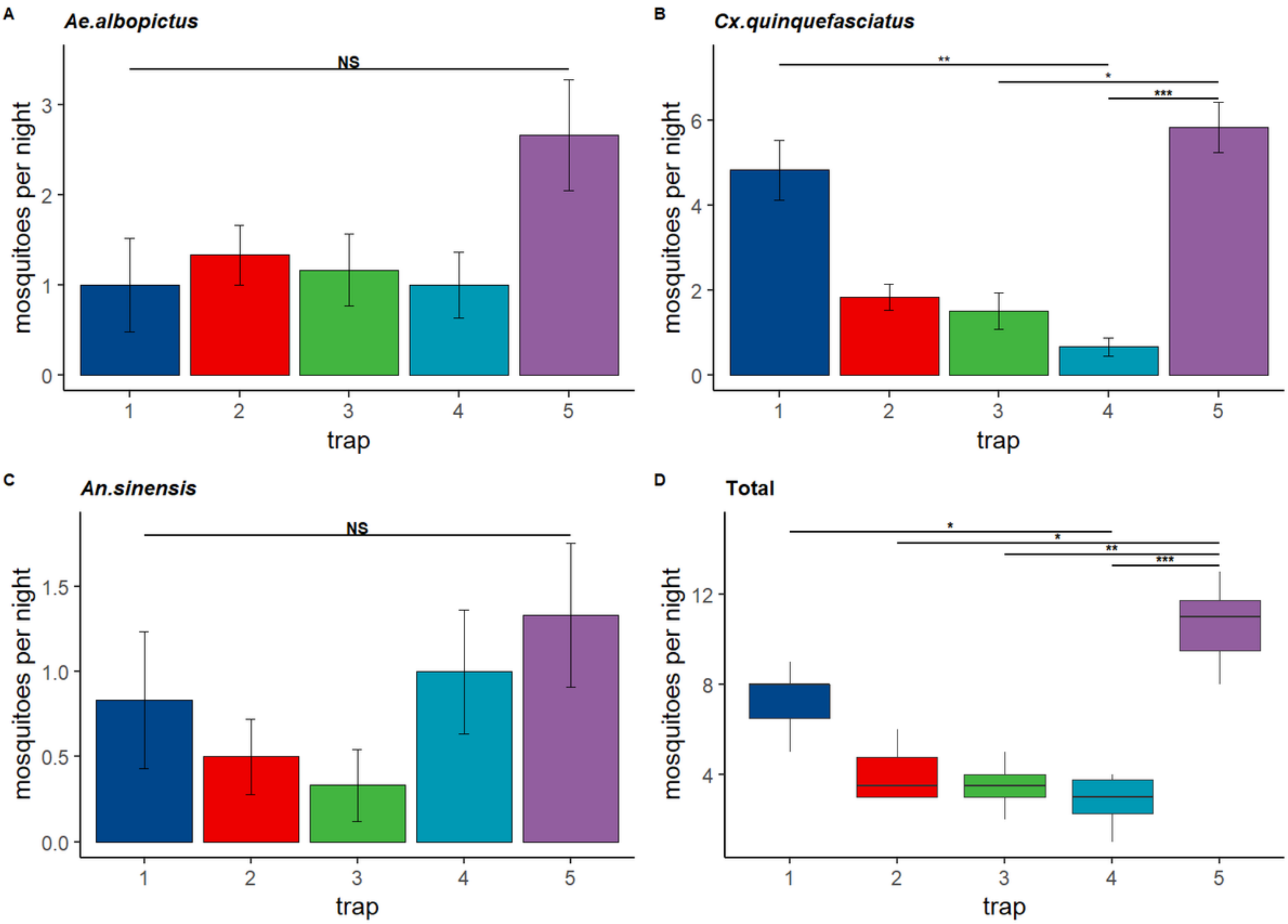

Figure 1

The number of trapped mosquitos per night among the five trapping devices. Mean +/-SE number of trapped individuals per trapping period among the five trapping devices for (A) Ae.albopictus, (B) Cx. quinquefasciatus and (C) An. sinensis.. (D)The box plots represent the median and first and third quartiles of the total species of mosquito collected in the five trap types.

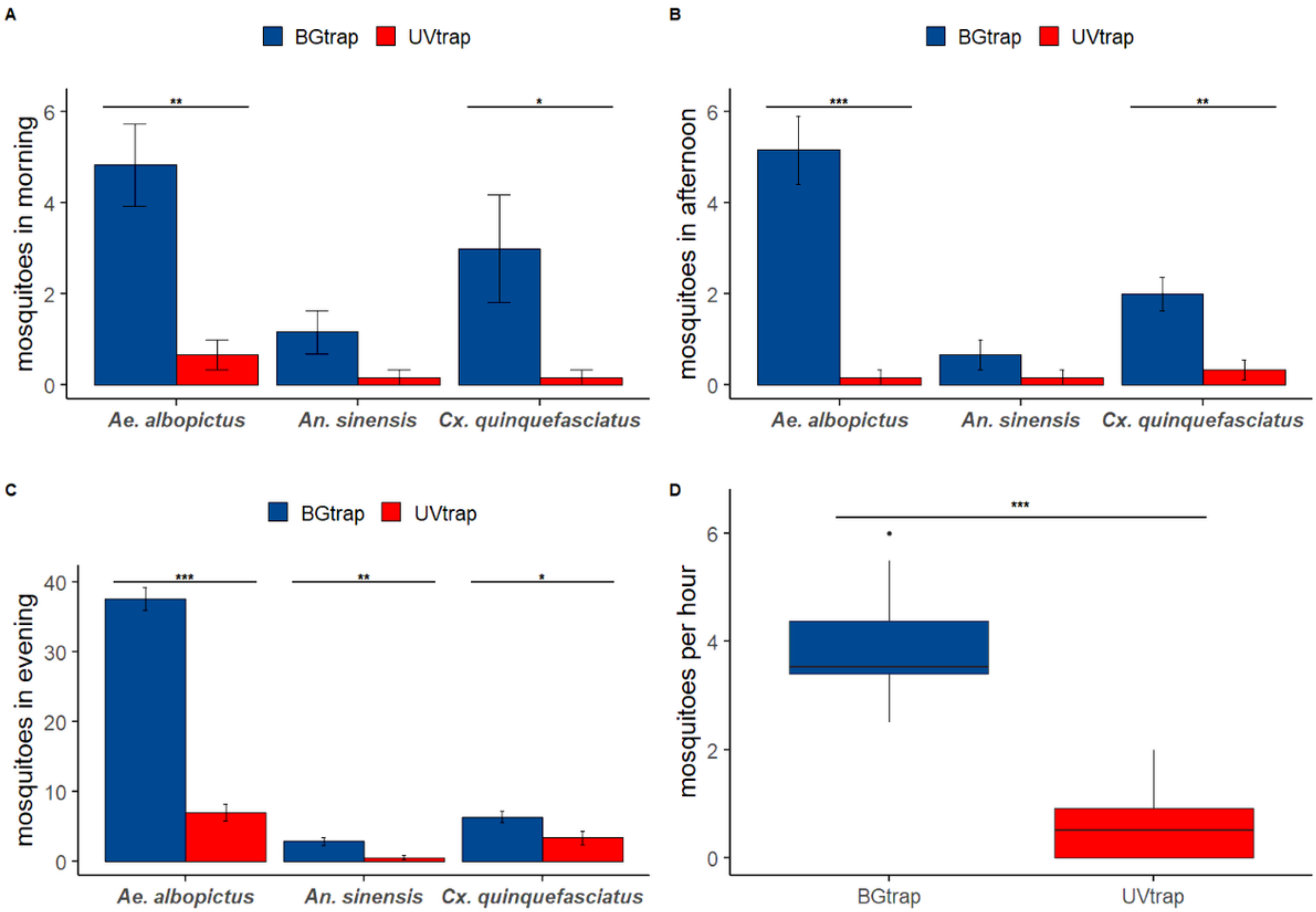

Figure 2

The number of trapped individuals per period between the two trapping devices. Mean +/-SE number of trapped individuals per trapping period between the BG-trap and UV-trap (A) in the morning, (B) afternoon, and (C) evening. (D) The box plots represent the median and first and third quartiles of the total species of mosquito collected per hour in the two trap types.

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