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## Exploration of Medicinal Plants Used in the Management of Malaria in Uganda

<sup>1</sup>Kungu Erisa, <sup>1</sup>Inyangat Raphael, <sup>2</sup>Ugwu Okechukwu Paul-Chima and <sup>2</sup>Alum Esther Ugo

<sup>1</sup>Department of Basic Science, Kampala International University Uganda.

<sup>2</sup>Department of Publication and Extension Kampala International University Uganda.

### ABSTRACT

Malaria is a major public health issue in Uganda, with over 90% of the population at risk, especially children and pregnant women. This paper explores malaria management in Uganda, combining traditional herbal remedies and modern pharmaceutical interventions. The country's diverse ecosystems have nurtured a rich tradition of herbal medicine, with indigenous communities using medicinal plants to combat malaria. The paper highlights specific medicinal plants used in malaria management, such as *Artemisia annua*, *Cinchona officinalis*, *Azadirachta indica*, *Cryptolepis sanguinolenta*, *Alstonia boonei*, *Carica papaya*, *Vernonia amygdalina*, and *Moringa oleifera*. The paper also discusses the significance, traditional uses, and challenges of these plants, emphasizing the need for standardization and quality control. The paper also discusses modern pharmaceutical interventions, including Artemisinin-Based Combination Therapies (ACTs), chloroquine, sulfadoxine-pyrimethamine (SP), primaquine, quinine and mefloquine. Prevention strategies include insecticide-treated nets, environmental interventions, community education, recommended drug doses, destruction of mosquito breeding sites, and medical screenings. The paper advocates for collaborative efforts that combine traditional wisdom with scientific advancements for a holistic approach to malaria management.

**Keywords:** Medicinal Plants, Malaria, Drugs, Management and Uganda

### INTRODUCTION

Malaria is a potentially fatal communicable disease caused mostly by the plasmodium falciparum parasite, which is transmitted through the bites of an infected female anopheles mosquito [1-3]. The parasite then travels to the liver via the bloodstream, where it multiplies and eventually invades red blood cells, causing malaria symptoms such as fever, chills, sweating, headache, muscle aches, and fatigue [2-5]. Uganda has a high malaria burden, with over 90% of the population at risk, making malaria the leading cause of death, particularly among children [6]. Malaria stands as a formidable global health challenge, particularly in sub-Saharan Africa, where Uganda has its share of the burden. Despite significant progress in recent years, the fight against malaria continues to demand innovative and sustainable approaches [6-7]. One such approach lies in the ancient wisdom of traditional medicine, where the lush landscapes of Uganda host a treasure trove of medicinal plants with the potential to contribute to the management of malaria [8-9].

Uganda, blessed with a diverse ecosystem ranging from dense forests to expansive savannahs, has been home to indigenous communities practicing herbal medicine for generations. The knowledge passed down through oral traditions reveals an intimate understanding of the healing properties of various plant species. In the context of malaria, these traditional healers have identified and harnessed the therapeutic potential of numerous medicinal plants, offering a unique and culturally embedded approach to disease management [10-13].

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The arsenal of medicinal plants employed in the management of malaria in Uganda encompasses a wide array of botanical species. Some of these plants are celebrated for their antimalarial properties, serving not only as treatment but also as preventive measures against the parasite responsible for the disease. Traditional healers, often the custodians of this invaluable knowledge, utilize their expertise to create remedies that not only address the symptoms but also target the root causes of malaria infection [14].

This exploration into medicinal plants used in malaria management in Uganda is not just a journey into the realm of herbal remedies; it is an acknowledgment of the symbiotic relationship between the people and their natural environment. As we delve into the scientific validation of these traditional practices, we begin to bridge the gap between ancient wisdom and modern medicine, offering a holistic approach to malaria management that draws from the best of both worlds [15-17].

In this comprehensive exploration, we will delve into the specific medicinal plants commonly employed, their active compounds, and the scientific evidence supporting their efficacy. Furthermore, we will assess the socio-cultural significance of these remedies, emphasizing the importance of integrating traditional knowledge into contemporary healthcare strategies. Through this journey, we aim to shed light on the untapped potential of Uganda's medicinal plants in the ongoing battle against malaria, emphasizing the need for collaborative efforts that leverage both traditional wisdom and scientific advancements for the greater good of public health [18].

### Methods

Between September 2022 and August 2023, a complete literature search was undertaken in Scopus, Web of Science Core Collection, PubMed, Science Direct, Google Scholar, and Scientific Electronic Library Online (SciELO). The study databases contained original papers on Medicinal Plants Used in Malaria Management in Uganda that were published in peer-reviewed journals and were current until September 2022.

## UGANDA'S EXPERIENCE WITH MALARIA

Malaria kills more pregnant women and children under the age of five in Uganda than the rest of the population [19] because their immune systems are weaker, making them less able to mount an effective defense against the malaria parasite and thus more susceptible to malaria infection [20]. Malaria can have serious consequences in pregnant women, resulting in a condition known as maternal malaria, which causes severe anaemia due to rupture and destruction of red blood cells by a process known as haemolysis, resulting in a significant reduction in the number of functional red blood cells and a decrease in the oxygen carrying capacity of blood. This results in fatigue and shortness of breath. This causes the mother to become weak and short of breath, and also lowers the oxygen flow to the baby, potentially harming its growth and development. Premature birth, poor birth weight, and miscarriage are also consequences.

Malaria can disrupt education, negatively impacting academic achievements, and have an environmental impact due to the release of harmful chemicals during malaria prevention measures. In Uganda, the average annual economic loss due to malaria is over \$500 million, with 13 million cases and 19,600 deaths in 2021. The financial burden of healthcare expenses, including purchasing antimalarial drugs, insecticides, and mosquito nets, affects both the government and local population, hindering the development of other sectors due to uneven distribution of finances. The inhalation of insecticides can also cause respiratory difficulties. Therefore, malaria prevention measures should be carefully managed to minimize the negative effects on the environment and human health [21].

Malaria remains a major public health concern in Uganda, with over 90% of the population at risk. In 2021, the World Health Organization estimated 12.4 million malaria cases and 31,350 deaths, with children under 5 years contributing the most. This is mainly due to their weak immune system and limited exposure to the parasite. Deaths are mainly due to delayed or inadequate treatment, limited access to healthcare facilities, challenges in accurate diagnosis, and the emergence of drug-resistant malaria strains. Severe malaria can also cause neurological complications, such as cerebral malaria, leading to long-term neurological impairments. Malnutrition, caused by reduced appetite and increased nutrient requirements, can also lead to impaired physical development in children.

### Traditional Medicinal Plants Utilized for Malaria Treatment in Uganda

Ethnobotany studies the relationship between plants and humans. In Uganda, herbs and herbal extracts are commonly used for malaria management due to their affordability and effectiveness. Researchers are exploring herbal plants as potential alternatives for more effective antimalarial drugs due to the resistance of pathogenic strains, including plasmodium species, to modern drugs [8-9].

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The leaves are the most widely utilized medicinal plant parts [19], followed by the roots and bark, while the whole plant and other plant parts are less commonly employed. The most typical method of administration is to boil the therapeutic plant component in water and then drink the decoction; fresh extracts, powdered versions of the herbs, and infusion are also used.

Table 1: Some medicinal plants used to treat malaria in Uganda [8]

S/N	Botanical Name	Family	Part(s) Used	Region
1	<i>Artemisia annua</i>	Asteraceae	Leaves	Africa, Uganda
2	<i>Cinchona officinalis</i>	Rubiaceae	Bark	Africa, Uganda
3	<i>Azadirachta indica</i>	Meliaceae	Leaves	Africa, Uganda
4	<i>Cryptolepis sanguinolenta</i>	Apocynaceae	Root	Africa, Uganda
5	<i>Alstonia boonei</i>	Apocynaceae	Bark	Africa, Uganda
6	<i>Carica papaya</i>	Caricaceae	Leaves	Africa, Uganda
7	<i>Vernonia amygdalina</i>	Asteraceae	Leaves	Africa, Uganda
8	<i>Moringa oleifera</i>	Moringaceae	Leaves, Roots	Africa, Uganda

#### *Artemisia annua*

*Artemisia annua*, also known as Sweet Wormwood, is a medicinal plant with potential in malaria management, particularly in Uganda. Its key compound, artemisinin, has potent antimalarial properties and is incorporated into artemisinin-based combination therapies (ACTs). Artemisinin and its derivatives are known for their rapid and effective action against Plasmodium parasites, the causative agents of malaria. *Artemisia annua* is often used in the preparation of herbal remedies or teas, with dried leaves powdered and encapsulated for easy consumption. Traditional healers and communities in Uganda may also prepare decoctions or infusions from *Artemisia annua* leaves for malaria symptoms management. Community-based initiatives and research projects in Uganda explore the use of *Artemisia annua* as a complementary approach to malaria management, often involving collaboration between local communities, herbalists, and healthcare professionals. However, challenges include standardization of dosages, quality control, and the need for more robust scientific evidence to support its efficacy and safety. *Artemisia annua*-based therapies may be used in conjunction with conventional antimalarial drugs as part of integrated malaria treatment approaches [8,10].

#### *Cinchona officinalis*

*Cinchona officinalis*, also known as the quinine tree, is a plant species with historical significance in malaria treatment. The bark of this tree contains quinine, a compound known for its antimalarial properties. Quinine has been used for centuries against Plasmodium falciparum parasites, disrupting their ability to digest hemoglobin, leading to their destruction. Indigenous communities and traditional healers in Uganda have traditionally used the bark or extracts to prepare malaria remedies. This knowledge may be embedded in local cultures and traditional healing practices. In some cases, traditional remedies containing *Cinchona officinalis* may be used alongside or integrated with conventional antimalarial drugs, especially in regions with limited access to modern healthcare. However, the use of *Cinchona officinalis* faces challenges such as standardization of dosages, quality control, and potential side effects or interactions with other medications. Scientific evidence supporting the efficacy and safety of traditional remedies should be established. Research and development may explore the potential of *Cinchona officinalis* and its derivatives in developing new antimalarial drugs or as complementary treatments. While traditional remedies may have cultural and historical significance, their use should be approached with caution, consulting with healthcare professionals, and adhering to established treatment guidelines [8,10].

#### *Azadirachta indica*

*Azadirachta indica*, also known as Neem, is a tree with a rich history of medicinal use, including malaria management. Its leaves have been studied for their potential antimalarial effects, with the leaves being particularly useful in traditional medicine in Uganda. Neem contains bioactive compounds like nimbin, nimbidin, and azadirachtin, which have shown antimalarial properties. These compounds may inhibit the growth and development of the Plasmodium parasite. Traditional use of Neem leaves in Uganda involves preparing decoctions or infusions, which are consumed as herbal remedies for managing malaria symptoms. Neem's fever-reducing properties are significant in malaria, where fever is a common symptom. Knowledge of Neem's medicinal properties may be deeply rooted in local communities. Scientific research has explored the efficacy of

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Neem extracts against malaria parasites, with Neem-based formulations being explored as alternative or complementary treatments. Neem-based remedies can be used alongside conventional antimalarial drugs or integrated into community health practices. However, challenges include the need for standardized formulations, dosage recommendations, and rigorous scientific validation, as well as potential side effects and interactions with other medications [8,10].

### ***Cryptolepis sanguinolenta***

*Cryptolepis sanguinolenta*, also known as Ghanaian quinine or Nibima, is a plant native to West Africa that has been traditionally used for malaria management. Its root extracts have been found to have potential antimalarial properties, with cryptolepine being a key component. Cryptolepine exhibits antimalarial activity by interfering with the life cycle of the malaria parasite, potentially inhibiting its growth and replication. In traditional medicine in Uganda and other regions, the root of *Cryptolepis sanguinolenta* is often used to prepare decoctions or infusions, which are consumed as herbal remedies for managing malaria symptoms. It may also possess fever-reducing properties, which is important in malaria, where fever is a prominent symptom. Knowledge of *Cryptolepis sanguinolenta*'s medicinal properties may be passed down through generations in local communities. Scientific studies have investigated its antimalarial efficacy, exploring its potential as an alternative or complementary treatment for malaria. *Cryptolepis sanguinolenta*-based remedies can be used alongside or integrated with conventional antimalarial drugs, sometimes in regions where traditional medicine plays a significant role in healthcare. Challenges include the need for standardized formulations, dosage recommendations, and rigorous scientific validation, as well as potential side effects and interactions with other medications [8,10].

### ***Alstonia boonei***

*Alstonia boonei*, also known as the African rubber tree, is a plant used for medicinal purposes, including malaria management. Its bark contains bioactive compounds, including alkaloids like echitamine and strictamine, which have been studied for their potential antimalarial effects. Research suggests that extracts from the bark may exhibit antimalarial activity, inhibiting the growth and development of the Plasmodium parasite. In Uganda and other regions, the bark of *Alstonia boonei* is often used to prepare decoctions or infusions, which are consumed as herbal remedies for managing malaria symptoms. *Alstonia boonei* may possess fever-reducing properties, which is significant in malaria, where fever is a common symptom. Knowledge of the medicinal properties of *Alstonia boonei* may be deeply rooted in local communities, with traditional healers and community members developing specific practices for using the plant in malaria treatment. Scientific studies have investigated the antimalarial efficacy of *Alstonia boonei*, exploring its potential as an alternative or complementary treatment. *Alstonia boonei*-based remedies may be used alongside conventional antimalarial drugs or integrated into community health practices, often seen in regions where traditional medicine plays a significant role in healthcare. Challenges include standardized formulations, dosage recommendations, and rigorous scientific validation, as well as potential side effects and interactions with other medications [8,10].

### ***Carica papaya***

*Carica papaya*, a tropical fruit, has been traditionally used for medicinal purposes and has been explored for its potential as an antimalarial agent. The plant contains bioactive compounds such as alkaloids, flavonoids, and other phytochemicals, which contribute to its therapeutic properties. Research suggests that extracts from various parts of the papaya plant, including leaves, seeds, and latex, may exhibit antimalarial activity. Traditional medicine in Uganda and other regions uses various parts of the papaya plant, with the leaves being particularly utilized for their medicinal properties. Papaya leaf extract has gained attention for its potential antimalarial properties, with studies exploring its efficacy in inhibiting the growth of the malaria parasite. Papaya is known for its fever-reducing properties, which can be beneficial in malaria treatment, especially in regions where fever is a common symptom. Traditional healers and communities in Uganda may have specific practices for using *Carica papaya* in malaria treatment, which are often passed down through generations. Scientific research has investigated the antimalarial potential of *Carica papaya*, exploring mechanisms of action and developing papaya-based formulations for malaria treatment. *Carica papaya*-based remedies may be used alongside conventional antimalarial drugs or integrated into community health practices. However, challenges include the need for standardized formulations, dosage recommendations, and rigorous scientific validation, as well as potential side effects and interactions with other medications [8,10].

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### *Vernonia amygdalina*

*Vernonia amygdalina*, also known as bitter leaf, is a plant with a long history of traditional use in Africa, including Uganda. It has been explored for its potential as an antimalarial agent due to its bioactive compounds, including sesquiterpene lactones, flavonoids, alkaloids, and other phytochemicals. Research suggests that extracts from *Vernonia amygdalina*, particularly from its leaves, may exhibit antimalarial activity, potentially inhibiting the development and reproduction of the Plasmodium parasite. In traditional medicine in Uganda and other African countries, *Vernonia amygdalina* is often used for its medicinal properties, including the preparation of remedies for managing various health conditions, including malaria. The bitter taste of the plant is often associated with its medicinal potency. Scientific research has investigated the antimalarial potential of *Vernonia amygdalina*, exploring the mechanisms of action and developing bitter leaf-based formulations for malaria treatment. These remedies may be used alongside conventional antimalarial drugs or integrated into community health practices, where traditional medicine is an integral part of healthcare. Challenges include the need for standardized formulations, dosage recommendations, and rigorous scientific validation, as well as potential side effects and interactions with other medications [8,10].

### *Moringa oleifera*

*Moringa oleifera*, a plant known for its nutritional and medicinal properties, has been explored for its potential as an antimalarial agent. The plant's rich nutrient content, including vitamins, minerals, and proteins, contributes to its overall health benefits. *Moringa oleifera* has been used traditionally in regions like Africa and Asia for various health conditions, including malaria management. The leaves of *Moringa oleifera* are commonly used in traditional medicine, with extracts from the leaves being studied for potential therapeutic effects. *Moringa oleifera* has been reported to have immunomodulatory effects, influencing the immune system, which is crucial for fighting off infections, including malaria. Traditional healers may incorporate Moringa-based remedies into their treatment approaches. Scientific research is ongoing to understand the bioactive compounds in *Moringa oleifera* and their potential effects on malaria parasites. *Moringa oleifera*-based remedies may be used alongside conventional antimalarial drugs or as complementary approaches, but it is essential to ensure no adverse interactions with prescribed medications. Challenges include the need for standardized formulations, dosage recommendations, and rigorous scientific validation, as well as the potential for variations in *Moringa* products on the market [8,10].

## DRUGS USED TO TREAT AND MANAGE MALARIA IN UGANDA

Malaria treatment and control often require the use of antimalarial medicines. Drug selection may be influenced by factors such as the severity of the infection, the species of malaria parasite, and local drug resistance trends. It is important to remember that drug recommendations and availability are subject to change, and medical advice should be sought from a healthcare expert for the most up-to-date information.

### COMMON ANTIMALARIAL DRUGS USED IN UGANDA INCLUDE

#### ARTEMISININ-BASED COMBINATION THERAPIES (ACTS)

- i. Artemether-Lumefantrine (Coartem)
- ii. Dihydroartemisinin-Piperaquine
- iii. Artesunate-Amodiaquine
- iv. Chloroquine

While chloroquine resistance is a concern in some areas, it may still be used for the treatment of uncomplicated malaria in some regions where the malaria parasite is sensitive to chloroquine.

#### SULFADOXINE-PYRIMETHAMINE (SP)

Often used for intermittent preventive treatment in pregnant women (IPTp) and infants (IPTi).

#### PRIMAQUINE

Used for the treatment of *P. vivax* malaria and as a gametocytocidal drug.

#### QUININE

Quinine and its derivatives are sometimes used for severe malaria or cases where other medications are not suitable.

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## MEFLOQUINE

Used for both treatment and prophylaxis. However, it may have side effects and is not suitable for everyone. It's crucial to emphasize that the choice of antimalarial drugs should be based on the latest guidelines from health authorities in Uganda, considering factors such as drug resistance patterns and individual patient characteristics. Additionally, the treatment should be administered under the supervision of qualified healthcare professionals. Since my information is based on the status up to September 2021, there may have been updates or changes in treatment guidelines and drug availability. Therefore, consulting with local healthcare authorities or professionals in Uganda for the most recent information is highly recommended. The drugs used in malaria treatment in Uganda are mainly antimalaria drugs. However, some antibacterial drugs such as tetracycline and clindamycin also have antiplasmodial activity though they are slow at malaria treatment. They are only recommended in combination with other antimalarial drugs.

### PREVENTION OF MALARIA IN UGANDA

#### Insecticide treated nets

To combat the effects of malaria and its spread, various primary, secondary, and tertiary prophylactic measures have been implemented. Because malaria is transmitted through the bites of an infected female anopheles mosquito, sleeping under an insecticide-treated mosquito net is the best way to prevent its bite because it reduces the chances of contact between the infected mosquito and the human skin (UNICEF). This has been greatly aided by various government initiatives to combat malaria, such as the distribution of free mosquito nets to the population through its various organizations such as the Ministry of Health (MoH), Uganda National Malaria Control Program (NMCP), and Village Health Teams (VHTs), as well as other international and non-governmental organizations such as the United Nations Children's Fund (UNICEF), World Health Organization (WHO), and the World Bank.

#### Destruction of mosquito breeding sites

Mosquito breeding areas must be destroyed in order to lessen mosquito infestation. By removing nesting facilities, mosquitoes find it more difficult to reproduce and grow, lowering the overall mosquito population and the danger of malaria transmission. This can be accomplished by cleaning up the surroundings and removing undesired vegetation, so disturbing the mosquito life cycle.

#### Ministry of Health community intervention

The Ministry of Health is doing community interventions through community-based Village Health Teams to deliver health education about malaria spread, prevention, and control through community dialogues. This is to give malaria knowledge and awareness, impact behavioral change through encouraging malaria prevention behaviors, and cultural sensitivity, all of which are concentrated on malaria prevention.

#### Taking recommended doses

Taking antimalarial medications as prescribed by a doctor. Antimalarial medications can be used prophylactically, which means they can be used before being exposed to the malaria parasite to avoid infection. Antimalarial medications also restrict the plasmodium parasite's development and replication within the human body, decreasing the severity of the infection and preventing it from advancing to life-threatening malaria. These medications, such as artemisinin-based combination treatments (ATCs), aid in the removal of parasites from the bloodstream.

#### Mosquito screens and repellants

Using mosquito nets, long-sleeved shirts and pants, and insect repellents on the skin. These act as a physical barrier between human skin and mosquitos, lowering the risk of mosquito bites and consequent malaria infection.

#### Use of Insecticide

Spraying buildings with mosquito insecticides such as Larvicides, Organophosphates, and Pyrethroids, which efficiently target mosquitos at various phases of their life cycle and lower their population, so breaking the malaria transmission cycle. Mosquito coils can also be employed since when burned, they emit pesticides.

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## Medical examination

Regular malaria screenings allow for the early detection and treatment of malaria infections, lowering the risk of severe disease and sequelae.

## CONCLUSION

Malaria is a significant health issue in Uganda, affecting a large population, particularly children and pregnant women. This paper explores malaria management in Uganda, combining traditional herbal remedies and modern pharmaceutical interventions. Traditional medicine, deeply rooted in Uganda's cultural heritage, relies on indigenous knowledge and the use of medicinal plants. Traditional healers harness the therapeutic potential of these plants, offering a unique and culturally grounded approach to treating symptoms and addressing the root causes of malaria. However, challenges such as standardization, quality control, and scientific validation persist, emphasizing the delicate balance between tradition and modern healthcare. Modern pharmaceutical interventions, including antimalarial drugs like Artemisinin-Based Combination Therapies (ACTs) and quinine, have made strides in combating the disease. However, the evolving landscape of drug resistance and the need for constant adaptation highlight the ongoing challenges in the fight against malaria. Prevention strategies, such as insecticide-treated nets and community education, demonstrate a holistic approach that integrates traditional practices and modern interventions. The paper advocates for a united front that leverages the strengths of traditional medicine and modern science, emphasizing the need for an integrated and holistic approach to malaria management for Uganda's public health.

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