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Research article

# Ethnobotanical study of plants used by the traditional healers to treat malaria in Mogovolas district, northern Mozambique

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ABSTRACT

*Introduction:* Malaria is an important parasitic disease that affects mostly the African continent. Traditional medicine is very important in Mozambique and traditional healers play a key role in the primary health care services, particularly in rural areas. We aim to report the results of an ethnobotanical survey undertaken in Mogovolas district, northern region of Mozambique. We recorded and identified the medicinal plants used by traditional healers for treatment of malaria, as well as the mode of preparation and administration.
*Methods:* The study was conducted in 14 villages from Mogovolas between June and August 2015. Sixteen traditional healers were interviewed using semi-structured questionnaires. Under their guidance, we collected medicinal plants and prepared herbarium specimens that were sent and kept at Eduardo Mondlane University Herbarium for scientific identification. We searched for information on the *in vitro* and *in vivo* studies of the cited plants for antiplasmodial activity.
*Results:* Traditional healers from Mogovolas district reported the use of 37 plants to treat malaria, belonging to 22 families. The most used species are *Ochna kirkii* Oliv. (5 citations), *Ehretia amoena* Klotzsch and *Pteleopsis myrtifolia* (M.A.Lawson) Engl. & Diels (both with 3 citations). These plants belong to Ochnaceae, Boraginaceae and Combretaceae families, respectively. The herbal remedies are prepared using leaves (22/37), roots (18/37), stem barks (16/37) and stems (3/37). The administration of the herbal remedies was made essentially by oral route and bathing.
*Conclusion:* The ethnobotanical data resulted from this study can be the starting point for further chemical and pharmacological studies aiming to identify medicinal species with antimalarial activity, thus, open the insights for the discovery of new antimalarial substances, as well as better integration of the traditional medicine into the national health systems, particularly in developing countries, as the health system coverage is limited.

## 1. Introduction

The use of medicinal plants to treat malaria dated from prehistoric times. Early writings of over 6,000 years ago in Egypt and China, and those of the Vedic civilization in India (1,600 B.C.) indicate that malaria has afflicted human beings since antiquity and was treated with antimalarial traditional remedies in virtually all cultures [1].

Historically, medicinal plants have been the focus of many studies aimed at discovering alternative antimalarial drugs in different parts of the world. More than 1,200 medicinal plants are described as having antimalarial or anti-fever properties [1, 2]. Studies of medicinal plants with antimalarial potential led to the discovery of numerous and distinct antimalarial compounds [3].

In the 19$^{th}$ century, the discovery of quinine, extracted from the bark of *Cinchona pubescens* Vahl, represented a milestone in the history of modern medicine for malaria [1]. In 1971, in China, a new antimalarial drug, artemisinin, was discovered from the extracts of *Artemisia annua* L., a plant used in Chinese traditional medicine to treat fever-related

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diseases [4, 5, 6]. With this finding, in 2015 Professor Youyou Tu, the principal investigator, won the Nobel prize of medicine [7].

As in most other southern African countries, timber, medicinal, edible, and ornamental species are the most important plant groups used in Mozambique. Close to 60% of the Mozambican population use medicinal plants for basic healthcare [8]. Due to the low coverage of the health services, particularly in rural areas, the majority of the population still depends on medicinal plants [9].

In Mozambique, approximately 15% of the total plant genetic resources (>800 of 5,500 plant species) are used by rural communities for medical purposes and play a key role in basic health care [10].

Malaria is a parasitic disease that affected nearly 228 million people worldwide and caused 405,000 deaths in 2018, most of them in Africa [11]. In Mozambique, although mortality by malaria is estimated to have decreased by 29% since 2010, it remains as one of the major causes of morbidity and mortality, particularly in children and pregnant women [12, 13].

Since the access to health care is still a great challenge in the country, particularly in rural areas, people still depend on medicinal plants and traditional medicine, which are often provided by traditional healers for their primary health care.

Only few investigations related to medicinal plants have been conducted in the country [9, 14, 15, 16, 17, 18, 19, 20, 21], but some of these publications are of limited availability.

In Mozambique, there are several plants with antimalarial potential, such as: *Alepidea amatymbica* Eckl. & Zeyh., *Adansonia digitata* L., *Acacia nilotica* (L.) Delile, *Acacia karroo* Hayne, *Bridelia cathartica* Bertol., *Euclea natalensis* A.DC., *Lippia javanica* (Burm.f.) Spreng., *Momordica balsamina* L., *Rauvolfia caffra* Sond., *Spirostachys africana* Sond., *Senna occidentalis* (L.) Link, *Salacia kraussii* (Harv.) Harv. and *Zanthoxylum capense* (Thunb.) Harv. [9].

In Marracuene, southern region of Mozambique, plants like *Bridelia cathartica* Bertol., *Clematis viridiflora* Bertol, *Crotalaria monteiroi* Baker f., *Momordica balsamina* L., *Spirostachys africana* Sond. and *Strychnos henningsii* Gilg are used by traditional healers for treatment of malaria [22].

The following plants are also used as antimalarials in Mozambique: *Aloe parvibracteata* Schönland, *Cassia abbreviata* Oliv., *Cassia occidentalis* L., *Crossopteryx febrifuga* (Afzel. ex G.Don) Benth., *Leonotis leonurus* (L.) R.Br., *Parkinsonia aculeata* L., *Pittosporum tobira* (Thunb.) W.T.Aiton, *Plumbago auriculata* Lam., *Senna didymobotrya* (Fresen.) H.S.Irwin & Barneby, *Schefflera actinophylla* (Endl.) Harms, *Trichilia emetica* Vahl. and *Tabernaemontana elegans* Strapt [23].

This ethnobotanical survey was conducted in order to record and identify the medicinal plants used by traditional healers for treatment of malaria, as well as the mode of preparation and administration in Mogovolas district, northern region of Mozambique.

## 2. Materials and methods

### 2.1. Study area

This study was conducted in Mogovolas district, located at Nampula province, in the northern region of Mozambique (Figure 1), between June and August 2015. The choice of this district was mainly based on the fact that Nampula province is one of the two provinces with the highest prevalence of malaria in the country (66%) [24]. We have also considered its low level of socio-economic development, and the fact that it is a difficult-to-reach district with insufficient hospitals and health

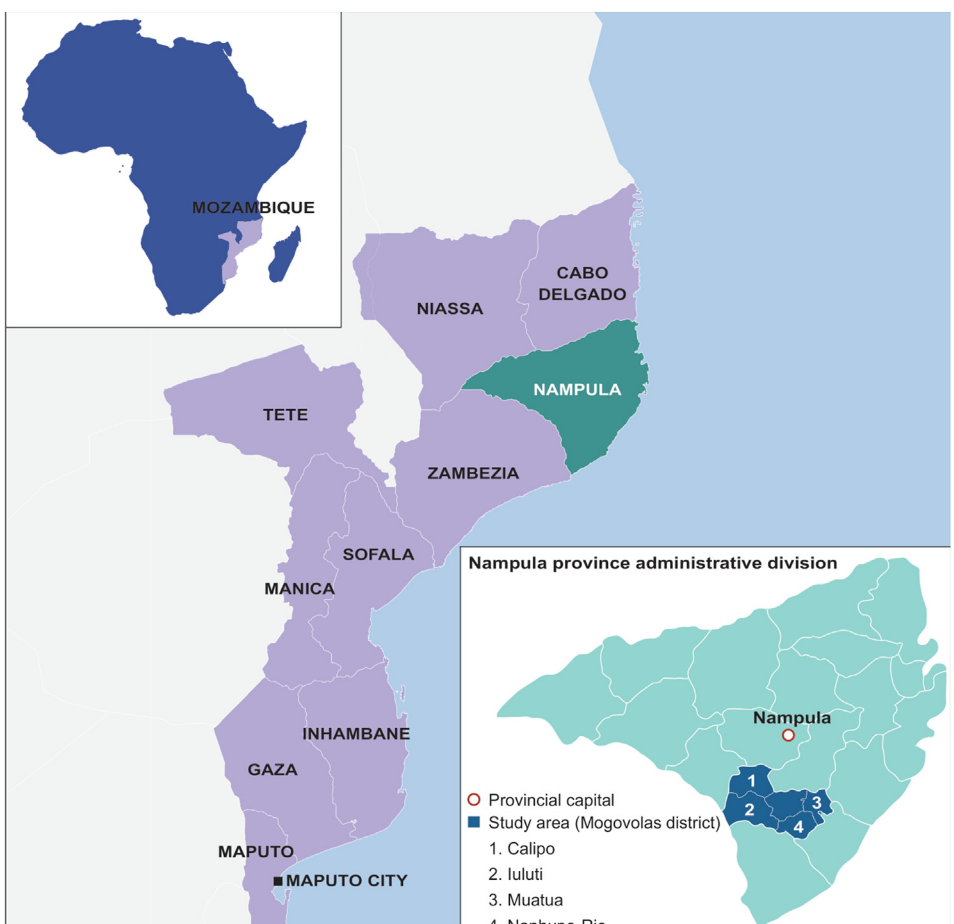


**Figure 1.** Study area.

centers. These are some of the reasons behind the dependence of the local people on traditional healers for primary health care.

Mogovolas district is situated 70 km away from the capital city of Nampula. It has a poorly developed road network and infrastructure. Most of the local residents belong to the Makhuwa ethnic group and 80% are illiterate, being Makhuwa the most spoken language [25].

The district is constituted by 5 administrative posts, namely: Calipo, Muatua, Nanhupo - Rio, Iuluti and Nametil (district seat). During the study, 4 administrative posts were involved:

**Calipo**, located between the geographic coordinates, S 15.6256 and E 039.1025, where the communities of Iolela, Tucua and Calipo were included;

**Muatua**, located between the geographic coordinates S 15.72498 and E 039.69460, where the communities of Meparo, Derruma, Mutulama and Muatua were included;

**Nanhupo-Rio**, located between the geographic coordinates S 15.71498 and E 039.69058, where the communities of Mopo, Mazezo, Nantira and Narre were included;

**Iuluti**, located between the geographic coordinates S 15.77449 and E 039.66144. In this administrative post, the communities of Nivini, Namutwama, and Mputho were included (Figure 1).

The study was approved by the scientific committee from the Lúrio University, located in Nampula Province and was authorized by the local authorities. No other regulatory boards exist in the country to regulate ethnobotanical studies. Further, national and international ethical guidelines [26] were followed.

With the support of the local leaders and the Mozambican Association of Traditional Healers (AMETRAMO), 16 traditional healers from these 4 different administrative posts, comprising the 14 villages, accepted to participate in the study.

The traditional healers were informed about the aim of the study and the methodology to be followed. There was a benefit-sharing agreement with the traditional healers and prior informed consents were obtained before starting the interviews. No traditional healer was coerced to participate in the study.

### 2.2. Data collection

A semi-structured questionnaire that was developed for this study was individually applied to the traditional healers in order to obtain information about their age, gender, ethnicity, years of experience, knowledge about malaria and its traditional treatment (see Supplementary Material 1). The vernacular names of the plants used by traditional healers to treat malaria, as well as the methods of preparation and administration of the remedies were also registered. The ethnobotanical surveys were conducted by the researchers Leonardo Manuel and Aurélio Bechel with support from a translator. Makhuwa language was used whenever required, through the translator that was native of Nampula province.

Under the supervision of the traditional healers, plant specimens were collected in order to produce voucher specimens and deposit in the herbarium. These were prepared and preserved in 70% alcohol moistened newspapers (wet conservation), and transported to the Eduardo Mondlane University LMU Herbarium, in Maputo, where they were dried, deposited and scientifically identified by using dichotomic keys and herborized plant samples for comparisons. This study was conducted under the Master's research project from Leonardo Manuel.

The names of the plants have been checked and updated according to The Plant List (www.theplantlist.org), accessed at 24 October 2020. The botanical families follow the Angiosperm Phylogeny Group (APG) IV system [27].

Data were entered into a database and grouped according to their similarities (e.g., knowledge about malaria or not) and analyzed using SPSS (version 24). The frequency of citation (FC) of each plant was presented as the sum of informants that cited the use of the species to treat malaria. The informant consensus factor (ICF) was calculated in order to estimate the agreement about the use of plants to treat given ailments [28], as follows:

$$ICF = (N_{ur} - N_t)/(N_{ur} - 1)$$

where, $N_{ur}$ = number of use-reports in each disease category, $N_t$ = number of species used for that use category. ICF values range between 0 and 1, where 1 indicates the highest level of informant consensus on the species to be used in the treatment within a category of illness [28].

## 3. Results

### 3.1. Socio-demographic details of traditional healers

All 16 interviewed traditional healers were from the Makhuwa ethnicity and 9 were male. The age ranged from 30 to 70 years, with an average of 52 years. Seven traditional healers were unschooled (most of them were women, n = 6). All those who attended school (n = 9) reported to have only primary level. The work experience as traditional healers varied from 2 to 46 years, with an average of 19 years.

### 3.2. Perceptions about malaria

From the 16 traditional healers, 10 exhibited knowledge about malaria and mentioned headache, fevers and anorexia as the main symptoms. Six informants believed that malaria was caused either by evil spirits or by small animals present in dirty waters. When they were asked about the use of medicinal plants for treatment of malaria, all of them reported relevant knowledge of plants used for such purpose.

### 3.3. Medicinal plants used as antimalarial remedies

A total of 37 plant species were recorded as used for treatment of malaria in Mogovolas district. Table 1 provides data on all the identified plants, voucher numbers, area of collection, used parts, other traditional uses, modes of preparation, administration and the frequency of citation of each plant. Three plants, namely: *Grewia* sp., *Passiflora* sp. and *Pavetta* sp., were only identified to genus level due to lack of sufficient taxonomic elements for identification at the species level (e.g. fruits and flowers).

The plant species with the highest Frequency of Citation (FC) were *Ochna kirkii* Oliv. (FC = 5), *Ehretia amoena* Klotzsch and *Pteleopsis myrtifolia* (M.A.Lawson) Engl. & Diels (FC = 3). Thirteen plant species presented a FC of 2 each, and the remaining plants were cited by only one traditional healer each (FC = 1) (Table 1). Table 2 presents the ICF values for the different ailment categories.

Both categories that included anemia and evil spirits presented the higher ICF values of 1.00. This indicates that there was consensus in the use of the cited plant species for treatment of these ailments, although both presented less use-reports.

Diseases of the nervous system, musculoskeletal and general ailments presented an average consensus. The only category with an ICF of 0.00 was of mental, behavioral or neurodevelopmental disorders, in which two plant species were cited by two different traditional healers. The infectious or parasitic diseases category which included malaria presented an ICF of 0.37. This reinforces the fact that a wide range of plants were cited by the traditional healers to treat malaria.

### 3.4. Plant parts used, modes of preparation and administration

The majority of plant remedies were prepared using a single plant part (22/37). However, some were prepared using a combination of two or more plant parts (15/37). Leaves (22/37), roots (18/37) stem barks (16/37) and stems (3/37) were the most used plant parts.

Cold maceration was the main technique used to prepare the traditional remedies (21/37). In addition, decoction (16/37), infusion (2/37) and hot maceration (1/37) were the other used techniques. According to

**Table 1.** Medicinal plants used by traditional healers for the treatment of malaria in the Mogovolas district.

| Family | Scientific name | Voucher number | Local name (Makhuwa) | Area of collection | Used parts | Other traditional uses | Preparation mode | Administration mode | FC |
|---|---|---|---|---|---|---|---|---|---|
| Annonaceae | *Monanthotaxis caffra* Verdc. | MP22 | Nankwekule | Muatua | Roots, barks and leaves | Muscle pain | Cold maceration | Oral and bathing | 1 |
| Apiaceae | *Steganotaenia araliacea* Hochst. | MP07 | Nimpepele | Muatua | Leaves | - | Hot maceration | Bathing | 2 |
| Asphodelaceae | *Aloe chabaudii* Schönland | MP01 | Elio | Iuluti | Roots | Abdominal pain | Decoction | Oral | 1 |
| Asphodelaceae | *Aloe zebrina* Baker | MP02 | Elio | Iuluti | Roots | Abdominal pain | Cold maceration | Oral | 1 |
| Bignoniaceae | *Stereospermum kunthianum* Cham. | MP27 | N'chapu | Calipo | Stem bark | Delusions | Cold maceration | Oral and bathing | 1 |
| Boraginaceae | *Ehretia amoena* Klotzsch | MP26 | Walacaka | Calipo | Roots | Muscle pain | Cold maceration | Oral and bathing | 3 |
| | | MP05 | Namulavilavi | Calipo | Roots, stem bark and leaves | Vomiting | | | |
| Capparaceae | *Boscia albitrunca* (Burch.) Gilg & Benedict | MP18 | Nayotho | Muatua | Roots | Muscle pain; anemia | Cold maceration | Oral | 2 |
| Combretaceae | *Pteleopsis myrtifolia* (M.A.Lawson) Engl. & Diels | MP15 | Muleva | Muatua | Roots, stem bark and leaves | Muscle pain; diarrhea | Cold maceration | Oral and bathing | 3 |
| Combretaceae | *Terminalia sericea* Burch. ex DC. | MP16 | Hai-hai | Muatua | Stem bark | Lack of appetite | Cold maceration | Bathing | 2 |
| Connaraceae | *Rourea orientalis* Baill. | MP36 | M'prunha | Nanhupo-Rio | Leaves | Lack of appetite | Cold maceration | Bathing | 2 |
| Dilleniaceae | *Tetracera boiviniana* Baill. | MP25 | Thuquene | Muatua | Roots and leaves | Lack of appetite; psychotic disorders | Cold maceration | Oral and bathing | 1 |
| Ebenaceae | *Diospyros verrucosa* Hiern | MP21 | Murriparripa | Calipo | Roots and leaves | Abdominal pain | Decoction | Oral | 1 |
| Euphorbiaceae | *Croton pseudopulchellus* Pax | MP24 | Murrupane | Muatua | Roots and leaves | Muscle pain; headache | Cold maceration | Oral and bathing | 1 |
| Fabaceae | *Acacia polyacantha* Willd. | MP09 | Muroca | Iuluti | Stem bark | Headache | Cold maceration | Oral | 1 |
| Fabaceae | *Bauhinia galpinii* N.E.Br. | MP30 | Muravarava | Nanhupo-Rio | Roots and leaves | Pain in bones and joints | Infusion | Bathing | 1 |
| Fabaceae | *Bauhinia thonningii* Schum. | MP28 | Muchequeche | Nanhupo-Rio | Roots, stem and leaves | Muscle pain; convulsions | Decoction | Bathing | 2 |
| Fabaceae | *Erythrina abyssinica* DC. | MP37 | Namucolocoma | Nanhupo-Rio | Stem bark | Delusions | Decoction | Bathing | 1 |
| Fabaceae | *Hymenaea verrucosa* Gaertn. | MP04 | Moco | Muatua | Leaves and stem | - | Infusion | Oral and bathing | 1 |
| Fabaceae | *Julbernardia globiflora* (Benth.) Troupin | MP12 | M'pakala | Muatua | Stem bark | Headache | Cold maceration | Oral and bathing | 2 |
| Fabaceae | *Millettia stuhlmannii* Taub. | MP19 | Campri | Iuluti | Leaves, stem bark and roots | Pain in bones | Decoction | Oral and bathing | 1 |
| Fabaceae | *Ormocarpum kirkii* S. Moore | MP33 | N'kutu | Nanhupo-Rio | Leaves | Headache; skin disorders | Decoction | Bathing | 1 |
| Fabaceae | *Pterocarpus angolensis* DC. | MP06 | M'pila | Iuluti | Leaves | - | Cold maceration | Oral | 2 |
| Fabaceae | *Senna petersiana* (Bolle) Lock | MP29 | Reperepe | Nanhupo-Rio | Roots, stem and leaves | Pain in bones; convulsions | Cold maceration and decoction | Oral and bathing | 2 |
| Fabaceae | *Xeroderris stuhlmannii* (Taub.) Mendonca & Sousa | MP11 | Mulotwe | Iuluti | Stem bark | Headache | Cold maceration | Oral | 2 |
| Linaceae | *Hugonia orientalis* Engl. | MP35 | N'tululu | Nanhupo-Rio | Leaves | Delusions; psychotic disorders | Decoction | Bathing | 1 |
| Malvaceae | *Adansonia digitata* L. | MP32 | Melapa | Nanhupo-Rio | Stem bark | Headache | Cold maceration and decoction | Oral and bathing | 1 |
| Malvaceae | *Grewia* sp. | MP23 | Terenhe | Nanhupo-Rio | Roots | Muscle pain | Decoction | Oral | 1 |
| Moraceae | *Ficus lutea* Vahl | MP13 | Mudjaia | Iuluti | Stem bark | Body aches | Cold maceration | Oral and bathing | 1 |
| Moraceae | *Ficus sur* Forssk. | MP31 | Mukuku | Nanhupo-Rio | Stem bark and leaves | Headache; weakness | Cold maceration | Oral and bathing | 2 |
| Myrtaceae | *Psidium guajava* L. | MP38 | M'pera | Nanhupo-Rio | Leaves and stem bark | Cough; headache | Decoction | Bathing | 2 |
| Ochnaceae | *Ochna kirkii* Oliv. | MP03 | Mulukamo | Nanhupo-Rio | Roots and leaves | Diarrhea; cough; headache | Cold maceration | Oral | 5 |
| Olacaceae | *Olax dissitiflora* Oliv. | MP08 | Mussilo | Iuluti | Leaves | Evil spirits | Decoction | Bathing | 2 |
| Passifloraceae | *Passiflora* sp. | MP20 | Nampitho | Muatua | Roots | Body aches | Decoction | Oral | 1 |
| Phyllanthaceae | *Cleistanthus schlechteri* (Pax) Hutch. | MP17 | Motheria | Muatua | Roots, stem bark and leaves | Headache | Cold maceration | Oral and bathing | 1 |
| Rubiaceae | *Breonadia salicina* (Vahl) Hepper & J.R.I.Wood | MP10 | Muconha | Muatua | Stem bark | Convulsions | Cold maceration and decoction | Oral and bathing | 2 |
| Rubiaceae | *Pavetta* sp. | MP14 | Nanrassimo | Muatua | Stem bark | - | Decoction | Oral | 1 |
| Salicaceae | *Flacourtia indica* (Burm.f.) Merr. | MP34 | M'pichi | Nanhupo-Rio | Leaves | - | Decoction | Bathing | 1 |

**Table 2.** ICF values for different ailment categories.

| WHO categories[1] | Recorded ailments | No. species ($N_t$) | No. use-reports ($N_{ur}$) | ICF |
|---|---|---|---|---|
| Certain infectious or parasitic diseases | Malaria | 37 | 58 | 0.37 |
| Diseases of the blood or blood-forming organs | Anemia | 1 | 2 | 1.00 |
| Mental, behavioral or neurodevelopmental disorders | Psychotic disorders | 2 | 2 | 0.00 |
| Diseases of the nervous system | Convulsions, headache | 13 | 24 | 0.48 |
| Diseases of the musculoskeletal system or connective tissue | Muscle pain | 7 | 13 | 0.50 |
| Symptoms, signs or clinical findings, not elsewhere classified | Delusions, abdominal pain, vomiting, diarrhea, cough, skin disorders, weakness, body aches, pain in bones, pain in bones and joints, lack of appetite | 20 | 38 | 0.49 |
| Unspecified | Evil spirits | 1 | 2 | 1.00 |

[1] The International Statistical Classification of Diseases and Related Health Problems (ICD) from the World Health Organization (WHO) was used to define the categories (https://icd.who.int/browse11/l-m/en), with the exception of the "Unspecified" category.

the traditional healers, plant remedies can be kept at a room temperature and under the shadow for many days. The main administration route was oral, followed by bathing.

Generally, the traditional healers recommended to administer the herbal remedies twice or three times per day for one, two or three consecutive days or many months until recovery.

## 4. Discussion

### 4.1. Traditional knowledge

This study has found that the use of plants for medicinal purposes by traditional healers in the Mogovolas district remains an important practice for people with limited or no access to modern health care.

In other countries such as Zimbabwe, traditional remedies are quickly accessible and affordable to the rural communities. However, they do not have detailed information about the dosage and adverse effects [1, 29]. The same scenario was observed with the traditional healers interviewed in this study.

The fact that about half of the interviewed traditional healers were male was unexpected, considering the African belief that traditional healers should be male [30]. The age average was 52 years and the mean years of experience as traditional healers was 19. This is common in Mozambique and other countries where traditional healers are older and have a vast experience in traditional medicine. This knowledge is mainly passed from elders to selected family members or to very few people through traditional teaching and ceremonies [31].

Despite the low literacy of the traditional healers, 10 (8 men and 2 women) presented some knowledge about malaria. It may be related to the existing campaigns against malaria in the district, which are promoted by the national malaria control program. The remaining 6 traditional healers believed that malaria was caused by evil spirits or by small animals present in dirty waters. In Nigeria, certain traditional healers also believe that malaria is caused by evil spirits [32]. In Uganda and Zimbabwe some people also believe that malaria is caused by dirty waters [33, 34]. They might be referring to mosquito breeding sites [29].

In many cases, traditional healers from neighboring communities present similar information about the plants used for treatment of malaria. This may be due to a common family heritage [29]. During our study in Mogovolas district, similar results were found, suggesting that traditional knowledge is often shared within family members or very close people.

### 4.2. Plants used by traditional healers for the treatment of malaria

In Mogovolas district, medicinal plants play a major role in the treatment of malaria. There is scientific evidence of the effectiveness for almost half of the identified species (19/37), which were tested for antiplasmodial activity [35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62].

No specific tool is used for the diagnosis of malaria in the sampled regions, such as rapid tests or blood smear microscopy. Therefore, a patient presenting at a traditional healer consultation with symptoms of fever may be incorrectly diagnosed as having malaria, and some of the plants provided may have applicability in the treatment of fever and not malaria.

In Table 3 we present a literature compilation of scientific studies performed on the identified species regarding the antiplasmodial activity and their phytochemical composition.

Of the plants cited in this study, only two, namely: *Adansonia digitata* L. and *Flacourtia indica* (Burm.f.) Merr., were reported for the treatment of malaria in ethnobotanical studies conducted in Mozambique [9, 18, 21]. Moreover, 4 of the 19 plants with scientific evidence of antiplasmodial activity were tested *in vivo* [92, 93, 94, 95, 96] as shown in Table 4.

**Table 3.** Literature review on *in vitro* pharmacological activity for antiplasmodial purpose and phytochemicals reported of the identified species.

| Plant name | Pharmacological activity | Part | Extract or compound | $IC_{50}$ | Citations | Phytochemicals reported | Citations |
|---|---|---|---|---|---|---|---|
| *Acacia polyacantha* | Antiplasmodial (PF) | Root bark | Crude ethanol | 93 μg/ml | [35] | Alkaloids, phenolic compounds, steroids, triterpenoids, saponins and flavonoids | [63] |
| | | | Petroleum ether | 27 μg/ml | | | |
| | | | Ethyl acetate | 13 μg/ml | | | |
| | | | Aqueous | >500 μg/ml | | | |
| *Adansonia digitata* | Antiplasmodial (PF) | Stem bark | Methanol | 423.9 ± 8.50 μg/ml | [36] | Flavonoids, terpenoids, saponins, tannins, alkaloids, anthraquinones, steroids, resins, phenols and cardiac-active glycosides | [64] |
| | | Fruit pulp | Aqueous | >50 μg/ml | [37] | | |
| *Aloe chabaudii* | - | - | - | - | - | Phenols, flavonoids and tannins | [65] |
| *Aloe zebrina* | - | - | - | - | - | Anthraquinones and anthraquinone glycosides | [66] |
| *Bauhinia galpinii* | - | - | - | - | - | Tannins, proanthocyanidins and flavonoids | [67] |
| *Bauhinia thonningii* | Antiplasmodial (PF) | Leaf | Ethanol | 15.06 μg/ml; 37.64 μg/ml; 67.51 μg/ml | [38, 39] | Alkaloids, tannins, saponins, steroids, terpenoids, flavonoids, cardiac glycosides and anthraquinones | [38, 68] |
| | | | Methanol | 6.20 μg/ml | | | |
| *Boscia albitrunca* | - | - | - | - | - | Phenolic compounds | [69] |
| *Breonadia salicina* | Antiplasmodial (PF) | Bark | Dichloromethane: methanol (1:1) | <20 μg/ml | [40] | Saponins, alkaloids, tannins and flavonoids | [70] |
| *Cleistanthus schlechteri* | - | - | - | - | - | Terpenoids | [71] |
| *Croton pseudopulchellus* | - | - | - | - | - | Terpenoids | [72] |
| *Diospyros verrucosa* | Antiplasmodial (PF) | Leaf | Methanol | Did not inhibit parasite growth by more than 75% | [41] | Naphthoquinones | [73] |
| | | Root bark | Methanol | Did not inhibit parasite growth by more than 75% | | | |
| | | Stem bark | Methanol | Did not inhibit parasite growth by more than 75% | | | |
| *Ehretia amoena* | - | - | - | - | - | - | - |
| *Erythrina abyssinica* | Antiplasmodial (PF) | Stem bark | Ethyl acetate | 7.9 ± 1.1 and 5.3 ± 0.7 μg/ml | [42, 43] | Alkaloids, pterocarpans, chalcones and flavonoids | [42, 43, 74] |
| | | | Chalcones, flavanoids and isoflavonoids | Ranging between 5.4 – 27.7 μM | | | |
| *Ficus lutea* | Plasmodial FAS-II enzyme inhibition % (at 1 μg/ml) | Leaf | Crude methanol | 0[a]; 0[b]; 0[c] | [44] | Polyphenolic compounds, ceramide and triterpenoids | [75, 76] |
| | | | Hexane | 5[a]; 29.3[b]; 33.8[c] | | | |
| | | | Chloroform | 59[a]; 89[b]; 75[c] | | | |
| | | | Aqueous methanol | 61.8[a]; 92.2[b]; 84.4[c] | | | |
| | | Stem bark | Crude methanol | 0[a]; 0[b]; 0[c] | | | |
| | | | Hexane | 31.5[a]; 0[b]; 0[c] | | | |
| | | | Chloroform | 70.7[a]; 57.9[b]; 66.2[c] | | | |
| | | | Aqueous methanol | 75.7[a]; 73.9[b]; 83.9[c] | | | |
| | | Root bark | Crude methanol | 0[a]; 0[b]; 90.6[c] | | | |
| | | | Hexane | 88.6[a]; 7[b]; 33.8[c] | | | |
| | | | Chloroform | 4.9[a]; 27.1[b]; 7.9[c] | | | |
| | | | Aqueous methanol | 9.5[a]; 92.7[b]; 91.8[c] | | | |

(*continued on next page*)

Table 3 (*continued*)

| Plant name | Pharmacological activity | Part | Extract or compound | $IC_{50}$ | Citations | Phytochemicals reported | Citations |
|---|---|---|---|---|---|---|---|
| *Ficus sur* | Antiplasmodial (PF) | Stem bark | Hexane | 19.2 ± 1.3 μg/ml | [45] | Saponins, steroids, tannins, volatile oils and phenols | [77] |
| | | | Chloroform | 9.0 ± 3.2 μg/ml | | | |
| | | | Ethyl acetate | >100 μg/ml | | | |
| | | | Methanol | >100 μg/ml | | | |
| | | | Water | >100 μg/ml | | | |
| *Flacourtia indica* | Antiplasmodial (PF) | Aerial part | Dichloromethane | 49 μg/ml | [46] | Alkaloids, tannins, saponins, flavonoids, glycosides, phenolic compounds, terpenoids and steroids | [78] |
| | | | Methanol | >50 μg/ml | | | |
| | | | Methanol/$H_2O$ (1/1) | >50 μg/ml | | | |
| | | | Aqueous | >50 μg/ml | | | |
| | | | Ethyl acetate | 3 μg/ml | [47] | | |
| | | | Pyrocatechol | 3 ± 1 μg/ml | | | |
| | | | Homaloside | 11 ± 1 μg/ml | | | |
| | | | Poliothrysoside | 3 ± 0 μg/ml | | | |
| *Grewia* sp. | Antiplasmodial (PF) | Combined leaves, twigs, and stems of *Grewia bilamellata* | Methanol: 3R,20-lupandiol | 19.8 and 19.1 μM | [48] | Coumarinolignans, lignans, triterpenes, quinol derivative and sterol glucosides | [48] |
| | | | Grewin | 11.2 and 5.5 μM | | | |
| | | | Nitidanin | 21.2 and 18.4 μM | | | |
| | | | 2R,3âdihydroxy-olean-12-en-28-oic acid | 21.2 and 8.6 μM | | | |
| | | | 2,6-dimethoxy-1-acetonylquinol | 42.2 and 23.0 μM | | | |
| | | Unidentified parts of *Grewia erythraea* | Methanol | 11.7 ± 3.5 μM | [49] | | |
| *Hugonia orientalis* | - | - | - | - | - | - | |
| *Hymenaea verrucosa* | - | - | - | - | - | Terpenes, quinones | [79] |
| *Julbernardia globiflora* | - | - | - | - | - | - | - |
| *Millettia stuhlmannii* | - | - | - | - | - | - | - |
| *Monanthotaxis caffra* | Antiplasmodial (PF) | Leaves and twigs | Ethanol | 5.86–18.94 μg/ml | [50] | Tannins, crotepoxide, 5,6-diacetoxy-1-benzoyloxymethyl-1,3-cyclohexadiene | [50, 80] |
| *Ochna kirkii* | - | - | - | - | - | - | - |
| *Olax dissitiflora* | Antiplasmodial (PF) | Bark | Dichloromethane | 45 μg/ml | [51] | Triterpenoids | [51] |
| | | | Ethanol | 15.6 μg/ml | | | |
| *Ormocarpum kirkii* | Antiplasmodial (PF) | Root | Methanol (flavonoids, coumarins) | 7.3 - >64.0 μM | [52] | Flavonoids and coumarins | [52, 54] |
| | | | Methanol | 15.6–31.25 μg/ml | [53] | | |
| | | Leaves | Methanol | 125–250 μg/ml | | | |
| | | Unidentified | Ethyl acetate: 4 compounds | 15.8–64.0 μM | [54] | | |
| *Passiflora* sp. | - | - | - | - | - | Alkaloids, phenols, cyanogenic compounds and flavonoids | [81, 82] |
| *Pavetta* sp. | Antiplasmodial (PF) | Leaves[d] | Chloroform | 1.23 μg/ml | [55] | Tannins, flavonoids, saponins, cardiac glycosides and flavonoids | [83] |
| | | | Alkaloid extract | 25–280 ng/ml | | | |
| | | Aerial part[d] | Aqueous | <7.5 μg equivalent | [56] | | |
| *Psidium guajava* | Antiplasmodial (PF) | Leaf | Methanol | 9–15 μg/ml | [57] | Triterpenoid acid alkaloids, steroids, | [84, 85] |
| | | | Ethyl acetate | 12.5–18 μg/ml | | | |

(*continued on next page*)

Table 3 (*continued*)

| Plant name | Pharmacological activity | Part | Extract or compound | $IC_{50}$ | Citations | Phytochemicals reported | Citations |
|---|---|---|---|---|---|---|---|
| | | | | | | glycosides, tannins, flavonoids and saponins | |
| *Pteleopsis myrtifolia* | - | - | - | - | - | Triterpenoids | [86] |
| *Pterocarpus angolensis* | Antiplasmodial (PF) | Stem bark | 50% dichloromethane and 50% methanol | 13.87 (±0.20) μg/ml | [58] | Phenols, triterpenoids, terpenoids, tannins | [58] |
| | | | 50% ethyl acetate and 50% hexane | 0.79 (±0.002) μg/ml | | | |
| | | | 10% ethyl acetate 90% methanol | 1.96 (±0.01) μg/ml | | | |
| *Rourea orientalis* | - | - | - | - | - | - | - |
| *Senna petersiana* | Antiplasmodial (PF) | Roots | Methanol | >30 μg/ml | [59] | Alkaloids, flavonoids, cardiac glycosides, anthraquinones, anthocyanins, polyphenols, triterpenes, steroids, saponins, tannins and phlobatannins | [87] |
| | | | Aqueous | >100 μg/ml | | | |
| | | | Dichloromethane | 13.26 μg/ml | | | |
| | | Leaves | Methanol | 2.67 μg/ml | | | |
| | | | Aqueous | 3.97 μg/ml | | | |
| | | | Dichloromethane | 6.94 μg/ml | | | |
| | | | Ethyl acetate | 0.84 μg/ml | | | |
| *Steganotaenia araliacea* | Antiplasmodial (PF) | Bark | Ethanol | >500 μg/ml | [60] | Alkaloids, flavonoids, tannins, coumarines, steroids, and phenols | [88] |
| *Stereospermum kunthianum* | Antiplasmodial (PF) | Root bark | Petrol ether– Ethyl acetate 1:1 | 7.0–16.8 μg/ml | [61] | Naphthoquinones and anthraquinones, sterols/ triterpenes, coumarins | [61, 89] |
| | | | Quinones | 0.4 - >25.0 μg/ml | | | |
| *Terminalia sericea.* | - | - | - | - | - | Saponins, lignans, steroids, glycosides, phenolic acids | [90] |
| *Tetracera boiviniana* | -[e] | - | - | - | [62] | Terpenoids | [91] |
| *Xeroderris stuhlmannii* | - | - | - | - | - | - | - |

PF: *Plasmodium falciparum*.

[a] Plasmodial FAS-II enzyme (FabG at 1 μg/ml) inhibition in Percentage (%).

[b] Plasmodial FAS-II enzyme (FabI at 1 μg/ml) inhibition in Percentage (%).

[c] Plasmodial FAS-II enzyme (FabZ at 1 μg/ml) inhibition in Percentage (%).

[d] *Pavetta crassipes*.

[e] Extract not tested. However, methyl ethyl ketone extract of twigs and stem bark contains Betulinic Acid which has antiplasmodial activity (19.6–25.9 μg/ml).

**Table 4.** Literature review on *in vivo* pharmacological activities of plants for antimalarial purpose.*

| Plant name | Assay | Model | Part | Extract (compound) | Outcomes | Conclusion | Citations |
|---|---|---|---|---|---|---|---|
| *Adansonia digitata* | Chemosuppression of parasitemia against *Plasmodium berghei.* Mice were divided in 4 groups. Oral administration of extracts (100 mg/kg/day) for 4 days. Positive and negative control groups were included. | Mice (*Mus musculus*) | Stem bark | Aqueous | Mean parasite density; chemosuppression; survival: 12.6%; 60.5%; 20% | Crude extracts of *Adansonia digitata* demonstrated promising antimalarial activity | [92] |
| | | | | Chloroform: Methanol ($CHCl_3$:MeOH) | Mean parasite density; chemosuppression; survival: 21.4%; 32.9%; 0% | | |
| | Suppressive and prophylactic potentials against *Plasmodium berghei.* Mice were administered with two different doses (200 mg/kg body weight and 400 mg/kg body weight) of extracts for 5 consecutive days. Control groups were included. | Albino mice | Stem Bark | Aqueous, methanolic extract, chloroform fraction and ethyl acetate fraction (EF) | The 400 mg/kg body weight was more effective on parasite clearance than the 200 mg/kg body weight in all groups. Both 200 mg/kg and 400 mg/kg body weight doses of EF exhibited the highest chemosuppression (% parasitemia 1.6–0.9%), (% clearance 67.9–81.7%) | EF of *Adansonia digitata* stem bark has potent antimalarial property | [93] |
| *Bauhinia thonningii* | Suppressive test against *P. berghei berghei.* Mice were randomly divided into 5 groups and treated for 4 consecutive days with 100, 200 and 400 mg extract/kg body weight orally respectively. Two control groups. | Albino mice | Leaf | Ethanolic | % Suppression (negative control, 100 mg/kg, 200 mg/kg, 400 mg/kg, positive control: 0%, 61.9%, 78.4%, 91.9%, 98.8%) | The plant has potent antiplasmodial effect | [94] |
| *Ficus sur* | Suppressive test against *P. berghei.* Oral administration of the test extract at a dose of 500 mg/kg body weight for 4 days. *In vivo* interactions of chloroquine (CQ) and the plant extracts were tested. Two control groups. | Mice | Leaf | Methanolic | Suppression; survival: 43.9%; 20% | *Ficus sur* showed significant antimalarial activity | [95] |
| | | | | MeOH + CQ | Suppression; survival: 0%; 0% | | |
| | | | Stem bark | Methanolic | Suppression; survival: 34.1%; 20% | | |
| | | | | MeOH + CQ | Suppression; survival: 0%; 0% | | |
| | | | Root bark | Methanolic | Suppression; survival: 48.8%; 0% | | |
| | | | | MeOH + CQ | Suppression; survival: 79.3%; 20% | | |
| *Psidium guajava* | Suppressive test against *P. berghei.* Oral administration with different dosages: 350 mg, 750 mg and 1,000 mg/kg body weight for 7 days. Two control groups. | White albino mice | Leaf | Aqueous | Suppression at 350, 750, 1,000 mg: 73.7%, 80.2%, 85.8% Parasitemia at 350, 750, 1,000 mg: 19.8%, 10.3%, 9.2% | The plant has potent antiplasmodial effect | [96] |
| | | | Unripe fruits | Aqueous | Suppression at 350, 750, 1,000 mg: 30%, 65.1%, 62%. Parasitemia at 350, 750, 1,000 mg: 52.7%, 26.3%, 25.6% | | |

* **Key to abbreviations**: AQ: Aqueous; CF: Chloroform Fraction; $CHCl_3$: Chloroform; CQ: Chloroquine; EF: Ethyl Acetate Fraction; ME: methanolic extract; MeOH: Methanol.

Among the 19 plants with pharmacological evidence, we emphasize *Pterocarpus angolensis* DC., *Senna petersiana* (Bolle) Lock, *Pavetta* sp. and *Flacourtia indica* (Burm.f.) Merr., that have a high antiplasmodial activitiy (half maximal inhibitory concentration ($IC_{50}$) < 5 μg/ml as grouped by Laryea and Borquaye [50]).

Furthermore, plants with promising antiplasmodial activity (5 < $IC_{50}$ < 15 μg/ml) were identified as the following: *Acacia polyacantha* Willd., *Bauhinia thonningii* Schum., *Breonadia salicina* (Vahl) Hepper & J.R.I.Wood, *Erythrina abyssinica* DC., *Ficus sur* Forssk., *Monanthotaxis caffra* Verdc., *Psidium guajava* L. and *Stereospermum kunthianum* Cham.

Only two plants presented a moderate antiplasmodial activity (15 < $IC_{50}$ < 50 μg/ml), namely: *Olax dissitiflora* Oliv. and *Ormocarpum kirkii* S.Moore.

*Adansonia digitata* L., *Diospyros verrucosa* Hiern and *Steganotaenia araliacea* did not present considerable antiplasmodial activities ($IC_{50}$ > 50 μg/ml or no inhibition of parasite growth by more than 75%). Nevertheless, *A. digitata* presented a promising *in vivo* antimalarial activity [92].

It should also be noted that of all 19 tested plants, only 5 had their active compounds analyzed, namely: *Erythrina abyssinica* DC., *Flacourtia indica* (Burm.f.) Merr., *Grewia* sp., *Ormocarpum kirkii* S.Moore and *Stereospermum kunthianum* Cham. Of these, the quinones isolated from *S. kunthianum* presented a high antiplasmodial activity ($IC_{50}$ < 5 μg/ml), followed by the phenolic compounds isolated from *F. indica*. The compounds from the other 3 plants had their antiplasmodial activity expressed in μM.

The *in vivo* studies focused on suppressing parasitemia in rats. All tested plants demonstrated promising antimalarial activity, although they were tested with quite different methods [92, 93, 94, 95, 96].

Most of the plants with proven antiplasmodial activity are used in African traditional medicine for treatment of malaria and other fever-related diseases [16, 17, 33, 61, 69, 84, 86, 97, 98, 99, 100, 101].

To our best knowledge, there is still no data available concerning the antimalarial properties of the most cited plants in this study, namely: *Ochna kirkii* Oliv., *Ehretia amoena* Klotzsch and *Pteleopsis myrtifolia* (M.A.Lawson) Engl. & Diels. Further phytochemical and pharmacological studies are needed. However, other plants with taxonomic proximity, such as *Ochna integerrima* (Lour.) Merr. present a significant *in vitro* antiplasmodial activity [102].

Since the Fabaceae family provided the highest number of species, it might be an important family for the study of antimalarial activity. However, this preference to treat malaria with plants from the Fabaceae family by the surveyed healers could certainly be attributed to their wide distribution range, large number of taxa and plant numbers in the region.

Regarding these findings, we suggest that *Ochna kirkii* Oliv., *Ehretia amoena* Klotzsch and *Pteleopsis myrtifolia* (M.A.Lawson) Engl. & Diels, the most cited plants in this study should be studied for antimalarial properties.

### 4.3. Plant parts used and modes of preparation and administration

The traditional healers mix several plant parts of the same medicinal plant to prepare the remedies used for the treatment of malaria. We reported the use of 15 medicinal recipes with more than one plant part.

Leaves were the most commonly used plant parts by traditional healers in the Mogovolas district (22/37). Regular harvest of leaves poses low threat to the survival of individual plants. This encourages the frequent and safe utilization of leaves in herbal preparations [103]. However, plant roots (18/37) and barks (16/37) constitute the second and third plant parts often utilized by the traditional healers of Mogovolas district. The frequent usage of roots or barks for herbal preparations can be risky to the survival of a plant species. Therefore, to ensure a sustainable utilization of these medicinal plant resources, it is necessary to assure the application of proper harvesting strategies and conservation measures.

The most frequently used solvent was water, and cold maceration was the most common mode of preparation. Since the extraction process requires a long period, and given the state of the patient suffering from symptoms of the disease, the remedies are possibly administered with a low concentration of the active substance, which could lead to poor results [29]. However, we have no data on successful treatment.

## 5. Conclusion

Ethnobotanical and ethnopharmacological research on indigenous antimalarial plants is still at a rudimentary stage in Mozambique. Moreover, available research evidence on indigenous antimalarial plants is highly fragmented and difficult to access.

This study highlighted that traditional healers still play a key role in the primary health care in Mogovolas district, using a total of 37 indigenous plants for treatment of malaria. Many of the identified plants are also used with the same purpose in other African countries, which reflects the common ethnic and cultural ties shared by the traditional healers.

Frequency of citation of particular plant species or families could indicate potentially higher bioactive antimalarial content. Such evidence is pertinent for prioritizing future pharmacological research agendas. The most cited plants in Mogovolas district were *Ochna kirkii* Oliv., *Ehretia amoena* Klotzsch and *Pteleopsis myrtifolia* (M.A.Lawson) Engl. & Diels, belonging to Ochnaceae, Boraginaceae and Combretaceae families, respectively. However, their antimalarial properties are still unknown, and should be studied to validate their therapeutic potential as antimalarials.

Some medicinal plants have already been studied and have antiplasmodial activity, which can vary from moderate to high, although some did not have considerable antiplasmodial activity. Thence, efforts should be made in order to improve the integration of traditional medicine into the national health system, particularly with the rational use of selected medicinal plants with higher efficacy and safety rates, by defining the appropriate dosage as well as the mode of preparation and storage of the remedies.

The ethnobotanical database resulting from this study constitutes an important way not only to preserve precious indigenous knowledge and biodiversity, but also to enhance community access and efforts in improvement of malaria control interventions.

These data are crucial for future research on safety and efficacy of medicinal plants and identification of new active substances, thus contributing to the discovery of new drugs for malaria.

## Declarations

### Author contribution statement

L. Manuel: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

A. Bechel: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

E.V. Noormahomed: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

D.F. Hlashwayo: Analyzed and interpreted the data; Wrote the paper.

M. do Céu Madureira: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

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### Data availability statement

Data included in article/supplementary material/referenced in article.

### Declaration of interests statement

The authors declare no conflict of interest.

### Additional information

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