Global journal of multidisciplinary and applied sciences
Available online at www.gjmas.com
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The Climate of North-central Nigeria and Potential Influence on Mosquito (Diptera: Culicidae) Vectorial Capacity, for Disease Transmission

Olayemi IK*, Idris B, Ejima IAA, Adeniyi K, Ukubuiwe AC and Isah B

Applied Entomology and Parasitology Research Unit, Department of Biological Sciences, Federal University of Technology, Minna, Nigeria

***Corresponding author*:** Olayemi IK

ABSTRACT: The overwhelming disproportionate burdens of mosquito-borne diseases recorded in the Tropics have been attributed, to a large extent, to the prevailing clement climatic conditions for enhanced mosquito vector population development and parasite embryogeny. Yet, spatial heterogeneity in tropical climatic conditions abound, and the exact inter-play between weather conditions and mosquito ecology is not well understood in different tropical localities. This study, therefore, established the climatic status of North-central Nigeria, and elucidated the potential influence of prevailing weather conditions on mosquito vectorial capacity in the area.
***Methodology*:** Minna, an ecological setting that represents the general ecotype of North-central Nigeria was selected for data collection. Meteorological data of rainfall, relative humidity and temperatures, spanning periods variously ranging from 1985 – 2010, were obtained from standard weather stations in the area. Collected data were processed and analyzed for mean monthly and annual values for each climatic variable.
Results: The results indicated mean cumulative annual and monthly rainfall in North-central Nigeria to be 1247.52±166.68mm and 103.96mm, respectively. Mean annual temperatures in the area were 22.55±0.42ºC minimum, and maximum of 33.54±0.23ºC. Mean annual relative humidity was barely above 50%, and varied within narrow limits (range = 50.08 – 52.75%). Monthly rainfall distribution extends from May through October, with a unimodal peak in August (274.23mm). The months of January and February were completely rainless while months of very little rainfall were recorded in April and November, respectively, regarded as pre- and post-rainy season transition periods.
Interpretation/Conclusion: The results clearly confirmed the climate of North-central Nigeria to be tropical and of the dry grassland Savanna type. However, while the amounts and distribution of rainfall as well as, temperatures of the area are such that, respectively, promote rapid mosquito population development and parasite maturation; the relative humidity appears limiting to mosquito survival.

***Keywords*:** Disease Transmission, Malaria, Rainfall, Relative Humidity, Temperature and Weather.

INTRODUCTION

Mosquito-borne diseases such as malaria, filariasis, yellow fever, encephalitis, etc, are the bane of suffering, under-development and poverty in the Tropics. Malaria alone is endemic in over 100 tropical countries, where it kills about 3 million people annually, initiates over 500 million new infections and threatens about 3 billion people (USAID, 2005; Muturi, 2008). The disease is responsible for an estimated global loss of about 45 million Disability Adjusted Life Years (DALYs). More than 90% global malaria health and socio-economic negativities are recorded in tropical sub-Saharan Africa, with the disease accounting for 20% infant mortality and 10% overall disease burden of the continent (Roll-Back-Malaria, 2002; WHO, 2003). It has been estimated that malaria kills two African children per minute (Shah, 2005). In Nigeria, malaria is the foremost public health challenge, affecting more than 90% of the country's over 140 million people (Federal Ministry of Health, 2004), and responsible for about 300,000 deaths yearly (Salako, 1997; Odaibo, 2006). Malaria costs Nigeria over $1 billion per annum in terms of treatment and prevention.

The other mosquito-borne diseases especially filariasis, yellow fever, dengue fever, encephalitis, etc, have had serious set-back impacts on the socio-economic development and medical well-being of people living in the Tropics, Nigeria inclusive. While, filariasis threatens the health of about 1.3 billion people and incapacitates over 40 million of them in more than 80 countries, mostly in the Tropics (Espino, 2004; WHO, 2011); dengue fever puts two-fifths of the world's population at risk of its debilitating infection, and yellow fever epidemics have wrecked havoc on human populations in the Tropics (Nasidi, 1989; Olaleye, 1988).

Mosquito-borne diseases are so deeply entrenched and widespread in the Tropics because the development, distribution and vectorial activities of the mosquito vectors are highly favoured by the prevailing clement ecological conditions of the area, especially, those related to climatic factors such as rainfall, relative humidity and temperature, which respectively, proliferates ground pools where mosquitoes breed; provides humid conditions which significantly extends adult mosquito longevity and vectorial activities; and relative warmth which quickens the development of both mosquitoes and the parasites within them (WHO, 1975). Studies have revealed tropical weather conditions to be ideally suited to providing these environmental requirements for the thriving of mosquitoes. For example, while mean monthly precipitation accumulation of at least 80mm, temperatures between 18 and 32^{o}C, and relative humidity of at least 60% are considered suitable for the sustenance of significant mosquito population density and vectorial capacity (WHO, 1975; McMichael and Martens, 1995). However, evidence abound of spatial heterogeneity in the critical climatic conditions of rainfall, relative humidity and temperature in different localities in the Tropics, to the extent that one or more of the climatic factors may not be adequate to support mosquito population development and disease transmission (WHO, 1975); yet, mosquito-borne diseases may be endemic in such habitats. This brings to the fore, the important roles played by other drivers, aside climatic factors, in the transmission of mosquito-borne diseases, and the need to correctly identify the true disease transmission drivers in an area. Elucidating the driving forces of mosquito-borne disease transmission in an area will aid in predicting temporal intensity and pattern of transmission, as well as, make possible optimum targeted control interventions. Presently, in Nigeria, there is a dearth of this understanding; and this study was therefore carried out to establish the prevailing climatic conditions of North-central Nigeria, and elucidate the potential influence of such conditions on the biology, ecology and vectorial capacity of mosquitoes in the area.

MATERIALS AND METHODS

Description of the Study Area

Minna was selected as site of data collection for this study, as the locality adequately represents the general ecotype of North-central Nigeria. Minna, located on Lat. 9^{0} 27´ N and Long. 6^{0} 33´ E, is the Capital city of Niger state, North-central Nigeria. The area serves as a gateway between the northern and southern parts of the country, especially, in the western axis. Minna occupies a land area of 88km^{2}, with a human population of 1.2 million people. The study area is relatively warm and enjoys moderate amounts and duration of rainfall, thus, given the area a typical tropical ecological setting. Minna is characterized by two distinct seasons namely, rainy (from May through October) and dry (December – March); with the two seasons often separated by somewhat transitional periods in April and November. While, the months of February and March typify the peak of the dry season, with very high temperatures, the rains climax usually in August. The months of November through January are marked by cold and dry weather conditions (i.e., the harmattan) under the influence of the northeast trade wind. The vegetation of the study area is characteristically grass-dominated, forming a mixture of the southern and northern Guinea Savanna ecological biomes. The prevailing climatic and ecologic conditions in Minna combine to support thriving agricultural practices that have earned the area the status of a 'food basket'.

Collection of Meteorological Data

Daily meteorological data of rainfall, relative humidity and temperature, spanning the period of January 2001 through December 2011 for Minna and environs, were obtained from the weather station of Minna Airport.

Data Analysis

Data collected were processed and analysed using SSPS (16.0 version) computer software package. While, mean daily values were calculated for temperature and relative humidity, mean monthly amounts and annual cumulative rainfall were determined for each of the years under study were compared for statistical significance, using the Chi-square test at P = 0.05.

RESULTS AND DISCUSSION

Results

Mean minimum and maximum temperatures in the study area between 2001 and 2009 were 22.55±0.42ºC and 33.54±0.23ºC, respectively (Tab. 1). While, annual cumulative rainfall was 1247.52±166.68mm, relative humidity of 51.43±0.84% was recorded during the period (Tab. 1).

Table 1. Mean annual climatic factors in Minna between 2001 and 2009

Climatic Factor	Annual Mean
Maximum Temperature (ºC)	33.54 ± 0.23
Minimum Temperature (ºC)	22.55 ± 0.42
Rainfall (mm)	1247.52 ± 166.68
Relative Humidity (%)*	51.43 ± 0.84

* For data between 2001 and 2007

Figure 1 shows the monthly distribution of monthly rainfall in Minna. Generally, monthly rainfall in the area presents a unimodal distribution with a peak in August (274.23mm), though amount of rainfall in September was equally high. It is noteworthy that peak monthly rainfall between August and September was preceded and followed by more-or-less exponential increase and drop in amounts of rainfall, respectively. The months of January and February (i.e., peak dry season), were completely devoid of rain. Amounts of rainfall during the months of March and November – December, had extremely low amounts of rainfall (i.e., range = 1.43 mm in December to 4.12mm in November), However, the dry-rainy transition period (i.e., April) recorded much higher amounts of rainfall (59.88mm) than the counterpart rainy-dry transition month of November. It is interesting to note that significant rainfall accumulation for sustaining mosquito larval habitats (i.e., rainfall amounts >80mm) was achieved only between the months of May and October.

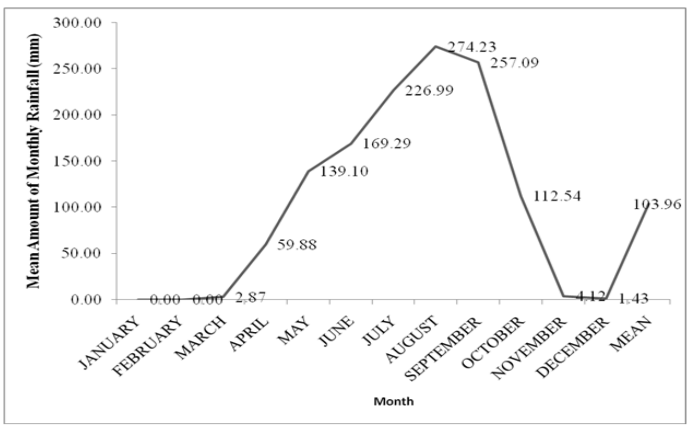

Figure 1. Mean monthly rainfall in Minna, North-central Nigeria, between 1985 to 2010

Figure 2 shows that mean monthly relative humidity in Minna were generally low and varied within narrow limits (range = 50.08% in 2002 to 52.57% in 2007), that were not significantly different ($P < 0.05$).

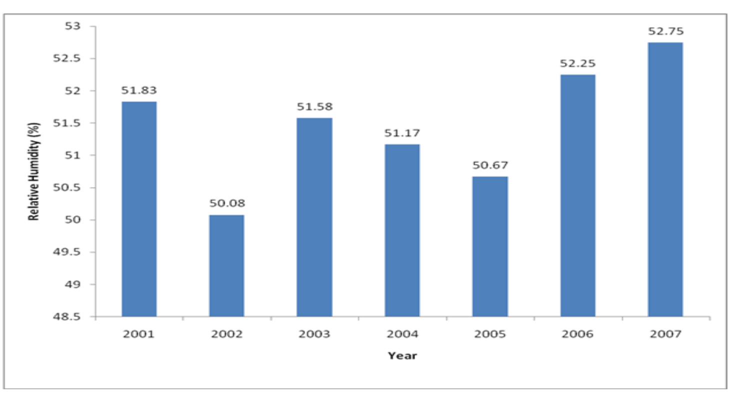

Figure 2. Mean relative humidity in Minna, North-central Nigeria, between 2001 and 2007

Discussion

The results of this study have established the climate of North-central Nigeria as typically tropical; with its attendant implications with respect to mosquito biology and ecology, as well as, the epidemiology of diseases vectored by the mosquitoes. During the study periods examined, temperatures in the area ranged from 22.55±0.42 to 33.54±0.23ºC while, mean annual rainfall and relative humidity were 1247.52±166.68mm and 51.43±0.84%, respectively. The magnitude of the climatic variables, recorded in the area, falls squarely within ranges reported for the Tropics as a whole. This finding regarding the climatic status of North-central Nigeria, has serious biologic, ecologic and epidemiologic implications for density dynamics and activities of the vectors and parasites of mosquito-borne diseases in the area.

The amounts of annual rainfall recorded in North-central Nigeria is such that is well above the threshold for wide-spread proliferation of temporary ground pools, as well as, large surface water bodies, e.g., swamps, that serve as active mosquito larval breeding habitats (Minakawa, 2001; 2002).Also, such amount of annual rainfall promotes above-ground humidity, especially during the rainy season; with its attendant positive impacts on mosquito adult life span, range of dispersal for blood meal and oviposition, degrees of endophagy and endophily, etc.

Though, the mean annual rainfall in Northcentral Nigeria is clearly tropical and falls within the range that proliferates mosquito larval breeding sites, more importantly, the volume of rainfall is such that ensures stability of created larval habitats. Moderate annual rainfall, as established for North-central Nigeria in this study, hardly results in the flooding of created larval habitats, which may flush out mosquito larvae from preferred breeding habitats to sites not capable of supporting larvae development. Thus, the annual amounts of rainfall in North-central Nigeria is such that will create and sustain highly productive mosquito breeding habitats thereby, resulting in the production of many high-density generations of mosquitoes particularly during the rainy season.

The results of this study show that the duration of the rainy season in North-central Nigeria covers half of the year, extending from May through October. In addition, mean total rainfall for each of the rainy season months (range = 59.88mm in May to 274.23mm in August), was above the threshold for the establishment of productive larval habitats. Mean monthly precipitation accumulation of at least 80mm is considered suitable for mosquito population development and disease transmission (WHO, 1975; McMichael and Martens, 1995). These findings, i.e., relatively long rainy season and ‘above-threshold’ monthly total precipitation, are further indications of the suitability of the climate of North-central Nigeria for high population development of mosquitoes, which is a critical determinant of the vectorial capacity of mosquitoes. Thus, control interventions against vector mosquitoes during the rainy season in North-central Nigeria, should be targeted principally at precipitation-dependent larval habitats for optimum impact. However, the completely rainless months of the dry season, as well as, below-threshold precipitation recorded during the transition months, suggest little or no mosquito production from rain fed habitats outside the rainy season. Yet, Olayemi, (2009; 2012) reported high prevalence of malaria, and intense mosquito breeding activities in the study area, during the dry season. These findings, therefore, suggest that mosquito population development and intensity of disease transmission in North-central Nigeria may not be so heavily dependent on rainfall, as earlier alluded to (Leighton and Foster, 1993), but perhaps equally influenced by non-climatic drivers, such as human behavior.

Mean temperatures in North-central Nigeria varied from 22.55±0.42ºC minimum to a maximum of 33.54±0.23ºC. This temperature range is highly suitable for metabolic reactions that promote mosquito immature development, blood meal digestion, egg maturation, etc, as well as significantly shortens the incubation period of parasites within mosquitoes. Studies have revealed that at temperatures between 18 and 32ºC, mosquitoes generally develop faster and take more blood meals (i.e., indication of infective bites) while, the parasites within them multiply more rapidly (Gillies and Warrell, 1993; MARA, 1998). Earlier, in North-central Nigeria, Olayemi and Ande, 2008 observed that a 4ºC increase in atmospheric temperature resulted in a shortening of Plasmodium duration of sporogony in mosquitoes by about two days. Therefore, the prevailing temperatures in North-central Nigeria, will complement the favourable indices of rainfall, in promoting rapid and perennial mosquito population development and vectorial activities.

The mean relative humidity established for North-central Nigeria (i.e., slightly >50%), is relatively low and may not be conducive for adult mosquito dispersal and foraging activities for blood meal and oviposition. Mosquitoes usually don’t live long enough to support complete development of parasites where relative humidity is consistently less than 60% (Pampana, 1969; WHO, 1975; Gillies and Warrel, 1993). Therefore, the relatively high mosquito density and intense malaria transmission in North-central Nigeria, may not be due entirely to the clemency of climatic factors, but the influence of other ecologic and anthropogenic drivers. It may also mean that mosquito populations in the area are principally endophagic and endophilic thus, are able to take advantage of the improved micro-climatic conditions that prevail indoors. While investigating the survivorship of Anopheles gambiae population in relation to indoor micro-climatic conditions in North-central Nigeria, Olayemi, (2011) recorded much higher relative humidity of almost 60% indoors, and such relative humidities correlated strongly with indoor mosquito resting density (i.e., endophily), daily survival and adult longevity. However, such endophagic and endophilic behaviours of adult mosquitoes will no doubts have serious implications for the selection and efficacy of mosquito adulticiding interventions in the area. A study to elucidate the exact influence of relative humidity on mosquito survival and vectorial activities in North-central Nigeria is, therefore, germane in order to have a clear understanding of the relative importance of the various ecological drivers of mosquito vectorial capacity in the area.

CONCULSION

The findings of this study have confirmed the climate of North-central Nigeria to be tropical, and of the drier grassland Savanna type. Typical of tropical climatic conditions, the amounts and distribution of rainfall, as well as, mean annual temperature in the area, are such that, respectively, promote widespread proliferation of stable mosquito larval breeding habitats and optimum metabolic activities that enhance rapid mosquito vector and parasite development. These favourable climatic conditions, therefore, pre-dispose North-central Nigeria to high mosquito vectorial capacity. However, the mean annual relative humidity in the area is much lower than required for significant extension of adult mosquito life span and foraging activities thus, attributing the present high prevalence of mosquito-borne diseases in the area, not only to clement climatic conditions but, perhaps, other environmental and anthropogenic drivers of disease transmission. The findings of this study have elucidated the potential influence of prevailing climatic conditions on the endemicity of epidemiologically important mosquito population density in North-central Nigeria. It is hoped that the new understanding of the potential inter-play between climatic conditions and mosquito ecology, in relation to disease transmission, will guide the selection, timing and mosquito life stage target, of vector control interventions, for sustainable optimum impact in the area.

ACKNOWLEDGEMENT

Sincere gratitude is expressed to the Management of Minna Airport Weather Station, for detailed meteorological data available to the author.

Authors' Contributions

OIK, conceptualized, designed and co-ordinated the study. He carried out literature search, data/statistical analyses, interpreted the results and prepared the manuscript. IB, participated in literature search and data acquisition/analysis. EIAA, participated in literature search, interpretation of results and edited the manuscript. IB, participated in data acquisition and analysis.

Conflicts of Interest/Competing Interests

The authors wish to declare no conflict of interests whatsoever, with respect to execution and outcome of this study.

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