

Original paper

Insecticidal Potential of *Ocimum gratissimum* (Scent Leaf) and *Cymbopogon citratus* (Lemon Grass) Crude Leaf Extracts on Female *Anopheles* Mosquitoes in Lafia Metropolis, Nasarawa State, Nigeria

Egya, R. E.*, Uzoigwe, N. R., Pam V. A., Ombugadu, A., Maikenti, J. I., Attah, S. A., Odey, S. A., Osidoma, E. O., and Dogo, S. K.

Department of Zoology, Faculty of Science, Federal University of Lafia, PMB 146, Lafia, Nasarawa State, Nigeria.

*Corresponding Author E-mail: eboruth2013@gmail.com; Tel: +2347039264867

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ABSTRACT: Mosquito-borne diseases are the most serious global public health issues, threatening 3.3 billion people. Better control tactics that are safe, less expensive, and more ecologically friendly are being promoted in order to control these vectors. To this end, a study on the insecticidal potential of *Ocimum gratissimum* and *Cymbopogon citratus* on female *Anopheles* mosquito was investigated. Fresh leaves of the plants were sought for and collected locally and were identified in Department of Botany, Federal University of Lafia. The leaves were washed with running tap water and air-dried for three weeks at room temperature. Crude leaf extract preparation was done followed by phytochemical analysis. Five metabolites (phenols, flavonoids, alkaloids, tannins and saponins) were present in the extracts of the two plants except ethanolic extract of *C. citratus*, which had three metabolites. For the metabolites quantified, *O. gratissimum* had higher proportion. Perching of mosquito decreased with increase in concentration of the extracts. However, there was no significant difference ($P > 0.05$) in the cumulative number of mosquito that perched for *O. gratissimum* aqueous extract, whereas there was a significant variation ($P < 0.05$) in *O. gratissimum* ethanolic extract. The cumulative frequency of mosquito that perched in relation to the different concentrations of *C. citratus* for both extracts showed a significant difference ($P < 0.05$). There was a significant difference ($P < 0.05$) between aqueous and ethanolic extracts for each plant extract as well as across concentrations. *C. citratus* aqueous extract showed higher percentage repellency (86%) at 0.001 mg/ml. Only ethanolic extract of *C. citratus* at 0.001 mg/ml concentration yielded mortality of 6.67%. The LC_{50} and LC_{90} for *C. citratus* were 0.0000661 mg/ml and 0.0000126 mg/ml respectively. Finally, this study found that the two selected plants exhibit biorepellant properties against malaria vectors.

Keywords: Repellency, *Ocimum gratissimum*, *Cymbopogon citratus*, crude extract, *Anopheles* mosquitoes, Lafia Metropolis

INTRODUCTION

Mosquito-transmitted diseases are the foremost global public health problems with 3.3 billion individuals at risk in 106 nations and territories in spite of years of malaria control efforts (Karunamoorthi *et al.*, 2014). Malaria, a mosquito-borne disease, continues to be a leading cause of illness and death, particularly among pregnant women and children (Alayo *et al.*, 2015). The disease causes low birth weight, miscarriages or stillbirths, and infant death in sub-Saharan Africa (Karunamoorthi, 2014). There are

around 500 species of *Anopheles* mosquitos that serve as *Plasmodium* parasite vectors worldwide (Sanghong *et al.*, 2015). There is currently no effective prophylactic anti-malarial vaccination available, and the only relevant preventative approach in use is vector control (Soonwera, 2015). Protection against mosquito bites is one way being used to reduce illness prevalence. Several factors which include, habitats, weather, physiochemical parameters account for distribution of mosquitoes

(Lapang *et al.*, 2019; Ombugadu *et al.*, 2020).

The solution to circumvent detrimental effects of insecticides on environment and human health therefore would be the use of natural mosquito repellent products as an alternative to develop non-detrimental repellents (Severini *et al.*, 1993). Excess use of these chemical insecticides, which are largely used to control mosquito growth, results into insecticide resistance in mosquitoes. In the tropical countries, where these diseases are rampant, insecticide resistance posed major threat to control of mosquitoes and mosquito-borne diseases (Severini *et al.*, 1993). Chemical insecticides are not only hazards to human and animal health they are also toxic to the environment and their bio-accumulation in the environment results in ecosystem imbalance (CDC, 2004). New and effective insecticides from other sources such as plants and microorganisms need to be sourced in order to overcome this problem (Sharma, 2001). Numerous plants have been screened for their phytotoxic properties against insect pests and vectors in the search for eco-friendly insecticides. According to reports, some of these plants have toxic effect on mosquitoes and can be used as potent source of mosquito control. Plants such as *Annona squamosa* L., *Gloriosa superba* L., *Millingtonia hortensis*, *Abuta grandifolia*, *Mintostachys setose*, *Azadirachta indica*, and *Hyptis suaveolens*, have been reported to be effective in control of mosquito population (Ciccia *et al.*, 2000; Kaushik and Saini, 2008; Bagavan *et al.*, 2009; Okigbo *et al.*, 2010).

Presently, insecticidal properties of plants have been the subject of intense research (Abok *et al.*, 2018; Ombugadu *et al.*, 2020; Pam *et al.*, 2021; Aliyu *et al.*, 2022) and one of such plants extensively distributed in the tropical and subtropical regions of Africa, Asia and America is *Cymbopogon citratus* (Poaceae) (Boukhatem *et al.*, 2014). The plant has been identified to contain vital phytochemicals that possess insecticidal properties (Asaolu *et al.*, 2009; Desai and Parikh, 2012). The plant is of great interest due to its commercial valuable of the vital oils that is used in food technology and traditional medicine (Mirghani *et al.*, 2012). *Ocimum gratissimum* L. (Lamiaceae) is also a plant with insecticidal properties, known by diverse people of the globe by different local names. It is universally called Scent leaf, (Scent leaf) 'Nchuanwa' or 'Ahuji' by the Igbo speaking populations of South Eastern Nigeria, 'Effirin-nla' by the Yoruba speaking people of South Western Nigeria and 'Daidoya' by the Hausa speaking populations of Northern Nigeria (Odugbemi, 2006; Saliu *et al.*, 2011). In southern part of the Nigeria, raw extract of *O. gratissimum* is usually used to cure epilepsy, high fever and diarrhea fungal infections, fever, cold, catarrh and management of the baby's cord, to keep the wound surfaces sterile, especially used by the Igbo community of south eastern Nigeria (Ijeh *et al.*, 2005).

Sequel to the above activities, the research under-studied the ways of destroying the mature stage of the malaria vector using the two focal plants, *Ocimum gratissimum* (Scent leaf) and *Cymbopogon citratus* (Lemon grass) whose insecticidal activity will pave way for the development of potent methods of eliminating and controlling mosquitoes that may not be toxic to the non-target fauna and flora.

MATERIALS AND METHODS

Plants material collection

Ocimum gratissimum (Scent leaf) and *Cymbopogon citratus* (Lemon grass) plant leaves were sought for and collected locally from farmlands around Lafia metropolis, Nasarawa State, Nigeria. The plant and the leaves collected were identified and authenticated in the Department of Botany Laboratory Federal University of Lafia. Fresh tender leaves of *Ocimum gratissimum* and *Cymbopogon citratus* after collection were washed with running tap water to remove dust and debris from their surface, and then allowed to air dry for 21 days at room temperature devoid of sunlight (Abok *et al.*, 2018) at the Department of Zoology Laboratory, Federal University of Lafia.

Preparation of plants extracts

When the leaves of *O. gratissimum* and *C. citratus* became brittle and easy to crush, they were pounded using a mortar and pestle, and sieved to obtain fine powder, using a 0.9 mm mesh size sieve. The plants extract preparation was made according to Rathi *et al.* (2006) and Handa *et al.* (2008). The extracts were prepared in the ratio 1:10 w/v, equivalent to 100g of the powder in 500 ml of solvent (Handa *et al.*, 2008). 100g of dried powder of both leaves were weighed in two different conical flask using ADAM PGW 453i Electric Weighing Balance. Exactly 500 ml of ethanol was added into each flask. The solution was agitated repeatedly and then allowed to stand for 72 hours (Handa *et al.*, 2008). The process is to soften and break the plant cell wall and release the soluble phytochemical contents of the cells (Handa *et al.*, 2008). The solutions were subsequently filtered using non-absorbent cotton wool and Whatman No. 1 filter paper into conical flasks. The ethanol filtrates were poured out into clean, grease free aluminum trays (33 cm - 22 cm) and allowed to evaporate to dryness at room temperature. The dried powder extract was then scrapped off the trays and transferred into a sample bottle and preserved in the refrigerator until they were used. For some modification the aqueous extraction was also carried out according to Handa *et al.* (2008).

One hundred gramme of the plant powder were weighed and 1000 ml of water (instead of 100 ml) was added, the solutions were agitated repeatedly and then allowed to stand for 72 hours with daily agitation. Addition of 1000 ml of water ensured total and complete mixing of the powder. The solutions were subsequently filtered using non-absorbent cotton wool and Whatman No. 1 filter paper into different conical flasks. The aqueous filtrates were poured out into a clean, grease free aluminum trays (33 cm-22 cm) and allowed to evaporate to dryness using a Memmert Beschickung Hot Air Oven (Loading Model 100-800) at 50°C. This ensured regulated heating as the aqueous extract required longer drying period and higher temperature. The dried extract was then scrapped off the trays and transferred into a sample bottle and preserved in the refrigerator. The crude leaf extracts and leaf powder of each plant were subjected to phytochemical analysis to ascertain their active ingredients composition.

Determination of Percentage Yield of Extracts

The percentage yield of the extracts were calculated according to Zhang *et al.* (2007), as follows:

$$\text{Percentage Yield} = \frac{\text{Weight of Extract (g)}}{\text{Weight of Crude Powder (g)}} \times \frac{100}{1}$$

Mosquito larvae collection

Larvae of *Anopheles mosquitoes* were collected between May to June, 2021. *Anopheles* mosquito's larvae first and second instar were collected using standard dippers from stagnant water around NNPC filling station in Mararraba-Akunza (Ombugadu *et al.*, 2020). Latitude 8°28'16.27"N and longitude 8°34'38.69"E, rice field close to the stream adjacent the female hostel Federal University of Lafia (8°28'32.02"N and longitude 8°33'19.62"E) and Gandu in Lafia (latitude 8°28'37.89"N and longitude 8°33'30.74"E). The collected larvae were identified according to Potter and Beavers (2005) and colonized in the Department of Zoology laboratory, Federal University of Lafia. The larvae were fed by adding finely ground powdered yeast and biscuit on the surface of the water (WHO, 2012). The adult mosquitoes were reared at 27±3°C and 80±10 Relative Humidity (RH) (Choochote *et al.*, 2005) and maintained in screened cages on 10% sucrose solution for a period of 1-5 days.

Preparation of Stock and Working Solution of *Ocimum gratissimum* and *Cymbopogon citratus* Extracts

The stock solutions were prepared according to the method outlined by Ibrahim (2009). One gramme of the extracts (ethanol and aqueous) was weighed using æ

ADAM PGW 453i Electric Weighing Balance. The weighed extract was added to one hundred milligrams of distilled water and weighed extract then agitated for two hours.

Test for repellency

The repellency test was carried out using the cage test (WHO, 2009). The prepared concentration of *Ocimum gratissimum* and *Cymbopogon citratus* were first tested with the lowest dilution for both ethanolic and aqueous extracts followed by the higher concentrations (0.001 mg/ml, 0.01 mg/ml and 0.1 mg/ml) respectively.

The volunteers' right hands were covered with treated material and the left hands were covered untreated material and allowed to stand for 15 minutes. After inserting both hands into different cages, the data on the number of landing on both hands were collected. If within three minutes, less than two mosquitoes landed on the untreated side, then the experiment will stop and the volunteers will remove their hands from the cages due to the fact that the volunteers might be naturally repellant to mosquitoes, therefore causing the results to be inconclusive. Thereafter, the hands were inserted concurrently into separate cages containing 30 starved adult female *Anopheles* mosquitoes and observed as described by WHO (2009) and Anuar (2016).

Mortality observation

At the end of the exposure period, all the mosquitoes in both cages were observed for mortality for a holding period of 24 hours and then recorded (Abok *et al.*, 2018).

Statistical analysis

Data obtained was analyzed using R Console software (version 4.0.2, 2020). Proportions between the two plants as well as across treatments were compared using Pearson's Chi-squared test. Level of significance was set at $P < 0.05$.

RESULTS

Qualitative and quantitative phytochemical metabolites of *C. citratus* and *O. gratissimum*

Five metabolites were present and include alkaloids, flavonoids, phenols, saponins and tannins (Table 1). All the metabolites analysed were present in both aqueous extracts of *C. citratus* and *O. gratissimum* as well as the ethanolic extract of *O. gratissimum* only while only three metabolites; flavonoids, phenols and tannins were present in *C. citratus* ethanolic extract.

Table 1: The phytochemical metabolites of *C. citratus* and *O. gratissimum*

Phytochemical parameter	Qualitative output				Quantitative output (%)		χ^2	df	P value
	<i>C. citratus</i>		<i>O. gratissimum</i>		<i>C. citratus</i>	<i>O. gratissimum</i>			
	Aqueous	Ethanol	Aqueous	Ethanol					
Alkaloids	+	–	+	+	1.4	61.5	57.425	1	0.0001**
Flavonoids	+	+	+	+	9.4	20.95	4.3955	1	0.03603*
Phenols	+	+	+	+	FNAD	FNAD			
Saponins	+	–	+	+	7.5	20.3	5.8935	1	0.0152*
Tanins	+	+	+	+	FNAD	FNAD			

Key: -: Not detected; +: Present; FNAD: Facility Not Available for the Determination; *: Significant; **: Highly significant

Table 2: Cumulative Perching activities of mosquitoes on human bait upon treatment with different concentrations of *C. citratus* and *O. gratissimum*

Concentrations	Plants			
	<i>C. citratus</i>		<i>O. gratissimum</i>	
	Aqueous	Ethanol	Aqueous	Ethanol
Control	31	46	44	39
0.001	3	20	37	16
0.01	15	41	31	15
0.1	14	24	29	8
χ^2	25.317	14.74	3.8794	27.949
df	3	3	3	3
P-value	0.0001*	0.002052*	0.2748 ^{ns}	0.0001*

*: Significant; ^{ns}: Not significant

The quantitative analysis shows that *O. gratissimum* had higher alkaloids (61.5%), flavonoids (20.95%) and saponins (20.30%) than *C. citratus* which had 1.4%, 9.4% and 7.55% for alkaloids, flavonoids and saponins respectively. Therefore, the variation in the quantitative proportions of the metabolites in relation to the two plants showed a significant difference ($P < 0.05$) as shown in Table 1.

Perching activities of mosquitoes on human bait upon treatment in relation to concentrations of *C. citratus* and *O. gratissimum*

Treatment at 0.001 mg/ml with the aqueous and ethanolic extracts, the *C. citratus* showed that 3 and 20 mosquitoes landed on the aqueous and ethanolic extracts respectively. Similarly, at 0.01 mg/ml only 15 mosquitoes landed while 41 mosquitoes landed on the ethanolic treated hand. At 0.1 mg/ml aqueous extract attracted 14 mosquitoes as against 24 for the ethanolic extract. In *O. gratissimum*, at 0.001 mg/ml aqueous extract had 37 mosquitoes landing while ethanolic extract had 16 mosquitoes landing. 0.01 mg/ml concentration recorded 31 and 15 mosquitoes landing on the aqueous and ethanolic respectively. Thereafter, 0.1 mg/ml concentration had 29 and 8 mosquitoes landing on the aqueous and ethanolic extracts respectively (Table 2).

Comparison of the efficacy between aqueous and ethanolic extract of *C. citratus* and *O. gratissimum* for each concentration

All concentrations showed significant difference ($P < 0.05$) with the exception 0.1 mg/ml concentration aqueous and ethanolic extract of *C. citratus* which showed no significant difference ($P > 0.05$) on the number of mosquitoes that landed (Table 3).

Repellency test of *O. gratissimum* and *C. citratus* on mosquito species

At 0.001 mg/ml, 0.01 mg/ml and 0.1 mg/ml concentrations of *C. citratus* aqueous extract repelled 86, 56 and 62 mosquitoes respectively while ethanolic extract with the three concentrations (0.001 mg/ml, 0.01 mg/ml and 0.1 mg/ml) repelled 50, 74 and 72 mosquitoes respectively (Table 4). *Ocimum. gratissimum*, aqueous extract at 0.001 mg/ml repelled 18 mosquitoes, 0.01 mg/ml repelled 24 mosquitoes and 0.1 mg/ml repelled 36 mosquitoes. Similarly, the ethanolic extracts at 0.001 mg/ml, 0.01 mg/ml and 0.1 mg/ml repelled 50, 74 and 72 mosquitoes respectively (Table 4). Three (3) concentrations (0.001 mg/ml, 0.01 mg/ml and 0.1 mg/ml) of the four (4) extracts were subjected to a repellency test out of which aqueous extract of *C. citratus* recorded the

Table 3: Comparison between the efficacy of aqueous and ethanol extract of *C. citratus* and *O. gratissimum* at different concentrations

Plant	Concentration (mg/ml)	No. perched		χ^2	df	P-value
		Aqueous	Ethanol			
<i>C. citratus</i>	0.001	3	20	12.565	1	0.000393
	0.01	15	41	12.071	1	0.000512
	0.1	14	24	2.6316	1	0.1048
<i>O. gratissimum</i>	0.001	37	16	8.3208	1	0.003919
	0.01	31	15	5.5652	1	0.01832
	0.1	29	8	11.919	1	0.000556

Table 4: Percentage repellency test of *C. citratus* and *O. gratissimum* on female *Anopheles* mosquitoes.

Concentration (mg/ml)	Plants			
	<i>C. citratus</i>		<i>O. gratissimum</i>	
	Aqueous	Ethanol	Aqueous	Ethanol
0.001	86	47	18	50
0.01	56	35	24	74
0.1	62	37	36	72
χ^2	7.4118	2.084	6.4615	5.4286
df	2	2	2	2
P-value	0.02458 ^{ns}	0.3527 ^{ns}	0.03953*	0.06625 ^{ns}

*: Significant; ^{ns}: Not significant

Table 5: Percentage mortality of mosquitoes upon treatment with *C. citratus* and *O. gratissimum* at 24 hours.

Plant	Solvent	Concentration (mg/ml)	No. of mosquitoes used	Mortality within 24 hours	Mortality rate (%)
<i>C. citratus</i>	Aqueous	0.001	30	-	-
		0.01	30	-	-
		0.1	30	-	-
	Ethanol	0.001	30	2	6.67
		0.01	30	-	-
		0.1	30	-	-
<i>O. gratissimum</i>	Aqueous	0.001	30	-	-
		0.01	30	-	-
		0.1	30	-	-
	Ethanol	0.001	30	-	-
		0.01	30	-	-
		0.1	30	-	-

highest repellency rate 86% (0.001 mg/ml) followed by ethanolic extract of *O. gratissimum* with 74% (0.01 mg/ml) and 72% (0.1 mg/ml), Aqueous extract of *C. citratus* 62% (0.1 mg/ml) and 56% (0.01 mg/ml), ethanolic extract of *O. gratissimum* 50% (0.001 mg/ml), ethanolic extract of *C. citratus* 47% (0.001 mg/ml) and 37% (0.1 mg/ml). The lowest repellency rate was recorded in aqueous extract of *O. gratissimum* 18% (0.001 mg/ml) and 24% (0.01 mg/ml) followed by ethanolic extract of *C. citratus* 35% (0.01 mg/ml) and aqueous extract of *O. gratissimum* 36% (0.1 mg/ml) as shown in (Table 4).

Percentage mortality of mosquitoes upon treatment with *C. citratus* and *O. gratissimum* at 24 hours

Only 2 mosquitoes died following exposure to 0.001mg/ml concentration ethanolic extract of *C. citratus*.

In *O. gratissimum*, no deaths were observed across all the concentrations (Table 5).

Lethal Concentration (LC₅₀ and LC₉₀) of *C. citratus* and *O. gratissimum* extracts that exhibit the insecticidal activities on malaria vector within 24 hours exposure period

The lethal concentration of *C. citratus* aqueous extracts that exhibits insecticidal activity against 50% and 90% were 0.0000661 mg/ml and 0.0000126 mg/ml respectively at 24 hours exposure period (Table 6). But, no mortality was record for *C. citratus* aqueous extracts as well as in *O. gratissimum* aqueous and ethanolic extracts, hence, lethal concentrations could not be obtained.

Table 6: Lethal Concentrations (LC₅₀ and LC₉₀) of *C. citratus* ethanolic extract against malaria vector within 24 hours exposure period.

Plant	LC ₅₀	LC ₉₀
<i>C. citratus</i>	0.0000661	0.0000126

DISCUSSION

The phytochemical tests of *O. gratissimum* and *C. citratus* in this work demonstrated the presence of flavonoids, alkaloids, saponins, tannins, and phenols in the aqueous extracts of *O. gratissimum* and *C. citratus*. The same metabolites were obtained from an ethanolic extract of *O. gratissimum*, but not from an ethanolic extract of *C. citratus*, which contained only three metabolites, comprising flavonoids, phenols, and tannins. These metabolites are known to possess insecticidal properties as reported by Gupta *et al.* (2011); Veniprasad *et al.* (2014); Alexander (2016) and Talabi and Makinidola (2017). Each of the phytochemical components is known for various protective and therapeutic effects against insects. For instance, phenol has been reported to cause DNA damage on mosquito larvae (Dua *et al.*, 2013). The findings of these metabolites are in agreement with the report of Akinmalodun *et al.* (2007) who also extracted all of them except the alkaloids and saponins. High numbers of mosquitoes landed in the ethanolic extract of *C. citratus* treatment which was devoid of two metabolites (alkaloids and saponins). But not on the aqueous extract of *C. citratus* which had all the metabolites present and had low landing rate. This probably suggests that these two metabolites (alkaloids and saponins) play active role in repellency of the mosquitoes. Furthermore, the inability of the ethanol to extract both alkaloids and saponins whose presence are proven qualitatively, suggest that the solvent may not be appropriate for their extraction, it could also be due to geographical factors where the plant were obtained. The presence of saponins in *O. gratissimum* could probably suggest its insecticidal potential as most saponins exhibit toxic effects at high doses over an extended period. However, the presence of saponins in *O. gratissimum* does not concur with the finding of Afolabi *et al.* (2007) who had previously reported absence of saponins in aqueous and methanolic extracts of *O. gratissimum*. Also, Alexander (2016) stated that the presence of saponins, alkaloids and flavonoids in *O. gratissimum* suggests its insecticidal potential and hence by extension some insecticidal properties as well. Insect developments as well as reproduction are affected by multiple saponins directly because these bioactive compounds repel the insect's herbivores from target host plants. However, if insect pest feeds on such defensive host plants, then such herbivores lose their further feeding and movement which leads them towards lethargy and resultantly into mortality due to high toxicity of saponins (Adel *et al.*, 2000 and Cai *et al.*, 2016).

The bitter taste from alkaloids serves as pesticides in most plants while saponins are generally known as antifeedants and also protect plants against microbes and fungi which may be responsible for the protective functions in plants. Alkaloids are used as chemical weapons by plants in pest invasion because they can lower the attractiveness of plants to insects; they can also make plants unpalatable or attract insects to poison them (Hirayama *et al.*, 2007 & Miresmailli *et al.*, 2014). This observation agrees with studies of Otabor *et al.* (2019) who also reported alkaloids, flavonoids, saponins and tannins from the methanolic extract of *C. citratus* and *O. gratissimum*. Higher proportion of alkaloids (61.50%), flavanoids (20.95%) and saponins (20.30%) were recorded in *O. gratissimum*.

In *C. citratus*, flavonoids, alkaloids, saponins, phenols and tannins were present in the aqueous extract which could suggest its insecticidal properties and the result conforms with several reports elsewhere (Asaolu *et al.*, 2009; Ewanshiba *et al.*, 2012; Christopher *et al.*, 2014; Umar *et al.*, 2016 & Unachukwu *et al.*, 2016). The high content of the above metabolites could therefore be the reason for the repellent activity observed in the two plants. Geetha and Geetha (2014) reported that methanolic extract of *C. citratus* had higher quantity of phytochemical constituents than the ethanolic extract; thus, suggesting that extraction solvent does play a role in detecting phytochemical constituents. This could possibly explain the observed absence of alkaloid and saponin in the ethanolic extract of *C. citratus*.

Result from this study reveals that *C. citratus* and *O. gratissimum* did prevent some landing attempts by mosquitoes which are due to their repellency properties. Baldacchino *et al.* (2013) and Prabhakar *et al.* (2013) documented evidence that *C. citratus* and *O. gratissimum* extracts are potent mosquito repellents. However, the prelanding time in this study, for aqueous and ethanol was of 4-5 minutes period after which landing attempts and bites were experienced unlike in *O. gratissimum* which showed a prelanding period of 0-2 minutes. The observed difference, in this study could be attributed to the presence and absence of alkaloid and saponin in *C. citratus* and *O. gratissimum* respectively. *O. gratissimum* which contained all the metabolites including saponin and alkaloid exhibited lower pre-landing times than *C. citratus* which lack both metabolites hence; it is possible to state that the two metabolites are responsible for the difference in the landing time.

In this investigation, it was discovered that lower concentrations of *C. citratus* aqueous extract repelled

more effectively than greater concentrations. However, *O. gratissimum* showed higher repellency at higher concentration. Aqueous extract of *C. citratus*, showed the highest degree of repellency of 86% (at 0.001 mg/ml concentration), 56% (at 0.01 mg/mg concentration) and 62% (at 0.1 mg/ml concentration), while aqueous extract of *O. gratissimum* showed the least degree of repellency of 18% (at 0.001 mg/ml concentration), 24% (at 0.01 mg/ml concentration) and 36% (at 0.1 mg/ml concentration), while other extracts have also shown some degree of repellency ranging from 35% to 74%. According to WHO (2009), the extract which shows the least number of mosquito landing signifies higher repellency. From this study, therefore *C. citratus* which shows less mosquito landing has higher repelling property/activity than *O. gratissimum* in ethanolic extract of *C. citratus* was shown to have recorded the only mortality rate 2(6.67%) at the lowest concentration (0.001 mg/ml) after 24 hours. The superior effect of the ethanolic extract could be due to its polarity which differs from that of aqueous extract. However, this finding differs with studies by Iza and Youkparigha (2019) who recorded a very high mortality rate of 85% on larvae of mosquitoes upon treatment with ethanolic extract of *C. citratus* at higher concentration. Egunyomi *et al.* (2010) and Badaki *et al.* (2018) also recorded higher mortality from *C. citratus* and *O. gratissimum* at higher concentrations.

Conclusion

The findings of this study clearly show that *Ocimum gratissimum* and *Cymbopogon citratus* leaf extracts can be used as an alternative to synthetic insecticides in the control of female *Anopheles* mosquitoes. This is good because phytochemicals are ecofriendly, biodegradable, readily available and inexpensive, hence it can be a favourable option in the control of malaria vectors and other insects. Since *O. gratissimum* and *C. citratus* possesses insecticidal properties, and the use is ecofriendly and inexpensive. There is a need for the local use of the plant extracts to prevent mosquito bites which will serve as malaria control. More research should be carried out using various concentrations, different solvents and methods of extraction.

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