PAPER • OPEN ACCESS

Development of Adult Mosquito Fanless Trap

View the article online for updates and enhancements.

Development of Adult Mosquito Fanless Trap.

M. O. Oriyomi [1*] and P. O. Babalola [1]

[1]Department of Mechanical Engineering, Covenant University, Ota, Ogun State, Nigeria.
Corresponding Author; omoseso@yahoo.com, +2348056254411

Abstract-
Passive electro-mechanical traps for recognisance of mosquitoes' menace continued to be advanced with the use of light-emitting diode (LED) as a lure for mosquitoes (Diptera: Culicidae) traps. This work further the advancement of mosquitoes LED trap deploying recently manufactured low energy LED. Tests were conducted to determine the best trapping funnel diameter. The task was situated inside the living region in Lagos State, Nigeria. The number of lured and caught mosquitoes were analysed. In the experiment conducted over five nights; funnel diameter of 12 mm had the highest number of catch with fifty-six (56) mosquitos, followed by 10mm diameter with twenty-five (25) mosquitoes. 14mm diameter captured nineteen (19) mosquitoes, and 8mm diameter attracted ten (10) mosquitoes. Other widths higher than 14mm and lower than 8mm caught zero mosquitoes. The trap did not capture male Anopheles mosquito. The low ratio of damage mosquitoes to identifiable mosquitoes shows that the trap can be compared to the Silva trap and Communicable Disease Center (CDC) traps.

Key words: Mosquito, trap, fanless, light-emitting diode, Culex

1 Introduction

Presently, the management of mosquito vector employs coordinated application, at the same time makes use of numerous intervention strategies. These strategies mainly incorporate long-lasting insecticidal nets (LLIN), synthetic insecticides, infecund insect method, synthetic repellents and transgenic mosquitoes which also created motivating outcomes. In any case, none of these procedures employ independently is entirely capable [1], [2], [3]. Besides, the pertinence of numerous commercially accessible engineered anti-mosquito formulations has shortened discernibly. This could be ascribed to their harmful impacts on the habitat and additionally on distinctive non-target life forms [4]. Furthermore, the rising issue of creating opposition to mosquito killer definitions continue to be a genuine issue [5], [6].

In a bid to reduce insects and arthropods population, insect traps are being used and also for monitoring. The usual baits use are food, chemical attractant, pheromones and visual lures. They are fixed in order not to injure other humans, including other animals or lead to remnants in feeds or foods. Shape, light and bright colours are visual lures use to attract pests. Some attractants only attract specific sex, such as chemical attractants or pheromones. Pest management sometimes utilised insect traps rather than pesticides which are regularly employed to view at the distributional and seasonal structure of pest phenomenon. Data collected can be further applied to manage the pest in other perspectives.

Traps for collection of adult female anophelines are of many and different methods, the latest and most versatile utilised assortment strategies for anthropophilic anophelines. Anopheline assortment strategies dependent on their primary lure and are categorised into four: biological, chemical, physical and physical/chemical [7].

Continued advancements of the physical trap with the odour-baited or/and light traps functioning in capturing grown-up anopheline mosquitoes mainly the host-seeking female, were developed to back malaria observation and surveillance. Moreover, based on points of interest of each of the active or passive catching gadgets, the utilisation of snares like that does have disadvantages with impediments [8]. In any case, light is categorised under the physical lure as a result of the physical property of bulbs deployment as sources of light in snares [7]. Mosquitoes among other insects are attracted to light traps that utilise rays with particular wavelengths. [9] stated that gnats light receptors response to wavelengths ranging from 350 to 600 nm, A light lure includes the chemical relationship of photons which are seen by insect receptor particles within the mosquito eyes.

Further development of passive trap and comparison of the Silva trap with the active Centers for Disease Control and Prevention (CDC) mini light snare in an animal's zone in north-eastern Brazil. The passive trap indicated satisfactory outcomes, and as a proficient device for examining anopheline mosquitoes, primarily in juxtaposition with the CDC light snare, that was utilised as a check [10]. However, most of these designs and studies were conducted outside West Africa, and design details continued to be a mirage. Subsequently, the main aim is to further develop a passive trap for trapping mosquitoes using LED as a lure.

2   Material and method
2.1   Material adopted for the mosquitoes trap

The parts that make-up the light trap area, the UPVC (Unplasticised polyvinyl chloride) cylindrical collection body (Figure 1, part 1) is caped with UPVC cap. In contrast, the vent holes on the tubular collection body are cover with a synthetic net to prevent the gnats from escaping. A transparent funnel was couple into the unit with the aid of Polyvinyl chloride gasket (Figure 1, part3). Part 5 is the reflective hood which is connected to the cylindrical collection body with the aid UPVC adaptor. Aluminium LED holder (Figure 1, part 7) is attached to the hood at the bottom to keep the LED in place, the power pack which is made up of the battery and control circuit is fixed to the inner hood part which is replaceable after each utilisation. This snare is used uprightly, permitting creepy crawlies to enter the round and hollow part from underneath. Following fascination by light bulbs, mosquitoes fly through the light-up inward hood surface of the rectangular capturing hood and after that wing straight up through the clear funnel into the collecting round and hollow component [10]. The hood part can be separated from the round and hollow body after each use to retrieve the caught insects.
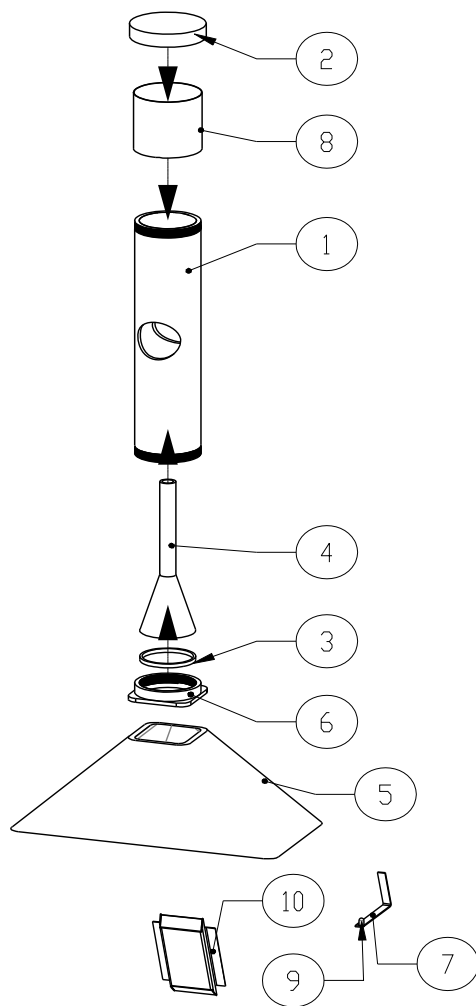
ITEM NO.	DESCRIPTION
1	Cylindrical Collection Body
2	UPVC Cap
3	PVC Gasket
4	Tube & Funnel
5	Hood
6	Adaptor
7	LED holder
8	Net
9	5mm LED
10	Power pack

Figure 1: Trap exploded diagram

2.1.1 Cylinder design

Mosquitoes are slim and moderately little creepy crawlies, that mostly measuring about 3 - 6mm in length [11]. While there are other species, it can be as short as 2mm whereas a few may be as long as 19mm. For this equipment, we assumed that the radius of mosquitoes is 3mm, and that leads us:

Area of mosquitoes (Area of Circle; A_1) = πr^2 (1)
Where r = 3mm
Therefore, $A_1 = \pi \times 3^2 = 28.27mm^2$

Volume of a single mosquito is assumed to be volume of a sphere of radius 3mm, therefore
Volume of mosquitoes (Volume of a sphere; V_1) = $\frac{4}{3}\pi r^3$ (2)

Therefore, $V_1 = \frac{4}{3}\pi \times 3^3 = 113.1mm^3$

The maximum mean daily capture rate per trap is 382 mosquitoes [12]; for this project, we assumed the capacity of trap that can hold mosquito for a week.

Therefore, the required capture for a week = 382 x 7 = 2,674 mosquitoes.
Then the minimum required capture volume for a week (V_2) = 2,674 x 113.1 = 302,429.4mm³

For cylinder, $V = \pi r_2^2 h$ $\qquad\qquad$ (3)

For a cylinder with 50mm diameter, then the required height (h) we be:

$$h = {V_2} / {\pi r_2^2} \qquad\qquad (4)$$

Where,
V_2 = 302,429.4mm^3
r = 25mm
Then,
h = 302,429.4/ π x 25^2
h =154.03mm

2.1.2 Funnel entrance

It was proposed that the entry of mosquitoes into the trap should be the best free entrance that is technically feasible; hence we opted for two stages of cone shape type of funnel. The first part which is the pipe will be a cone-shaped type of pipe, with a minimum top diameter of 8mm and maximum diameter 14mm and the bottom side of the pipe diameter, is to halve of the trap cylinder diameter which is 25mm with a total height of 100mm. The second part of the funnel provides a link between the pipe and trap cylinder with a top internal diameter of 25mm and 50mm bottom diameter and a height of 50mm.

2.1.3 Entrance hood

For mosquito's upward movement it is intended to make the journey as smooth as possible. For this purpose, a low canopy type hood is chosen. The aluminium sheet is selected for the hood for ease of fabrication, lightweight and its ability to withstand outdoor conditions including its cheap price. American Society of Heating Refrigerating and Air Conditioning Engineers, 2007, recommends that the face zone of the hood must have at slightest twice a range of the duct [13].

Minimum area of the hood (Ah) = 2 x Area of containing cylinder [14]

$A_h = 2 \times \pi \times r^2$ $\qquad\qquad$ (5)

Where,
r = 25mm
Then,
A_h = 2 x π x 25^2
A_h = 3,926.99mm^2 = 0.003927m^2

       i.   *Circular hood*
From the area of a circle:

minimum hood diameter, $d = \sqrt{\dfrac{4 \times A_h}{\pi}}$ $\qquad\qquad$ (6)

Therefore:

$$d = \sqrt{\dfrac{4 \times 0.003927}{\pi}} \qquad\qquad (7)$$

d = 0.12533m = 125.33 mm

      ii.   *Rectangular hood*
Let length be 100 mm,
then:
Minimum width = A_h/0.1 = 0.003927/0.1 $\qquad\qquad$ (8)

Minimum width = 0.03927 m ≈ 40 mm

To increase the capture area, we multiply the length and the width by 2.5 and 3.125 respectively, therefore the hood entrance will be 250 mm x 125 mm.

2.2 The battery pack

The battery pack includes the electronic board and the battery. The circuit in Figure 2 was designed to light the bulb when dark falls automatically, it will snap in the middle full on and full off, and it can drive the bulb to full brightness. Resistors R1 and R2 shape the voltage divider. This voltage goes up as R2 goes up, which implies a higher voltage when dark. When this voltage gets to almost 500 or 600 mV, a small current stream through the base of the transistor Q2. This causes a little more current to stream through its collector, which at that point streams through the base of the transistor Q1. This permits a more current to stream through the collector of Q1 and lights the bulb. With the values appeared, the driven current will be about 20 mA when on, which is the ceiling for most standard discrete LEDs. If R4 is higher, we have less bulb current.

Resistor R3 gives a small positive response, as well is called hysteresis. It includes or subtracts a little current from the base of Q2, but sufficient to tip the total circuit to one side or the other when the light level is exactly at the edge between on and off. It turns Q2 on more when current is streaming through the bulb. This typically gives the snap activity. The resistor R5 is included precisely to constrain the Q1 base current. Without it in darkness, Q2 will be restricting the Q1 base current. It is not a great thought to depend on the greatest pick up of a transistor. It is seldom indicated and can ordinarily be more than the guaranteed least gain. The rating of R5 was chosen to permit sufficient Q1 base current so that Q1 can be saturated at the most extreme LED current of 20 mA. R1 alters the light level at which the circuit trips. Lower values will move the limit towards light and higher values towards dark. Figure 3 shows the simulation assembly of the circuit done with Tinkercad.
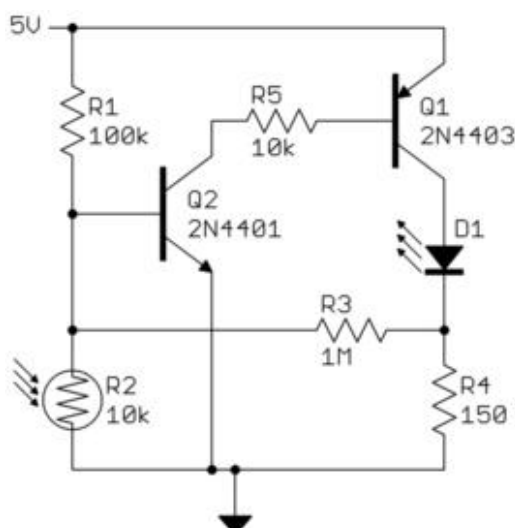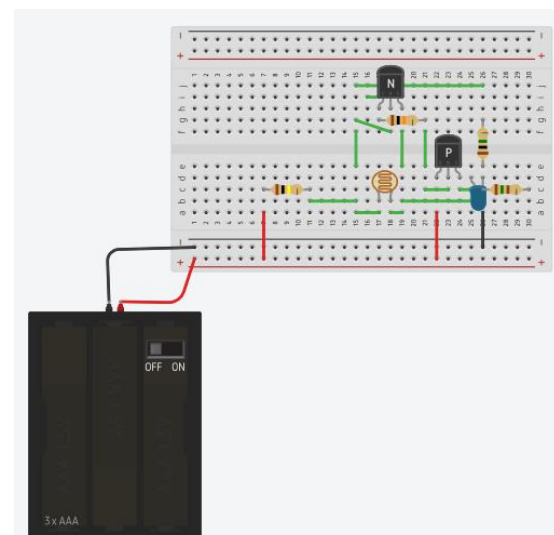

Figure 2: Circuit schematic

Figure 3: Tinkercad circuit simulation

2.3 Method of trapping

Four trap replicates were made to assess on the field the productivity of the snare in trapping grown-up anopheline mosquitoes. The four trap duplicates were named Trap A, Trap B, Trap C and Trap D for phase I and another ten trap replicates were also used (Trap

Blue, Trap Purple, Trap Pink, Trap Red, Trap Orange, Trap Yellow, Trap GreenYellow, Trap Green, Trap Warm White and Trap White) for phase II. Each of the traps for phase I was equipped with one 5mm circular kind high concentrated blue LEDs (450-455 nm, 7,000 - 8,000 milicandella, 30°, 20 mA, 3.2 V) which were energised by rechargeable 3.7V Li-ion standard batteries (a battery per trap). The capacity of each cell is 1150 mAh and this may take about ± 57.5hs (1150/20) or ± 4 12h-nights of work. All the four trap's batteries are fully charged before deployed to the position in the experiments and recharge every third day of the test before redeployed for collection. The four mosquitoes' traps were set outside a living environment and were separated from one another at a distance of 6m in an L-shaped arrangement (Figure 4). These traps were operated between 18:00 to 06:00 at night in May 2019. They were hung on the fence wall at approximately 1.5m above ground from the light sources (see Figure 5). Randomly the light traps were rotated each night.
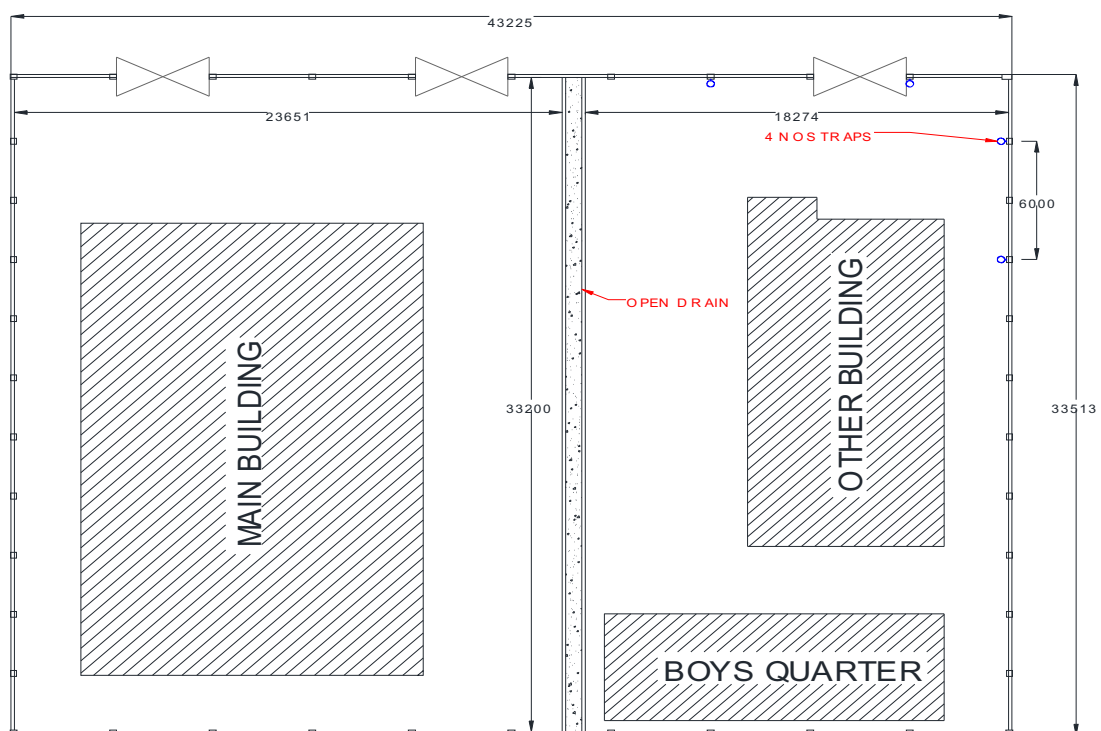

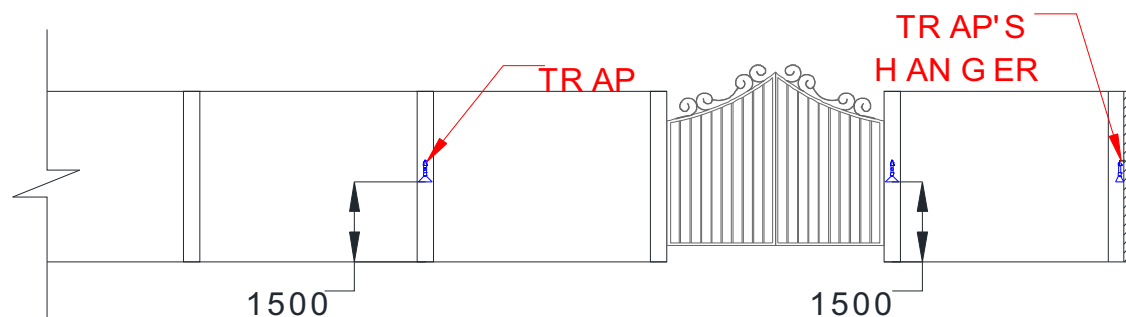Figure 4: Study site layout and trap locations

Figure 5: Front view showing traps arrangement

The capture gnats were analysed using a portable 8-LED digital USB microscope with a magnification of 1600. The microscope was interconnected via USB port to Window Surface 1 tablet computer. The system configuration is Intel(R) Core (TM) i5-3317U CPU

@ 1.70GHz, 4.00GB RAM, X64 - based processor running on Window 10 operating system (Figure 6).

Figure 6: Digital microscope and tablet computer

3   Results and discussion

3.1   Role of funnel entrance diameter on the effectiveness of mosquitoes' trap

This test shows the significant impact of the width of the funnel in Figure 1, part 4 used in connection to the whole capture number of mosquitoes. Four traps namely A, B, C and with different sizes of the funnel (outlet diameters) 14, 12, 10 and 8 mm θ respectively, were tested over the five-night period of study using single blue LED only for all the traps. One hundred twenty-six (126) specimens and one species of mosquitoes were found. Only one (0.007 %) male was captures. Female Culex mosquito genus was the predominant with a mean number of 26.6 ± 7.718 (mean $\pm$ standard error of the mean (SEM)) per night, followed by other insects with a mean number of 3.2 ± 1.96. The male Culex mosquito has a mean number of 0.2 ± 0.2, unidentified mosquitoes with a mean number of 0.2 ± 0.2, and zero Anopheles species were recorded in Table 1.

Multiple t-tests of data from the four tested funnels applying Holm-Sidak method, with alpha = 0.05. The calculations assume that all rows are a sample from populations with the same scatter standard deviation (SD) and the number of t-tests equals 6, the result of which are represented in Volcano Plots as shown in Figure 7. When we compared this result with multiple comparison tests on 3way ANOVA of the same data, female Culex mosquito indicated better statistical significance in the 12 mmø outlet funnel trap better than other sizes as shown in Figure 8.

Table 1: Mean capture per night per snare with the total number of individuals and mosquitoes percentage of captured with 14 mm ø, 12 mm ø, 10 mm ø and 8 mm ø trap funnel outlets in Lagos, South-West of Nigeria.

| Mosquitoes | Outlet Diameter | | | | | | | | | | | | Total | % |
| | 14 mm ø | | | 12 mm ø | | | 10 mm ø | | | 8 mm ø | | | | |
	Mean	SEM	N	Mean	SEM	N	Mean	SEM	N	Mean	SEM	N		
Female Anopheles Mosquitoes	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0	0.00
Male Anopheles Mosquitoes	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	0	0.00
Female Culex Mosquitoes	3.40	2.23	17	11.20	5.66	56	5.00	3.30	25	2.00	0.95	10	108	85.71
Male Culex Mosquitoes	0.20	0.20	1	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	1	0.79
Other Mosquitoes	0.20	0.20	1	0.00	0.00	0	0.00	0.00	0	0.00	0.00	0	1	0.79
Other insect	1.00	1.00	5	1.40	0.75	7	0.60	0.40	3	0.20	0.20	1	16	12.70
Total number of individuals			24			63			28			11	126	
Total number of males			1									1	2	1.59
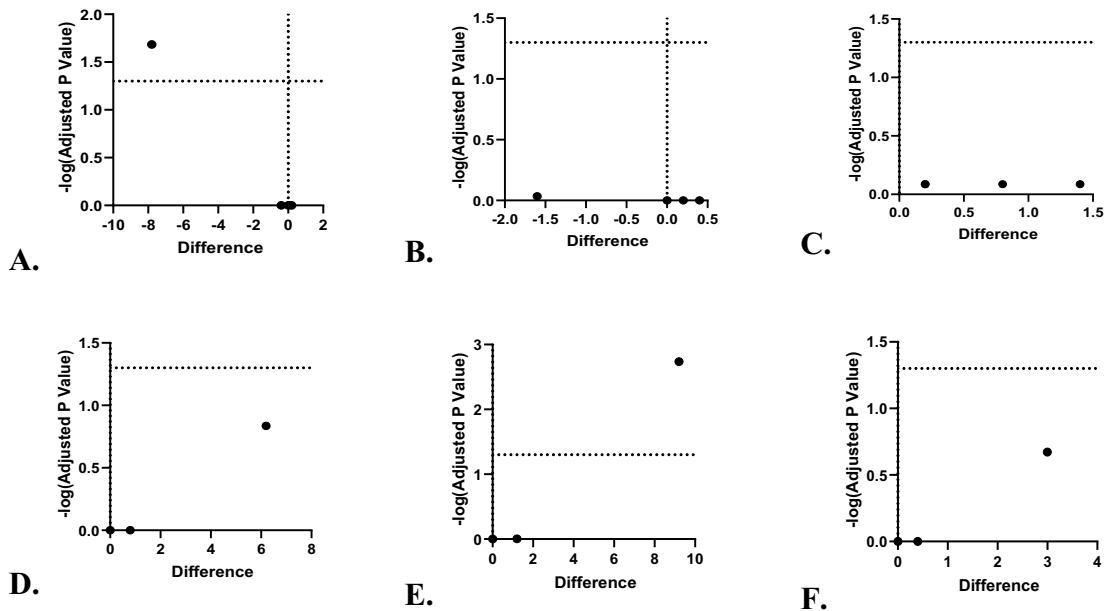
Figure 7: Volcano plots of multiple t tests of data. A: 14 mm ø and 12 mm ø funnel outlets. B: 14 mm ø and 10 mm ø funnel outlets. C: 14 mm ø and 8 mm ø funnel outlets. D: 12 mm ø and 10 mm ø funnel outlets. E: 12 mm ø and 8 mm ø funnel outlets. F: 10 mm ø and 8 mm ø funnel outlets
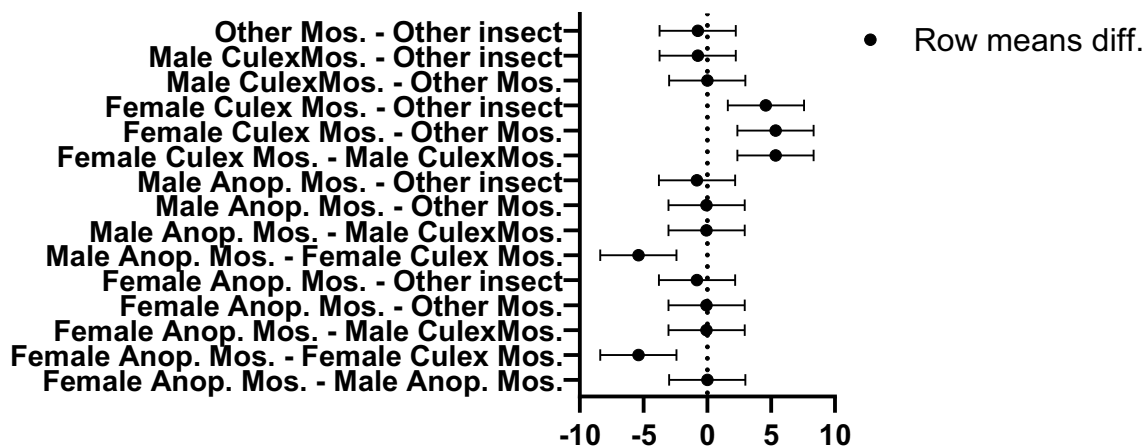
Figure 8: Multiple comparison tests on 3way ANOVA of data from trapped insects per day

All these outcomes illustrated that this trap is an effective device in capturing Culex mosquitoes than anopheles mosquitoes based on the result of the light snare [15]. This snare is a light-dependent gadget. The utilisation of LEDs have displayed an acceptable option for enhancing light-trap productivity [16], [17], [18]. There are several advantages of LED light sources over the glowing bulb utilisation within the standard light traps. They are low cost, low energy utilisation, broadly accessible commercially, lightweight, durability and long life in contrast to incandescent lamps that most of its radiation is either transmitted as heat or infrared. LEDs have limited and explicit frequencies (noticeable, ultraviolet or close to infrared light) [19]. Furthermore, in as much that LEDs are utilised at moderately low current densities (20 mA), the snare can run from little and lightweight rechargeable batteries. Other than enumerated focal points, the cost of LEDs that is low and its accessibility, in contrast to different kinds of lures, give rise to its benefit financially [15].

4   Conclusion and recommendation

Developed fanless mosquito trap was tested using four funnel sizes namely 14, 12, 10 and 8 mm Ø , for five nights, funnel diameter of 12 mm had the highest number of catch with 56 mosquitoes, while female Culex mosquito was the dominant species with mean of 26.6 (± 7.718) and after multiple comparison tests on 3-way ANOVA of same data, female Culex mosquito indicated better statistical significance in 12 mm Ø outlet funnel trap compared to other sizes.

The low ratio of damage to identifiable mosquitoes' samples shows that the fanless trap can be compared to the Silva trap, with the extra bit of leeway that it requires lower power consumption and that it can likewise be utilised to trap mosquitoes outdoor. This fanless trap does not need odour bait, CO_2 or dragging fan which as a result improve its outdoor use capabilities. The trap had not been able to attract significant anopheles mosquitoes for a reason unknown, and this also pointed out that the area is heavily populated with Culex mosquitoes that transmit malaria and committing most mosquitoes nuisance.

Extra examinations require, with an attention on the utilisation of multiple (more than one number) LEDs of high-intensity, but of the same colour to ascertain their impact on mosquitoes in like manner, LEDs of different colours that are controlled by a microcontroller to be ON and OFF alternatively between the promising colours as

observed in this project. This trap may be a further test with bait such as human-bait, chemical-bait and animal bait, for a general upgrade of mosquito light-trap. Also, collections may be extended to other regions in Nigeria.

Acknowledgements

References

[1] Benelli, G., Caselli, A., & Canale, A. (2017). Nanoparticles for mosquito control: Challenges and constraints Nanoparticles for mosquito control. Journal of King Saud University - Science. 29(4), 424–35.

[2] Lees, R. S., Knols, B., Bellini, R., Benedict, M. Q., Bheecarry, A., Bossin, H. C., et al. (2014). Review: Improving our knowledge of male mosquito biology in relation to genetic control programmes. Acta Tropica. 132(1), S2–11.

[3] Pavela, R., & Benelli, G. (2016). Ethnobotanical knowledge on botanical repellents employed in the African region against mosquito vectors - A review. Experimental Parasitology. 167, 103–8.

[4] Chattopadhyay, P., Dhiman, S., Borah, S., Rabha, B., Chaurasia, A. K., & Veer, V. (2015). Essential oil based polymeric patch development and evaluating its repellent activity against mosquitoes. Acta Tropica. 147, 45–53.

[5] Bigoga, J. D., Ndangoh, D. N., Awono-Ambene, P. H., Patchoke, S., Fondjo, E., & Leke, R. G. F. (2012). Pyrethroid resistance in Anopheles gambiae from the rubber cultivated area of Niete, South Region of Cameroon. Acta Tropica. 124(3), 210–4.

[6] Nikou, D., Ranson, H., & Hemingway, J. (2003). An adult-specific CYP6 P450 gene is overexpressed in a pyrethroid- resistant strain of the malaria vector, Anopheles gambiae. Gene. 318(1–2), 91–102.

[7] Lima, J. B. P., Rosa-Freitas, M. G., Rodovalho, C. M., Santos, F., & Lourenço-de-Oliveira, R. (2014). Is there an efficient trap or collection method for sampling Anopheles darlingi and other malaria vectors that can describe the essential parameters affecting transmission dynamics as effectively as human landing catches? - A review. Memorias do Instituto Oswaldo Cruz. 109(5), 685–705.

[8] Medlock, J., Balenghien, T., Alten, B., Versteirt, V., & Schaffner, F. (2018). Field sampling methods for mosquitoes, sandflies, biting midges and ticks. Stockholm and Parma; 2018.

[9] Alencar, J., de Mello, V. S., Serra-Freire, N. M., Silva, J. dos S., Morone, F., & Guimarães, A. É. (2012). Evaluation of Mosquito (Diptera: Culicidae) Species Richness using Two Sampling Methods in the Hydroelectric Reservoir of Simplício, Minas Gerais, Brazil. Zoological Science. 29(4), 218–22.

[10] Soares, F., Costa-neta, B. M., Sousa, M. De, Almeida, D., Carvalho, E., Araújo, D., et al. (2019). Acta Tropica Field performance of a low cost , simple-to-build , non-motorized light- emitting diode (LED) trap for capturing adult Anopheles mosquitoes (Diptera : Culicidae). Acta Tropica. 190(September 2018), 9–12.

[11] Service, M. (2012). Medical Entomology for Students. Fifth Edit. New York: Cambridge University Press; 2012.

[12] Poulin, B., Lefebvre, G., Muranyi-kovacs, C., & Hilaire, S. (2017). Mosquito Traps : An Innovative , Environmentally Friendly Technique to Control Mosquitoes. Environmental Research and Public Health. 14(313).

[13] American Society of Heating Refrigerating and Air Conditioning Engineers (2007). 2007 ASHRAE Handbook HVAC Applications. 2007. 21 p.

[14] Babalola, P. O., & Oriyomi, M. O. (2018). The Development of Fume Extractor for a Welding Booth. IOP Conference Series: Materials Science and Engineering. 413(1).

[15] Oriyomi, M. O., & Babalola, P. O. (2020). Comparison of Mosquitoes Response to Different Diodes Wavelengths. International Journal of Science and Research. 9(7), 218–23.

[16] Cohnstaedt, L. W., Gillen, J. I., & Munstermann, L. E. (2008). Light-Emitting Diode Technology Improves Insect Trapping Light-Emitting Diode Technology Improves Insect Trapping. Journal of the American Mosquito Control Association. 24(2), 331–4.

[17] Costa-Neta, B. M., Lima-Neto, A. R., da Silva, A. A., Brito, J. M., Aguiar, J. V. C., Ponte, I. S., et al. (2018). Centers for Disease Control-type light traps equipped with high-intensity light-emitting diodes as light sources for monitoring Anopheles mosquitoes. Acta Tropica. 183(March), 61–3.

[18] Silva, F. S., Costa-Neta, B. M., de Sousa de Almeida, M., de Araújo, E. C., & Aguiar, J. V. C. (2019). Field performance of a low cost, simple-to-build, non-motorized light-emitting diode (LED) trap for capturing adult Anopheles mosquitoes (Diptera: Culicidae). Acta Tropica. 190(September 2018), 9–12.

[19] Tchouassi, D. P., Sang, R., Sole, C. L., Bastos, A. D. S., Cohnstaedt, L. W., & Torto, B. (2012). Trapping of Rift Valley Fever (RVF) vectors using Light Emitting Diode (LED) CDC traps in two arboviral disease hot spots in Kenya. Parasites and Vectors. 5(1), 1–7.