



Volume 2	Issue 3	October (2022)	DOI: 10.47540/ijias.v2i3.605	Page: 219 – 233
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Ethnobotanical Study of Plants Used by Traditherapists for the Treatment of Malaria in the City of Butembo, North Kivu, East of the Democratic Republic of Congo

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ARTICLE INFO

Keywords: Ethnobotanical Study, Malaria, Pharmacological Analysis, Traditherapists.

Received : 15 July 2022

Revised : 25 September 2022

Accepted : 27 September 2022

ABSTRACT

Malaria is a serious public health problem in the Democratic Republic of Congo (DRC) in general and in the city of Butembo in particular. To complete the lack of information, the objective of this article is to identify the different plant species used in the traditional treatment of malaria in the city of Butembo. Ethnobotanical investigations were conducted among 91 traditherapists. Semi-structured interviews with the use of a pre-established questionnaire were used for data collection. This study allowed the inventory of 26 plant species belonging to 18 botanical families. The species of the *Asteraceae* family are the most solicited by the therapists of the city of Butembo (25.27%). This family is followed by the *Myrtaceae* and *Rubiaceae* families, each with a total of 12.09%. Then come the *Caricaceae*, *Poaceae*, and *Fabaceae* with respectively 9.89%, 9.89%, and 8.79% of citations. Leaves are the most used organ (70.33%) in the preparation of drugs. The pharmaceutical form of preparation is decoction (81.32%). The antimalarial recipes are administered by oral (100%). The species most solicited by the therapists are *Artemisia annua* (12.09%), *Eucalyptus maideni var globulus* (10.99%), *Cinchona ledgeriana* (10.99%), *Cymbopogon citratus* (9.89%), *Carica papaya* (9.89%), *Cassia occidentalis* (7.69%), and *Bidens pilosa* (8.79%). In consideration of these results, phytochemical and pharmacological analysis of these plants is essential to help validate their traditional use and to find new plants with antimalarial potential that would play the first role in the development of improved traditional medicines (ITM) with antimalarial activity.

INTRODUCTION

Malaria is a serious public health problem in tropical regions. Indeed, the natural history of malaria reveals that humans, living in a biotope that the *Plasmodium falciparum* vector, would have co-evolved with both the vector and the parasite by developing a mis-mutation of the β globin family gene located on the short arm of chromosome 11 (Ngbolua et al., 2013). In the world, 3.4 billion people are exposed to malaria. In 2012, there were

approximately 207 million cases of malaria in the world with 80% of cases resulting in death in Africa. These deaths were mostly encountered in children under 5 years of age with 77% according to World Health Organization statistics (Dénou et al., 2017). In addition, malaria continues to be one of the causes of mortality and morbidity. The African continent has a significant diversity of medicinal plants (Dibong et al., 2020). As a result of reduced access to conventional drugs in rural African areas where malaria is endemic, 80% of the population

uses traditional medicine to cure malaria (AguiaDaho, 2020; Dénou et al., 2017; G nondoli et al., 2015; Yolidje et al., 2020). This phenomenon is not new because, for centuries and even millennia, our ancestors have used plants to relieve their pains, heal their ailments and dress their wounds (Kouchade et al., 2017). It can be that among the diseases treated in traditional medicine, malaria represents about 20% of the cases (Brice et al., 2015).

Like other tropical countries, the Democratic Republic of Congo is not exempt from malaria. According to a survey by the Kinshasa School of Public Health, malaria is the primary cause of infantile morbidity and mortality in the Democratic Republic of Congo. It is responsible for 67% of external consultations and 47.3% of deaths of children under 5 years old. Indeed, a Congolese child under 5 years of age experiences between 6 and 10 episodes of malaria fever per year (Mutombo et al., 2020; Mutombo et al., 2014). To combat this endemic, the National Malaria Control Program in DR Congo (NMCP) has implemented different strategies for malaria control as proposed by the WHO. Despite the availability of funds and the existence of means of control, malaria continues to fill hospitals and kill children under 5 years of age (Mutombo et al., 2014). Indeed, the Democratic Republic of Congo is a country with considerable floristic biodiversity. This flora abounds in medicinal plants of biopharmaceutical interest and is capable of providing new lead molecules (Ngunde et al., 2021) in this context where despite the use of anti-malarial drugs, cases of drug resistance represent a major obstacle to the fight against malaria (Rusaati et al., 2021).

Despite a possible probability of finding favorable results recorded by traditional medicine, doubt reigns in the mentality of many Congolese as to the diagnosis, dosage, and healing of diseases by this medicine. This is why it is necessary to evaluate the quality of traditional medicine in the DRC, starting with an inventory of the plants used in the traditional treatment and the different ways they are used, before proceeding to various analyses of some specimens of therapeutic interest identified by the survey (Rusaati et al., 2021). In view of this situation, it is necessary to know whether some of the plants used against malaria in the DRC could be used for a truly effective treatment. The richness of

the flora of the DRC provides hope of finding effective plant-based treatments.

With this in mind, an ethnobotanical study in the city of Butembo proved necessary. In this city, we observe a more and more massive recourse of the population to traditional medicine. The number of practitioners of this medicine is increasing and many of the traditherapists are recognized by the Congolese State while others work in the informal sector. Unfortunately, knowledge about the plants used by traditherapists is very fragmentary. Therefore, this article is of great importance because it serves as a basis for future researchers who may be interested in the phytochemical analysis of these plants to extract effective drugs against malaria and thus reduce mortality in the city of Butembo. The objective of this article is to identify the main plants used in the traditional treatment of malaria and their distribution in families, the different organs of the plant that are used, the modes of preparation of the cures, and the posology. The interest of this article is to provide basic data that can be used as a starting point in research aimed at the development of new antimalarial drugs.

METHODS

Study area

The ethnobotanical investigation was realized in the city of Butembo (Figure 1), province of North Kivu in the East of the Democratic Republic of Congo. This city is located between 0°05" and 0°10" North latitude and 29°17" and 29°18" East longitude. It is 17 km north of the equator. It is located near the western ridge of the Albertine Rift northwest of Lake Edward (Sahani, 2011). Indeed, the city center is drained by the Kimemi River, which flows through the urban area in a south-north direction. This river flows through former swampy areas called *dambo* (Kaleghana & Mweru, 2018; Sahani, 2011). The city of Butembo enjoys a humid subtropical climate (*Afi*) tempered by the mountains (Vyakuno, 2006). The average temperature hovers around 18°C, with two rainy seasons, March-April-May and August-September-October-November, influenced by the passage of the Intertropical Convergence Zone. The two relatively dry seasons are from June to July and January to February. The average annual rainfall (1365 mm) in the region is typical of the equatorial zone, as the area borders

the forest of this zone (Sahani et al., 2012; Sahani, 2011).

The soils of Butembo are diversified according to the parent rocks, texture, water, and organic matter content. The milieu of Butembo is inhabited by the *Nande*, also called *Yira*, who have populated the region for several centuries. Among the *Nande*, life is organized around families or households, considered to be the basic units for the undertaking of socio-economic activities. These activities are essentially based on agriculture and business. Livestock raising has not in itself constituted the foundation of *Nande* social organization, but it has mainly served to maintain relationships between individuals that are based on social contacts, and

accessible to all (Vyakuno, 2006). It should be noted that among the *Nande*, livestock breeding has a pragmatic vocation: small livestock is used as currency to settle disputes between men, disputes, land royalties, dowries, etc. Agriculture is essentially traditional. Sweet potatoes, bananas, beans, corn, cabbage, amaranths, etc. are produced. Often, trees accompany these crops in the city's landscape (Moïse et al., 2022). The commercial dynamic that the city of Butembo has experienced has also contributed greatly to the improvement of the city's housing (Mirembe, 2005). The population of the city of Butembo is estimated at 936,329 habitants for the year 2020 according to the statistics of the City Hall of Butembo.

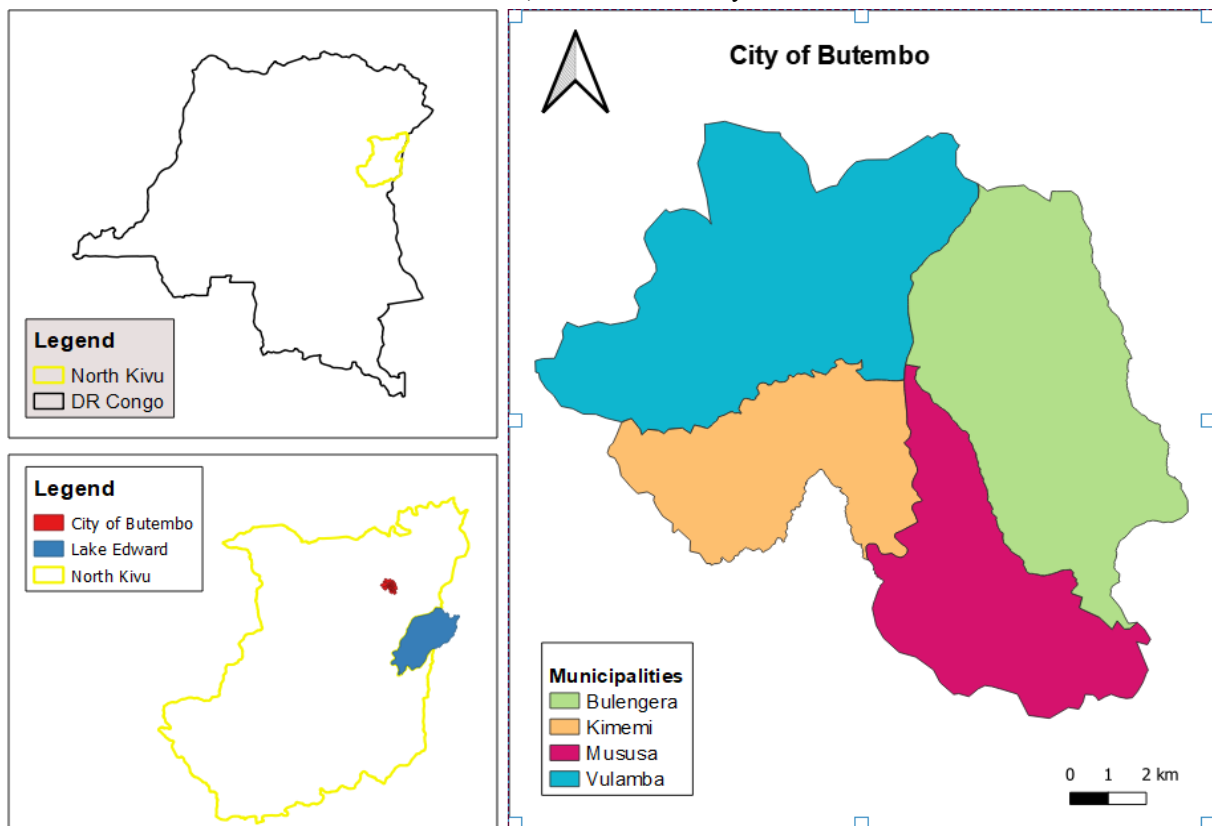


Figure 1. Map of the study area: City of Butembo

Sampling

Because it is not easy to locate traditherapists throughout the city of Butembo, snowball sampling allowed us to reach traditherapists and interview them in their facilities where they administer medicines to patients. This method is necessary when individuals who could be part of the sample are difficult to contact (Audemard, 2016; Johnston & Sabin, 2010; Semaan, 2010; Touko et al., 2010). According to Audemard (2016), snowballing is therefore a sampling technique in which the aim is

to expand a starting sample composed of a limited number of individuals by mobilizing their social capital. In the first stage, the researcher selects a limited number of participants who are asked to nominate other people likely to be of interest to the research. In the second stage, these people are interviewed and may in turn nominate others, and so on (Audemard, 2016).

In this way, we were able to identify traditional healers in the urban area of Butembo, given the scale of the city and the random

distribution of traditherapists. A total of 91 traditherapists agreed to answer our questions out of an estimated average of nearly 250 traditherapists in the city of Butembo. This sample is considered sufficiently representative because it was difficult to reach many traditherapists in view of the informal nature of the activity and the refusal to agree to answer us fearing that we were State authorities. The sample included all traditherapists working in the city of Butembo who had a traditional medicine unit, regardless of gender, age, or length of experience in traditional medicine.

Data collection

Semi-structured interviews were used to collect data using a previously established survey questionnaire. To limit errors during data collection, the questionnaire was formalized in the KoboCollect v1.25 application. This application automatically generated an Excel file of the data through the KoboToolbox tool. This was a transverse survey conducted during two months between April 13 and June 13, 2020. The sample was a combination of male and female traditherapists who were randomly selected. For data collection, an ethnobotanical survey form in one language (French) was used. This form included specific questions on age, gender, knowledge of the occupation, length of time in the occupation, plants used in treatment, vernacular and scientific names of the plants, manner of recognition of these plants, time of harvesting, parts of the plants used, their mode of preparation and associated plants or substances.

Data analysis

Data analysis was done according to the nature of the variables. The calculation of the mean

followed by the standard deviation was done for the quantitative variables, specifically the age of the traditherapists. The comparison of age means between women and men was performed using the Wilcoxon rank test at the 5% threshold because the age data do not follow a normal distribution and the variances were not equal. The percentages of citations of species, families, organs, and methods of preparation of the cures were calculated for the qualitative variables. Analyses were performed using the R 4.1.2 software (R Core Team, 2021).

RESULTS AND DISCUSSION

Socio-demographic characteristics of traditherapists

The results show that the majority of the traditherapists are men (94.51%) compared to 5.49% of women. The age of women varies from 21 to 43 years with an average of 33.8 ± 9.36 years. On the other hand, the age of the men varied from 20 to 78 years with an average of 41.62 ± 12.95 years. The Wilcoxon test indicates that there is no significant difference between the average age of men and women ($W=144$, $p\text{-value}=0.2189 > 0.05$).

In relation to the time experience in the profession of traditherapists, figure 3 demonstrates that 31.87% have already done 1 to 5 years of activity while 31.87% have already practiced this profession for 6 to 10 years and 26.37% for 11 to 15 years. On the other hand, those who have accumulated 16 to 20 years of professional practice represent 18.68%. Finally, the traditherapists who had practiced for 21 to 25 years, 26 to 30 years, and 31 to 40 years represented 5.49%, 1.10%, and 1.10% respectively (Figure 2).

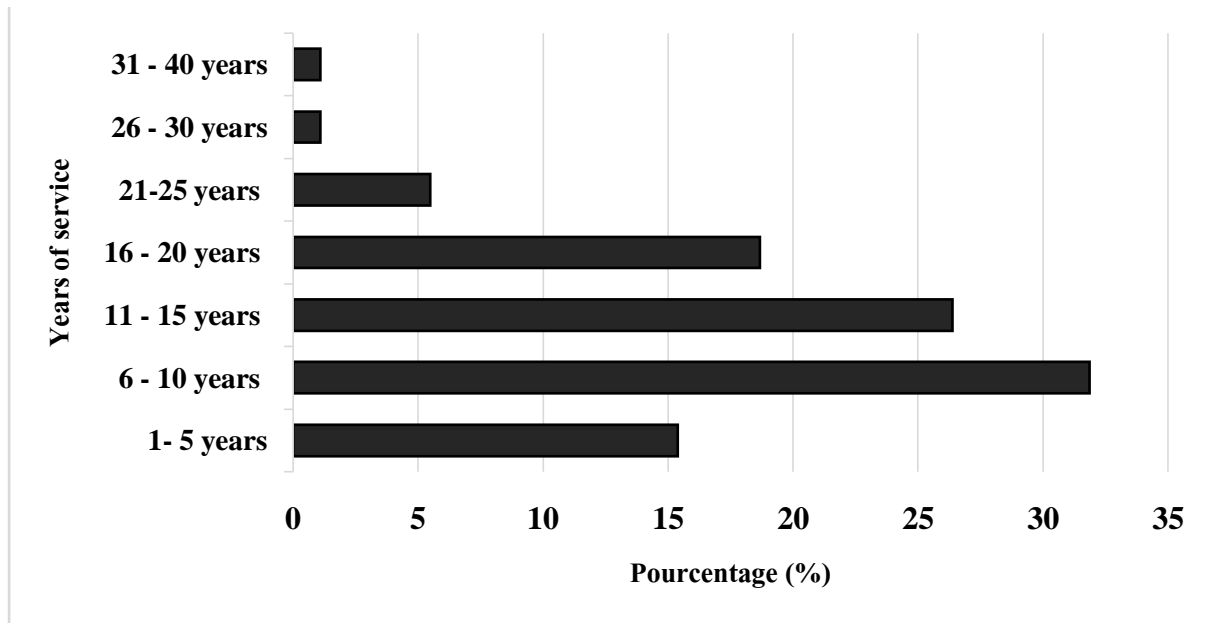


Figure 2. Experience of traditherapists in the occupation (in years)

Of the 91 traditherapists interviewed, 83.52% practiced this profession because they had received professional training in traditional medicine. Those who cited training in traditional medicine + transcendence represent 8.79%. The traditherapists who practice their profession because they have

inherited the knowledge of their family (transcendence) constitute only 5.49% of the sample. Finally, 2.20 % of the traditherapists know the traditional treatment of diseases from other traditherapists (Figure 3).

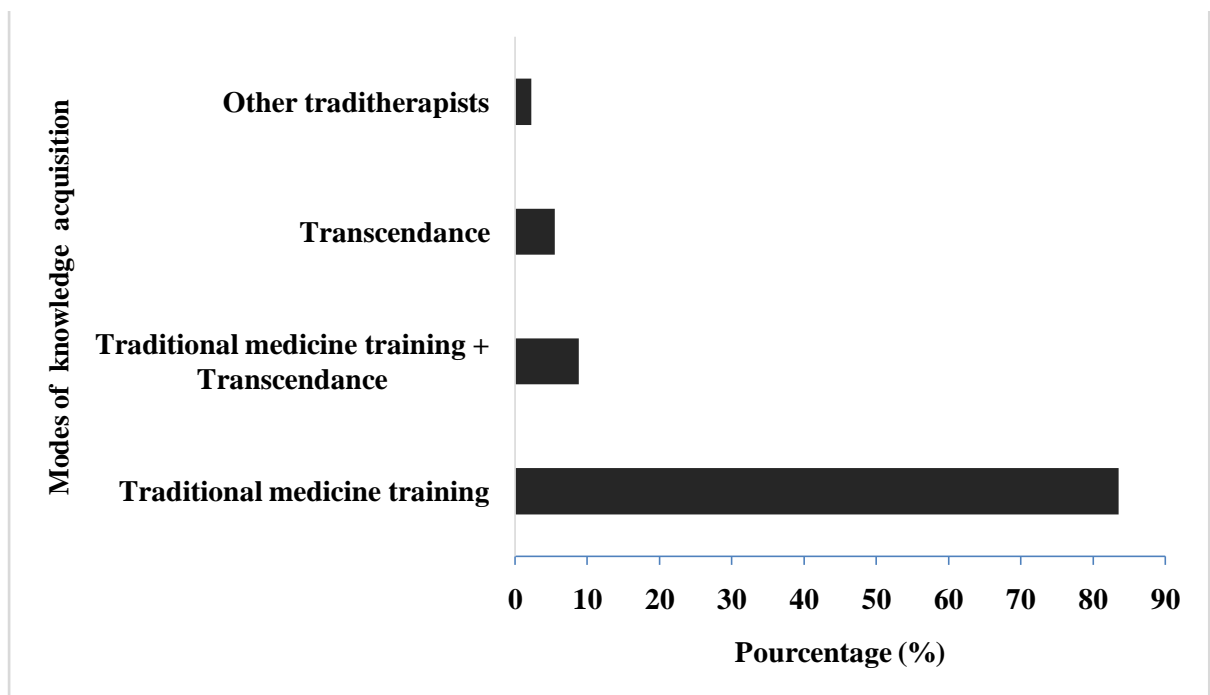


Figure 3. Modes of knowledge acquisition

Diversity of species families used by the traditherapists

The results show that the species of the *Asteraceae* family are the most sought after by traditherapists in the city of Butembo with 23

traditional therapists, i.e. 25.27%. This family is followed by the *Myrtaceae* and *Rubiaceae* families, each with 11 traditional therapists (12.09%). Among the families most frequently used in the treatment of malaria, *Caricaceae*, *Poaceae* and

Fabaceae present respective percentages of quotation of 9.89%, 9.89%, and 8.79% (Table 1).

Table 1. Families of species used in malaria treatment

Families	N=91	Percentage (%)
<i>Asteraceae</i>	23	25.27
<i>Myrtaceae</i>	11	12.09
<i>Rubiaceae</i>	11	12.09
<i>Caricaceae</i>	9	9.89
<i>Poaceae</i>	9	9.89
<i>Fabaceae</i>	8	8.79
<i>Xanthorrhoeaceae</i>	4	4.4
<i>Anacardiaceae</i>	3	3.3
<i>Apocynaceae</i>	2	2.2
<i>Solanaceae</i>	2	2.2
<i>Verbenaceae</i>	2	2.2
<i>Cupressaceae</i>	1	1.1
<i>Lamiaceae</i>	1	1.1
<i>Loganiaceae</i>	1	1.1
<i>Moringaceae</i>	1	1.1
<i>Myricaceae</i>	1	1.1
<i>Passifloraceae</i>	1	1.1
<i>Rosaceae</i>	1	1.1
Total	91	100

Diversity of species used by traditherapists

The different species used in the treatment of malaria, the organs used, their modes of preparation, the mode of administration, the dose, and other associated species are summarized in Table 2.

Table 2. Plants used in the treatment of malaria

No	Scientific name	Families	P.U	TP	M.A	Q/P	NP	DT	SPA
1	<i>Cinchona ledgeriana</i>	Rubiaceae	F, E	Dec	Peros	1/2 glass	2 times	7 days	G, V
2	<i>Artemisia annua</i>	Asteraceae	F	Dec, Infu	Peros	½ glass	2times	7days	CC
3	<i>Eucalyptus globulus</i>	Myrtaceae	F	Dec, Dist	Peros	1spoon	3times	14days	G, GY, LE, AC, AA, CC, TR
4	<i>Cassia occidentalis</i>	Fabaceae	F	Dec	Peros	½ glass	2times	7days	CL, G
5	<i>Conyza sumatrensis</i>	Asteraceae	F	Dec	Peros	½ glass	2times	14days	CL
6	<i>Carica papaya</i>	Caricaceae	Fr, G	Dec	Peros	1 glass	2times	14days	-
7	<i>Tetradenia riparia</i>	Lamiaceae	P.E	Dec	Peros	1 glass	2times	14days	-
8	<i>Mangifera indica</i>	Anacardiaceae	E	Dec	Peros	½ glass	2Times	14days	-
9	<i>Physalis peruviana</i>	Solanaceae	F	Dec	Peros	½ glass	3times	7days	CL
10	<i>Cupressus lusitanica</i>	Cupressaceae	F	Dec	Peros	1 glass	2times	7days	CL
11	<i>Lantana camara</i>	Verberaceae	F	Dec	Peros	½ glass	3times	5days	CC, TP
12	<i>Alloe verra</i>	Xanthorrhoeaceae	F	Mac	Peros	1 glass	2times	21-30	G
13	<i>Vernonia amygdalina</i>	Asteraceae	F, E	Dec, Dist	Peros	3spoon	3times	14days	-
14	<i>Azedarachta indica</i>	Anacardiaceae	F, E	Dec	Peros	½ glass	3times	5days	EU, TH, TM
15	<i>Passiflora edulis</i>	Passifloraceae	F	Dist	Peros	1spoon	2times	14days	TH, TP
16	<i>Erigeron canadensis</i>	Asteraceae	F	Mac	Peros	3spoon	3times	7days	PA, TPCC, CL
17	<i>Anthocleista grandiflora</i>	Loganiaceae	F	Dec	Peros	½ glass	2times	14days	-
18	<i>Rauvolfia vomitoria</i>	Apocynaceae	F, E	Dec, Dist	Peros	5spoon	2times	7days	CL, CI
19	<i>Moringa oleifera</i>	Moringaceae	F	Dec	Peros	2spoon	2times	31days	-
20	<i>Prunus africana</i>	Rosaceae		Dec	Paros	1 glass	2times	7days	-
21	<i>Psidium guyava</i>	Myrtaceae	F	Dec	Peros	½ glass	2times	30days	CL, PR
22	<i>Morindamorindoides</i>	Rubiaceae	F	Infu	Peros	½ glass	2times	14days	-
23	<i>Senna didymobotrya</i>	Fabaceae	F	Dec	Peros	½ glass	2times	14days	-
24	<i>Myrica salcifolia</i>	Myricaceae	E	Dec	Peros	½ glass	2times	30days	CC
25	<i>Bidens pilosa</i>	Asteraceae	F	Dec	Peros	½ glass	2times	14days	CL, PA
26	<i>Cymbogogoncitratrus</i>	Poaceae	F	Dec	Peros	1 glass	2times	7days	CL

Legend: **PU:** Parts Utilized; **TP:** Techniques of Preparation; **MA:** Modes of Administration; **Q / P:** Quantity per Taken; / **J:** Number of Taken per Day; **DT:** Duration of Treatment; **SPA:** Substances or associated plants; **F:** Leaves; **R:** Roots; **E:** Bark; **G:** Grains; **Fr:** Fruits; **PE:** Whole plants; **Dec:** Decoction; **Mac:** Maceration; **Infu:** Infusion; **Dist:** Distillation

Substances or associated plants (SPA)

CI: Cinchona sp.; **G:** Garlic (*Allium sativum*); **V:** *Erigeron canadensis*; **PR:** *Persea americana*; **TP:** *Tropaelum majus*; **EU:** *Eucalyptus* sp.; **CC:** *Cymbopogon citratus*; **LE:** *Leucaena leucocephala*; **GY:** *Psidium guayava*; **AC:** *Acacia* sp.; **CL:** *Citrus limon*; **AA:** *Ananas comosus*; **TR =** *Tetradenia riparia*; **TH:** *Thymus vulgaris*; **PA:** *Carica papaya*; **TM=***Tagetes minuta*.

Frequency of citation of species by traditherapists

Table 3 indicates the frequency of repetition of antimalarial medicinal plants used by our respondents, as well as the vernacular and scientific

names of these plants. The most used are *Artemisia annua* (12.09%), *Eucalyptus maideni var globulus* (10.99), *Cinchona ledgeriana* (10.99), *Cymbopogon citratus* (9.89%), *Carica papaya* (9.89%), *Cassia occidentalis* (7.69%), and *Bidens pilosa* (8.79%)

Table 3. Frequency of citation of species

Local name or vernacular name	Scientific name	n	Percentage
<i>Artemizia</i>	<i>Artemisia annua</i>	11	12.09
<i>Citronnelle</i>	<i>Cymbopogon citratus</i>	9	9.89
<i>Dira ou Arubaini</i>	<i>Melica azedarach</i>	2	2.20
<i>Muratusi</i>	<i>Eucalyptus maideni var globulus</i>	10	10.99
<i>Herbepuante</i>	<i>Cassia occidentalis</i>	7	7.69
<i>Kantingakake</i>	<i>Rauvolfia vomitoria</i>	2	2.20
<i>Kavingande</i>	<i>Conyza sumatrensis</i>	1	1.10
<i>Kilau</i>	<i>Cupressus lusitanica</i>	1	1.10
<i>Kongobololo</i>	<i>Morindamorindoides</i>	1	1.10
<i>Lantanier</i>	<i>Lantana camara</i>	2	2.20
<i>Mambupuru</i>	<i>Physalis peruviana</i>	2	2.20
<i>Hembe</i>	<i>Mangifera indica</i>	1	1.10
<i>Mapera</i>	<i>Psidium guyava</i>	1	1.10
<i>Maracuja</i>	<i>Passiflora edulis</i>	1	1.10
<i>Mubiriri</i>	<i>Vernonia amygdalina</i>	2	2.20
<i>Mukuvokuvo</i>	<i>Anthocleista grandiflora</i>	1	1.10
<i>Muravumba (Mutuvia)</i>	<i>Tetradenia riparia</i>	1	1.10
<i>Muriga</i>	<i>Moringa oleifera</i>	1	1.10
<i>Mutsikili</i>	<i>Myrica salcifolia</i>	1	1.10
<i>Ngaka</i>	<i>Alloe vera</i>	4	4.40
<i>Ngote</i>	<i>Prunusafricana</i>	1	1.10
<i>OmutSORA</i>	<i>Senna didymobotrya</i>	1	1.10
<i>Papayi</i>	<i>Carica papaya</i>	9	9.89
<i>Quinquina</i>	<i>Cinchona ledgeriana</i>	10	10.99
<i>Vergerette du Canada</i>	<i>Erigeron canadensis</i>	1	1.10
<i>Vukuto</i>	<i>Bidens pilosa</i>	8	8.79
Total		91	100

Different organs used in the treatment of malaria

It can be seen that the organs most solicited by the traditherapists in the treatment of malaria are the leaves (70.33% of the traditherapists) followed by

the combination of leaves and bark (10.99%), bark (7.69%), fruits (4.40%), grains (4.40%) and finally, the combination of leaves and roots (1.10%) and the use of the whole plant (1.10%) (Figure 4).

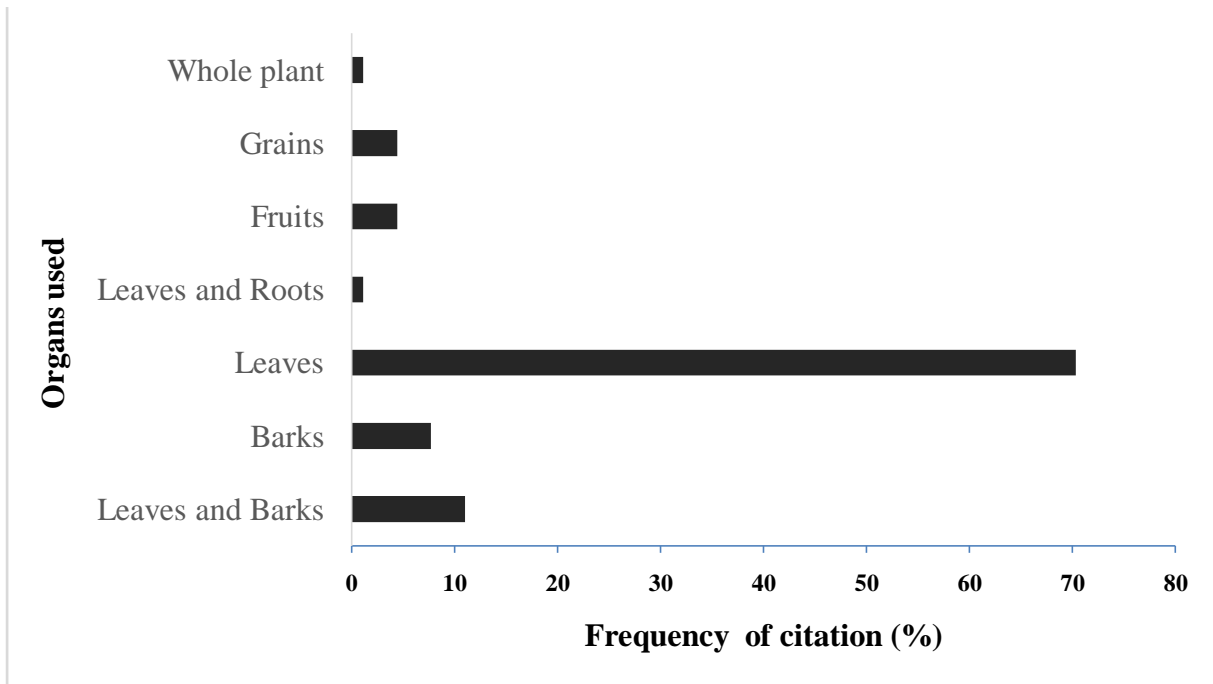


Figure 4. Methods of preparation of cures

The remedies used by the traditherapists are derived from decoction (81.32%), maceration of organs in water (6.59%), and distillation (5.49%). In

addition, 3.30% of the traditherapists use both distillation and decoction, 2.20% use both decoction and infusion, and 1.10% use infusion only in the treatment of malaria (Figure 5).

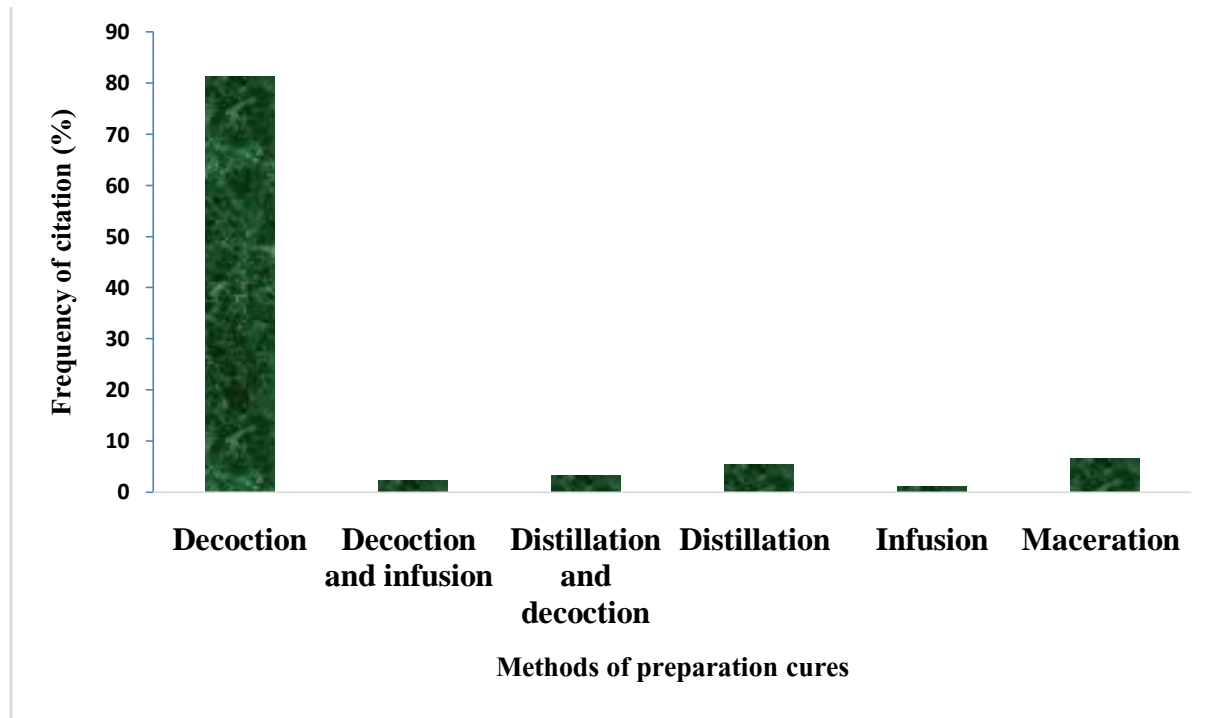


Figure 5. Modes of preparation cures in malaria treatment

Families of species used

The results of this study show that the species of the *Asteraceae* family are the most sought after by traditional therapists in the city of Butembo with 23 traditional therapists, i.e.25.27%. This family is

followed by the *Myrtaceae*, *Rubiaceae*, *Caricaceae*, *Poaceae*, and *Fabaceae* families (Table 1). These results are contrary to those of Dénou et al. (2017) who found that the antimalarial species used by the populations of the district of Bamako (Mali)

predominantly belonged to the *Fabaceae* family (22.22%) and *Rubiaceae* and *Combretaceae* represented by 12.97% and 11.11% respectively. In Niger, Yolidje et al. (2020) found that the most representative families in the control of malaria vector mosquitoes are *Papilionaceae* (21.4%), *Lamiaceae* (7.1%), *Euphorbiaceae* (7.1%), *Combretaceae* (7.1%) and *Capparidaceae* (7.1%). In Togba (commune of Abomey-Calavi in Benin), Aguiadaho (2020) found that antimalarial species belonged to the families *Rubiaceae*, *Fabaceae* (4 species), then *Euphorbiaceae* (3 species). Families such as *Meliaceae*, *Arecaceae*, *Verbenaceae*, *Caesalpiniaceae*, and *Bignoniaceae* were each represented by (2 species). Finally, the families of *Moringaceae*, *Amaranthaceae*, *Anarcadiaceae*, *Caricaceae*, *Boraginaceae*, *Chailletiaceae*, *Combretaceae*, *Sterculiaceae*, and *Asteraceae* each have only one species (Aguiadaho, 2020).

In Central Ivory Coast, Brice et al. (2015) found that antimalarial plants belonged predominantly to the *Euphorbiaceae* family. In Abidjan district (Ivory Coast), Sylla et al. (2018) found that *Rubiaceae* and *Combretaceae* (5 species; 9.25%) followed by *Fabaceae* and *Meliaceae* (4 species; 7.41%) are the most represented families in antimalarial treatment. In the Democratic Republic of Congo, Rusaati et al. (2021) found based on a literature review of 28 papers on ethnomedicine published between 2001 and 2019, 232 plant species belonging to 67 plant families for malaria treatment. Many species belong to the *Fabaceae*, *Asteraceae*, *Euphorbiaceae*, *Rubiaceae* and *Apocyanaceae* families. In the city of Bangui, Lakouéténé et al. (2009) identified 27 plant species divided into 25 genus and 14 families, 11 of which are Eudicotyledons and 3 Monocotyledons (*Cyperaceae*, *Poaceae*, and *Xanthorrhoeaceae*). The families most cited by the people of Bangui are the *Fabaceae* and *Asteraceae* with 6 and 4 species. In the city of Bamako in Mali, Diarra et al. (2016) found that five families grouped more than half of the species recorded in the treatment of malaria: *Rubiaceae* and *Caesalpiniaceae* were reported with similar percentages (13.47%); *Euphorbiaceae* and *Combretaceae* had 9.62% of the citations each and *Fabaceae* 7.69%.

Species used in the treatment of malaria

In the city of Butembo, the most commonly used species are *Artemisia annua* (12.09%),

Eucalyptus maideni var globulus (10.99), *Cinchona ledgeriana* (10.99), *Cymbopogon citratus* (9.89%), *Carica papaya* (9.89%), *Cassia occidentalis* (7.69%), and *Bidens pilosa* (8.79%) (Table 3). Species cited for more use in DR Congo include *Cymbopogon citratus*, *Vernonia amygdalina*, *Rauvolfia vomitoria*, and *Catharanthus roseus*. Most of the species identified as antimalarial plants are woody species, mainly phanerophyta (Rusaati et al., 2021). In Cameroon, *Azadirachta indica*, *Mangifera indica*, *Psidium guajava*, *Cassia occidentalis*, *Khayasenegalensis*, *Tamarindus indica*, *Citrus limon*, *Eucalyptus* sp., *Carica papaya*, and *Cymbopogon citratus* are the most commonly used plants for the traditional management of malaria (Dénou et al., 2017). Ngbolua et al. (2013) found that plants with good antimalarial activity in the Democratic Republic of Congo and Madagascar are: *Annona senegalensis* Pers., *Catharanthus roseus* (L.) G. Don, *Annickiachlorantha* (Oliv.) Setten & Maas, *Entandrophragmapalustre* Staner, *Garcinia punctata* Stapf, *Morindamorindoides* (Baker) Milne-Redh, *Phyllanthus niruri* L., *Rauvolfia vomitoria* Afzel., *Sarcocephalus latifolius* (Sm.) E.A. Bruce, *Senna occidentalis* (L.) Linkage, *Vernonia amygdalina* Del., *Polyalthiamadagascariensis* Cavaco & Keraudren, *Uvariasp*, *Tabernaemontanacoffeoides* Bojer ex A.DC., *Vernonia cinerea* L. subsp. *subsp. vialis* (D.C.) H. Humb., *Garcinia lorii* Benja, *Garcinia verrucosa* Jum. subsp. *typica* H. Perr., *Paederia* sp. In the literature, there is a variability of antimalarial plants. This variability of antimalarial plants from one region to another is due to community-specific beliefs and doctrines (Brice et al., 2015).

Organs used in the treatment of malaria

It was found that the organs most solicited by the traditional therapists in the treatment of malaria are the leaves (70.33% of the traditional therapists) followed by the combination of leaves and bark, bark, fruits, grains, and finally, the combination of leaves and roots (1.10%) and the use of the whole plant (1.10%) (Figure 4). These results are similar to those of Aguiadaho (2020) who also found that the different organs of antimalarial plants used by the population are mainly leaves, fruits/grains (Brice et al., 2015) found that leaves (61.53%) are the most used during malaria treatment. In Zanzan District (Côte d'Ivoire), Kouadio et al. (2016) also

found that leaves (including leafy twigs) are the most used parts with 63.96%.

In the Bamako district of Mali, Dénou et al. (2017) found that plants are mostly used in the form of the leafy stem (65.52%), aerial part (12.07%), trunk bark (8.62%) and leaf (6.90%). Based on 28 articles on ethnobotany in the DRC, Rusaati et al. (2021) found that the main ingredients identified for the preparation of remedies are the leaves, used in decoction and most often administered orally. Sylla et al. (2018) also found that the plant organs most used in the different recipes in the Abidjan district are leaves (68.89%). In the city of Bangui, leaves are the most used organs in the treatment of malaria. Leaves are the most used organs (67%), followed by root parts (15%), bark and whole plants (7% each), and finally fruits (4%) (Lakouéténé et al., 2009). In the department of Agboville, southeast of Ivory Coast, the organs used as antimalarial treatment are leaves (49.3%), stem bark (40.0%), roots (9.3%), and leafy branches (1.3%) (Kipre et al., 2017). In the south of the Dja Biosphere Reserve in Cameroon, Betti (2001) found that bark is instead the most used organ (66%), followed by fruits and grains (21%), and finally, leaves (13%) in the treatment of malaria.

In the city of Bamako, the majority of people use leaves (78.4%) (Diarra et al., 2016). According to Diarra et al. (2016), this organ is used more because it is very important not only for the survival of the plants and it is the organ that is easily renewed Sylla et al. (2018) add that this high preference for use of leaves would be explained by the ease and speed of harvesting but also and especially by the fact that these organs are the seat of photosynthesis and sometimes the place of storage of secondary metabolites responsible for pharmacological properties of the plant. The fact that the roots and the whole plant are little used is justified by the fact that this directly eliminates the possibility of subsequent harvesting. This observation had been discussed also by Sylla et al. (2018).

Methods of preparation of antimalarial cures

The cures used by traditherapists in the city of Butembo are prepared by decoction (81.32%), maceration of organs in water (6.59%), distillation (5.49%), and infusion (1.10%) when treating malaria (Figure 5). All recipes were used orally (*Peros*). These findings are similar to those obtained

by (AguiaDaho, 2020) who identified two forms of preparation: decoction (90%) and trituration (10%) under which the plants are used by the populations. According to the same study, the product resulting from the preparation is mostly used orally (81.25% of the interviewees) and by a bath (8.75%). In Ivory Coast, the results of Brice et al. (2015) distinguish various modes of drug preparation during malaria treatment (decoction, expression, infusion, maceration, kneading, pounding, pulverization, softening, and trituration). The decoction is the most used method of preparation (65.38%). Similar to this study, (Brice et al., 2015) also found that the oral way is more used to administer decoctions when treating malaria. This finding is similar to that of Kouadio et al. (2016) who found that the pharmaceutical form most used by people in the Zanzan District (Ivory Coast) is the decoction.

In Abidjan District, Sylla et al. (2018) found that the preparation method most proposed by traditherapists is decoction (76.97%) and that most preparations are administered orally (84.09%) in the form of a drink. Decoction (76%) is the dominant method of preparation and administration is mostly by mouth in the city of Bangui. This medicinal form is followed by maceration (16%) and infusion (8%) (Lakouéténé et al., 2009). In the department of Agboville, southeast of Ivory Coast, Kipre et al. (2017) note that several preparation techniques are used namely: decoction (55.1%), kneading (24.7%), maceration (15.7%), infusion (3.4%) and expression (1.1%). The modes of drug administration were: drinking (35.5%), enema (20.6%), bathing (14.9%), ocular instillation (9.9%), nasal instillation (8.5%), massage (5.7%) and fumigation (5.0%) (Kipre et al., 2017). In the southern Dja Biosphere Reserve (Cameroon), Betti (2001) also found that decocted (39%) and macerated (36%) forms were the most used when preparing cures. He also found that 8% of the recipes were not prepared at all, 4% as ash, 3% as juice, and 2% as oil. According to Brice et al. (2015), this preference is justified by the fact that the ingestion of bio-active principles orally involves a much faster and more efficient metabolic process than by skin (brushing, ablution) and aeropharyngeal (nasal instillation, steam bath) ways.

CONCLUSION

This research consisted in carrying out an ethnopharmacological survey on the traditional treatment of malaria in the city of Butembo. Its purpose was to list the plant species used in the city of Butembo in the traditional treatment of malaria and their different modes of preparation to provide basic data for research aimed at the production of new drugs from local plants. The results indicated that the traditherapists used a variety of species. Leaves are the most used plant organ. The formulations are prepared by decoction and are ingested orally. In view of these results, we suggest that future researchers further investigate this new field of research by identifying the active principles within each plant species cited by the traditionalists, to produce locally improved antimalarial drugs (TADs). This research will make it possible to produce traditional antimalarial drugs (TADs) adapted to the local environment by limiting the cases of antimicrobial resistance. In addition, such investigations could help guide traditherapists in the dosage of traditional recipes administered to patients suffering from malaria and thus reduce mortality due to this disease in the city of Butembo.

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