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Seasonal carriage of *Plasmodium falciparum* in selected rural communities in Adamawa State, Nigeria

Jasini Alexander Wahedi[1*], Emmanuel Yakubu[1], Asiyina Elihu[1], Adedapo O. Adeogun[2], Denbon Genesis Williams Chintem[3] and Victor Miyananiyi Vincent[1]

[1] Department of Zoology, Adamawa State University, Mubi, Nigeria

[2] Nigerian Institute of Medical Research, Yabba, Lagos, Nigeria

[3] Department of Science Laboratory Technology, Taraba State Polytechnic, Jalingo, Nigeria

*Corresponding author: Jasini Alexander Wahedi

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Abstract

Plasmodium falciparum, the prevalent malaria parasite in Nigeria, is transmitted by anopheline mosquitoes that has fully adapted to Nigerian ecosystems. However, limited data on this malaria parasite transmission is few in the country, requiring additional data for decision making. This study hence, investigated the seasonal carriage of *P. falciparum* among individuals in selected rural communities in Adamawa State, Nigeria, assessing how transmission varies with weather conditions. Cross-sectional surveys were conducted during the peak rainy and dry seasons to determine the parasite prevalence. A total of 1152 blood samples was collected from people residing in three communities, namely Bazza, Mboi, and Yebbi, were examined for the presence or absence of *Plasmodium falciparum* parasite using microscopy. Results revealed the Prevalence of *Plasmodium* infection in the study communities were 56.77%, 78.39%, and 76.82%, respectively. The prevalence of malaria infection was higher during the wet season than the dry season. There was a significant (P<0.05) difference across seasons for infection and non-infection. carriage rates during the rainy season compared to the dry season, emphasizing the influence of seasonal dynamics on malaria epidemiology. These findings underscore the need for seasonally tailored control strategies to reduce malaria transmission and morbidity in rural Nigerian communities. Exposure to malaria bites and proliferation factors for malaria transmission were identified. Sustainable prevention practices and intervention measures to mitigate these problems are crucial, especially among dwellers in the study communities.

Keywords: Seasonal carriage, *Plasmodium falciparum*, Bazza, Mboi, Yebbi

1. Introduction

Malaria is a major endemic disease in the tropics due to the high frequency of transmission of *Plasmodium* species by *Anopheles* mosquitoes [1]. It has been reported to be one of the top ten (10) principal causes of morbidity and mortality among infected persons [2]. Malaria in Nigeria is caused principally due to *Plasmodium falciparum*, which accounts for 94% - 98% of infections [3]. Evidence shows that malaria transmission is high across Nigeria, with higher transmission occurring in the rural communities and in communities situated by the banks of major rivers and other bodies of water such as irrigation dams in the northern parts of the country [4,5]. The disease is endemic in Adamawa State, where rural communities often experience high transmission rates due to environmental and socioeconomic factors that favour mosquito breeding and limit access to preventive measures. The most vulnerable groups are young children who are yet to develop immunity against malaria and pregnant women whose immunity has been decreased by pregnancy, increasing the risk of illness, severe anaemia, spontaneous abortion, still birth, premature delivery, low birth weight, and death. Malaria is one of the causes of child mortality [4]. An estimated 627,000 people die of malaria, mostly children below five years old, in Sub-Saharan Africa annually [1].

In Adamawa State in the northeast Nigeria, malaria infection is highly endemic [6]. Less severe form of malaria caused by *P. malariae* has also been reported [4]. Childhood morbidity is generally high in Adamawa State [6] and a prevalence level of up to 80% in the southern region has been recorded [7].

The spread of malaria is related to climate change because temperature and rainfall are key parameters of climate change. Fluctuations in temperature affect the spread of malaria by lowering or speeding up its rate of transmission [8,9]. Malaria transmission is also seasonal in some parts of the world, with the highest usually during the rainy season [10]. Understanding the seasonal patterns of *P. falciparum* carriage is essential for optimizing malaria control interventions, including the timing of insecticide-treated net distribution, indoor residual spraying, and community sensitization efforts. Therefore, this study aimed to determine the prevalence of *P. falciparum* infection during distinct seasonal periods among selected rural communities in Adamawa State.

2. Materials and Methods

2.1 Study area

Adamawa State is located on latitude 9°19'60.00"N and longitude 12°29'59.99"E. It is one of the largest states in Nigeria with about 28,700km^2 land area. It is characterized with different vegetational formations which include Sudan savanna, northern guinea savanna and southern guinea savanna [11]. Sudan savanna has an average rainfall between 700mm and 900mm, northern guinea savanna has between 900 and 1100mm, and southern guinea savanna has between 1100mm and 1600mm [12]. Adamawa State has a tropical climate with a mean monthly temperature from 26.7°C to 27.8°C [13]. The state is also characterized with the all-year round availability of both open surface and ground water due to the presence of river Benue, streams and other rivers, which are used for activities like fishing and agricultural irrigation especially during the dry season [13,14]. Three study sites (rural areas) were drawn each from 3 Local Government Areas (LGA). Each of the LGA was selected from the 3 different vegetational zones in the State. This is because, vegetation strongly influences mosquito breeding, survival, and transmission dynamics. From Sudan savanna, the site selected is Bazza in Michika LGA (10°34'19"N and 13°19'6"E); in northern guinea savanna is Mboi in Song LGA (09°55'20"N and 12°31'12"E); and in southern guinea savanna is Yebbi from Ganye LGA (8°35'50"N and 11°54'51"E), as shown in Figure 1.

2.2 Sample size determination

The sample size was determined using the formula described by Taherdoost [15] as follows:

$$n = \frac{P\,(100 - P)Z2}{E2}$$

n = required sample size; P = percentage occurrence of a state or condition; E= percentage maximum error required; Z = value corresponding to level of confidence.

Based on the formula, 384 individuals were used for the study in each of the locality.

2.3 Study design and target population

A purposive study design was employed. Children under 5 years of age were used, and this is because children between the ages of 0 and 5 have the highest malaria burden worldwide, and most especially in sub-Saharan Africa, where they account for about 75% of malaria deaths [16]. Participants were recruited during two distinct season periods i.e. dry season (November to April) and wet season (May to October). Eligible participants were children who were provided consent by their parents; those with recent antimalarial treatment were excluded.

2.4 Ethical approval

Ethical approval to the study was provided by Adamawa State Ministry of Health and Human Services on a letter with reference number *S/MOH/11371*, and an approval number *ADHREC14/05/2025/016*, addressed to Yakubu Emmanuel.

2.5 Demographic data collection

Demographic data were obtain using a well-structured questionnaire. Questionnaires were responded by the households during the blood sample collection in the study localities.

2.6 Blood sample collection and laboratory analysis

Peripheral blood samples were collected via finger prick. Thick and thin blood films were prepared, stained with Giemsa solution, and examined under light microscopy for malaria parasites following WHO standards. HRP2-based Rapid Diagnostic Tests (RDTs) were also used to complement microscopy findings.

2.7 Data analysis

Data were analyzed using statistical software (SPSS version 23.0). Descriptive analysis using percentage was used to analysed the prevalence of *P. falciparum*. This was computed as the percentage proportion of individuals testing positive for *P. falciparum* in each season, and were presented in tables. Chi-square tests were used to compare seasonal differences, with significance set at $p < 0.05$.

3. Results

3.1 Demography of respondents

In Bazza, in Michika Local Government Area, the age group with the highest respondents (73) is 36-40 years, while 41-45 years in Mboi (74) and 26-30 years in Yebbi (74). Majority of the respondents in all the selected areas are males. Bazza had 234 males as against 150 females; Mboi had 204 males as against 180 females; while Yebbi had 202 males as against 182 females. Also, the marital statuses of the respondents showed that those that are married are majority across the 3 selected rural communities. Bazza appeared to have the highest (300) followed by Mboi (252), while Yebbi had 160 married respondents. Similar trend was also observed in the educational statuses of the respondents across the study areas, with tertiary education level as the highest. Bazza and Yebbi both had 201 while Mboi had 169 respondents. In terms of occupation, the public servants were recorded highest respondents in all the 3 selected study areas with Bazza having the highest (168), followed by Yebbi (147), then Mboi (143). Meanwhile, all the study areas recorded 2 respondents that are into craftmanship, respectively. The household's population in the study areas shared a common trend, with 6-10 being the highest. Bazza had 129 respondents, which is the highest, followed by Yebbi (186), then Mboi (168), as shown in Table 1.

Table 1: Demography of respondents

	Bazza		Mboi		Yebbi	
Parameter	**No. of Resp**	**Mean ± SD**	**No. of Resp**	**Mean ± SD**	**No. of Resp**	**Mean± SD**
Age group						
18-25	32	1.63±0.49	34	1.59±0.50	51	1.53±0.50
26-30	54	1.43±0.50	69	1.48±0.50	74	1.47±0.50
31-35	45	1.62±0.49	47	1.51±0.50	52	1.65±0.48
36-40	73	1.45±0.50	64	1.47±0.50	54	1.61±0.49
41-45	71	1.41±0.50	74	1.45±0.50	60	1.45±0.50
46-50	53	1.21±0.41	45	1.47±0.50	43	1.30±0.46
51-60	32	1.09±0.30	34	1.35±0.49	26	1.27±0.45
60<	24	1.13±0.34	17	1.41±0.50	24	1.25±0.44
Sex						
Male	234	4.78±1.98	204	4.28±1.95	202	4.27±2.22
Female	150	3.59±1.68	180	3.94±1.94	182	3.52±1.84
Marital status						
Single	67	2.75±1.65	77	3.40±1.97	77	3.08±1.94
Married	300	4.67±1.86	252	4.40±1.87	160	4.14±2.03
Divorce	13	4.85±1.28	31	4.23±1.86	53	4.11±2.01
Separated	2	1.00±0.00	9	3.56±2.07	52	4.07±2.33
Widow	2	3.00±0.00	15	3.33±2.23	42	4.14±1.96
Level of education						
Non-formal Education	10	4.60±1.71	23	4.61±1.75	10	4.50±1.84
Primary	27	5.67±2.09	50	4.78±2.23	27	5.37±2.32
Post primary	146	3.70±2.01	142	3.54±1.94	146	3.55±2.07
Tertiary	201	4.56±1.76	169	4.36±1.78	201	3.95±1.98
Occupation						
House wife	24	2.92±1.38	31	3.35±1.45	50	3.48±1.71
Farmer	44	4.89±2.18	91	4.57±2.05	61	4.39±2.40
Public servant	168	4.49±1.76	143	4.02±1.82	147	3.97±1.96
Businessman/trading	146	4.15±2.08	117	4.09±2.09	124	3.77±2.16
Craft man ship	2	5.00±0.00	2	5.00±0.00	2	5.00±0.00
Household population						
1-5	104	3.00±1.45	64	3.64±1.93	106	2.88±1.59
6-10	229	4.56±1.80	168	4.01±1.90	186	3.91±2.00
11-15	45	6.02±1.76	90	4.63±1.99	86	5.17±2.08
16-20	2	7.50±0.70	38	4.24±1.76	2	4.50±3.54
20<	4	4.08±2.89	24	4.08±2.17	4	4.00±2.45

SD = Standard Deviation

3.2 Prevalence of *Plasmodium* Infection based on locations

Table 2 presents infection across the study locations. The results show a varying infection rate across the study areas. The result revealed that Bazza has the highest case of *Plasmodium* infection (43.23%), followed by Yebbi (23.18%), and then Mboi (21.61%). The highest occurrence of *Plasmodium* infection in Bazza suggests that the location may require more intensive *Plasmodium falciparum* control measures.

Table 2: Prevalence of *Plasmodium* infection in selected rural areas of Adamawa state

Location	Number examined	Positive (%)	Negative (%)	Chi-square (χ^2)
Bazza	384	166 (43.23)	218 (56.77)	35.75
Mboi	384	83 (21.61)	301 (78.39)	11.05
Yebbi	384	89 (23.18)	295 (76.82)	7.03

3.3 Prevalence of *Plasmodium* infection based on sex

Table 3 shows the prevalence of *Plasmodium* infection in three locations (Bazza, Mboi, and Yebbi) based on sex. In Bazza, 163 males were examined, and 75 were infected (46.01%), while 221 females were examined, and 143 were infected (64.70%). In Mboi, 201 males were examined, out of which 160 were infected (79.60%). The number of females examined were 183 and 141 were infected (77.05%). In Yebbi, 181 males were examined, and 130 infected (71.83%); while the females examined were 203, and 165 were infected (81.28%). Overall, the results revealed that females have higher infection rates in Bazza and Yebbi, while males have a slightly higher rate in Mboi.

Table 3: Overall Prevalence of malaria infection based on location and sex

Location	Sex	Number examined	Number infected (%)
Bazza	Male	163	75 (46.01)
	Female	221	143 (64.70)
	Total	384	218 (56.77)
Mboi	Male	201	160 (79.60)
	Female	183	141 (77.05)
	Total	384	301 (78.39)
Yebbi	Male	181	130 (71.83)
	Female	203	165 (81.28)
	Total	384	295 (76.82)

3.4 Prevalence of *Plasmodium* infection across wet and dry seasons

Table 4 presents the prevalence of *Plasmodium falciparum* infection in the three study locations (Bazza, Mboi, and Yebbi) during the dry season (November to April) and wet season (May to October). In Bazza,17.7% (68 out of 384) were tested positive for *P. falciparum* infection during the dry season and 37.06% (150 out of 384) were tested positive during the wet season. The chi-square is 120.19, indicating a significant difference in *P. falciparum* prevalence between the dry and wet seasons. In Mboi, 39.06% (150 out of 384) were tested positive during the dry season. In the wet season, 39.32% (151 out of 384) tested positive. The chi-square is 111.06, indicating a significant prevalence between the seasons. In Yebbi, 36.20% (139 out of 384) were tested positive for *P. falciparum* during the dry season, and 40.63% (156 out of 384) tested positive during the wet season. The chi-square value is 10.67, indicating a relatively smaller difference in *P. falciparum* prevalence between the dry and wet seasons compared to Bazza and Mboi.

Table 4: Prevalence of *Plasmodium* infection across dry and wet seasons

Location	No. examined	Dry Season (Nov-April)		Wet Season (May-Oct)		(χ^2)
		Positive (%)	Negative (%)	Positive (%)	Negative (%)	
Bazza	384	368 (17.7)	124 (32.29)	150 (37.06)	42 (10.68)	120.19
Mboi	384	150 (39.06)	42 (10.94)	151 (39.32)	41 (10.68)	111.06
Yebbi	384	139 (36.20)	53 (13.80)	156 (40.63)	36 (9.38)	10.67

Overall chi-square = 241.92, *p*-value = 0.0000

3.5 Least square mean for location, sex, and season for non-malaria and malaria infection

Table 5 shows the variation of least square means for non-malaria and malaria infections based on location, sex, and season.

Location: For non-malaria infections, Bazza has the highest mean (6.958), significantly different from Mboi (3.375) and Yebbi (4.033), and for malaria infection, Yebbi (12.708) and Mboi (12.500) have higher means compared to Bazza (8.208).

Sex: For non-malaria infections, males (5.278) and females (4.333) have similar means, with no significant difference. For malaria infections, females (12.167) have a slightly higher mean than males (10.111), but the difference was not dramatic.

Season: For non-malaria infections, the dry season (6.083) has a higher mean than the wet season (3.528). For malaria infection, the wet season (12.361) has a higher mean than the dry season (9.917). Non-malaria malaria infections in Bazza (6.958) are significantly different from Mboi (3.375). Overall, the table suggests that malaria infections are more prevalent in certain locations (Yebbi and Mboi) and during the wet season, while non-malaria infections are more prevalent in Bazza and during the dry season.

Table 5: Least square mean for location, sex, and season for malaria and non-malaria infection

Variable	Mean values for non-malaria infection	Mean values for malaria infection
Location		
Bazza	6.958^a	8.208^b
Mboi	3.375^b	12.500^a
Yebbi	4.033^b	12.708^a
SE±	0.966	1.169
Sex		
Male	5.278^a	10.111^b
Female	4.333^a	12.167^a
SE±	0.789	0.955
Season		
Dry (Nov-April)	6.083^a	9.917^b
Wet (May-Oct)	3.528^b	12.361^a
SE±	0.789	0.955

a, b = mean in a column with the same superscript are statistically similar, ns = not significant, SEM Standard error of the mean.

3.6 Correlation coefficients of malaria infection among the people across the study areas

Table 6 shows a positive medium relationship with location. It suggests there is a moderate correlation with location and season for *P. falciparum* infection in the selected rural communities in Adamawa State. Attributes such as sociodemographic, socioeconomic status (wealth), environmental factors, seasonality, household population, and type of dwelling structures all play a crucial role in parasite infection. The correlation ranges from -0.657 to 0.391, which is positive. Positive implies a strong correlation between the variables.

Table 6: Correlation coefficient of malaria infection among the people across locations

	Location	Season	Negative	Positive
Season	0.00ns			
Negative	−0.306*	−0.333*		
Positive	0.391*	0.259*	−0.657**	
Sex	0.000ns	0.000ns	−0.123ns	0.219*

* = (p<0.05), ** = (p<0.01), *** = (p<0.001), ns = non-significant.

4. Discussion

This study demonstrated distinct seasonal variation in *Plasmodium falciparum* carriage among rural communities in Adamawa State, with significantly higher prevalence during the rainy season. Increased rainfall enhances the availability of mosquito breeding habitats, leading to elevated *Anopheles* mosquito populations and heightened transmission risk. These findings align with other studies in similar ecological zones, which report peak malaria transmission during rainy periods. The study revealed seasonal variation in malaria incidence. The results show that malaria infection was noted throughout the year of study, demonstrating that the infection is widespread in the study areas. Malaria incidence fluctuates throughout the months, due to climatic conditions influencing malaria infection [17]. Malaria infection also varies across locations as revealed in the results. Bazza had a prevalence rate of 43.23%, Mboi is 21.61% and Yebbi 23.18%. The differences in prevalence rates across locations may be attributed to various factors, such as socioeconomics (wealth) and environmental factors [18]. Higher infection rate may be associated with traditional beliefs, poverty, limited knowledge of malaria transmission, and deficient measures to prevent vectors. This is in accordance with the work of Ani [19], who reported that illiteracy and ethnic beliefs among rural dwellers can further encourage the transmission of malaria parasites. The prevalence reported in Mboi and Yebbi communities was similar to the work of Abubakar *et al.* [20], which determined the prevalence of malaria parasites among people residing along the Hadejia River Valley, Jigawa State, Nigeria, reporting 17.5% and 25.4% in Shawara and Dukkun village, respectively. According to the results, *Plasmodium* infection-positive rates confirmed using the microscopy test were higher in females than in males in Bazza (64.70%) and Yebbi (81.28%). However, this result is not in accordance with the research by Oladele *et al.* [21], which found that among patients visiting the Murtala Muhammed Specialist Hospital in Kano, Nigeria, males have a greater frequency of *P. falciparum* than females. In Mboi, the prevalence of *Plasmodium* infection was found to be higher in males (79.60%) than in females (77.05%). This could be that females wear clothes that cover their bodies in the area like in Mboi, thereby limiting the possibility of mosquito bites outdoors; while males usually expose their bodies and usually stay outdoors especially during the hot weather, thereby making them more predisposed to mosquito bites [22] compared to the females who usually stay indoors with their bodies covered [23]. Mosquitoes depend on favorable climate for malaria infection of their hosts [24]. This study showed that the wet season had a significant higher *Plasmodium* infection (39.32%), which is in accordance with increased precipitation, availability of the breeding habitats for the vectors [25]. The presence of adequate vegetation and stagnant water bodies during the wet season increases the transmission of malaria parasites due to availability of the vectors. This agrees with Mattah *et al.* [26] who reported that rainfall favors malaria vector breeding sites. The quality of the environment and types of housing (poor), houses lacking cross-ventilation thereby discouraging the use of mosquito nets (LLINs) because of the heat also add to the factors that favour the proliferation of the malaria vectors and mosquito bites. This reveals the reason why the infection is common during the dry season. Overall, the wet season show 39.00% of *P. falciparum* infection, while the dry season saw 31.99% prevalence, which is in agreement with Yakubu *et al.* [27] who reported 59.44% during the wet season and 49.56% dry season in seasonal variation of malaria prevalence among patients at Bichi General Hospital, Kano, Nigeria. The prevalence of *Plasmodium* infection among the gender are consistent across the study locations. In Bazza, females had a significant higher (64.70%) infection compared to males (46.01%), and similar trend was also observed in Yebbi. This result is contrary to the findings of Oladele *et al.* [21] who reported higher malaria infection in males than the females. However, the results are in in agreement with the work of Ukwubile *et al.* [28] who reported higher prevalence of malaria infection in females (71.4%) than males (49.1%). The prevalence rate of *Plasmodium* infection in Mboi community for males is slightly higher in males 160 (79.60%) as compared to 141 (77.60%) in females. There is no significant difference for the least square mean of malaria infection for the sexes (male 5.278 and female 4.333). However, the least square mean for location and seasons differ significantly (P<0.05) for the malaria infection. For the seasonal variation, the wet season (12.361) was significantly (P<0.05) higher than the dry season (9.917). This result indicates that the malaria infection across all the study areas (Bazza, Mboi, and Yebbi) was higher during the wet season. The Correlation coefficients indicate that the seasonal relationship among sexes did not differ significantly across the location for the infection. The rainfall pattern, temperature, and environmental factors correlate with malaria infection and transmission between seasons (dry and wet) across all the study communities. Although malaria prevalence is high during the wet season, asymptomatic malaria infection acquired during the previous transmission occur [29]. When the rainfall and surface water are unavailable during the dry season, the mosquitoes develop adaptive mechanisms to survive, and this is in accordance with the work of Diniz *et al.* [30]. Asymptomatic carriers of malaria with infected RBCs influence the transmission of infections to the vector host, which is in accordance with the report of Kiattibutr *et al.* [31]. Asymptomatic carriers of malaria are important reservoirs for sustaining malaria transmission for a long time [31].

5. Conclusion

The findings from the prevalence study in Bazza, Yebbi, and Mboi rural communities of Adamawa State highlight important epidemiological patterns of *Plasmodium* infection. On community-level prevalence, it suggests that Bazza and Yebbi have the most malaria-burdened communities among the three, requiring intensified control measures. Again, females were more affected in Bazza and Yebbi, whereas in Mboi, males had slightly higher infection rates. This variation may reflect differences in exposure risks, daily activities, or sociocultural roles across communities. Bazza and Yebbi showed higher infection rates during the wet season, consistent with increased mosquito breeding in rainy conditions. Interestingly, Mboi had higher prevalence in the dry season, which may point to unique ecological or behavioral factors sustaining transmission outside the typical peak season. The observed differences in prevalence across communities, sexes, and seasons underscore the need for location-specific interventions rather than a one-size-fits-all approach. Strengthening vector control, improving access to preventive measures, and tailoring health education to community-specific risk factors will be crucial in reducing malaria transmission in Adamawa State.

6. Recommendations

- **Seasonal Malaria Chemoprevention (SMC):** Implement SMC for vulnerable age groups during high transmission months.
- **Vector Control:** Intensify environmental mosquito control before and during the rainy season.
- **Health Education:** Enhance community awareness on seasonal risk and proper use of preventive measures.
- **Surveillance:** Establish periodic parasitological monitoring to guide adaptive control strategies.

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