Laboratory and Field Performance of Five Cheap Commercial Light Traps for Capturing Mosquitoes In China

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Research

Abstract

Background

Mosquito light traps for household use are popular because they are small, cheap, 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 rates, and the field capture rate of 5 popular mosquito traps intended for household use.

Results

The study found that in the laboratory experiment, the capture rate of the mosquito traps selected was between 34.7%-65.0%. The analysis showed that the 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 high catch rates for *Culex quinquefasciatus.* The average percentage of *Cx. quinquefasciatus*, *Aedes albopictus*, *Anopheles sinensis,* and other flying insects captured every night was 51.76%, 25.29%, 14.12%, and 8.82%, respectively. There was no significant difference in the capture rate of *Ae. Albopictus* and *An. sinensis* by the 5 mosquito traps in the greenhouse, but a significant difference in the catch rate of *Cx. Quinquefasciatu.*

Conclusions

The ultraviolet wavelength (395-400nm) involved in the selected mosquito traps is not the main reason that affects the mosquito catching effect, but the fan speed and the air guide may be the reason for the difference in the catching effect among the five mosquito traps. Therefore, the mosquito traps intended for household use can be improved by adjusting the fan speed and optimizing the air guide.

Introduction

Mosquito-borne diseases such as malaria, dengue fever, Chikungunya fever, and Zika infection are major threats to global health, especially dengue fever, which has increased 30-fold in the past 50 years[1, 2, 3, 4]. Of the more than 50 known mosquito-borne diseases, vaccines are available only for epidemic encephalitis and yellow fever. The Basic way to curb other mosquito-borne diseases is mosquito control[5, 6, 7, 8, 9]. 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 residential 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[10, 11, 12, 13, 14]. 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) [15, 16, 17, 18]. Mosquito traps for household use are popular because they are small, cheap, 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 320−400 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 200 RMB ($30) 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.

Materials 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 (JD.com,stock code: JD). We selected five of high sales and popular variations of mosquito traps with a price not exceeding 200 RMB ($30) 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)	Band	Price (RMB)	Color	Place of origin
Trap 1	DH-03S	5	DC5V	430	120*174	SOHOW	161	Balck	Guangdong province, China
Trap 2	MY-100	5-0.5	DC5V-0.5A	370	137*225	GREEN	99	White	Henan Province, China
Trap 3	KLY-188	5	220V/50HZ	200	120*215	XianJuYuan	79	White	Guangdong province, China
Trap 4	N/A	5	DV 5V-1A	310	120*220	MrClean	49	White	Hebei Province, China
Trap 5	N/A	4	220v	500	170*340	Greensky	199	Purple	Guangdong province, China

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*[19]. 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.

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

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.

Determination of ultraviolet mosquito trap air suction fan speed

The test was carried out following the stipulations of the Chinese National Standard *A. C. Fans and Regulators*[20], 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 simulation of field test experiment

A laboratory test was conducted in the Pesticide Evaluation Laboratory of Ningbo Yuying Vector Control 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*[21]. 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 insecticide-sensitive strain of *Cx. quinquefasciatus* was bred in this laboratory and 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, and turn off other irrelevant power sources. 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.

Comparison of household mosquito traps in field settings

The greenhouse field capture test was performed in November 2019. The site used for the field tests were three connected greenhouses 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 ranging from 20−29°C and annual average precipitation of 1304.2 mm. The greenhouse is 21 m long, 14 m wide, and 5 m high. It is surrounded by walls on four sides, and both sides of the longitudinal wall have a 1-square-meter ventilation window. Corn, eggplants, rice, peppers, and other crops were grown in the greenhouse during the test. When testing the mosquito traps, stop related crop trials one month in advance to reduce unnecessary interference and impact. The average daily temperature and humidity in the greenhouse are 30°C and 80%, respectively.

The test method followed the mosquito trap method and the human landing catch method stipulated in the China National Standard for *Vector Density Monitoring Method—Mosquitoes* [22]. In the mosquito trap method, we placed the mosquito traps in a sheltered area away from any interfering light source. The light source of the mosquito trap was placed 1.5m 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. Repeat three times for each trap. 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.

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. Shapiro-Wilk test, Kruskal-Wallis test, analysis of variance, tukey test and Pearson correlation coefficient were used to analyze the data. 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* [19], 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 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 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).

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.

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 mosquitoes 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.

Discussion

It was reported that there was no significant difference in the capture efficiency of light traps among the three kinds of mosquitoes widely distributed in China, *Cx. quinquefasciatus, Ae. Albopictus* and *An. sinensis* in laboratory tests. [17]. *Cx. Quinquefasciatus* is stipulated as tested insects by Chinese National Standard *Laboratory Efficacy Test Methods and Criterion of Public Health Equipment— Electronic Trap for Mosquitoes and Flies*[21]. In this study, *Cx. Quinquefasciatus* was also chosen to evaluate the capture efficiency of five light traps.

The ultraviolet light of all five household mosquito traps had a wavelength range of 390-400nm, 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 of capture rate in the selected mosquito traps. In the study of David P Tchouassi, the attraction preferences of blue(430nm), green(570nm), red(660nm) and ultraviolet(390nm) light to mosquitoes were compared, and the results showed that blue and green light in visible light have relatively higher mosquito trapping efficiency than others[23]. B M Costa-Neta's research also supports that LED mosquito traps equipped with green(520nm) and blue(470nm) light have higher trapping efficiency[24]. However, Alongkot Ponlawat's research shows that the traps that emit ultraviolet light (10-400nm) are

better than green(490-570nm) and red(620-780nm) light, which is completely opposite to the results of previous studies[25]. In the study of Emmanuel P. Mwanga, the effect of UV (364nm) LED mosquito trap is equal to or better than CDC incandescent lamp, and the indoor effect is better than outdoor[26]. The mosquito traps in this study have a relatively small range of ultraviolet light and does not involve research in the visible light band. Follow-up will expand the ultraviolet light band and select the blue and green light in the previous research conclusions for the next step.

In this study, the fan speed and laboratory capture rate exhibited a linear relationship according to Pearson correlation coefficient analysis on the air suction efficiency of the mosquito traps, which showed that fan speed might be a crucial factor influencing the mosquito capture performance of the traps ($P < 0.05$). Other researchers also 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 bodies of captured mosquitoes[27]. In our study, mosquito trap 5 had the highest capture rate with an air suction rate of 2m/s. And the mosquitoes captured did not show critical damage to their bodies. Therefore, we guess that the mosquito capture performance can be enhanced by appropriately increasing the air suction rate, but whether this conclusion can be drawn remains to be further studied.

Mosquito trap 5 and trap 1 had the highest mosquito capture rates during the laboratory and field tests. This may be due to their shape and structural design, which were different from the other three mosquito traps (Fig. 2). 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 (Fig. 2B), 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.

National Institute for Communicable Disease Control and Prevention, Chinese Center for Disease Control and Prevention reported that the mosquito species in residential areas in 2018 was mainly *Cx. quinquefasciatus*, accounting for 60.25% of the total[28]; in 2019, the species of mosquitoes in residential areas were *Cx. quinquefasciatus* Mainly 57.73%, followed by *Anopheles sinensis*, *Cx. tritaeniorhynchus*, and *Ae. albopictus*, which accounted for 20.27%, 12.22%, and 2.29%, respectively[29]. In the greenhouse experiment of this study, the 5 kinds of mosquito traps caught the most mosquito species were *Cx. quinquefasciatus*, accounting for 51.76%, followed by *Ae. albopictus* (25.29%). The capture of *Cx. quinquefasciatus* is roughly in line with the national survey and monitoring in the past two years. The population density of *Ae. albopictus* is higher than the national total, which also reflects one of the reasons for the frequent outbreaks of dengue fever in Guangxi in recent years, which may be caused by the increasing population density of *Ae. albopictus*.

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.

There were 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 field test and preliminary data obtained, which provided research and development ideas for improving the performance of mosquito traps marketed for household use in China.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing Interest

Author details

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Figures
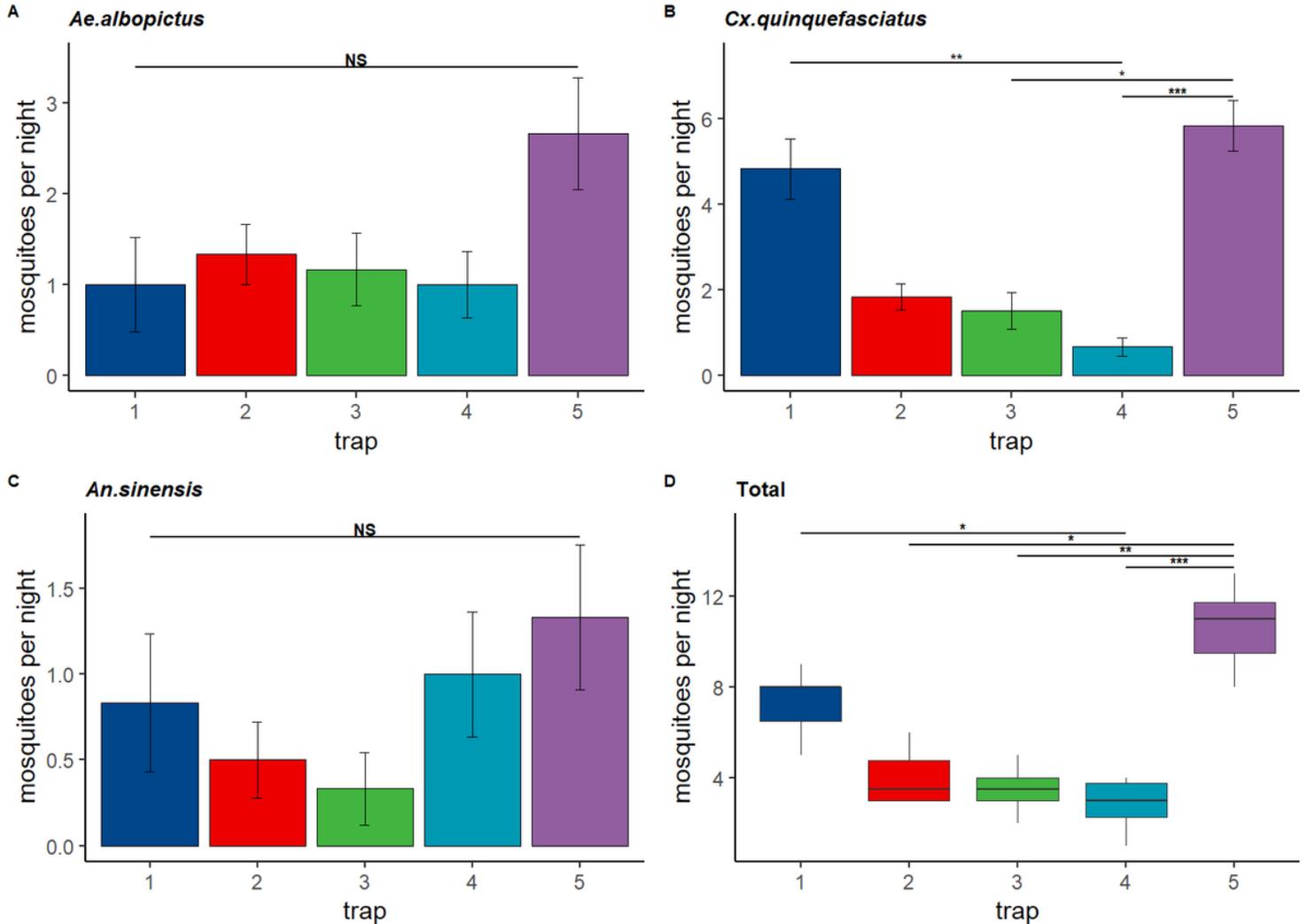
Figure 1

The number of trapped mosquitoes 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.
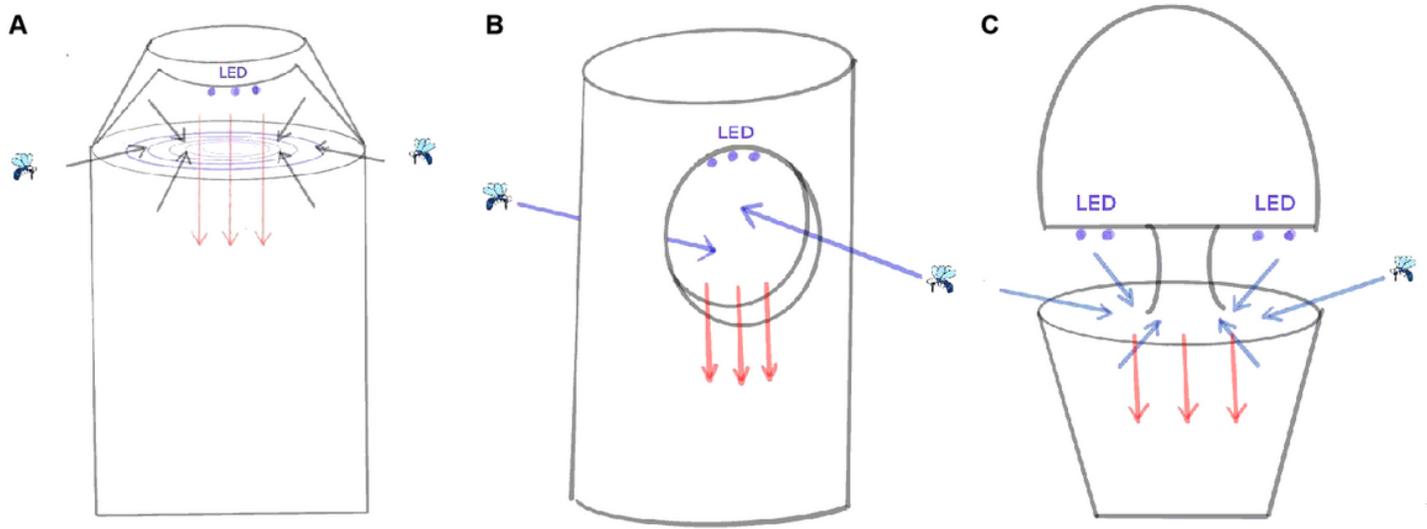
Figure 2

Schematic view of the mosquito traps. The red arrow represents the fan suction direction, and the blue arrow represents the mosquito attracted direction. (A): Trap 1; (B): trap 3(trap 2 and trap 4 are similar to this); and(C): trap 5.

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