International Journal of Entomology Research
www.entomologyjournals.com
ISSN: 2455-4758
Received: 17-07-2026, Accepted: 17-08-2026, Published: 01-08-2026
Volume 11, Issue 3, 2026, Page No. 393-399

Usage pattern and associated factors of natural mosquitoes remedies in endemic communities of Borno State, Nigeria

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DOI: https://doi.org/10.66856/ijer.2026.11.3.11300

Abstract

Background: Malaria remains a severe public health concern in Borno State, Nigeria. While conventional vector control tools face operational hurdles and insecticide resistance, many endemic populations depend heavily on locally sourced botanical remedies. This study aimed to evaluate the prevalence, exact usage patterns, processing modalities, and independent socio-demographic predictors of natural mosquito remedy reliance in the region.

Methods: A multi-stage cross-sectional survey was conducted across three distinct communities (Lagos Street in the Maiduguri Metropolitan Council (MMC) Local Government Area (LGA), Furi and Mairi in the Jere LGA). Households were chosen using systematic random sampling governed by a calculated household jump-interval. Data were collected via face-to-face interviews using a structured questionnaire adapted from the validated World Health Organization (WHO) Malaria Indicator Survey (MIS) instrument, which was peer-reviewed by an expert medical entomologist and translated into the local Kanuri language. Statistical predictors of natural remedy consumption were isolated using Pearson's Chi-square tests and multivariate binary logistic regression modeling.

Results: Of the 450 households, 437 completed the survey (response rate of 97.1%). Natural mosquito remedy utilization was notably high at 68.4% (N = 299). Azadirachta indica (Neem) leaf/seed extract spraying was the most common individual modality (45.9%), followed by Cymbopogon citratus (Lemon Grass) at 31.2%. Indoor fumigation through the thermal combustion of dried plant biomass (C. citratus and Eucalyptus globulus) was practiced by 37.3% of the active users. Alarmingly, 70.6% of users relied exclusively on unstandardized, crude home preparations. Multivariate binary logistic regression confirmed that a rural residential setting (Odds Ratio [OR] = 2.11; 95% CI: 1.34 to 3.32; p = 0.001) and a lower formal educational background (primary school or less) (OR = 1.80; 95% CI: 1.10 to 2.95; p = 0.020) were significant independent predictors of higher botanical remedy reliance.

Conclusion: Natural plant products provide a major, community-driven first line of vector defense in Borno State, particularly among economically vulnerable and rural demographics. However, widespread domestic reliance on unstandardized formulations and indoor biomass burning poses hidden environmental hazards, including severe long-term respiratory health risks and potential vector resistance through sub-lethal dosing. Regional integrated vector management frameworks should capitalize on this high community adoption rate by actively investigating methods to process raw local extracts into safe, standardized, and non-thermal delivery mechanisms (such as non-combustible liquid diffusers or topical creams), while simultaneously ensuring the equitable distribution of conventional long-lasting insecticide-treated nets (LLINs) to high-risk areas.

Keywords: Anopheles, malaria, natural repellents, vector control, biomass burning, public health

Introduction

Mosquitoes are responsible for the transmission of malaria [1, 2], Dengue fever [3], Zika virus [4], Yellow fever [5], Chikungunya [6], Filariasis [7], Japanese Encephalitis [8], and West Nile virus [9]. The World Health Organization (WHO) estimated that half a million people are killed annually through infections transmitted by mosquitoes [10]. Malaria control is crucial for achieving United Nations Sustainable Development Goals (SDGs) 3 and 9 [11]. Current control measures implemented to tackle the adverse effects of malaria in Nigeria include the distribution of Insecticide-Treated Nets (ITNs), Indoor Residual Spraying (IRS), Artemisinin-based Combination Therapies (ACTs), and vaccination (RTS, S) [12].

Despite progress, significant challenges persist, ranging from vector resistance to insecticides and antimalarial drugs [13, 14] to limited access to healthcare services, inadequate funding [15], climate change, and environmental factors [16]. According to the WHO, there were an estimated 236 million malaria cases (95% of global cases) and 590,935 malaria deaths (97% of global deaths) in African member states in 2022, with Nigeria bearing one of the highest diseases loads globally [17, 18]. In 2022, the WHO African region accounted for about 94% of global malaria cases (233 million), with Nigeria alone accounting for 27% of global cases and 31% of all malaria deaths globally [19, 20].

Borno State, located in the North-East geopolitical zone of Nigeria, presents a particularly challenging landscape for malaria control due to high endemicity, internal displacement, insecurity, and limited infrastructure, which restrict the consistent use of conventional tools like ITNs and IRS [21, 22]. The escalating insecticide resistance in *Anopheles* populations, especially to pyrethroids used in ITNs, further necessitates the exploration of complementary control strategies [15, 23]. Historically, local communities have employed plant-based repellents and fumigants due to their accessibility, low cost, and cultural acceptability [24, 25]. Previous studies highlight the potential of various plant extracts and essential oils; for instance, essential oils from Citronella (*Cymbopogon nardus*), Lemongrass (*Cymbopogon citratus*), and Catnip (*Nepeta cataria*) have demonstrated high repellency against *Aedes aegypti* and *Anopheles gambiae* [26, 27, 28]. Likewise, plant extracts from Neem (*Azadirachta indica*), Tulsi (*Ocimum sanctum*), and Basil (*Ocimum basilicum*) have shown significant repellent activity against *Culex* and *Anopheles* mosquitoes [29, 30, 31, 32]. However, a significant knowledge gap exists concerning the actual usage patterns of these products in high-risk areas like Borno State and the respiratory health risks associated with burning dried plant matter indoors [33]. While previous studies have focused primarily on laboratory efficacy, little is known about community adoption, specific plant material preferences, preparation and application modalities, and the socio-demographic factors influencing these choices over conventional methods. The objective of this study was to assess the usage patterns and identify the socio-demographic factors associated with the use of natural repellents and adulticides against mosquito vectors in selected endemic communities of Maiduguri and Jere, Borno State, Nigeria.

Study Area

This cross-sectional, community-based study was conducted in Borno State, Nigeria, between July and September 2024, corresponding to the peak malaria transmission season. To capture a diverse gradient of socio-economic contexts, infrastructure development (Fig 1), and varying baseline access to conventional vector control tools, three distinct communities were purposefully selected across two Local Government Areas (LGAs).

Lagos Street: An urban settlement located within the Maiduguri Metropolitan Council (MMC) LGA.
Furi: A semi-urban community located within the Jere LGA.
Mairi: A rural community also situated within the Jere LGA.

Maiduguri lies within the Ngadda Basin between latitudes 11°45′ N to 11°51′ N and longitudes 13°2′ E to 13°9′ E, featuring an equatorial environment where seasonal variations heavily dictate vector dynamics. The rainy season establishes in June, peaking in August, followed by a prolonged dry season spanning October to May, with temperatures fluctuating from a harmattan low of 15°C to a dry season high of 48°C. The mean annual relative humidity transitions from 40% in dry periods to 60% during the rainy months.

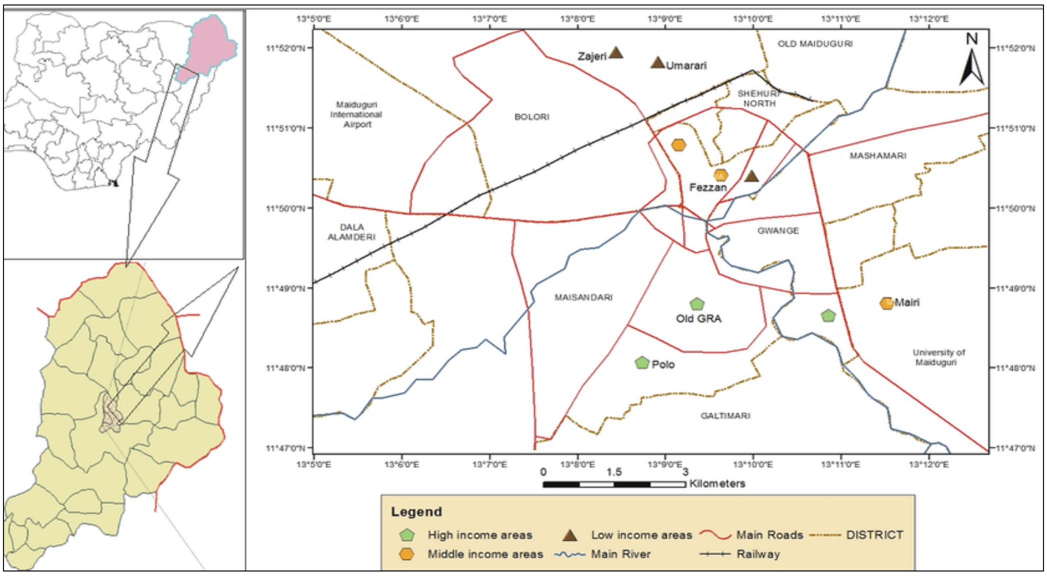

Fig 1: Map of Maiduguri with Selected Communities (Map of Study Area) *(Ref: Kelechi Friday Kwoncha)*

Sampling Size

The minimum required sample size (n) was calculated using Cochran's single population proportion formula:

$$n = \frac{Z^2 . P(1 - P)}{d^2}$$

Where:

- Z is the standard normal deviation at a 95% confidence interval (set at 1.96).
- P is the expected prevalence of natural mosquito remedy utilization, conservatively estimated at 50% (0.50) to yield the maximum variability capability since localized baseline data were unavailable.
- d is the acceptable margin of error or level of precision, set at 5% (0.05).

This yielded an initial base sample requirement of 384 households. To safeguard the statistical power of the study against missing data, incomplete responses, or field attrition, an anticipated 15% non-response rate was factored in, establishing a final targeted study sample size of 450 households.

Sampling Structure and Participant Selection

A robust multi-stage random sampling was deployed to eliminate cluster biases across the region. The target LGAs (MMC and Jere) were demarcated, and the index communities (Lagos Street, Furi, and Mairi) were selected based on their urban-rural classification designations.
Within each designated community zone, constituent administrative wards and sub-settlements were randomly cataloged using simple random sampling.

Households within the selected settlements were chosen using systematic random sampling governed by a calculated household jump-interval (k). The sampling interval was determined independently for each community cluster by dividing the total estimated household count within the settlement boundary by its proportionally allocated sample size quota ($k = N/n$). Field teams established a central, recognizable community landmark as a random starting point, determined a baseline directional vector via a coin-flip mechanism, and subsequently approached every k-th household along the designated trajectory.

Within each selected household, the eligible respondent was strictly defined as the household head or the primary designated caregiver who was at least 18 years of age and provided informed consent. If a selected household was unavailable or declined participation, the immediate adjacent household was substituted.

Questionnaire Design, Validity, and Pre-testing

Data collection was executed utilizing a highly structured, interviewer-administered questionnaire specifically adapted from the standardized World Health Organization (WHO) Malaria Indicator Survey (MIS) instrument. Adaptations were meticulously applied to expand sections tracking localized ethnobotanical practices, traditional adulticide applications, and specific plant processing methods relevant to the Northeastern Nigerian context. The finalized instrument was partitioned into four structurally distinct modules:

1. Socio-demographic characteristics, capturing age, gender, educational attainment, household income, residential setting, and household headship status.
2. Knowledge, ownership, and utilization patterns of conventional vector control interventions, primarily focused on Insecticide-Treated Nets (ITNs) and Indoor Residual Spraying (IRS).
3. Consumption patterns of natural plant-based mosquito remedies, tracking specific botanical taxonomies, acquisition sources, exact preparation forms, application frequencies, and localized target deployment sites.
4. Community-perceived therapeutic efficacy, administrative satisfaction, and perceived safety profiles regarding indoor botanical deployment.

To establish rigorous content and face validity, the initial English draft of the instrument was subjected to a formal expert panel review led by a Professor of Medical Entomology who is of Kanuri descent, at the University of Maiduguri. This review evaluated the technical precision of the botanical nomenclature, the epidemiological relevance of the behavioral metrics, and the overall clarity and operational flow of the questions.

To ensure linguistic accuracy and minimize cultural-response biases during field deployment, the validated instrument underwent a rigorous translation workflow. The questionnaire was translated from English into Kanuri, the dominant local language of the sampled communities by an advanced public health researcher (M.Sc. graduate of Biotechnology University of Maiduguri) of native Kanuri descent. This ensured that complex entomological and epidemiological concepts were rendered with exact semantic and contextual equivalence.

Prior to full-scale deployment, a pilot study was conducted among a cohort representing 10% of the targeted sample size ($n = 45$ households) within a neighboring community in Jere LGA (Gomari Costin) that exhibited identical socio-demographic features but was strictly excluded from the final analysis. This pre-testing phase was utilized to evaluate field logistics, determine the average administration time per household, and statistically evaluate internal reliability and clarity. The pilot feedback demonstrated exceptional face validity, high baseline comprehensibility, and zero conceptual ambiguity among respondents. Consequently, no structural or linguistic modifications were required, confirming the instrument's stability and field readiness prior to the commencement of primary data collection.

Study Variables

To evaluate the epidemiological and socio-demographic drivers of community-driven vector control, variables were operationally defined and coded within the statistical software prior to modeling:

1. **Dependent Variable:** The primary outcome was the utilization status of natural plant-based mosquito remedies, measured as a binary categorical variable (*Yes* (Current/Past User) vs. *No* (Non-User)).

2. **Independent Variables:** Based on baseline socio-demographic tracking, the independent variables included:

- ***Geographic Location:*** Coded bivariately as Rural (Mairi and Furi communities) vs. Urban (Lagos Street).
- ***Educational Attainment:*** Dichotomized into Low Educational Level (Primary school completion or less) vs. High Educational Level (Secondary school attainment or higher).

Statistical Analysis

Raw field data were checked for completeness, double-entered into Microsoft Excel to ensure data integrity, and subsequently exported to the Statistical Package for the Social Sciences (SPSS) version 26.0 for formal statistical evaluation.

Descriptive statistics, comprising absolute frequencies (N) and percentages (100%), were calculated to summarize the cohort's socio-demographic profiles, preferred plant taxonomies, preparation types, and specific application methodologies. Bivariate analyses were performed using Pearson's Chi-square (χ^2) tests of independence to evaluate the association between categorical socio-demographic factors and natural product consumption patterns.

Variables demonstrating statistically significant associations in the bivariate cross-tabulations ($p < 0.05$) were simultaneously entered into a multivariate Binary Logistic Regression model. This allowed for the calculation of adjusted Odds Ratios (OR) and corresponding 95% Confidence Intervals (CI) to isolate independent predictors of natural remedy reliance while controlling for confounding effects. For all statistical procedures, two-tailed significance thresholds were strictly set at $\alpha = 0.05$ ($p < 0.05$).

Socio-Demographic Characteristics of Respondents. Of the 450 structured questionnaires originally distributed across the sampled communities, 437 were fully completed and returned, yielding an overall response rate of 97.1%.

The comprehensive socio-demographic profile of the study cohort is detailed in Table 1. The descriptive analysis reveals that more than half of the participants resided in rural designations (55.0%, n = 240), while the remainder were distributed across urban and semi-urban settings. A majority of the respondents identified as female (61.8%, n = 270) and held status as the primary household head (75.3%, n = 329). In terms of educational attainment, a substantial proportion of the study population reported low formal literacy levels, with 42.1% (n = 184) having completed only a primary school education or less.

Table 1: Socio-Demographic Characteristics of Respondents (N = 437)

Socio-Demographic Variable	Category	Frequency (*n*)	Percentage (%)
Gender	Female	270	61.8%
Household Status	Household Head	329	75.3%
Education Level	Primary school education or less	184	42.1%
Residential Setting	Rural	240	55.0%

Prevalence and Taxonomies of Natural Product Usage

The community reliance on natural alternatives for malaria vector control was remarkably high within the study area. Out of the 437 total respondents analyzed, 299 individuals reported active current or past use of botanical remedies, establishing a localized prevalence rate of 68.4%. This cohort of users formed the active consumer subsample (N = 299) utilized to evaluate targeted plant preferences and application mechanics (Table 2).

Ethnobotanical tracking demonstrated that *Azadirachta indica* (Neem) was the single most dominant natural product utilized in the region, favored by 45.9% (n = 137) of active users. *Cymbopogon citratus* (Lemon Grass) emerged as the second most prevalent choice at 31.2% (n = 93), followed by *Ocimum gratissimum* (African Basil) at 12.7% (n = 38). Conversely, *Eucalyptus globulus* (Eucalyptus) was the least common botanical remedy, cited by only 6.1% (n = 18) of the active user population.

Table 2: Taxonomies and Prevalence of Natural Products Among Active Users (N = 299)

Natural Product / Botanical Source	Frequency (n)	Percentage of Users (%)
Azadirachta indica (Neem)	137	45.9%
Cymbopogon citratus (Lemon Grass)	93	31.2%
Ocimum gratissimum (African Basil)	38	12.7%
Eucalyptus globulus (Eucalyptus)	18	6.1%

Preparation Dynamics and Application Modalities

The structural processing methods and home delivery mechanisms of these botanicals were highly plant-specific (Table 3). Spraying liquid leaf or seed extracts was the most frequent application mechanism, accounting for 45.9% of total usage—driven entirely by the *A. indica* user segment. Indoor fumigation through the combustion of dried plant matter also represented a major exposure pathway, combining *C. citratus* (31.2%) and *E. globulus* (6.1%) to constitute 37.3% of cumulative community applications.

Direct topical application of crushed fresh leaves rubbed onto exposed skin surfaces was confined strictly to *O. gratissimum* users (12.7%).

Regarding safety and quality standardization, an overwhelming majority of the consumer cohort (70.6%, n = 211) relied exclusively on crude home preparations characterized by unstandardized, manual crushing or raw biomass burning. Only 29.4% (n = 88) of respondents utilized commercial or pre-processed formulations.

Table 3: Preparation Types and Application Methods of Natural Products (N = 299)

Application & Processing Metric	Category / Operational Description	Frequency (n)	Percentage of Users (%)
Extract Spray	Leaf/seed extract fluid (*A. indica*)	137	45.9%
Indoor Fumigation (Burning)	Smoke from dried leaves (*C. citratus, E. globulus*)	112	37.3%
Topical Application	Crushed fresh leaves rubbed on skin (*O. gratissimum*)	38	12.7%
Crude Home Preparation	Unstandardized manual crushing or burning	211	70.6%
Commercial Formulations	Standardized or pre-processed retail purchases	88	29.4%

Socio-Demographic Predictors of Natural Product Reliance

Bivariate analysis revealed significant behavioral divergences across geographic lines, with daily botanical deployment being significantly more concentrated among rural respondents (65.0%) than urban respondents (35.0%; $\chi^2 = 18.5$, $p < 0.001$).

To isolate independent predictors of natural remedy reliance while adjusting for confounding variables, significant demographic factors were modeled using multivariate binary logistic regression (Table 4). The model confirmed that geographic setting was a powerful, independent driver of behavior: individuals residing in rural areas were over twice as likely to rely on natural products for mosquito control compared to their urban counterparts (Odds Ratio (OR) = 2.11; 95% CI: 1.34 to 3.32; p = 0.001).

Furthermore, household educational background played a pivotal role in vector control choices. Respondents with a lower educational background (attaining a primary school education or less) were 1.8 times more likely to exploit these unstandardized natural remedies than those possessing higher educational credentials (OR = 1.80; 95% CI: 1.10 to 2.95; p = 0.020).

Table 4: Logistic Regression Predicting Community Reliance on Natural Mosquito Remedies

Predictor Variable	β	S.E.	Wald χ2	p-value	Odds Ratio (OR)	95% CI for OR
Rural vs. Urban Setting	0.749	0.231	10.51	0.001	2.11	(1.34, 3.32)
Low Ed. vs. High Ed.	0.587	0.252	5.43	0.020	1.80	(1.10, 2.95)

β = Regression coefficient, S.E = Standard error, CI = Confidence interval.

Discussion

This study confirms that natural plant products are a major, community-driven component of mosquito vector control in Maiduguri, Borno State, Nigeria, with over two-thirds of households (68.4%) reporting current or past usage. The high reliance observed, particularly in rural settings (55.0%), likely stems from socio-economic factors critical to the region: low cost, immediate local accessibility, and high levels of structural or economic displacement that often make obtaining conventional, subsidized insecticide-treated nets (ITNs) and commercial repellent sprays inconsistent.

The distinct prominence of *Azadirachta indica* (Neem) and *Cymbopogon citratus* (Lemon Grass) as the preferred choices aligns closely with regional ethnobotanical literature, which has demonstrated their high repellent and larvicidal properties in controlled laboratory settings [27, 29]. However, the breakdown of usage patterns introduces an important nuance for public health strategies. While leaf/seed extract spraying was the most frequent single application method (45.9%, driven entirely by Neem users), the widespread practice of indoor fumigation via burning dried plant matter (comprising 37.3% of users across Lemon Grass and Eucalyptus) presents a complex public health trade-off.

Although burning dried biomass is a simple, cost-effective adulticide method favored by communities, the resulting regular inhalation of indoor smoke poses documented risks to long-term respiratory health, particularly for vulnerable demographics like young children and the elderly [33]. Toxicologically, the incomplete combustion of raw botanical materials inside poorly ventilated domestic environments releases a hazardous matrix of air pollutants, including ultra-fine particulate matter (PM2.5), carbon monoxide (CO), polycyclic aromatic hydrocarbons (PAHs), and volatile organic compounds (VOCs). Chronic exposure to these combustion byproducts triggers severe mucosal and pulmonary inflammation, which is epidemiologically linked to an increased incidence of Acute Respiratory Infections (ARIs), Chronic Obstructive Pulmonary Disease (COPD), and the exacerbation of bronchial asthma.

This environmental health hazard is severely amplified by the housing architecture common to rural communities in Borno State, where domestic spaces often feature mud walls, thatched roofs, and highly restricted ventilation windows. Because botanical fumigation is primarily conducted during evening and night hours to target nocturnal *Anopheles* vectors, the trapped smoke continuously exposes occupants during sleep. Young children who possess developing pulmonary architecture and higher baseline metabolic rates experience a disproportionate relative dose of these inhaled toxins, significantly compounding their clinical risk of developing severe, life-threatening pneumonia.

Furthermore, because 70.6% of active users rely entirely on unstandardized, crude home preparations, the active ingredient concentration remains completely unknown. This lack of uniformity leads to variable and potentially sub-lethal efficacy during home deployment, which could inadvertently contribute to localized insecticide resistance among local *Anopheles* populations.

The strong statistical association between rural residence (OR = 2.11, p = 0.001) and lower educational attainment (OR = 1.80, p = 0.020) with a higher reliance on these botanicals reinforces the notion that natural alternatives function as a primary line of defense for the most economically vulnerable populations. This highlights a critical need for targeted public health interventions. Instead of dismissing these deeply embedded community strategies, regional vector control programs should investigate methods to optimize and standardize the preparation of the most effective local botanicals. Translating raw Neem, Lemon Grass, or Eucalyptus extracts into non-thermal distribution mechanisms such as safer, regulated topical creams, stable aqueous liquid sprays, or non-combustible diffusers would preserve community-driven vector control while completely eliminating the hazardous indoor biomass smoke exposure pathway. Concurrently, efforts must be doubled to guarantee that conventional, standardized vector control tools are distributed consistently to these high-risk areas.

Limitations

While this study provides critical foundational insights into community-driven vector control in Northeastern Nigeria, the findings acknowledged several limitations:

1. **Lack of Phytochemical and Entomological Validation:** This study evaluated behavioral usage patterns but did not include laboratory-based chemical profiling of the active ingredients within the crude home preparations, which were used by 70.6% of the active users. Consequently, we could not empirically quantify the volatile oil yields or determine the exact entomological efficacy (e.g., spatial repellency or knockdown rates) of these localized applications against local *Anopheles* populations.

2. **Geographic and Generalizability Constraints:** Due to logistical realities and the unique security landscape of Borno State, sampling was strategically confined to three selected communities within the Maiduguri Metropolitan Council (MMC) and Jere Local Government Areas (LGAs). While these sites perfectly captured an urban-to-rural socio-economic gradient, the findings may not be entirely generalizable to more remote or volatile agrarian districts across the wider Lake Chad basin region.

3. **Temporal and Seasonal Scope:** Data collection was conducted strictly between July and September, capturing behavioral dynamics exclusively during the peak wet-season malaria transmission cycle. As a result, this study may not fully reflect potential seasonal shifts, alterations in botanical availability, or changing household compliance patterns that occur during the long dry and harmattan months.

Conclusion

This study demonstrates that the utilization of natural plant-based repellents and adulticides is a highly prevalent approach to mosquito control in Maiduguri and Jere Local Government Areas of Borno State, Nigeria. With an overall usage prevalence of 68.4%, these botanical remedies primarily *Azadirachta indica* (Neem) and *Cymbopogon citratus* (Lemon Grass) serve as a primary line of vector defense. The widespread community reliance on crude, unstandardized home preparations (70.6%) and thermal indoor fumigation via burning dried biomass (37.3%) poses significant public health challenges. While these practices offer low-cost, immediate vector relief, they expose household occupants particularly the vulnerable to hazardous indoor air pollutants and chronic respiratory risks. Lack of uniformity in crude extractions risks delivering sub-lethal active ingredient dosages, which may inadvertently accelerate localized insecticide resistance within local *Anopheles* vector populations.

The high community adoption rate of these botanicals represents a unique, underutilized opportunity for regional malaria control programs. Rather than dismissing these deeply embedded ethnobotanical strategies, public health and state ministries of health should actively integrate safe, standardized, and scientifically validated natural product formulations into the broader regional Integrated Vector Management (IVM) Program. Future policy initiatives should prioritize processing raw local botanicals into stable, non-thermal application methods such as regulated topical creams, aqueous liquid sprays, or non-combustible diffusers thereby preserving community-driven vector control while completely eliminating the hazardous indoor biomass smoke exposure pathway. Simultaneously, structural efforts must be intensified to ensure the consistent, equitable distribution of conventional vector control tools, such as long-lasting insecticide-treated nets (LLINs), to these vulnerable, high-risk populations.

Ethical Considerations

Ethical approval for this study was obtained from the Head of the Department of Zoology, University of Maiduguri, Borno State, Nigeria, and the Health Research Ethics Committee of the Borno State Ministry of Health. Verbal informed consent was secured from every participant before interviews commenced, and strict participant anonymity and data confidentiality were maintained throughout the research process.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors. Authors were supported by personal funds.

Authors' contributions

Raphael Kawep Njapdze conceptualized and designed the study, developed the structured survey questionnaire, performed the field data curation across the selected communities, and drafted the original manuscript.

Idorenyin Bassey Ekerette contributed to the methodology design, conducted the statistical analyses (including chi-square tests and binary logistic regression modeling).

Dorathy Uduak Inyang assisted in the validation and synthesis of the survey data, and critically reviewed and edited the manuscript for intellectual content.

All authors read and approved the final version of the manuscript.

References

1. World Health Organization. World malaria report 2021. World Health Organization, 2021, 1–322.
2. World Health Organization. Malaria fact sheet. World Health Organization, 2024, 1–8.
3. Centers for Disease Control and Prevention. Dengue clinical guidance. Centers for Disease Control and Prevention, 2024, 1–5.
4. World Health Organization. Zika virus fact sheet. World Health Organization, 2024, 1–6.
5. World Health Organization. Yellow fever fact sheet. World Health Organization, 2024, 1–6.
6. Centers for Disease Control and Prevention. Chikungunya virus overview. Centers for Disease Control and Prevention, 2024, 1–4.
7. World Health Organization. Lymphatic filariasis (Fact sheet No. 102). World Health Organization, 2020, 1–5.
8. World Health Organization. Japanese encephalitis fact sheet. World Health Organization, 2024, 1–5.
9. Centers for Disease Control and Prevention. West Nile virus disease. Centers for Disease Control and Prevention, 2024, 1–4.
10. World Health Organization. World malaria report 2023: Estimated malaria cases and deaths in African member states. World Health Organization, 2023, 12–15.
11. United Nations Development Programme. Malaria and the Sustainable Development Goals. United Nations Development Programme, 2020, 1–12.
12. World Health Organization. Malaria burden and control measures. World Health Organization, 2020, 1–10.
13. Ranson H, Lissenden N, Pluess B. Insecticide resistance in mosquito vectors of malaria. Lancet Infectious Diseases,2020:20(8):e27–e37.
14. Ogungbola OF, Oduola OT, Oyeniyi AT. Assessment of insecticide resistance status in Anopheles gambiae in Nigeria. Malaria Journal,2021:20(1):45–54.
15. Federal Ministry of Health. National Malaria Strategic Plan 2021–2025. Federal Ministry of Health Nigeria, 2022, 1–88.
16. Suleiman MM, Aminu YS, Musa AA. The effect of dry periods on mosquito breeding sites. International Journal of Environmental Research and Public Health,2022:19(18):11847–11855.
17. World Health Organization. World malaria report 2023. World Health Organization, 2023, 1–210.
18. Kumar S, Chaurasia SK, Gupta KK. A review on mosquito control methods: chemical, biological, and physical approaches. Environmental Science and Pollution Research International,2023:30(3):5701–5715.
19. World Health Organization. World malaria report 2023: Global malaria cases and deaths. World Health Organization, 2023, 20–23.
20. World Health Organization. World malaria report 2023: Malaria incidence and mortality rates. World Health Organization, 2023, 30–33.
21. Marte RA. Maiduguri: an oasis in the Sahel. Nigerian Geographical Journal,1986:29(1-2):15–28.
22. World Health Organization. The health situation in Borno State, Nigeria. World Health Organization, 2018, 1–4.

23. Isman MB. Botanical insecticides in the twenty-first century: Challenges and opportunities. Crop Protection,2018:107:115–121.
24. Minijas R, Sarda P. Larvicidal properties of Swartzia madagascariensis extract against Anopheles gambiae and Aedes aegypti. Journal of Agricultural and Food Chemistry,1986:34(5):811–814.
25. Mabaso MLH, Mfune RL, Mshana SE. The current status of traditional herbal medicines in the control of malaria. African Journal of Traditional, Complementary and Alternative Medicines,2017:4(1):1–10.
26. Tawatsin A, Wratten SD, Gibson G. Repellency of essential oils from guava and fingeroot rhizomes against mosquitoes. Journal of Vector Ecology,2006:31(2):281–289.
27. Zhang W, Li N, Wang J. High repellency of Nepeta cataria essential oil against Anopheles gambiae. Pest Management Science,2022:78(4):1481–1488.
28. Kumar S, Dubey NK, Saxena RK. Essential oils of Cymbopogon nardus and C. citratus: repellency against Aedes aegypti and Anopheles gambiae. Journal of Vector Ecology,2020:45(2):256–263.
29. Singh S, Maurya P, Tripathi AK. Repellent activity of Azadirachta indica and Ocimum sanctum extracts against Culex pipiens. Journal of Medical Entomology,2021:58(5):2045–2053.
30. Oliveira M, Santos M, Pereira M. Ocimum basilicum extract as a natural mosquito repellent. PLoS ONE,2023:18(9):e0287812–e0287820.
31. Lee B. Essential oils from medicinal plants: mortality effects on A. aegypti, C. pipiens and C. pallens. Journal of Medical Entomology,2006:43(5):885–891.
32. Sujatha C, Mohankumar J, Govindarajan M. Larvicidal efficacy of Citrus medica and Madhuca longifolia extracts against Anopheles stephensi. Journal of Vector Borne Diseases,1988:25(3):141–144.
33. Barnes BR, Roberts MJ, Green TL. Indoor air pollution from domestic fires and respiratory health. Environmental Health Perspectives,2019:127(4):047001–047010.