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## Influence of Meteorological Variables on Diversity and Abundance of Mosquito Vectors in Two Livestock Farms in Ibadan, Nigeria: Public Health Implications

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### Abstract

This study was undertaken to determine mosquito vector diversity and abundance in two livestock farms with previous history of arboviral activities in Ibadan, southwestern Nigeria. The influence of weather on mosquito populations was also studied. Adult mosquitoes were collected weekly in two proximate University of Ibadan livestock farms from March 2015 to February 2016 using CO<sub>2</sub> baited CDC light trap and human landing collection methods. Mosquitoes were identified to species using morphological keys. Relationships and interaction of temperature, relative humidity, rainfall patterns and mosquito abundance were analysed using GENSTAT 4<sup>th</sup> edition. Among 6,195 adult mosquitoes collected, 16 species belonging to 5 genera were morphologically identified. *Culex quinquefasciatus* constituted the most abundant mosquito, representing 46.49% of all mosquitoes encountered. High abundance in mosquito population was noted in periods succeeding months with heavy rainfall, this is when arbovirus transmission risk is highest. A positive correlation was observed between relative humidity and abundance of *Mansonia* mosquitoes. This study shows the effect of weather on natural populations of mosquito vectors. The diverse mosquito species capable of transmitting arboviruses from animal reservoirs to human and animals in livestock farms and its environment in Ibadan, Nigeria was also revealed. There is need for intensive vector control strategies targeted at reducing mosquito populations and ultimately prevention of disease outbreaks.

### Keywords

Arbovirus vectors; Rainfall; Temperature; Relative humidity; Nigeria

### Background

Mosquitoes (Diptera: Culicidae) are considered the most important arthropods of medical and veterinary importance as they rank first in the spread of many pathogens including

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arthropod-borne viruses (arboviruses) (Service, 2003). Over 3,500 species of mosquitoes (Harbach and Howard, 2007) are distributed throughout the tropical and temperate regions (Rajendran, 2000). Approximately 300 species of mosquitoes can transmit arboviruses with varying health implications. *Aedes* and *Culex* mosquitoes are the species most frequently associated with arbovirus transmission (Karabatsos, 1985). Arboviruses are maintained in nature through complex sylvatic, peri-domestic and urban cycles involving vectors and vertebrate host reservoirs while humans are incidental hosts (Paulo et al., 2015).

Of the over 500 known arboviruses (Karabatsos, 1985; Tsai and Chandler, 2003; Hayes et al., 2008), approximately 100 are responsible for most human/animal diseases (Karabatsos, 1985). Many arboviruses are zoonotic (Kuno, 2005). Livestock farms often serve as wildlife-livestock-human interface areas (Jones et al., 2011), as human activities interface with livestock and wildlife such as rodents, primates and birds in the search for food and water. Humans attending to livestock are exposed to vectors that maintain and transmit arboviruses and animal reservoirs that maintain these arboviruses. This scenario provides avenue for arboviruses, which are multi host infections to jump from one species to the other through shared vectors (Parrish et al., 2008).

The epidemiology of arboviruses is significantly influenced by climate. Temperature, rainfall pattern and humidity are important factors in the life-cycle of arthropod vectors, the arbovirus transmitted and the reservoirs (Rogers and Randolph, 2006; Semenza and Menne, 2009; Paz, 2015). Temperature increase causes an upsurge in the growth rates of mosquito populations, decrease the interval between blood meals, shorten incubation periods from infection to infectiousness in mosquitoes and accelerate the virus evolution rate (Baba et al., 2012). Above-average precipitation can also lead to a higher abundance of mosquitoes and increase the potential for disease outbreaks in humans (Landesman et al., 2007). A good knowledge of the changes and fluctuations that occur in natural populations of mosquito vectors is very important in the prevention and control of arboviral diseases in order to identify high and low risk transmission zones and periods (WHO, 1975).

Many arboviruses circulate in Nigeria, yellow fever for example has caused large epidemics in the past (Carey et al., 1972; Fagbami et al., 1976; Nasidi et al., 1989, there are also serologic evidence of human infection with yellow fever, Dengue, West Nile and Zika virus (Fagbami, 1979; Baba et al., 2013, Onoja et al., 2016). Antibodies to Rift Valley fever have been demonstrated in sera of humans and animals in Nigeria (Olaleye et al., 1996a; b). Antibody to WNV have also been documented in horses in Nigeria (Olaleye et al., 1989; Sule et al., 2015). There are reports that many clinical arbovirus infections have been misdiagnosed as malaria and typhoid fever in the country as well (Baba et al., 2013). All these reflect the activities of several competent mosquito vectors, capable of transmitting arboviral infections from reservoirs to other host in the country, some of these mosquito vectors have been implicated following past arbovirus epidemics (Lee and Moore, 1972; Nasidi et al., 1989; Onyido et al., 2009). Entomological surveys have documented the presence of many mosquito species in Nigeria (Boorman and Service, 1960; Okogun et al., 2005; Onyido et al., 2008; Mgbemena and Ebe, 2012). However, there are few studies that specifically target the mosquito species in livestock farms, which are wildlife-livestock-human interface areas where vectors can make contact with reservoirs before urban

transmission of arboviruses occur. Knowledge of the species composition and fluctuations that takes place in mosquito vector populations in response to abiotic environmental conditions, principally weather is necessary to identify periods when these vectors thrive the most and arboviruses are at their peak of transmission.

In this study, we investigated the different mosquito species present in two livestock farms with previous history of arboviral activities. Abadina virus, Rift Valley fever virus, West Nile virus, Shamonda virus and Sabo virus have been previously isolated from animal blood samples collected from these farms in the late 1960s (University of Ibadan arbovirus research project, 1970). The study also shows the influence of rainfall, temperature and relative humidity on fluctuations in the mosquito populations in the two farms.

## 1 Materials and Methods

### 1.1 Study locations

This study was carried out in Ibadan, South west Nigeria. The city has a tropical climate with two distinct seasons; a dry season from November to February characterized by low relative humidity, high environmental temperatures with low or no rainfall followed by a wet/rainy season from March to October, with high relative humidity, lower environmental temperatures, abundant rainfall and often flooding (Ogolo and Adeyemi, 2009). This climatic condition favours all year round proliferation of arthropod vectors. Mosquitoes were collected from March 2015 to February 2016. The study was carried out in two livestock farms namely, the University of Ibadan dairy farm (7°27'28.6"N 3°53'57.6"E) and University of Ibadan Teaching and Research farm (07°27'14.6"N 03°53'43.4"E). They are about 2 km apart. Selection of the University of Ibadan dairy farm was based on previous documentation of establishment of vector-host arbovirus transmission cycles. The vegetation of the farms consists mainly of residual native forests and grassy areas. The vertebrate species include ruminants, reptiles, amphibians, birds and rodents. Natural water bodies are present close to the farms and water supply for animals often create artificial breeding sites where immature mosquitoes can develop. The University of Ibadan Teaching and Research farm is very close to a protected area (University of Ibadan, botanical garden) where natural forest vegetation and a variety of flowers are preserved; this park is also the home to many birds and rodents.

### 1.2 Mosquito collection and identification

Mosquitoes were collected using carbon dioxide-baited Centre for Disease Control (CDC) light traps and human landing collection (HLC) methods. HLC is the only effective method for sampling sylvatic *Aedes* and the most appropriate method for determining human risk of infection (Diallo et al., 2012). The two methods were combined in order to have representative catch of the different mosquito species present at the farms. For each site, one CDC trap was set close to the cattle shed while two trained mosquito scouts collected mosquitoes from two locations in the vegetation within the farm. Collectors were dressed in thick clothing materials with hoods, hand gloves and socks. They collected mosquitoes landing on their socks covered legs to minimise exposure to mosquito bites. The collection was done once weekly on each farm for a 5 hours trapping periods from 16:00 to 21:00. The

sampling pattern defined at the beginning of the collection season and taken throughout the study period and trap sites were not changed. Weather data namely rainfall, relative humidity and temperature were taken into consideration throughout the study period. This was obtained from the meteorological station in the Department of Geography, University of Ibadan. Mosquitoes that were collected were killed by freezing and stored in an icebox containing dry ice. They were then transported to the Department of Virology, University of Ibadan laboratory where they were identified using morphological keys, including Edwards (1941); Gillies and de Meillon (1968) and Harbach (1988).

### 1.3 Statistical analysis

Data on rainfall, temperature, relative humidity, and the different mosquito genera were documented using the MS Excel 2013 software and statistical analysis was done using GenStat 10.3DE software package 4<sup>th</sup> Edition. Pearson's correlation ( $r$ ) was calculated to ascertain the relationship between various metrological variables and abundance of mosquitoes from different genera at 5% level of significance.

## 2 Results

### 2.1 Mosquito diversity and abundance

Overall, 6,195 mosquitoes belonging to five genera and 16 species were captured. The most common species was *Culex quinquefasciatus* (46.49%), followed by *Mansonia africana* (24.87%) (Table 1).

### 2.2 Influence of weather on mosquito population

Populations of mosquitoes in different genera fluctuated during the study period (Figure 1). Total mosquito abundance ranged from 179 to 1062. The monthly quantities of rainfall ranged from 0.00 mm to 184.30 mm, while the mean monthly environmental temperature ranged from 24.96°C to 29.24°C. The mean monthly relative humidity ranged from 47.33% to 88.00% (Figure 2). A positive correlation ( $r = 0.60$ ,  $P = 0.04$ ) was observed between relative humidity and abundance of *Mansonia* mosquitoes.

*Aedes aegypti* and *Ae. mcintoshi* were the two most occurring *Aedes* mosquitoes, population of *Ae. aegypti* was higher during the rainy season compared to the dry season. The population of *Ae. mcintoshi* declined towards the end of the rains. However, a sharp rise in population was observed immediately after the heavy rains subsided (Figure 3).

*Culex quinquefasciatus* and *Cx. pipiens* were the two most occurring *Culex* mosquitoes, population of *Cx. quinquefasciatus* was high at the beginning of the rains and at the end of heavy rains. *Cx. pipiens* was present throughout the study period at a relative low number (Figure 4).

*Mansonia africana* and *Ma. uniformis* were the two most occurring *Mansonia* mosquitoes, population of *Ma. africana* was high during the rainy season. *Mansonia uniformis* was present throughout the study period in good numbers (Figure 5).

### 3 Discussion

Sixteen mosquito species were encountered in this study out of which *Aedes aegypti*, *Ae. africanus*, *Ae. albopictus*, *Ae. mcintoshi*, *Culex pipiens*, *Cx. quinquefasciatus*, *Mansonia Africana* and *Ma uniformis* are of significant medical importance. In addition, high vector population was found in periods succeeding months with high rainfall quantities. Activities of arboviruses have been previously documented in the study sites with the detection of Abadina virus in 1967 and 1969 from *Culicoides* and *Aedes fowleri* respectively, Rift Valley fever virus was isolated from *Culicoides* and *Cx. antennatus* in 1970, West Nile Virus from liver and spleen samples of rodents in 1969, Shamonda virus was isolated from cow blood sample in 1969 and 1970 and Sabo virus from *culicoides* in 1970 (University of Ibadan arbovirus research project, 1970). In essence many of the mosquito species collected in this study are important vectors of arboviruses. It is worthy of note that large outbreaks of yellow fever have occurred in Nigeria in the past (Carey et al., 1972; Monath, 1973; Fagbami et al., 1976; Nasidi et al., 1989). *Aedes aegypti*, *Ae. albopictus* and *Ae. africanus* are potential vectors for yellow fever virus, and have been captured following previous yellow fever epidemics in some states in Nigeria (Lee and Moore, 1972; Onyido et al., 2009). These vectors can also transmit Dengue, Zika and other viruses. Evidence of other important viruses like Dengue and Zika viruses have also been previously documented in Nigeria (Carey et al., 1971; Fagbami, 1979; Fagbami, 1977; Fagbami et al., 1977). Other mosquito vectors of health significance encountered during the study included *Ae. mcintoshi*, *Cx. quinquefasciatus*, *Ma. uniformis* and *Ma. africana*, which are vectors for Rift Valley fever virus in some east African countries (Sang et al., 2010). *Culex quinquefasciatus*, a notable vector of West Nile virus was the most prevalent species encountered during this study. The presence of these vectors in farm environments implies that an outbreak can occur if a vireamic animal is introduced to this region. Similarly, a disease outbreak can occur if a vireamic wild reservoir is attracted to these farms.

Mosquito populations varied during the study period in response to prevailing weather conditions. This is expected since insect vectors are poikilothermic and subject to the fluctuating effects of abiotic factors in their environment of which weather is significant (Shope, 1991). The interplay of weather especially rainfall which provides the aquatic environment for larval development and also facilitates egg hatching for species that lays in containers and rely on flooding to trigger hatching is very important. Increased rainfall promotes development of favourable habitats for developing stages of insect vectors particularly the larval stage (Patz et al., 2003), thus favouring population growth (Gubler et al., 2001). Amount of precipitation in an area can also affect the availability of mosquito breeding sites. In our study, the highest abundance of mosquitoes did not occur in the month of June, September and October with the highest amount of rainfall. This may be due to the effect of excess rainfalls resulting into flooding that could wash off mosquito larval habitats before their complete development, thereby having a negative effect on local mosquito populations (Epstein, 2004). A similar finding was reported in the study of Uttah et al. (2013) in Imo state, Nigeria, where a decline in mosquito abundance was found in the months with the highest rainfall during the first year of their study. However, the highest abundance of mosquito was recorded during the month with highest rainfall in the second

year of their study. Nevertheless, a sharp rise in mosquito population was recorded in the months succeeding the months with high rainfall, and this may be the result of a balanced interplay of abiotic factors, since flooding of larval habitats has ceased and mosquitoes have opportunity to complete their development. Similar spikes in the mosquito populations have been recorded in many countries in periods following abundant rainfall and are usually associated with disease outbreaks, for example Rift Valley fever outbreaks in Kenya (Davies et al., 1985; Himeidan et al., 2014). Different mosquito species responded differently to this effect of rainfall as seen in Figure 3, Figure 4 and Figure 5. However natural populations *Ae. mcintoshi*, a major vector of Rift Valley fever virus and *Cx. quinquefasciatus*, a vector of West Nile virus followed this pattern. Periods following months with high amount of rainfall represent seasons of highest risk for arbovirus transmission in our study sites. *Mansonia africana* responded differently to the effect of excessive rainfall because its larvae attaches to the roots of aquatic plants to obtain oxygen, therefore the effect of flooding was not pronounced on its population thus making it abundant in the rainy season. For these species the rainy season represent the period of highest risk for arbovirus transmission.

Temperature is also a very important factor in the dynamics of mosquito populations. Increase in environmental temperature has been observed to causes a decrease in mosquito generation time, longevity and life expectancy and increases the growth rate of vector populations, as well as decreasing the extrinsic incubation period and increasing the length of the pathogen transmission period (Patz et al., 2003). In this study temperature fluctuations recorded during the study period was not significantly correlated with mosquito abundance. Higher humidity increase mosquito survival (Gubler et al., 2001), decrease in humidity can adversely affect mosquitoes since they desiccate easily; survival rates decrease in dry conditions (Patz et al., 2003). Fluctuations in relative humidity during the study period were not significantly correlated with mosquito abundance except for *Mansonia* mosquito in which population increased as relative humidity did. Overall, the different mosquito genera responded differently to weather variables, their response may be related to their individual lifecycle or the duration of sampling, which was only 5 hours of 24 hours in a day.

## 4 Conclusions

In this study, we have shown the diversity and relative abundance of different mosquito species capable of propagating arboviral infections in livestock farms in Ibadan, southwestern Nigeria. The abundance of different mosquito vectors varied based on prevailing climatic conditions. An increase in mosquito population was recorded in months following heavy rainfalls. Overall, the abundance and diverse population of mosquito in two livestock farms are described. There is also a need to start intensive vector control efforts. Further studies aimed at detecting arboviruses from mosquitoes captured in these farms is ongoing in our laboratory.

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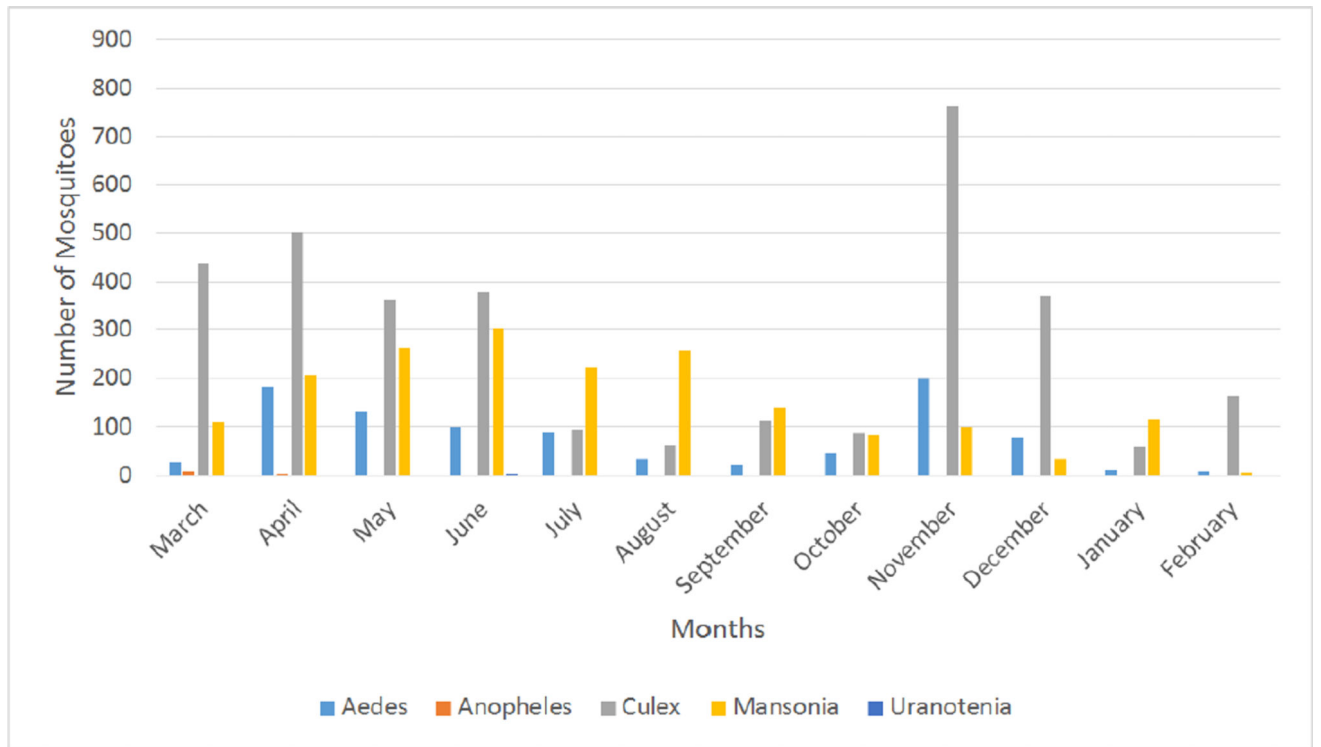
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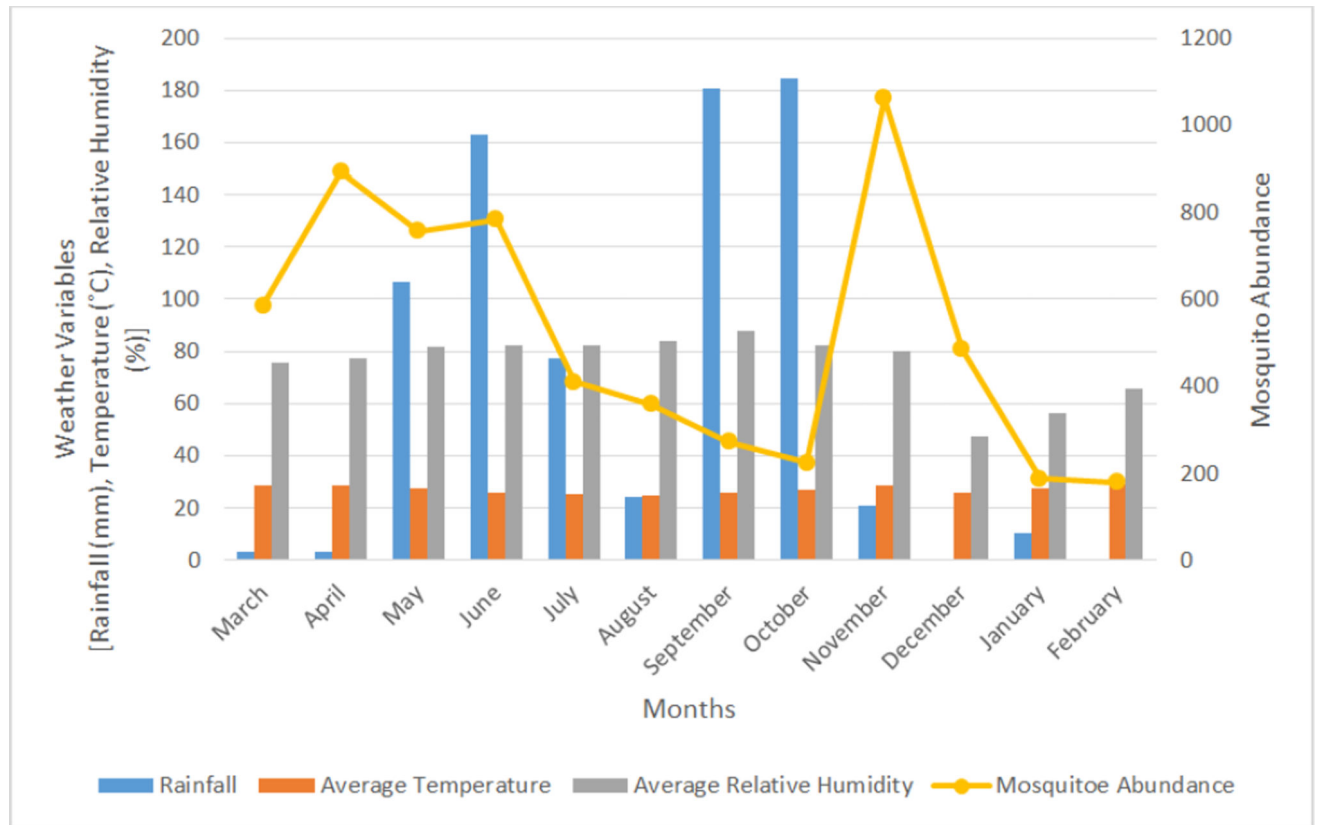
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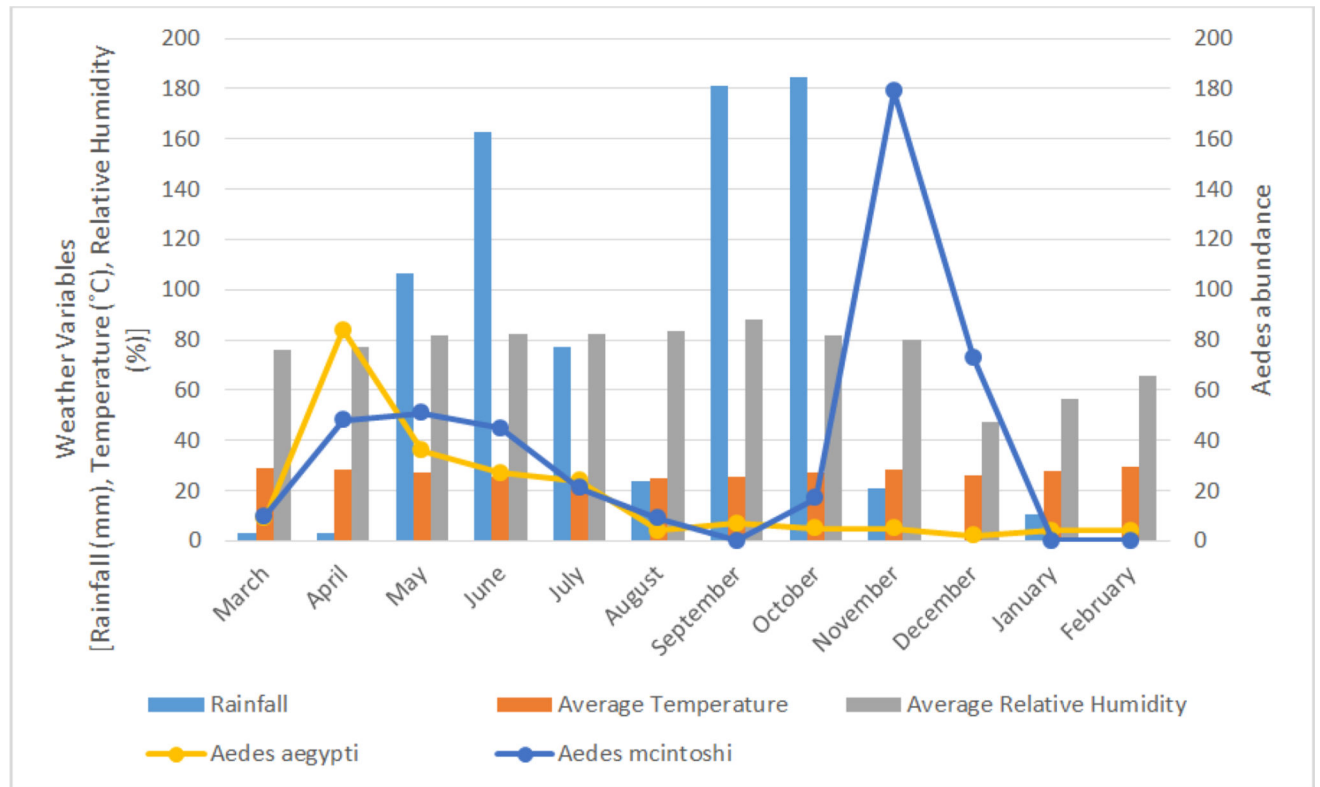
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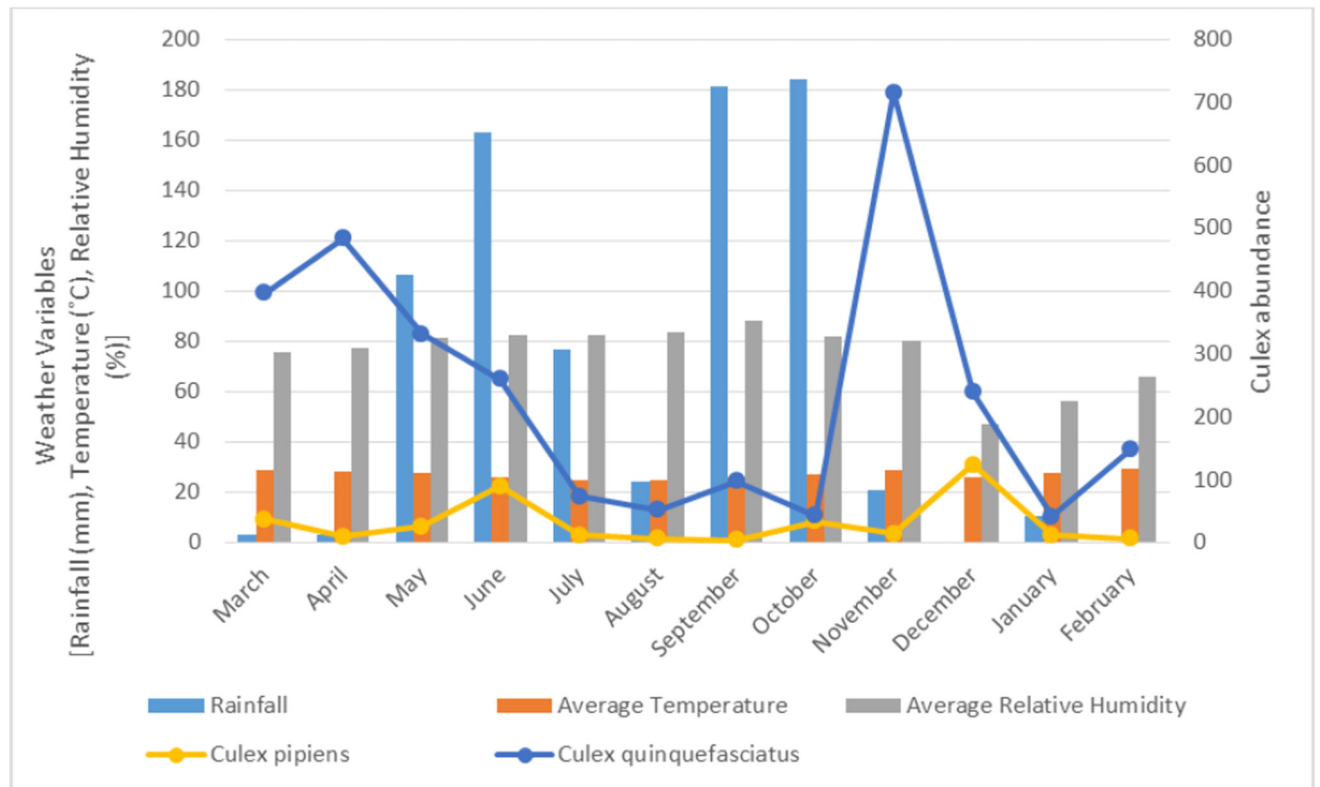
**Figure 1.**  
Genera of mosquitoes collected from March 2015 to February, 2016



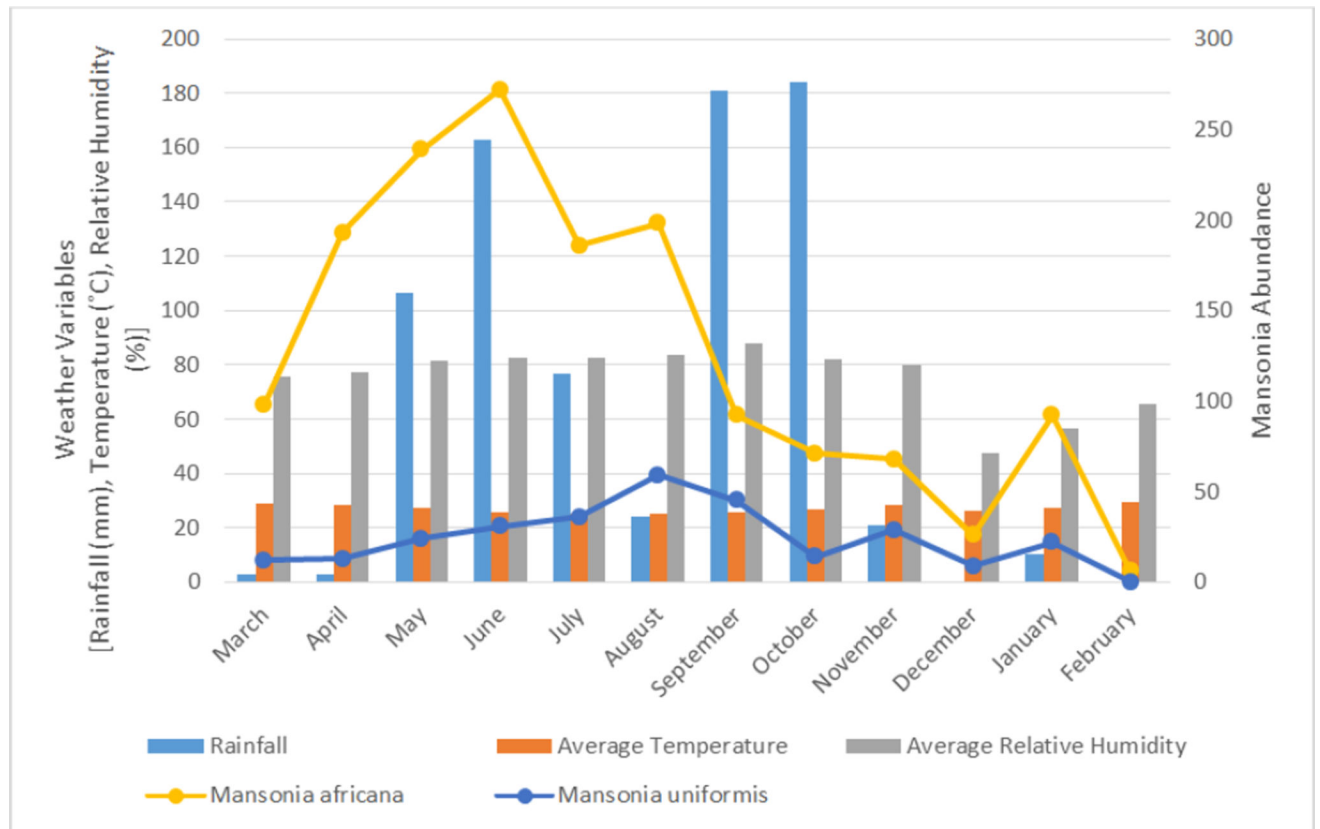
**Figure 2.** Mosquito abundance, amount of rainfall, temperature and relative humidity from March 2015 to February 2016



**Figure 3.** Two most occurring *Aedes* mosquitoes, amount of rainfall, temperature and relative humidity from March 2015 to February 2016



**Figure 4.** Two most occurring *Culex* mosquitoes, amount of rainfall, temperature and relative humidity from March 2015 to February 2016



**Figure 5.** Two most occurring *Mansonia* mosquitoes, amount of rainfall, temperature and relative humidity from March 2015 to February 2016

**Table 1**

List of mosquitoes collected from the University of Ibadan dairy farm and Teaching and Research farm from March 2015 to February 2016

<b>Mosquito species</b>	<b>Number</b>	<b>Relative abundance (%)</b>
<i>Aedes aegypti</i> (Linnaeus)	211	3.41
<i>Aedes africanus</i> (Theobald)	9	0.15
<i>Aedes albopictus</i> (Skuse)	109	1.76
<i>Aedes mcintoshi</i> (Huang)	453	7.31
<i>Aedes metallicus</i> (Edwards)	37	0.60
<i>Aedes simpsoni</i> (Theobald)	28	0.45
<i>Aedes vittatus</i> (Bigot)	50	0.81
<i>Aedes sp.</i>	36	0.58
<b>Total Aedes</b>	<b>933</b>	<b>15.07</b>
<i>Anopheles funestus</i> (Giles)	7	0.11
<i>Anopheles gambiae</i> (Giles)	10	0.16
<b>Total Anopheles</b>	<b>17</b>	<b>0.27</b>
<i>Culex decens</i> (Theobald)	28	0.45
<i>Culex nebulosus</i> (Theobald)	69	1.11
<i>Culex pipiens</i> (Linnaeus)	374	6.04
<i>Culex quinquefasciatus</i> (Say)	2 880	46.49
<i>Culex sp.</i>	45	0.73
<b>Total Culex</b>	<b>3 396</b>	<b>54.82</b>
<i>Mansonia africana</i> (Theobald)	1 541	24.87
<i>Mansonia uniformis</i> (Theobald)	294	4.75
<b>Total Mansonia</b>	<b>1 835</b>	<b>29.62</b>
<i>Uranotaenia annulata</i> (Leicester)	9	0.15
<i>Uranotaenia sp.</i>	5	0.08
<b>Total Uranotaenia</b>	<b>14</b>	<b>0.23</b>
<b>Total Mosquito Species</b>	<b>6 195</b>	<b>100</b>