ISSN: 2643-461X

Nyasvisvo et al. Int J Trop Dis 2024, 7:076
DOI: 10.23937/2643-461X/1710076
Volume 7 | Issue 1
Open Access

International Journal of
Tropical Diseases

REVIEW ARTICLE

Natural Plant-Based Mosquito Repellent Products: A Potential Complementary Tool for Malaria Vector Control Intervention and Elimination in Zimbabwe

David Singleton Nyasvisvo[1*], Tamuka Nhiwatiwa[1,2], Rudo Sithole[1] and Shadreck Sande[3]

[1]*Department of Biological Sciences and Ecology, University of Zimbabwe, Mt. Pleasant, Harare, Zimbabwe*

[2]*University Lake Kariba Research Station, Kariba, Zimbabwe*

[3]*Zimbabwe Assistance Program in Malaria, Suite 1 & 2 House East Westgate Complex, Harare, Zimbabwe*

***Corresponding author:** *David Singleton Nyasvisvo, Department of Biological Sciences and Ecology, University of Zimbabwe, Mt. Pleasant, Harare, Zimbabwe*

Abstract

Malaria claims millions of lives globally and it is an important public health threat in Zimbabwe where more than half of the population is at risk of contracting it annually. This paper reviews published data on the evaluation of natural plant-based mosquito repellent products for malaria vector control intervention in Zimbabwe and proposes enhanced assessments of several plants with mosquito-repellent properties given the necessity of new products to prevent malaria in the country. Chemical-based vector control intervention is an important strategy to reduce malaria morbidity in moderate to high transmission settings in Zimbabwe. Yet, increasing insecticide resistance coupled with behavior changes in mosquitoes and humans suggest that the benefits of chemical-based malaria vector control intervention may soon and be seriously undermined in most regions of the country. A systematic literature search was conducted on Google and Google Scholar search engines and Medline database using the following key phrases, "ethnobotanical surveys, Zimbabwe", "plant extracts for mosquito control, Zimbabwe", and "evaluation of plant-based mosquito control products, Zimbabwe". The search yielded 10 articles that were published between 1990 and 2022 and were eligible for this review. More than 15 plants were evaluated and reported effective at repelling mosquitoes in Zimbabwe. However, shorter protection periods were reported when compared to standard synthetic repellents. Different methodologies were used for extracting plant volatile compounds and in the estimation of repellency. Inadequate documentation of plants traditionally used for repelling mosquitoes and the development of natural plant-based mosquito repellents in the country were important gaps. We make recommendations for more ethnobotanical surveys for the documentation of additional plants used for repelling mosquitoes in malaria-endemic parts of Zimbabwe and standardization of protocols for the development of safer, cost-effective, and environmentally friendly natural plant-based mosquito repellent products that will complement the main malaria vector control tools as part of an integrated vector management (IVM) strategy for the country. The production of such products locally would lessen the burden of the high-cost importation of chemical-based mosquito repellent products and create employment for locals.

Keywords

Malaria, Repellent, Chemical-based, Plant-based, Integrated vector management, Zimbabwe

Abbreviations

IRS: Indoor Residual Spraying; ITN; Insecticide Treated Bednet; IVM: Integrated Vector Management; SADC: Southern African Development Community; WHO: World Health Organization

Introduction

Malaria, though preventable and treatable, is a very complex infectious and life-threatening disease that directly affects human health and imposes a heavy socio-economic burden on poor countries. It is prevalent in the tropical and sub-tropical regions of the world with about 50% of the world's population at risk of contracting the disease [1]. Young children, pregnant women, and non-immune travelers from malaria-free areas are the most vulnerable. Malaria

Citation: Nyasvisvo DS, Nhiwatiwa T, Sithole R, Sande S (2024) Natural Plant-Based Mosquito Repellent Products: A Potential Complementary Tool for Malaria Vector Control Intervention and Elimination in Zimbabwe. Int J Trop Dis 7:076. doi.org/10.23937/2643-461X/1710076

Accepted: March 11, 2024; **Published:** March 13, 2024

is caused by the protozoan *Plasmodium* parasite and is transmitted through the bite of an infected female *Anopheles* mosquito. There were an estimated 247 million cases and 619,000 deaths in 2021, 95% of cases and deaths occurred in sub-Saharan Africa and mostly in children below the age of 5 years [1]. An estimated 35 million children under 5 and over 8 million pregnant women are at risk of contracting malaria in the World Health Organization (WHO) African region each year [2]. Malaria is a risk to over 75% of the Southern African Development Community (SADC) population [3]. With an estimated population of 390 million people, SADC is a 16-member organization for countries in eastern and southern Africa [3,4].

Zimbabwe is a lower-middle-income country in southern Africa with an estimated population of around 16 million people, 79% of whom are at risk of contracting malaria [4-6]. The primary malaria vectors are *Anopheles gambiae*, *An. arabiensis* and *An. funestus* [7-9] while the predominant malaria parasite is *Plasmodium falciparum* which accounts for over 98% of all reported malaria cases [10]. There has been no downward trend in recent years as the annual number of reported malaria cases has been fluctuating between 250,000 and 500,000 cases [11]. According to WHO [12], vector control is an important component of integrated malaria control and elimination programs. The core malaria vector control intervention strategies in Zimbabwe are insecticide-based indoor residual spraying (IRS) and insecticide-treated bed nets (ITNs) [13]. While effective, IRS and ITNs are intra-domiciliary and predominantly target indoor biting and resting vectors. Larval control, using chemical and biological larvicides, is undertaken to supplement IRS and ITNs in areas where a high proportion of the anopheline breeding sites within the malaria vectors' flight range of the community to be protected are few, fixed, findable, and manageable [12,13]. Larval control affects only vector density and longevity and requires a high coverage to be effective [14]. Insecticide resistance has been recorded amongst the primary malaria vectors in the country with the potential to reverse all the gains made towards controlling and eliminating malaria in the country [15]. In addition to insecticide resistance, chemical insecticides have negative effects on both human health and the environment.

Outdoor malaria transmission and growing levels of insecticide resistance are a threat to the efficacy of IRS and ITNs in Zimbabwe. To meet set disease reduction and elimination targets, new sustainable and alternative tools that are more locally driven and target-specific are required to be used in an IVM context and provide a valuable supplement to the core malaria intervention strategies in the country. The country can accelerate efforts toward malaria elimination through new interventions (tools, technologies, and approaches) that are tailored to the local context. Several existing tools that are underdeveloped or underexploited can be rapidly mobilized to enable the implementation of far more diverse, cost-effective, and sustainable malaria vector control strategies in the country. One such strategy is the use of natural plant-based products for malaria vector control.

Repellents are recognized by the WHO as a useful disease prevention tool to complement IRS and ITNs in malaria vector control [16,17]. Topical repellents confer protection against outdoor-biting vectors [17]. However, synthetic mosquito repellents used for malaria vector control are non-biodegradable in nature, expensive for everyday use, have high toxicity and safety concerns, and can cause irreversible damage to the environment [16,18]. In comparison, plant-based mosquito repellents are generally target-specific, biodegradable, inexpensive, environmentally friendly, readily available, widely accepted by the public, and relatively non-toxic to humans [17,19]. Plant-based mosquito repellents can play a unique role in preventing mosquito bites in low-income communities, reduce the level of malaria transmission in areas with day-biting, and exophagic vectors, and push the country toward the goal of malaria elimination.

Plant essential oils have better mosquito repellent efficacy compared to plant extracts but are however unsuitable for use as sole mosquito repellents because of their poor longevity since they are highly volatile [19]. Plant extracts and essential oils can be increasingly studied, evaluated, and ameliorated to serve as environmentally friendly and safer alternatives to synthetic repellents. Plants that have traditionally been used for killing or repelling mosquitoes either as extracts or as whole plants in many parts of the world include *Citronella winterianus* (Citronella), *Lippia javanica* (Zumbani), *Tagetes erecta* (Marigold), *Lavandula angustifolia* (Lavender), *Cymbopogon citratus* (Lemon grass) and *Salvia rosmarius* (Rosemary) [16,18].

In Zimbabwe, people in malaria-endemic communities use local ethnomedicinal plants to repel mosquitoes and other nuisance insects [20]. This, therefore, means that some local plants have mosquito-repellent properties that could be studied, evaluated, and used as part of vector control interventions in the country. The local development of natural plant-based repellents that are environmentally friendly and safe for public use, with more effective long-lasting protection is of paramount importance to the country for the innovative implementation of IVM for malaria prevention and control.

We reviewed the literature on studies on the evaluation of natural plant-based mosquito repellent products for malaria vector control in Zimbabwe. The aim was to summarise current knowledge and highlight gaps that require further research for the generation of new knowledge and products for accelerating progress toward malaria elimination in the country.

Materials and Methods

We conducted a literature review on the evaluation of natural plant-based products for malaria vector control interventions in Zimbabwe. A systematic literature search was conducted on Google and Google Scholar search engines and Medline database using the following key phrases, "ethnobotanical surveys, Zimbabwe", "plant extracts for mosquito control, Zimbabwe", and "evaluation of plant-based mosquito control products, Zimbabwe". A manual search was also performed by analyzing the references of the included articles. The search yielded 10 articles that were eligible for this review since it was refined to manuscripts that reported on the evaluation of natural plant-based products for malaria vector control in Zimbabwe covering the period 1990 to 2022. The exclusion criteria were preliminary reports and articles that were not available in full.

Results and Discussion

Studies conducted revealed that people in rural and malaria-endemic communities in Zimbabwe use different mosquito repellent plants for protection against mosquito bites and to prevent malaria infection. For instance, it was reported in a study to assess peoples' perceptions and knowledge about malaria transmission and control with special reference to the use of plants as mosquito repellents at the Mandeya ward in Honde Valley of Mutasa district in Manicaland Province that 24% of study participants applied plant extracts to their skin as mosquito repellents [21]. Similarly, a study to establish what rural people use to repel mosquitoes in the absence of modern products held in Buhera District, Manicaland Province revealed that people in this rural community traditionally used plants such as *Colophospermum mopane, Dicoma anomala,* and *L. javanica* to repel mosquitoes [22]. This is substantial evidence to suggest that mosquito-repellent plants provide a prophylactic measure for protection against mosquito bites and malaria infection to individuals and communities in the country. The use of plants for protection against mosquito bites is a common practice in Africa where before the advent of synthetic insecticides and repellents people traditionally used plant and plant-derived materials to repel or kill mosquitoes [23]. The inhabitants of Ethiopia, South Africa, Nigeria, Kenya, and Tanzania traditionally used 64 plant species belonging to 30 families as repellents against mosquitoes, with aromatic plants such as *Citrus* spp, *Eucalyptus* spp, *Lantana camara*, *Ocimum* spp, and *Lippia javanica* being the most used plants [24].

Ethnobotanical surveys are required to document additional plants that are used or were traditionally used for repelling mosquitoes by communities in malaria-endemic areas of the country. Such documentation will add to a growing base of knowledge on the diverse options and directions for the utilization of plants and plant-based compounds in the management of disease vectors, including mosquitoes in the country. The documented mosquito-repellent plants would warrant protection from abuse and extinction and communities would be encouraged to assist in their conservation. The most commonly used methods for protection against mosquito bites in Africa are the production of repellent smoke from burning plants, hanging plants inside the house, sprinkling leaves on the floor, and use of plant oils, and juices from crushed fresh parts of the plants and the application of extracts on uncovered body parts [24]. It is also important to document the traditional methods of application of plants in killing or repelling mosquitoes in the country for future reference and research purposes.

Smoke and herbal derivatives of more than 15 plants, consisting of both indigenous and exotic ones, were evaluated as mosquito repellents and mosquitocides and reported effective against *Aedes aegypti*, *Anopheles gambiae* sensu stricto (s.s.) and *Anopheles arabiensis* mosquitoes in Zimbabwe (Table 1). Essential oils from three plants namely *Artemisia afra* (Asteraceae), *Lantana angiolensis* (Verbenaceae), and *Syzygium huillense* (Myrtaceae) were also evaluated and found ineffective in inhibiting mosquito biting [31]. This demonstrates that experimental validation can confirm the claims of mosquito repellency by the communities and is important in ensuring the preservation of effective plant species and the promotion of the traditional ways of malaria control as sustainable malaria transmission control tools in remotely located communities. It can also render useless some plant species that are perceived to have mosquito-repellent properties by the communities.

Only one study in this review evaluated the effect of smoke on killing or repelling mosquitoes. The use of smoke is a common traditional method of repelling biting mosquitoes throughout the world [18]. More field-based experimental studies on the evaluation of the insecticidal properties of smoke generated from burning different mosquito-repellent plants in repelling or killing mosquitoes are recommended in the country. This would validate the claims of communities regarding the effect of smoke in repelling or killing mosquitoes and promote the use of smoke from burning mosquito-repellent plants as an effective and conventional method of repelling or killing mosquitoes in the country.

The leaf was the main part of the plant used in the preparation of repellents in most of the studies and most of the plants were from families rich in essential oils. The prominent application of leaves for most repellent plants is due to the readily available volatile compounds in leaves [32]. Different concentrations of extracts were used in all the studies that *Ae. aegypti* were used as test mosquitoes complicating the interpretations of

Table 1: Summary of studies on the evaluation of plant products for mosquito control in Zimbabwe from 1990 to 2022.

Author [Reference]	Objectives	Study area	Plant species used	Plant part used	Mosquito species tested	Method	Result
Lukwa, et al. [25]	To evaluate the effectiveness of *Lippia javanica* and *Ocimum canum* as larvicides	Kamhororo, Gokwe South district, Midlands Province	*L. javanica* and *O. canum*	Leaves	*An. gambiae* s.s. larvae	WHO susceptibility tests	Plant larvicides were effective against *An. gambiae* s.s. mosquito larvae
Lukwa, et al. [26]	To determine the major constituents of *Lippia javanica* leaf extracts and their repellency against laboratory-reared *Aedes aegypti* mosquitoes	Musana Communal lands in Bindura district, Mashonaland Central Province	*L. javanica*	Leaves	*Ae. aegypti* adult mosquitoes	Arm-in-cage experiments	Leaf extracts of *L. javanica* were effective at repelling *Ae. aegypti* mosquitoes
Kazembe and Jere [22]	To investigate the effectiveness/efficacy of ethanolic extracts of *Colophospermum mopane*, *Dicoma. anomala* and *Lippia javanica* and their mixtures in repelling *Aedes aegypti* mosquitoes	Buhera district, Manicaland Province	*C. mopane*, *D. anomala* and *L. javanica*	Leaves	*A. aegypti* adult mosquitoes	Arm-in-cage experiments	Higher repellencies were observed for extract mixtures than for individual plant extracts.
Kazembe and Nkomo [20]	To evaluate the repellency and mosquitocidal effects of extracts from plants *Blumea alata, Bidens pilosa* and *Chenopodium ambrosioides* against *Aedes aegypti* mosquitoes	Hurungwe District, Mashonaland West Province	*B. alata*, *B. pilosa* and *C. ambrosioides*	Leaves	*Ae. aegypti* adult mosquitoes	Arm-in-cage experiments	Individual extracts from *O. americanum* and *B. alata* had short protection periods (2 hrs and below). The protection period increased when using a mixture of extracts.
Kazembe, et al. [27]	To evaluate the potential of the extracts of *Ocimum americanum* and *Blumea alata* as sources of mosquito repellents	Mt Darwin district, Mashonaland Central Province, and Hurungwe district in Mashonaland West Province	*O. americanum* and *B. alata*	Leaves	*Ae. aegypti* adult mosquitoes	Arm-in-cage experiments	Individual extracts from *O. americanum* and *B. alata* had short protection periods (2 hrs and below). The protection period increased when using a mixture of extracts.
Lukwa, et al. [28]	To investigate the knockdown and insecticidal effect of the plants *Tagetes minuta*, *Lippia javanica*, *Lantana camara*, *Tagetes erecta,* and *Eucalyptus grandis* against *Anopheles arabiensis* mosquitoes	Mumurwi Village in Bindura district, Mashonaland Central Province	*T. minuta*, *L. javanica*, *L. camara*, *T. erecta* and *E. grandis*	Leaves	*An. arabiensis* adults	Burning (smoke) in field experiments	Smoke from burning dried leaves of all these plants had varying knockdown and insecticidal effects against *An. arabiensis* mosquitoes.

Kazembe and Makusha [29]	To evaluate mosquito repellencies of *Capsicum frutescens*, *Carica papaya* and *Cyanodon dactylon* extracts and the effect of mixtures	Chiredzi district, Masvingo Province	*C. frutescens*, *C. papaya* and *C. dactylon*	Leaves and fruits of *C. frutescens*, leaves and seeds of *C. papaya*, and the leaves of *C. dactylon*	*Ae. aegypti* adult mosquitoes	Arm-in-cage experiments	Individual extracts from *C. frutescens*, *C. papaya* and *C. dactylon* had short protection periods (2.5 hrs and below). The protection period increased when using a mixture of extracts.
Kazembe and Chauruka [30]	To evaluate mosquito repellencies of the individual extracts and mixtures of *Astrolochii hepii*, *Cymbopogon citratus*, and *Ocimum gratissimum*.	South of Harare	*A. hepii*, *C. citratus* and *O. gratissimum*	Whole plant	*Ae. aegypti* adult mosquitoes	Arm-in-cage experiments	Individual extracts from the plants had very short protection periods (1.5 hrs and below). The protection period increased when using a mixture of extracts.

the results. There is a need for standardization of the concentrations of extracts from different plants that are evaluated using one mosquito species so that results are comparable.

Herbal derivatives from mosquito repellent plants used in these studies were effective for shorter periods when compared to synthetic repellents which are known to provide up to 8 hours or more of protection. The short protection periods can be attributed to the high volatility of essential oils. The protection period of herbal derivatives can be enhanced through the development of formulations that extend the duration of the protection period. Only the extracts from *L. javanica* were comparable to synthetic repellents since they provided protection from *Ae. aegypti* biting for 8 hours. The phytochemical constituents of *L. javanica* have known pharmacological properties for mosquito repellency [26,33].

The repellency efficacy of individual plant extracts and their mixtures indicated that the individual extracts from the tested plants had short protection periods of 3.5 hours and below but the protection period increased when using mixtures of the extracts (Table 2). Combinations of extracts and essential oils from different plants had higher repellency and protection periods than individual extracts indicating that combining extracts and essential oils from different plants is a possibility that can increase the effectiveness and economic value of extracts and essential oils with mosquito repellent activity. However, the potential of synergies using mixtures of essential oils and extracts derived from different mosquito-repellent plants in elevating the longevity of these volatile plant products for mosquito control under field conditions in Zimbabwe requires evaluation. Further investigations on plant products for malaria vector control interventions in Zimbabwe should also focus on extending the duration of repellency and consequent efficacy of natural plant-based mosquito repellents by using different formulations.

Lippia javanica extracts showed variations in protection periods for the same mosquito species in different studies. These differences can be attributed to factors and conditions of the site of plant cultivation and collection, handling, and processing procedures of the plant raw material. Variations shown by plant products call for standardization of all procedures to guarantee consistent product efficacy, quality, and safety.

There were no studies conducted on the evaluation of the repellent activities of plants, plant extracts, or essential oils against *An. funestus* group mosquitoes, which are amongst the primary malaria vectors in Zimbabwe. The studies were mainly laboratory-based and focused on *Ae. Aegypti*, a non-malaria vector mosquito. Research on the evaluation of plant-based mosquito control products under natural field conditions

Table 2: Protection periods of plant extracts and essential oils evaluated in Zimbabwe from 1990 to 2022.

Extract	Plant	Protection period	Mosquito species	Type of Study	Reference
Individual	*L. javanica*	8 hrs	*Ae. aegypti*	Laboratory study	Lukwa, et al. [26]
	C. mopane	2 hrs	*Ae. aegypti*	Laboratory study	Kazembe and Jere [22]
	D. anomala	1.5 hrs			
	L. javanica	3.5 hrs			
	B. alata	3.5 hrs	*Ae. aegypti*	Laboratory study	Kazembe and Nkomo [20]
	B. pilosa	2 hrs			
	C. ambrosioides	3.5 hrs			
	O. americanum	3.5 hrs	*Ae. aegypti*	Laboratory study	Kazembe, et al. [27]
	B. alata	3.5 hrs			
	C. frutescens	2.5 hrs	*Ae. aegypti*	Laboratory study	Kazembe and Makusha [29]
	C. papaya	2.5 hrs			
	C. dactylon	1.5 hrs			
	A. hepii	1.0 hrs	*Ae. aegypti*	Laboratory study	Kazembe and Chauruka [30]
	C. citratus	1.5 hrs			
	O. gratissimum	0.5 hrs			
Mixtures	*C. mopane* + *D. anomala*	2.5 hrs	*Ae. aegypti*	Laboratory study	Kazembe and Jere [22]
	C. mopane + *L. javanica*	4 hrs			
	D. anomala + *L. javanica*	3 hrs			
	C. mopane + *D. anomala* + *L. javanica*	4 hrs			
	B. alata + *B. pilosa*	3.5 hrs	*Ae. aegypti*	Laboratory study	Kazembe and Nkomo [20]
	B. alata + *C. ambrosioides*	4.5 hrs			
	B. pilosa + *C. ambrosioides*	3.5 hrs			
	O. americanum + *B. alata*	6 hrs	*Ae. aegypti*	Laboratory study	Kazembe, et al. [27]
	C. frutescens + *C. papaya*	4 hrs	*Ae. aegypti*	Laboratory study	Kazembe and Makusha [29]
	C. frutescens + *C. dactylon*	3 hrs			
	C. papaya + *C. dactylon*	2.5 hrs			
	C. frutescens + *C. papaya* + *C. dactylon*	4 hrs			
	O. gratissiumum + *A. hepii*	1.5 hrs	*Ae. aegypti*	Laboratory study	Kazembe and Chauruka [30]
	O. gratissimum + *C. citratus*	2.5 hrs			
	A. hepii + *C. citratus*	3.5 hrs			

is required and significant. Furthermore, there is a need for rigorous research on the repellent efficacy of these plant-based products on *An. arabiensis* and *An. funestus* s.s., the primary malaria vectors in the country so that a robust conclusion can be made regarding the best herbal candidates for developing new plant-based mosquito repellents from local mosquito-repellent plants for malaria vector control and elimination in the country.

The studies in this review applied different methodologies from collection, handling, and processing of raw plant materials to extractions of essential oils and the estimation of repellency time or protection periods. Different solvents (ethanol and methanol) were used for the extraction process while different criteria were used to estimate repellency (landing time or complete protection time). The absence of standardization is an obstacle to the comparison or evaluation of results from these studies. To ensure that research findings are comparable, a standardized protocol for the collection, handling, and processing of raw plant materials, extraction of essential oils, and estimation of repellency time in evaluating the repellency efficacy of different plants with mosquito repellent activity is recommended for the country.

Lippia javanica was the only plant investigated in terms of its general constituents and the isolation of bioactive compounds responsible for toxicity, insecticidal, and repellency activity against mosquitoes in Zimbabwe [26,33]. The major constituents were 1,3,5 cycloheptatriene, alphapinene, and eucalyptol while the other phytochemicals were caryophyllene, carvone, linalool, ocimenone, sabinene, piperitenone, tagetenone, ipsenone, myrcenone, ipsdienone, and p-cymene [26,33]. The phytochemistry of other mosquito-repellent plants needs to be evaluated as well.

Secondary metabolites such as essential oils, alkaloids, phenols, terpenoids, steroids, and phenolics have been isolated from different plant extracts and reported for their mosquitocidal activities in studies conducted in other parts of the world [34].

Despite all the knowledge accumulated from several studies that were conducted on the evaluation of natural plant products for mosquito control in Zimbabwe, no single plant-based mosquito control product has been produced in this country. However, this can be achieved or made possible with further research that focuses on i) More research-based documentation of local mosquito repellent plants for knowledge preservation, ii) Scientific evaluation and validation of the efficacy of documented mosquito repellent plants under natural field conditions, iii) Isolating and identifying the chemical constituents and bioactive molecules of test plants and their mode of action, iv) Investigating and comparing the volatility and efficacy of individual extracts and essential oils against *An. gambiae* complex and *An. funestus* group, the main malaria vectors in the country, v) Rigorous research in synergies using mixtures to extend the duration of repellency and consequent efficacy of plant-based repellents, vi) Elevating longevity of volatile plant-based repellents by improving the formulations of plant extracts through fixatives, vii) Determining the effect of plant-based mosquito repellents on non-target species and the environment and, viii) Developing, registering, patenting, and commercializing new, safer, and cost-effective natural plant-based mosquito repellents and advocating for their use as complementary malaria vector intervention tools in malaria-endemic parts of the country.

Conclusion

Malaria can be eliminated in Zimbabwe by incorporating various innovative strategies along with the existing vector control measures. Innovations for the development of new tools, technologies, and approaches are required to ensure the maximum impact of sustainable malaria vector control interventions in the country. Past research has shown that there is enough evidence to support natural plant-based products in integrated malaria vector control in Zimbabwe since this literature review clearly illustrated that plants used traditionally for repelling mosquitoes in the country have significant repellent activity against human-biting mosquitoes. Further research can be done on the repellency of traditional mosquito-repellent plants or plant extracts against the primary malaria vectors in the country. Furthermore, to develop effective plant-based products for malaria vector control as alternatives to synthetic ones, there is a need for standardization of protocols on the collection, handling, and processing of plant raw materials, estimation of protection time, and the evaluation of the quality and safety of bioactive compounds derived from various local mosquito-repellent plants. In addition to saving lives in malaria-endemic and epidemic-prone regions of the country, the production of safe, low-cost, environmentally friendly, and cost-effective plant-based malaria vector control products using local mosquito repellent plant sources will generate employment for the country, reduce costs on imports of expensive synthetic repellents, and stimulate efforts to enhance public health amongst communities in malaria-endemic areas in the country.

Acknowledgments

This manuscript was made possible by the use of materials developed by other scientists. Authors of all materials used in this manuscript are thus duly acknowledged.

Funding

No grant was received from any funding agency for this work.

Competing Interests

The authors declare that they have no competing interests.

Author Contributions

All the authors contributed to the drafting and revisions to this manuscript. All authors approved the final version of the manuscript to be published.

References

1. World Health Organization (2022) World Malaria Report 2022. Geneva, Switzerland.
2. African Union (2021) African Union Malaria Progress Report.
3. Southern African Development Community (SADC) (2009) Situation and response analysis report on malaria in the SADC Region.
4. World Bank (2023) Population Total-South Africa, Botswana, Lesotho, Namibia, Eswatini, Angola, Comoros, Democratic Republic of Congo, Madagascar, Malawi, Mauritius, Mozambique, Seychelles, Tanzania, Zambia, Zimbabwe.
5. Mundagowa PT, Chimberengwa PT (2020) Malaria outbreak investigation in a rural area south of Zimbabwe: A case-control study. Malar J 19: 197.
6. World Health Organization (2022) Global health observatory data repository/World Health Statistics.
7. USAID President's Malaria Initiative (2021) The PMI Vectorlink Project Zimbabwe Annual Entomological Report March 2020-February 2021.
8. Sande S, Zimba M, Chinwada P, Masendu HT, Makuwaza A (2015) Malaria vector species composition and relative abundance in Mutare and Mutasa Districts, Zimbabwe. J Entomol Acarol Res 47: 4955.
9. Mpofu SM (1985) Seasonal vector density and disease incidence patterns of malaria in an area of Zimbabwe. Trans R Soc Trop Med Hyg 79: 169-175.
10. Pasi CP, Katsidzira L (2009) Guidelines for management of malaria in Zimbabwe: Diagnosis, management of uncomplicated and severe malaria. Ministry of Health and Child Care.

11. National Malaria Control Program (2020) Trends in malaria incidences in Zimbabwe. Harare: Ministry of Health and Child Care.

12. WHO (2006) Malaria vector control and personal protection: Report of a WHO Study Group. WHO Technical Report Series 936. World Health Organization, Geneva, Switzerland.

13. (2016) Zimbabwe Malaria Programme Review (MPR). Ministry of Health and Child Care: Harare.

14. Mpofu M, Becker P, Mudambo K, de Jager C (2016) Field effectiveness of microbial larvicides on mosquito larvae in malaria areas of Botswana and Zimbabwe. Malar J 15: 586.

15. Soko W, Chimbari MJ, Mukaratirwa S (2015) Insecticide resistance in malaria-transmitting mosquitoes in Zimbabwe: A review. Infect Dis Poverty 4: 46.

16. Maia MF, Moore SJ (2011) Plant-based insect repellents: A review of their efficacy, development, and testing. Malar J 10: S11.

17. World Health Organization (2009) Guidelines for efficacy testing of mosquito repellents for human skin. Geneva, Switzerland.

18. Moore SJ, Lenglet A, Hill N (2006) Plant-based insect repellents. In: Insect repellents: Principles, Methods, and Use. CRC Press, Boca Raton Florida, 420-423.

19. Ranasinghe MSN, Arambewela L, Samarasinghe S (2016) Development of herbal mosquito formulations. Int J Collab Res Intern Med Public Health 8.

20. Kazembe TC, Nkomo S (2012) Use of Blumeta alata, Bidens pilosa and Chenopodium ambrosioides as mosquito repellents and mosquitocides. Bull Environ Pharmacol Life Sci 1: 59-66.

21. Lukwa N, Nyazema NZ, Curtis CF, Mwaiko GL, Chandiwana SK (1999) People's perceptions about malaria transmission and control using mosquito repellent plants in a locality in Zimbabwe. Cent Afr J Med 45: 64-68.

22. Kazembe T, Jere S (2012) Malaria control with mosquito repellent plants: Colophospermum mopane, Dicoma anomala, and Lippia javanica. World J Life Sci and Med Res 2: 141-158.

23. Waka M, Hopkins RJ, Curtis C (2004) Ethnobotanical survey and testing of plants traditionally used against hematophagous insects in Eritrea. J Ethnopharmacol 95: 95-101.

24. Pavela R, Benelli G (2016) Ethnobotanical knowledge on botanical repellents employed in the African region against mosquito vectors-A review. Exp Parasitol 167: 103-108.

25. Lukwa N (1994) Do traditional mosquito repellent plants work as mosquito larvicides? Cent Afr J Med 40: 306-309.

26. Nzira L, Per M, Peter F, Claus B (2009) Lippia javanica (Burm F) Spreng: its general constituents and bioactivity on mosquitoes. Trop Biomed 26: 85-91.

27. Kazembe T, Chaibva M, Nkomo S (2012) Evaluation of mosquito repellence of Ocimum americanum and Blumea alata plants. J Sci Res Pharm 1: 55-57.

28. Lukwa N, Mduluza T, Nyoni C, Lukwa AT, Zimba M (2018) Knockdown and insecticidal activity of the plants Tagetes minuta, Lippia javanica, Lantana camara, Tagetes erecta and Eucalyptus grandis on Anopheles arabiensis mosquitoes. J Entomol Acarol Res 50: 7241.

29. Kazembe T, Makusha C (2012) Evaluation of mosquito repellencies of Capsicum frutescens, Carica papaya, and Cyanodon dactylon extracts and extract mixtures. Bull Environ Pharmacol Life Sci 1: 34-40.

30. Kazembe T, Chauruka D (2012) Mosquito repellence of Astrolochii hepii, Cymbopogon citratus and Ocimum gratissimun extracts and mixtures. Bull Environ Pharmacol Life Sci 1: 60-64.

31. Lukwa N, Molgaard P, Furu P, Bogh C, Gundidza M (2000) Ineffectiveness of essential oils from Artemisia afra (Asteraceae), Lantana angiolensis (Verbenaceae) and Syzygium huillense (Myrtaceae) in inhibiting mosquito biting. Cent Afr J Med 46: 232-233.

32. Youmsi RDF, Fokou PVT, Menkem EZ, Bakarnga-Via I, Keumoe R, et al. (2017) Ethnobotanical survey of medicinal plants used as insect repellents in six malaria-endemic localities of Cameroon. J Ethnobiol Ethnomed 13: 33.

33. Chagonda LS, Chalchat JC (2015) Essential oil composition of Lippia javanica (Burm. F.) Spreng chemotype from Western Zimbabwe. J Essen Oil-Bearing Plants 18: 482-485.

34. Bett PK, Ogendo JO, Matasyoh JC, Kiplatag AJ (2022) Chemical characterization of Kenyan Cupressus lusitanica Mill., Ocimum americanum L. and Lippia javanica (Burm. F.) Spreng essential oils. Afr J Environ Sci Technol 16: 79-90.