UNIVERSITY OF BURUNDI

FACULTY OF SCIENCE

Anti-malaria and anti-mosquito plants in Burundi: Ethnobotany and conservation perspectives

Célestin HAVYARIMANA

DISSERTATION

Submitted for:

Master's Degree in Science and Integrated Environmental Management

Option: Natural Resource Management

Under the supervision of: **Prof Tatien MASHARABU** (Director)

Dr. Jacques NKENGURUTSE (Co-Director)

Bujumbura, June 2020

DEDICATION

To our dear father Liboire SINZOHAGERA,

To our late mother Pétronie GAKOBWA,

To our brothers and sisters,

To all our loved ones,

We dedicate this dissertation.

ACKNOWLEDGEMENTS

This work could not have been successful without the strong support of several people whom we would like to thank from the bottom of our hearts through these few lines.

First of all, we would like to express our sincere thanks to **Prof Tatien MASHARABU** and **Dr. Jacques NKENGURUTSE**, respectively Director and Co-Director of the dissertation, for guiding our work. The invaluable advice they gave us and the trust they showed us were decisive in the accomplishment of this research work.

Our thanks also go to all the professors of the University of Burundi, especially those who taught us at the Master's level in Science and Integrated Environmental Management, for the knowledge and passion they transmitted to us throughout these two years.

We express our deepest thanks to the **Chinese Embassy** in Burundi, for the financial support it has given us throughout these two years of training.

Our warm thanks are also expressed to **ICIPE** who, through the AIDS-funded ***BioInnovate Africa programme***, has agreed to support this work financially. Through this programme, all the field resources necessary to carry out this work have been made available to us.

As it is impossible to mention all the names, we deeply thank all the members of our family as well as all the people who, in one way or another, have made this work possible through their advice and skills.

Célestin HAVYARIMANA

SUMMARY

As malaria is a disease that is rampant in Africa, where people have difficulties of accessing health care, traditional medicine remains the main remedy for the vast majority of people. This research work is a contribution to the study of plant resources used by the Burundian population in the fight against malaria. Its objective is to constitute a database of plant resources used in the treatment of malaria and in the fight against its vector (mosquito). The information was obtained by ethnobotanical methods from interviews carried out with 341 informants from rural and urban areas, in 7 provinces of Burundi, chosen based on their geoclimatic difference. 44 plant species from 23 families were identified. The Asteraceae are the most represented (9 species), followed by the Fabaceae (5 species), the Lamiaceae (4 species) and the Poaceae (4 species). The inventoried plant species are mainly prepared by expression (52%) and administered orally (76%), while the leaf (46%) is the most exploited organ. The most dominant morphological type is that of shrubs (20 species). The study shows that the Burundian population has little knowledge of mosquito repellents, compared to knowledge of anti-malaria plants. Some species are reported for the first time and therefore in-depth phytochemical analyses are necessary to assess the level of phytotherapeutic effectiveness of these species. The vulnerability factors of these species should be sufficiently documented to make them sustainable management.

Key words: Ethnobotanical methods, antimalarial plants, mosquito repellents, sustainable management

RÉSUMÉ

Le paludisme étant une maladie qui sévit de manière endémique en Afrique où la population a des difficultés d'accès aux soins de santé, la médicine traditionnelle demeure le recours principal pour une grande majorité des populations. Le présent travail de recherche est une contribution à l'étude des ressources végétales utilisées par la population burundaise, dans la lutte contre le paludisme. Son objectif est de constituer une base de données des ressources végétales utilisées dans le traitement du paludisme et dans la lutte contre son vecteur (moustique). Les informations ont été obtenues par des méthodes ethnobotaniques à partir d'entretiens réalisés avec 341 informateurs des milieux ruraux et urbains, dans 7 provinces du Burundi, choisies compte tenu de leur différence géoclimatique. 44 espèces de plantes réparties dans 23 familles ont été recensées. Les Asteraceae sont les plus représentées (9 espèces), suivies par les Fabaceae (5 espèces), les Lamiaceae (4 espèces) et les Poaceae (4 espèces). Les espèces de plantes inventoriées sont essentiellement préparées par expression (52 %) et administrées par voie oral (76 %), tandis que la Leaf (46 %) est l'organe le plus exploité. Le type morphologique le plus dominant est celui des arbustes (20 espèces). L'étude montre que la population burundaise dispose de très peu de connaissances sur les espèces répulsives de moustiques, comparativement aux connaissances des plantes anti-malaria. Certaines espèces sont citées pour la première fois et des analyses phytochimiques plus approfondies sont donc nécessaires pour évaluer le niveau d'efficacité phytothérapeutique de celles-ci. Les facteurs de vulnérabilité de ces espèces devraient être suffisamment étudiées en vue d'en faire une gestion durable.

Mots clés : Méthodes ethnobotaniques, plantes antipaludiques, répulsifs de moustiques, gestion durable

LIST OF ABBREVIATIONS

FABI	**:**	Faculty of Agronomy and Bio-Engineering
FC	**:**	Citation Frequency
GPS	**:**	Global Positioning System
ICIPE	**:**	International Centre of Insect Physiology and Ecology
ICs	**:**	Informant Consensus Index
ISABU	**:**	Institute of Agronomic Sciences of Burundi
MEEATU	**:**	Ministère de l'Eau, de l'Environnement, de l'Aménagement du Territoire et de l'Urbanisme (former name of the current Ministry of Environnement, Agriculture and Livestock)
MSPLS	**:**	Ministry of Public Health and the Fight Against AIDS
OBPE	**:**	Burundian Environmental Protection Office
WHO	**:**	World Health Organization
Sida	**:**	Swedish International Development Cooperation Agency
UICN	**:**	International Union for Conservation of Nature
WHO	**:**	World Health Organisation

LIST OF TABLES

LIST OF FIGURES

TABLE OF CONTENTS

GENERAL INTRODUCTION

Malaria is a parasitic, potentially fatal disease caused by a protozoan of the genus Plasmodium (WHO, 2014). It represents a major public health problem with nearly 3.3 billion people, i.e. more than half of the world's population exposed to the risk of this disease (Sylla et al., 2018). According to the annual report of the World Health Organization (WHO, 2018), Africa is the most affected continent. Ninety-three percent (93%) of malaria cases reported in 2018 were in the World Health Organization African Region (WHO, 2019). The disease is endemic in Africa. In this region, it is not only a health disaster; it also represents a major impediment to the economic and social development of the continent (Sani, 2013).

Vector control, through the use of insecticides directed against Anopheles, since the 1950s, has contributed to the regulation of the global incidence of malaria cases (Rubert et al., 2016). It is also the main means of preventing and reducing malaria transmission. If coverage with vector control interventions is sufficiently high in a given area, the entire community will be protected (WHO, 2018).

However, the effectiveness of vector control is threatened by the resistance that mosquitoes that carry the disease develop to the insecticides used in insecticide-treated nets and indoor residual spraying. Of the 65 countries reporting monitoring data for 2010-2013, 53 reported resistances to at least one class of insecticides, and 41 to at least two classes. In 2013, resistance to pyrethoids was the most common, with two thirds of the countries monitoring reported resistance to this class of insecticides (WHO, 2014).

More widespread in Africa, insecticide resistance in Anopheles is an obstacle to malaria control. It has been detected against at least two insecticides in two-thirds of African countries where malaria is endemic (WHO, 2018). Resistance of Anopheles (Anopheles gambiae) to pyrethroids has also been confirmed in three sub-Saharan African countries, namely Côte d'Ivoire, Burkina Faso and Benin (Chandre et al., 1999). The resistance of Plasmodium to antimalarial drugs is also a major challenge to malaria control. Studies have shown that Plasmodium falciparum is resistant to all currently used antimalarial drugs, including artemisinin-based combinations. However, this species is responsible for most of the morbidity and almost all of the mortality attributed to malaria, mainly in children under 5 years of age (Pradines et al., 2010).

However, the use of all available, accessible and culturally acceptable resources, as promoted by the WHO in the Alma-Ata declaration (WHO, 1978), is more than necessary to address these threats due to the resistance of the vector to insecticides on the one hand and that of the causal agent to antimalarial drugs on the other hand (Rokia, 2013).

As malaria is a scourge that affects the countries of the South where the population has difficulty in accessing conventional medicines (Koné, 2018), the study of the traditional antimalarial remedies used by the population is essential.

Thus, researchers are increasingly turning to traditional remedies used by populations living in endemic areas to treat malaria and to search for new antimalarial molecules (Soh, 2008).

Considered as an important part of cultural heritage (Koné, 2018), traditional pharmacopoeias play an important role in the discovery of new molecules of therapeutic interest (Rokia, 2013).

Plant species have traditionally been used for the treatment of malaria (Asase & Oppong-Mensah, 2009). Research has confirmed the use of plant organs such as leaves, bark and roots in the treatment of common diseases including malaria (N'Guessan, K., Trabi, FH., Kone, 2009). Through its Traditional Medicine Programme, the World Health Organization encourages countries to identify and propose safe and effective remedies and practices for use in public and private health services (WHO, 2002).

The present research work is a contribution to the study of plant resources used by the Burundian population in the fight against malaria in order to propose conservation strategies. Its overall objective is to constitute an information base for the search for new molecules with anti-malaria and/or anti-mosquito potentialities, likely to contribute to the reduction of malaria incidence and to the conservation of the species involved.

More specifically, the study seeks to: (i) gather information on the plant species used, the therapeutic uses (organs used, preparation and administration) practiced by the local population; (ii) determine the origin (exotic or indigenous) of the plants used in malaria control and their availability; (iii) analyze their vulnerability.

In seeking to discover these plant resources, three hypotheses are examined: (i) the Burundian population has knowledge of anti-malaria and anti-mosquito plants; (ii) the anti-malaria and anti-mosquito plants known in Burundi are essentially indigenous; (iii) the methods of collection of "anti-malaria" and "anti-mosquito" plants known in Burundi and their morphological types make them vulnerable.

The study is based on an ethnobotanical survey supplemented by documentary research. Thus, the survey data collected was supplemented with information on the origins (exotic or indigenous) and morphological types of the plant species surveyed. The analyses included the calculation of frequencies and importance indices of the listed species.

CHAPTER I. STATE OF KNOWLEDGE ON ANTI-MALARIA AND ANTI-MOSQUITO PLANTS

I.1. Situation at the regional level

Plants have always played an important role in the health of Africans. More than 70% of its populations have always used traditional medicine, considered to be the rich heritage of African culture (Gassita, 1995). Many plant species used in Africa have been studied botanically, chemically and pharmacologically. For example, traditional herbal medicines are authorized in various African countries, including Ghana, Guinea, Madagascar, Cameroon, the Democratic Republic of the Congo and Nigeria (Ousset, 2006). The use of traditional medicine in Africa ranges from 70 per cent in Benin to 90 per cent in Burundi and Ethiopia (WHO, 2013).

Although we could not draw up an exhaustive list of all known anti-malarial plant species in the African region, it should be noted that the population of this region has a fairly broad knowledge of this category of plants.

Research has identified 70 plant species used in the treatment of malaria in Africa (Jansen et al., 2008). A study carried out in 10 communes in Abidjan led to the inventory of 54 plant species of interest in the fight against malaria. The most important are *Morinda lucida, Cochlospermum planchonii, Sarcocephalus latifolius, Harungana madagascariensis, Cochlospermum tinctorium and Hymenocardia acida* (Sylla et al., 2018).

In addition, the efficacy of various medicinal plants used in the treatment of malaria has been confirmed in West Africa. The species most studied for their strong antiplasmodial activity include *Sida acuta, Icacina senegalensis, Chrozophara senegalensis, Acanthosermum hispidum, Croton labatus, Hybanthus enneaspermus Combretum fragrans, Terminalia macroptera, Pavetta crassipes, Anogeissus leiocarpus, Canthium multiflorum, Ocimum gratissimum, Trema orientalis, Nauclea latifolia, Pavetta corymbosa, Tamarindus indica, Argemone mexica, Cassia nigricans, Sebastiani Chamaelea, Euphorbia hirta and Fagara macrophylla.* (Agbodeka et al., 2017).

Other species of anti-malaria plants are also used in the African region. For example, the annual mugwort (*Artemisia annua* L.) which is cultivated on a large scale in Kenya, Tanzania, Uganda and Madagascar to extract artemisinin from its tissues, a molecule that is particularly effective in preventing the development of protozoa responsible for malaria (Mergeai, 2014). This species is also popularized in a number of African countries by an association of French origin "La maison de l'*Artemisia*" and thus planted in gardens to enable the population to treat each malaria attack without the need to consult a health worker (Danis, 2019). In addition, Manalaria (from *Nauclea latifolia* and *Cassia occidentalis*) is used to treat malaria in the form of tablets and syrup (Ousset, 2006).

On the other hand, knowledge about plants used as mosquito repellents seems limited in the African region. Indeed, few studies have focused on mosquito repellent plant species in this region.

Aqueous extracts of *Tetraclinis articulata* and leaves of *Ricinus communis* are promising larvicides for the control of mosquito pests such as *Culex pipiens*, *Aedes caspius*, *Culiseta longiareolata* and *Anopheles maculipennis*. The preliminary evaluation of the larvicidal activity of these extracts showed that they were more effective on second-stage larvae than on fourth-stage larvae. (Aouinty et al., 2006). The herbaceous *Hyptis spicigera* was also mentioned as a species used to repel mosquitoes and has been shown to be effective. (Asase et al., 2005).

Sahel region of Burkina Faso have identified many plants used as mosquito repellents to protect against mosquito bites. The most commonly reported in this region include *Sorghum bicolor*, *Pennisetum glaucum* and *Boscia senegalensis* (L. Bonkian et al., 2017). Other mosquito repellent plants reported in the African region are *Azadirachta indica* and *Citrus limon* (Innocent et al., 2014; Yerbanga et al., 2016) as well as *Ocimum americanum* and *Cymbopogon citratus* (L. Bonkian et al., 2017; Innocent et al., 2014).

Other research has focused on plants used as biopesticides but has not paid particular attention to "mosquito repellent" species. For example, work on biopesticidal and other medicinal plants used in the Central Meru District of Kenya (Gakuya et al., 2013) has classified the species *Plectranthus barbatus* and *Tephrosia vogelii* among the main biopesticide species in the study area.

I.2. Situation at the national level

I.2.1. Origins of knowledge on medicinal plants in Burundi

According to the National Strategy and Action Plan on Access to Genetic Resources and Benefit Sharing in Burundi (MEEATU, 2016), the population's traditional knowledge on medicinal plants is divided into general and special knowledge.

General traditional knowledge is that held by almost all Burundians and is easily transmitted. This includes knowledge about the species and uses of medicinal plants in the enclosure.

Special traditional knowledge includes that held by specific individuals such as traditional practitioners and witch doctors. In the case of traditional practitioners and witch doctors, their knowledge is only passed on from father to son. They almost never provide information on species and their uses and always give processed products in liquid and powder form.

I.2.2. Knowledge on anti-malaria and anti-mosquito plants: State of things

Burundi is one of the African countries with a high incidence of malaria, which is probably the leading cause of death in Burundi and other East African countries (Lapenna et al., 2008). In 2017 the annual cumulative malaria cases reached 7 879 957 cases and 4 415 deaths, an incidence of 815.2 per 1000 people (Sinzinkayo, 2018).

The fight against this disease is currently being carried out within the framework of the Integrated National Malaria Control Programme. Prevention activities are mainly carried out through the distribution of impregnated mosquito nets, targeting vulnerable groups such as pregnant women and children under the age of five (MSPLS, 2009).

However, data provided by the literature show that the Burundian population also uses plants to treat the first symptoms of malaria (fever, headache and chills) as defined by the World Health Organization (WHO, 2018). An example is *Geneosporum rutundifolium*, a species of the Lamiaceae family whose sap is used to treat headaches (Benoît Nzigidahera, 2017).

Other plant species that have also been studied to test their effectiveness in the fight against malaria are being used in Burundi. These are the catnip (*Nepeta cataria* L.), used as mosquito repellent and anti-malaria such as Absinthe douce or annuelle *(Artemisia annua* L.) and *Cinchona officinalis* L. (*Quinquina*).

Results from a study in Burundi show that untransformed catnip has repellent effects on mosquitoes (R. Sibomana et al., 2017). According to this study, the use of catnip during the vegetation phase, without undergoing transformation, is an ecological alternative that is recommended for all categories of people exposed to mosquito bites, particularly night watchmen. Its use in hut gardens or as an ornamental plant would have positive effects on reducing the bites of mosquitoes, vectors of malaria. The introduction and use of *Artemisia annual* in Burundi is the result of proposals by some non-governmental organizations and international agencies working in Burundi (Lapenna et al., 2008).

Other plant resources would also be used in the prevention and/or treatment of this disease, thanks to traditional knowledge handed down from generation to generation. The study of these species is therefore essential.

CHAPTER II. MATERIALS AND METHODS

II.1. Description of the Study Area

The results presented in this work are based on an ethnobotanical survey conducted in 7 provinces of Burundi, a mountainous country with a tropical climate tempered by altitude and covering an area of 27,834 km2. It borders the Republic of Rwanda to the North, the Democratic Republic of Congo to the West and the United Republic of Tanzania to the South and East. The digitization of the study area (Figure 2.1) was carried out using ArcGIS software, version 10.2.

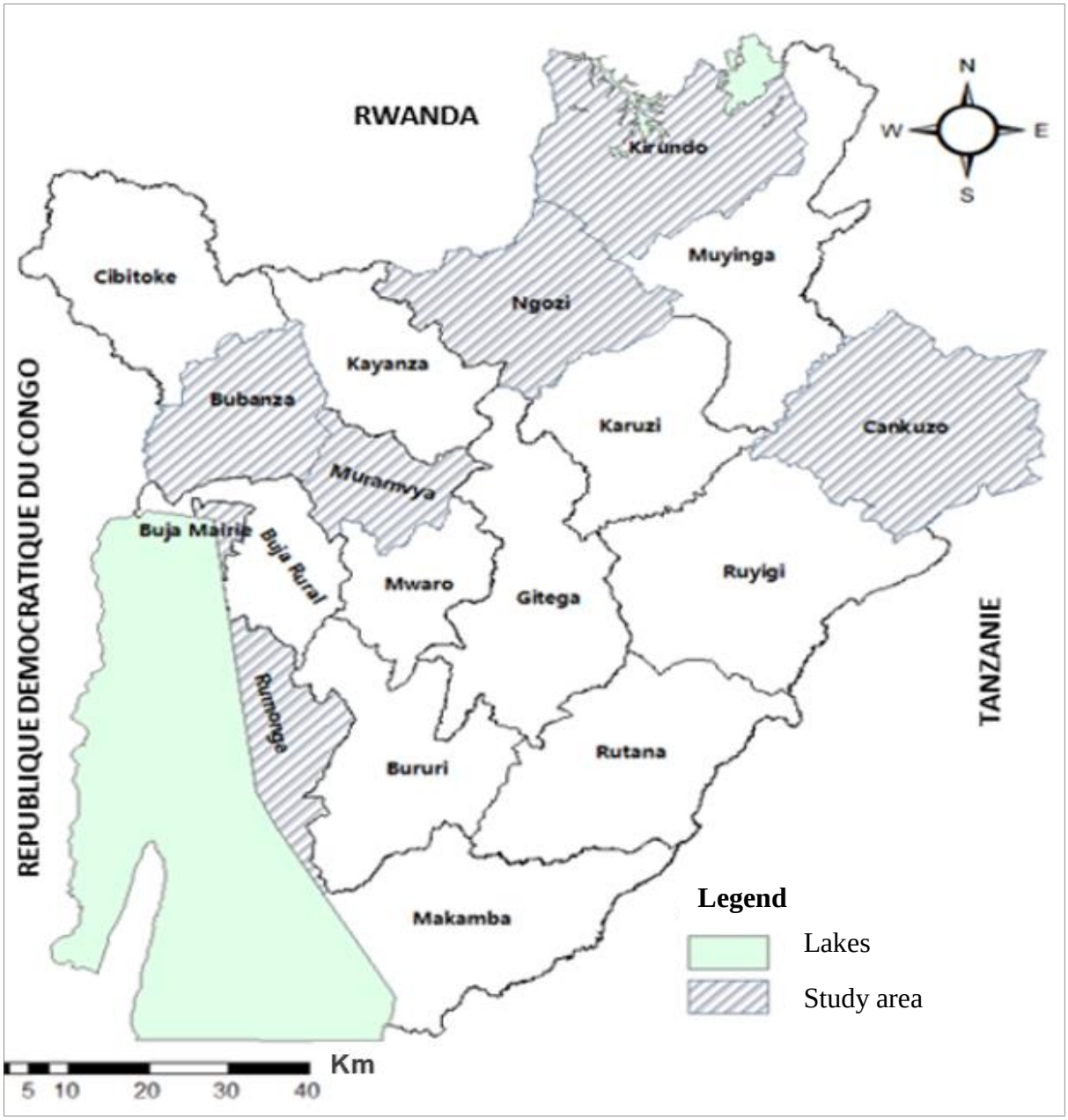

Figure 2. 1. Location of the study area: the seven provinces covered by the ethnobotanical survey are hatched on the map of Burundi.

The provinces concerned by this survey were chosen for their significant ecoclimatic diversity, the latter being a factor influencing the distribution of species (Benoît Nzigidahera, 2012). These provinces are indeed located in the different ecoclimatic regions of Burundi. The ecoclimatic regions of Burundi, their characteristics and the provinces sampled in each region are listed in Table 2.1.

Table 2. 1. Situation of the 7 sampled provinces in the ecoclimatic regions of Burundi

Regions	**Altitude (meter)**	**Average annual temperature (°C)**	**Average annual rainfall (mm)**	**Province**
Imbo Lowlands	800 -1100	Sup. to 23 °C	800-1100	Bujumbura-Mairie ; Rumonge ; Bubanza
Mumirwa Buttresses	1000-1700	18°C-28°C	1100-1900	Muramvya
Congo-Nile Ridge	1700-2500	14°C-15°C	1300-2000	Bubanza
Central Platforms	1350-2000	17°C-20°C	1200-1500	Ngozi
Eastern and Northern Lows	1100-1400	20°C-23°C	1100-1550	Cankuzo ; Kirundo

Source : (Benoît Nzigidahera, 2012)

II.2. Ethnobotanical survey

This study is an ethnobotanical study of anti-malaria and anti-mosquito plants in Burundi. The data were collected during a survey using a questionnaire designed for this purpose. The questionnaire was subdivided into two parts relating to (i) the identity of the respondent and (ii) his/her knowledge of plants with anti-mosquito and/or anti-malaria properties. The questionnaire focused on the use of plants in the fight against malaria. The information collected included (i) the vernacular name of the species, (ii) the organs or parts of the plant used, and (iii) the method of preparation (Appendix 1).

The survey was carried out by direct contact with the respondent, using a simple random sampling method. A total of 136 women and 205 men from different socio-economic backgrounds (rural, urban or semi-urban) were surveyed. Education levels and religions, age and occupation were also recorded. Field data collection consisted of the completion of the survey questionnaire by the interviewers. These data were then compiled using a mobile "Field Task" application, which was connected to a "Smap server, version 19.04", before being transferred to the Excel 2016 software for processing.

The work was completed by collecting samples of species from the survey to constitute the herbaria. These allowed the scientific identification of species (taxonomy) and were deposited at the Herbarium of the University of Burundi.

The numbers of the herbaria are listed in Table 3.2. These herbaria also serve as a reference for future studies and possible taxonomic verifications. Each sample collected was accompanied by the geographical coordinates and altitude of the place of collection.

II.3. Data processing and analysis

II.3.1. Counting and compilation of survey data

The analysis enabled us to present our results in the form of a summary table gathering information on the anti-malaria and mosquito repellent plants held by the Burundian population.

The method used is that of flat sorting (Chardon, 1981). This consists of a simple count of the appearance of the different modalities of a single variable. The tables obtained makes it possible to answer the standard question "how many? "without giving any indication of the relations between the variables, and therefore without providing explanatory elements.

We used this method in order to compare the profiles of the respondents' identification variables with the profiles of these same variables in the population studied, in order to ensure that the sample was representative.

II.3.2. Species identification

Species identification was carried out at the level of two *herbaria* available in Burundi. These are the herbarium of the Department of Biology at the University of Burundi and that of the OBPE. The names of the plants were verified using reference books such as:

- Lebrun & Stork (1991-2010) reprise en ligne pour l'Afrique tropicale dans la base des données des Conservatoire et Jardin Botaniques de la ville de Genève et South African National Biodiversity Institute, Pretoria (*http://www.ville-ge.ch/musinfo/bd/cjb/africa/*).
- Collection des données sur la médecine traditionnelle vétérinaire et humaine d'Afrique, reprise en ligne dans la base des données dénommée « Prélude », available at : *http://www.ethnopharmacologia.org/recherche-dans-prelude/.*
- Habitats du Parc National de la Ruvubu au Burundi (B Nzigidahera et al., 2016).
- Aménagement durable des forêts : statistiques des produits forestiers non-ligneux du Burundi (Ndabirorere, 1999).

II.3.3. Constitution of herbarium specimens

The herbarium data are a valuable source of information that is used by several scientific fields such as ecology, plant biogeography, ethnobotany and human sciences. The herbarium beds can also serve as references for various public institutions: criminology (deposit of samples related to an investigation), customs (identification of imported plants for verification of compliance with international biodiversity conservation provisions (Durand & Loup, 2007).

In this study, the reference herbaria were constituted by collecting structures bearing the characters used for the identification of specimens. Thus, only flowering and/or fruiting plants were collected. A variety of equipment was used for this purpose, including a hand-held pruning shears to collect the samples; a Canon IXUS 190 digital camera (5 megapixels, 4x optical zoom) to take images; a Garmin GPS to take geographic coordinates; a notebook and pen to record information; newspaper and plastic bags to hold the samples; and metal presses to dry the samples.

In the laboratory, the herbarium specimens were first dried in an oven at 50° C (freshly collected samples) and then put in the freezer for a minimum stay of 3 days to eliminate insect pests and fungi that would damage the other specimens kept in the herbarium.

The herbariums are then mounted in folders, then labelled before storage in the Herbarium of the Department of Biology of the University of Burundi with the universal indications of the *herbarium* specimens: the name of the plant (vernacular and scientific name), the locality of harvest with the coordinates of latitude, longitude and altitude; the date of harvest, the name of the collector, as well as a brief description of the plant if any.

II.3.4. Analysis of the medicinal interest of the listed plant species

To confirm the medicinal interest of the species identified during the survey, we calculated the Confirmation Index or Consensus of Informant rated ICs. The latter is defined by Ilumbe *et al.* (2014) *in* (Sylla et al., 2018) as the ratio between the number of people citing a species (Na) and the total number of people interviewed (Nt).

$$\mathrm{ICs} = \frac{\mathrm{Na}}{\mathrm{Nt}}$$

The Confirmation Index varies between 0 and 1 (Sylla et al., 2018). A low value, close to 0, indicates that informants disagree on the plant. A high value, close to 1, indicates a high or total consensus around the use of the plant. Several researchers have shown that high consensus reflects a good knowledge of medicinal plants, a collective knowledge of their uses, but also an exchange of information between traditional practitioners (Rodrigo et al., 2005; Treyvaud et al., 2016). Lack of information exchange can lead to the disappearance of traditional knowledge (Chantal, 2016).

CHAPTER III. PRESENTATION OF RESULTS

III.1. Socio-demographic profile of respondents

Each informant is characterized by gender, age, education, religion and profession. A total of 341 informants, comprising 136 men against 205 women, participated in the survey in the 7 targeted provinces (Bubanza, Bujumbura Mairie, Cankuzo, Kirundo, Muramvya, Ngozi and Rumonge). The age of the respondents ranged from 19 to 100. The occupations of the respondents are divided among farmers, traditional practitioners, students, craftsmen, government officials and traders. The levels of education are divided into primary, secondary and university levels. We also report that illiterate people participated in this survey (Table 3.1).

Table 3. 1. Socio-demographic characteristics of the survey population

	Variable	**%**
Gender	Man	39.9
	Woman	60.1
Age range	< 30 years	16.1
	[30 - 45] years	35.5
	> 60 years	48.4
Level of education	Illiterate	18.8
	Primary	45.7
	Secondary	18.5
	University	6.7
	No answer	10.3
Profession	Farmers	60.4
	Tradipractitioners	0.6
	Students	6.5
	Handcrafts	3.8
	Civil servants	19.1
	Traders	9.7
Religion	Adventists of 7th Day	7.0
	Catholics	61.3
	Muslims	4.1
	Evangelicals	4.4
	Pentecosts	12.3
	Protestants	9.1
	Religion non specified	0.9

Despite the remarkable difference between the characteristics of our sample, the links between the variables (gender, age, occupation, etc.) and knowledge of plants of medicinal interest against malaria can only be confirmed using statistical tests.

III.2. Inventory of anti-malaria and anti-mosquito plants in Burundi

The survey carried out enabled us to identify 44 species of plants used by the Burundian population as antimalarials. Some species are directly used to treat malaria (anti-malaria) while others are used to control the vector of this disease (anti-mosquitoes). The plant species inventoried are divided into 23 botanical families. The Asteraceae family is the most represented (9 species). Other families are also more important compared to the other families. The family Lamiaceae (4 species), Poaceae (4 species) and Fabaceae (3 species) are also more important compared to the other families (Figure 3.1).

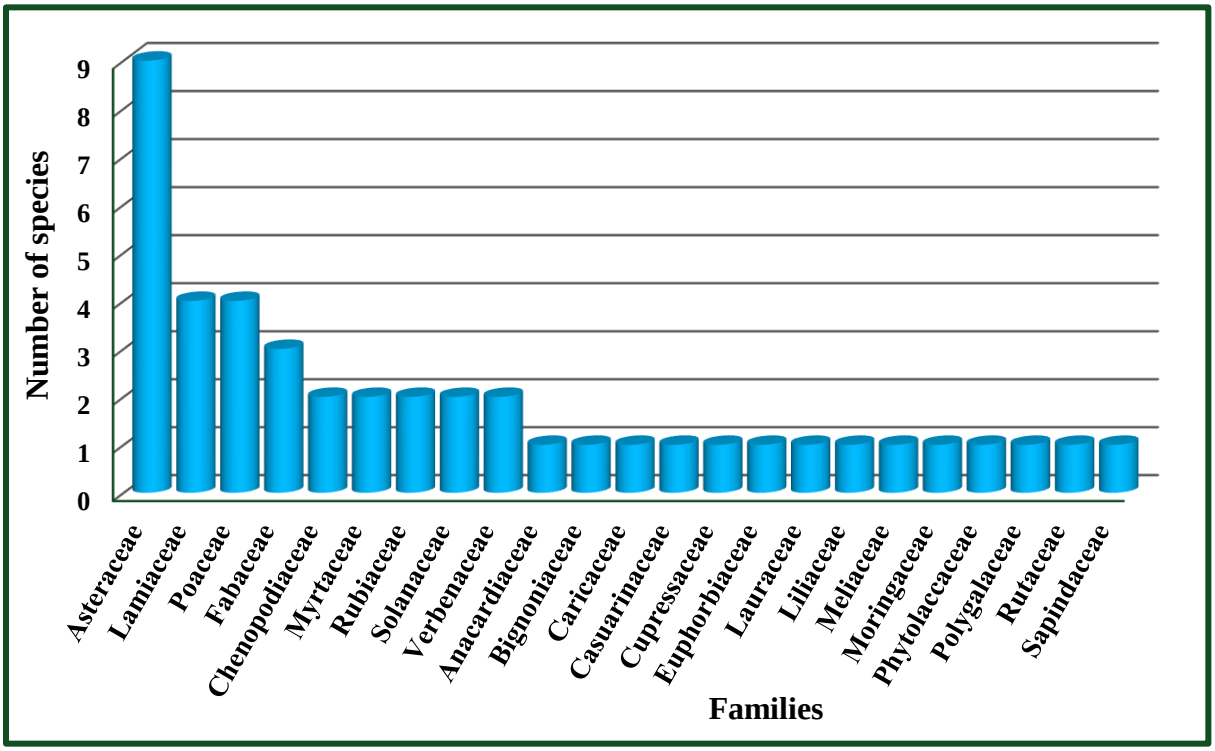

Figure 3. 1. Specific importance of the plant families identified

The list of listed plant species , their taxonomy, the parts of the plant used to prepare the medicinal recipe, and the method of preparation and use of the recipe are listed in Table 3.2. Information on the herbarium samples, including the numbers and morphological types of each species, as well as the confirmation index of the informants corresponding to each species, is also presented.

Forty-two of the 44 plant species inventoried, i.e. 89%, are known as "anti-malaria" in Burundi. Compared to the "anti-mosquito" property, 8 species, i.e. 18%, are recognized. 6 species are recognized both to treat malaria and to fight against its vector. These include *Cymbopogon citratus; Eucalyptus globulus* subsp. *maidenii* (F. Muell.) Kirkp.; *Ocimum gratissimum* L. var. *gratissimum; Citrus limon* (L.) Osbec *; Euphorbia grantii* Oliv. et *Azadirachta indica* A. Juss.

Table 3. 2. List of listed species of medicinal interest against malaria in Burundi, their taxonomy and methods of use

Scientific name	**Vernacular name**	**Family**	**Herbier**		**Vertue**	**Part used**	**Method of preparation**	**Method of use**	**ICs**
			Morphological type	**Code**[#]					
Aloe sp.**	Igikakarubamba ; impfiziyumusozi ; ingagari	Liliaceae	Herbaceous	-	Anti-malaria	Fe	Maceration; infusion; decoction	Oral	0.0264
Artemisia annua L.	Aritemiziya	Asteraceae	Shrub	-	Anti-malaria	Fe	Infusion ; decoction	Oral	0.0146
Azadirachta indica A. Juss.	Arubayine	Meliaceae	Tree	HC&NK039	Anti-malaria and mosquito repellent	Fe, Ec	Expression; decoction	Oral ; vapor bath [&]	0.0586 ; 0.0088[a]
Baccharoides lasiopus (O. Hoffm.) H. Rob	Umuvuma	Asteraceae	Shrub	HC&NK023	Anti-malaria	Fe	Expression	Oral	0.0205
Bidens pilosa L.	Icanda ; igifashi	Asteraceae	herbaceous	HC&NK040	Anti-malaria	Fe	Expression	Oral	0.0234
Cajanus cajan (L.) Huth	Umukunde; intengwa ; incaruzo	Fabaceae	Shrub	HC&NK022	Anti-malaria	Fe	Expression	Oral	0.0967
Carica papaya L.	Igipapayi	Caricaceae	Shrub	-	Anti-malaria	Fe	Decoction	Oral	0.0146
Casuarina equisetifolia L.	Akajwari	Casuarinaceae	Tree	HC&NK032	Mosquito repellent	Fe	Burning in the house	Smoke extension in the house	0.0117[a]
Cenchrus purpureus (Schumach.) Morrone	Urubingo	Poaceae	Herbaceous	HC&NK021	Anti-malaria	Fe	Decoction ; maceration	Oral	0.0146
Chenopodium ambrosioides L.	Akavunjahoma ; umusuziwingona	Chenopodiaceae	Herbaceous	-	Anti-malaria	Fe, Ple	Expression	Oral	0.0411

Chenopodium ugandae (Aellen) Aellen**	Umugombe	Chenopodiaceae	Herbaceous	HC&NK033	Anti-malaria	Fe	Expression	Oral	0.0176
Cinchona officinalis L.	Ikinini ; kenkina	Rubiaceae	Shrub	HC&NK034	Anti-malaria	Fe, Ec	Decoction	Oral	0.1085
Citrus limon (L.) Burm. f.	Indimu	Rutaceae	Shrub	-	Anti-malaria et Mosquito repellent	Fe	Maceration, expression	Oral ; skin application	0.0205 ; 0.0117[a]
Cupressus sp.	Isederi	Cupressaceae	Tree	HC&NK016	Mosquito repellent	Fe	Burn	Smoke expansion in the house	0.0293[a]
Cymbopogon citratus (DC.) Stapf	Cayicayi	Poaceae	Herbaceous	-	Anti-malaria et Mosquito repellent	Fe, Ple	Planting near the house; burn	Expansion of volatile compounds or smoke around or in the house	0.0087 ; 0.0645[a]
Digitaria abyssinica (Hochst. ex A. Rich.) Stapf	Urwiri	Poaceae	Herbaceous	HC&NK043, HC&NK044	Anti-malaria	Fe	Decoction ; Expression	Oral	0.0176
Dodonaea viscosa Jacq.	Umusasa	Sapindaceae	Shrub	HC&NK025	Anti-malaria	Fe	Expression	Oral	0.0352
Erigeron sumatrensis Retz.	Umururasase, mukobwandagowe	Asteraceae	Herbaceous	HC&NK027	Anti-malaria	Fe	Expression	Oral	0.0498

Eucalyptus globulus subsp. *maidenii* (F. Muell.) Kirkp.*	Umukaratusi wera ; marideni ; sinambugu ; umukaratusi w'ikizungu	Myrtaceae	Tree	HC&NK028	Anti-malaria et Mosquito repellent	Fe, Ec	Expression ; decoction	Oral and vapor bath [&] ; Smoke extension in the house ; expansion of volatile products in the home	0.1525 ; 0.0264[a]
Euphorbia grantii Oliv.*	Imambura	Euphorbiaceae	Shrub	HC&NK015	Anti-malaria et Mosquito repellent	Fe, Latex	Decoction	Expansion of volatile products	0.0058 ; 0.0117[a]
Guizotia scabra (Vis.) Chiov.	Ikizimyamuriro ; umuhoza	Asteraceae	Herbaceous	HC&NK031	Anti-malaria	Fe	Expression	Oral	0.0117
Gutenbergia cordifolia Benth. ex Oliv.**	Umweza	Asteraceae	Herbaceous	HC&NK004	Anti-malaria	Fe	Maceration	Oral	0.0176
Gymnanthemum amygdalinum (Delile) Sch. Bip. ex Walp.	Umubirizi ; umufumya ; kirurugunja	Asteraceae	Shrub	HC&NK009, HC&NK010, HC&NK011	Anti-malaria	Fe	Expression ; decoction	Oral	0.5777
Lantana camara L.	Mavyiyakuku	Verbenaceae	Shrub	HC&NK038	Anti-malaria	Fe	Expression	Oral	0.0146
Lantana trifolia L.*	Umuhengerihengeri	Verbenaceae	Herbaceous	HC&NK014	Anti-malaria	Fe, Rc, Ec	Expression	Oral	0.0146
Mangifera indica L.	Umwembe	Anacardiaceae	Shrub	-	Anti-malaria	Fe	Decoction	Oral	0.0293
Markhamia lutea (Benth.) K. Schum.	Umusave	Bignoniaceae	Tree	HC&NK001, HC&NK002, HC&NK003	Anti-malaria	Fe	Expression	Oral	0.0293

Moringa oleifera Lam.	Moringa	Moringaceae	Shrub	-	Anti-malaria	Fe	Expression	Oral	0.0205
Ocimum gratissimum L. var. *gratissimum*	Kabugagwe ; agatunduzi ; agatuntura ; simama nikwambiye	Lamiaceae	Herbaceous	HC&NK007, HC&NK008	Anti-malaria et Mosquito repellent	Fe, Ple	Decoction ; hang the plant or leaves in the house	Oral ; expansion of volatile compounds in the house	0.0205 ; 0.0205[a]
Persea americana Mill.	Ivoka	Lauraceae	Tree	-	Anti-malaria	Fe	Decoction , expression	Oral	0.0205
Physalis angulata L.	Intumbaswa, amahwibiri, agaperi	Solanaceae	Herbaceous	HC&NK024	Anti-malaria	Fe	Decoction	Oral	0.0264
Phytolacca dodecandra L'Hér.	Umwokora	Phytolaccaceae	Shrub	HC&NK029, HC&NK030	Anti-malaria	Fe	Expression	Oral	0.0322
Plectranthus barbatus Andrews	Igicuncu	Lamiaceae	Herbaceous	HC&NK035, HC&NK036	Anti-malaria	Fe	Expression	Oral	0.0234
Plectranthus esculentus N.E.Br.*	Inumpu, akajumbu	Lamiaceae	Herbaceous	-	Anti-malaria	Fe	Maceration	Oral	0.0205
Psidium guajava L.	Ipera	Myrtaceae	Shrub	HC&NK020	Anti-malaria	Fe	Decoction , expression	Oral	0.0234
Rubia cordifolia L. subsp. *conotricha* (Gand.) Verdc.	Umukararambwa	Rubiaceae	Herbaceous	HC&NK012	Anti-malaria	Fe	Decoction	Oral	0.0117
Securidaca longipedunculata Fresen.	Umunyagasozi	Polygalaceae		-	Anti-malaria	Fe	Expression	Oral	0.0234
Senna didymobotrya (Fresen.) H. S. Irwin & Barneby	Umubagabaga	Fabaceae	Shrub	HC&NK013	Anti-malaria	Fe	Decoction ; expression	Oral	0.0439

Sesbania sesban (L.) Merr.	Umunyegenyege	Fabaceae	Shrub	HC&NK005	Anti-malaria	Fe	Expression	Oral	0.0322
Solanecio mannii (Hook.f.) C.Jeffrey*	Umutagari ; umugango	Asteraceae	Shrub	HC&NK017, HC&NK018, HC&NK019	Anti-malaria	Fe	Expression	Oral	0.0439
Solanum terminale Forssk.*	Umuhanurankuba	Solanaceae	Shrub	HC&NK037	Anti-malaria	Fe	Expression	Oral	0.0117
Tetradenia urticifolia (Baker) Phillipson	Umuravumba	Lamiaceae	Shrub	HC&NK006	Anti-malaria	Fe	Expression ; decoction	Oral ; bain de vapeur	0.0938
Tithonia diversifolia (Hemsl.) A. Gray	Banyakuyumye; ibamba; umufumya w'ikizungu; munuko; ikinyamuhora; kivyeyi; umuburizi wa Tanzaniya; igifumyabenge	Asteraceae	Herbaceous	HC&NK026	Anti-malaria	Fe	Expression	Oral	0.0821
Zea mays L.	Ikigori	Poaceae	Herbaceous	-	Anti-malaria	Fe	Expression	Oral	0.0733

Fe : Leaf ; **Ple** : Whole plant; **Ec** : Bark ; **Rc** : Root ;

#: the codes given in the table correspond to the herbarium numbers of the specimens deposited at the Herbarium of the Department of Biology of the University of Burundi;

& : " vapor bath " : " Sauna " kind of bath that one makes by putting oneself under a blanket around a pot filled with the medicinal recipe heated to boiling. It offers a contact of the skin and the nostrils allowing to sweat intensely and to inhale the volatile compounds of the plant used;

* : Species reported as "anti-malaria" for the first time;

** : Species rarely reported as "anti-malaria";

α : Informant consensus index for "Mosquito repellent" species.

The "anti-malaria" species surveyed have informant consensus indices ranging from 0.5777 to 0.0058, while these indices vary from 0.0645 to 0.0058 for the "Mosquito repellent" plants surveyed.

It emerges from this table that more than half of the plants used as anti-malaria drugs are cited by few informants and therefore have low informant consensus indices. Three plant species have higher consensus indices than the other species surveyed. These include *Gymnanthemum amygdalinum* (Delile) Sch. Bip. ex Walp (ICs=0,5777), *Eucalyptus globulus* subsp. *maidenii* (F. Muell.) Kirkp. (ICs=0,1525) and *Cinchona officinalis* L. (ICs=0,1085).

Informant consensus ratings for the "Mosquito repellent" plants identified were very low compared to the "anti-malaria" species presented in the previous table. Mosquito repellent" plants with higher consensus ratings than the others are *Cymbopogon citratus* (DC.) Stapf (ICs=0,0645), *Cupressus* sp. (ICs=0,0293), *Eucalyptus globulus* subsp. *maidenii* (F. Muell.) Kirkp. (ICs=0,0264) and *Ocimum gratissimum* L. var. *gratissimum* (ICs=0,0205).

III.3. Parts operated, method of preparation and administration

The organs of exploited plants are generally leaf, bark, root, seeds, fruit, stem, flower, rhizome and peelings. Some constituents extracted directly from the plant such as sap and latex may also be used (Figure 3.2). The most commonly used parts are leaf (46%), bark (12%) and root (8%). It should also be noted that some plants are used as a whole (10%).

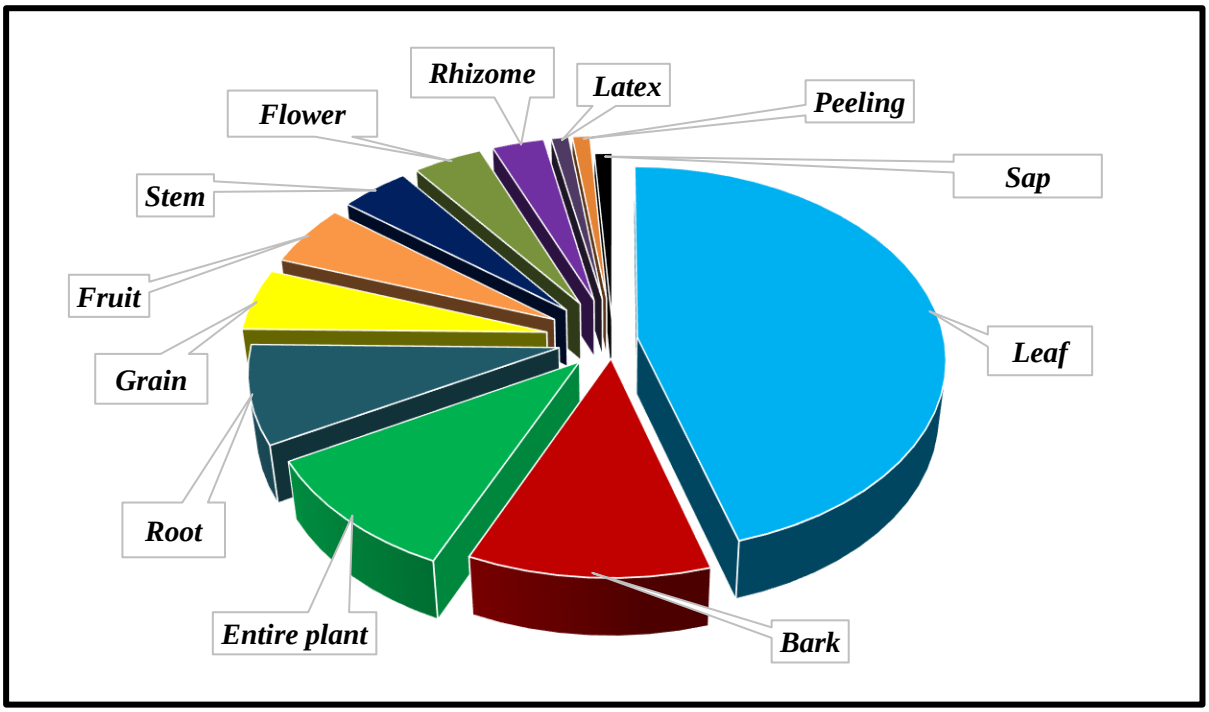

Figure 3. 2. Used parts of listed plant species

The methods of preparation of the medicinal recipe are expression, decoction, burning in the house, infusion, planting the species near the house and hanging the plant in the house (Figure 3.3). The most common methods are expression (52%) and decoction (31%).

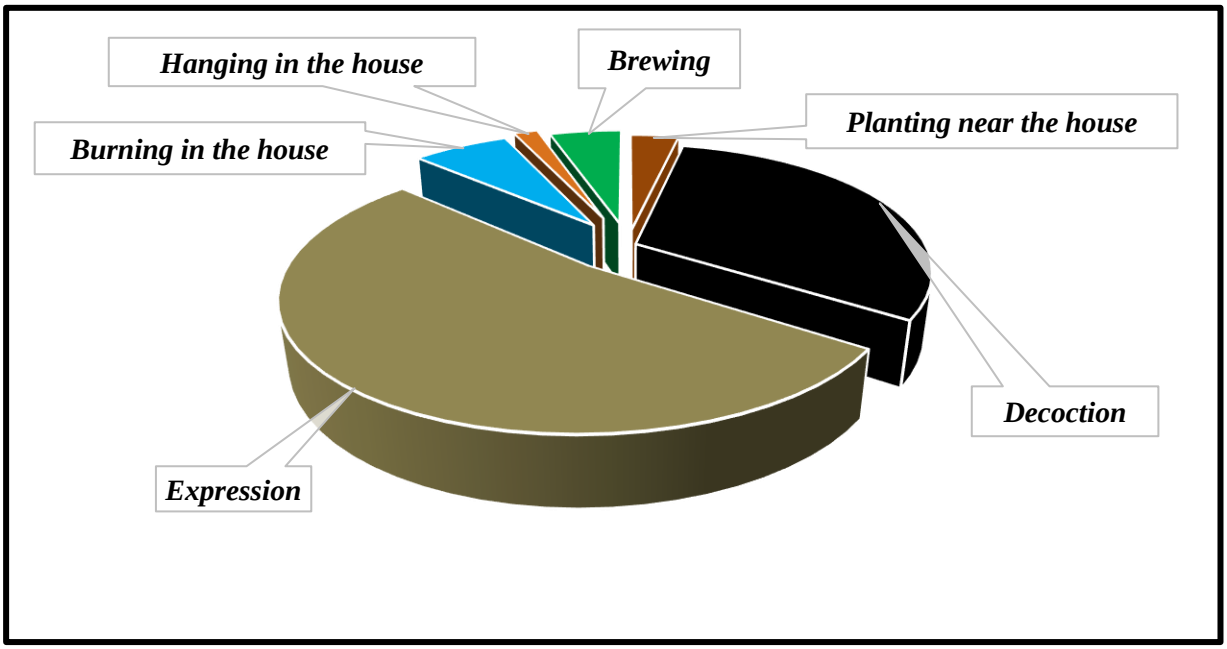

Figure 3. 3. Methods of preparation of listed plant species

Herbal medicines are administered orally, by vapor bath, smoke expansion, expansion of volatile compounds, application to the skin and smoke expansion (Figure 3.4). The oral route (76%) is the most common method of administration.

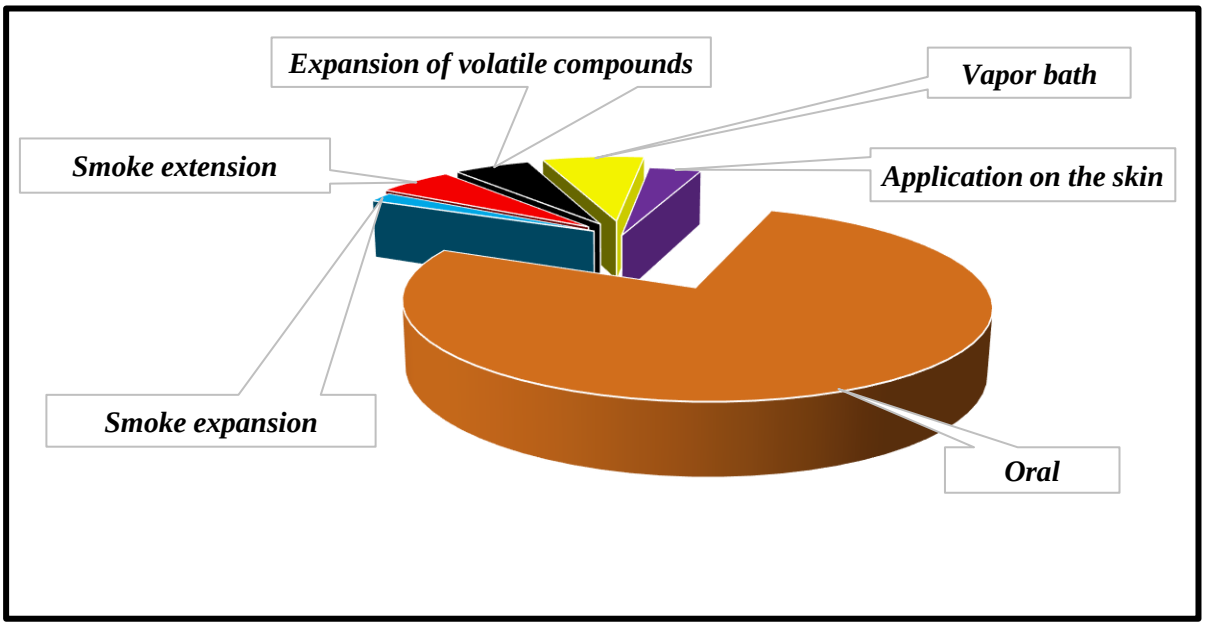

Figure 3. 4. Methods of administration of the listed plant species

III.4. Morphological types of plants surveyed

The anti-malaria and Mosquito species repel listed plants in the form of herbaceous species (18 species), shrubs (20 species) and trees (6 species).

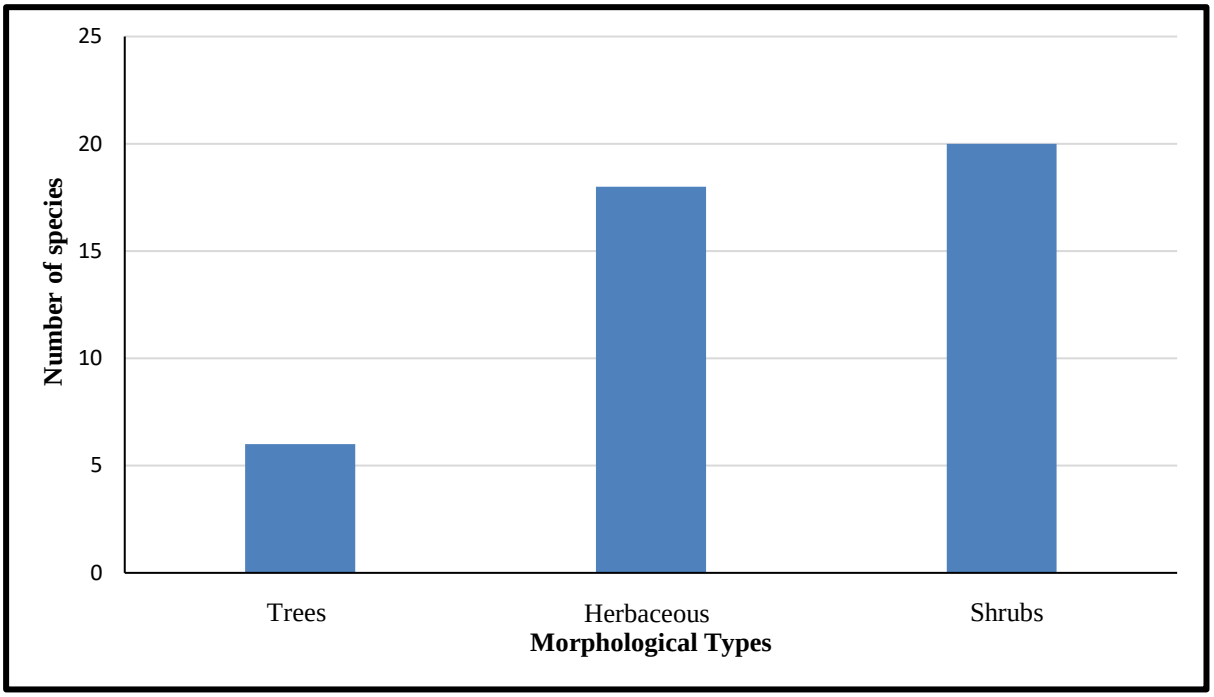

Figure 3. 5. Morphological types of anti-malaria and anti-mosquito plants recorded in Burundi

III.5. Habitats, status of origin and availability of anti-malaria and Mosquito repellent plants surveyed

This study identified 24 exotic species and 20 native species. The habitats of these species are divided into forests, savannas, gardens, fields and fallow lands. Some species are found on roadsides, while others are domesticated by the population and planted around households to support fences.

The survey revealed that most of the species in our inventory are found in degraded forests, artificial afforestation, fallows, gardens and cultivated fields; but rarely in natural forests. However, some species in our inventory are found in totally degraded forests or those that have suffered little disturbance.

The main species found in fallow land include *Bidens pilosa* L., *Guizotia scabra* (Vis.) Chiov., *Tithonia diversifolia* (Hemsl.) A. Gray and *Erigeron sumatrensis* (S.F. Blake) Pruski & G. Sancho. The species found in gardens are mainly fruit plants such as *Carica papaya* L., *Citrus limon* (L.) Osbeck, *Persea americana* Mill., *Mangifera indica* L., *Physalis angulata* L. et *Psidium guajava* L.

Forest species include those found in natural woodlands, which are cultivated for their socio-economic interest. We will cite here *Eucalyptus globulus* subsp. *maidenii* (F. Muell.) Kirkp., *Cupressus* sp. and *Casuarina equisetifolia* L.

In the fields, food crops such as *Zea mays* L. and *Cajanus cajan* (L.) Huth. However, the results of the survey showed that a species can be found in different habitat types. For example, species such as *Bidens pilosa* L. and *Tithonia diversifolia* (Hemsl.) A. Gray which can be found in forests, savannas, gardens, fields and fallows.

In addition, the results of this study show that the anti-malaria and Mosquito repellent plants recorded in Burundi are not all indigenous: only 20 species or 46% of the species recorded are indigenous (Figure 3.6).

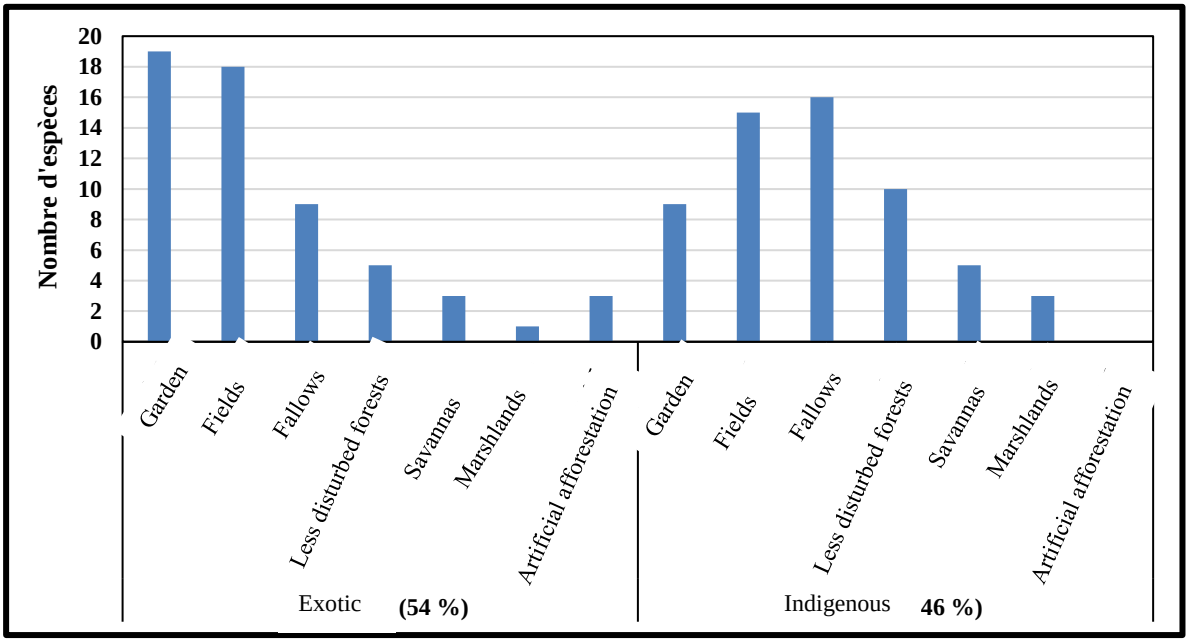

Figure 3. 6. Distribution of recorded species according to their original status and habitats

Furthermore, the survey revealed that some native species are also almost impossible to find in some localities. For example, informants told us that *Chenopodium ambrosioides* L. is a rare species in Bujumbura, part of our study area. However, others are abundant in the study area, such as the species *Bidens pilosa* L. which is abundant in the study area.

Table 3.6 lists the habitats, original status and availability of species of interest against malaria recorded in Burundi. The province(s) associated with each species corresponds to the province where the species was cited. The attributes given to plants by informants include: "Very abundant", "Abundant", "Less abundant", "Rare", and "Nearly untraceable". It should also be noted that the fact that a species is not listed in a particular province does not mean that it is not present there.

Table 3. 3. Habitats, status of origin and availability of species of interest against malaria recorded in Burundi

Scientific name	**Habitats**	**Origin**	**Province**	**Availability**
Casuarina equisetifolia L.	Artificial afforestation	Exotic	Kirundo	Less abundant
			Rumonge	Less abundant
Chenopodium ambrosioides L.	Fields, gardens, fallow land	Exotic	Bujumbura	Almost impossible to find
			Bubanza	Abundant
			Rumonge	Less abundant
Artemisia annua L.	Gardens, fields	Exotic	Ngozi	Rare
			Rumonge	Abundant
Azadirachta indica A. Juss.	Gardens, fields	Exotic	Bujumbura	Less abundant
			Cankuzo	Less abundant
			Ngozi	Rare
			Kirundo	Less abundant
			Rumonge	Less abundant
Cymbopogon citratus (DC.) Stapf	Gardens, fields	Exotic	Ngozi	Less abundant
			Bujumbura	Rare
			Bubanza	Abundant
			Cankuzo	Less abundant
			Kirundo	Less abundant
			Rumonge	Less abundant
Tithonia diversifolia (Hemsl.) A. Gray		Exotic	Bujumbura	Less abundant

	Slightly disturbed forests, fallow land, Gardens, fields		Bubanza	Very Abundant
			Cankuzo	Abundant
			Kirundo	Very Abundant
			Rumonge	Abundant
Bidens pilosa L.	Fallow land, fields, gardens, marshes	Indigeneous	Ngozi	Abundant
			Bujumbura	Abundant
			Bubanza	Abundant
			Cankuzo	Abundant
			Kirundo	Very Abundant
			Rumonge	Abundant
Plectranthus barbatus Andrews	Forests with little disturbance, fields, fallows	Indigeneous	Bujumbura	Rare
			Bubanza	Abundant
			Cankuzo	Less abundant
			Muramvya	Abundant
			Rumonge	Less abundant
Aloe sp.	Gardens, fields	Exotic	Ngozi	Rare, Less abundant
			Bujumbura	Less abundant
			Bubanza	Less abundant
			Kirundo	Less abundant
			Rumonge	Rare
Carica papaya L.	Gardens, fields	Exotic	Ngozi	Less abundant
			Bubanza	Abundant
			Muramvya	Abundant
			Rumonge	Abundant
Zea mays L.	Fields, marshes	Exotic	Ngozi	Abundant

			Bubanza	Abundant
			Cankuzo	Abundant
			Kirundo	Very Abundant
			Rumonge	Abundant
Cinchona officinalis L.	Artificial afforestation, fields, gardens	Exotic	Ngozi	Less abundant
			Bujumbura	Less abundant
			Bubanza	Less abundant
			Muramvya	Less abundant
			Rumonge	Rare
Guizotia scabra (Vis.) Chiov.	Slightly disturbed forests, fields, fallow land, savannas	Indigeneous	Ngozi	Abundant, Rare
Euphorbia grantii Oliv.	Fields, gardens	Exotic	Rumonge	Abundant
Citrus limon (L.) Osbeck	Gardens, fields	Exotic	Bujumbura	Abundant
			Bubanza	Very Abundant
			Kirundo	Abundant
			Rumonge	Abundant
Cajanus cajan (L.) Huth	Gardens, fields	Exotic	Ngozi	Less abundant
			Bubanza	Abundant
			Cankuzo	Less abundant
			Bujumbura	Rare
			Muramvya	Abundant
			Rumonge	Rare
Physalis angulata L.		Indigeneous	Bubanza	Less abundant

	Forests with little disturbance, Gardens, fields, fallow land		Kirundo	Less abundant
			Rumonge	Abundant
Plectranthus esculentus L.	Savannas	Exotic	Rumonge	Rare
Psidium guajava L.	Slightly disturbed forests, fields, gardens, savannas	Exotic	Ngozi	Abundant
			Bubanza	Abundant
			Cankuzo	Abundant
			Muramvya	Abundant
			Rumonge	Less abundant
Cupressus sp.	Slightly disturbed forests, savannas	Exotic	Ngozi	Less abundant
			Bubanza	Less abundant
			Cankuzo	Less abundant
			Kirundo	Less abundant
Persea americana Mill.	Fallows, Gardens, fields	Exotic	Bubanza	Very Abundant
			Kirundo	Abundant
			Rumonge	Less abundant
Ocimum gratissimum L. var. *gratissimum*	Gardens, fields, fallows	Exotic	Bujumbura	Rare
			Rumonge	Abundant
Lantana camara L.	Forests with little disturbance, savannas, gardens, fallows	Exotic	Ngozi	Abundant
			Kirundo	Abundant
Moringa oleifera Lam.	Gardens, fields, fallows	Exotic	Bujumbura	Less abundant
			Bubanza	Less abundant
			Rumonge	Rare
	Fields, forests with little disturbance, fallows	Indigeneous	Ngozi	Rare
			Cankuzo	Rare

Senna didymobotrya (Fresen.) H. S. Irwin & Barneby			Bujumbura	Less abundant
			Kirundo	Less abundant
			Muramvya	Rare
Gymnanthemum amygdalinum (Delile) Sch. Bip. ex Walp	Fields, gardens, fallow land	Indigeneous	Ngozi	Abundant
			Bujumbura	Less abundant
			Bubanza	Very Abundant
			Cankuzo	Less abundant
			Kirundo	Abundant
			Muramvya	Very Abundant
			Rumonge	Abundant
Chenopodium ugandae (Aellen) Aellen	Fallows, Gardens, fields	Exotic	Bujumbura	Rare
			Kirundo	Less abundant
			Muramvya	Abundant
Solanum terminale Forssk.	Forests with little disturbance, fallows	Indigeneous	Rumonge	Less abundant
Lantana trifolia L.	Fields, savannas, fallows	Indigeneous	Rumonge	Abundant
Phytolacca dodecandra L'Hér.	Fields, fallows, gardens	Indigeneous	Bubanza	Abundant
			Bujumbura	Rare
			Muramvya	Less abundant
			Rumonge	Less abundant
Rubia cordifolia L. subsp. *Conotricha*	Forests with little disturbance, fallows	Indigeneous	Kirundo	Abundant
Eucalyptus globulus subsp. *maidenii* (F. Muell.) Kirkp	Artificial afforestation, fallows	Exotic	Ngozi	Abundant
			Bubanza	Very Abundant
			Bujumbura	Rare
			Cankuzo	Abundant
			Kirundo	Abundant
			Muramvya	Very Abundant

			Rumonge	Less abundant
Securidaca longipedunculata Fresen.	Savannas	Indigeneous	Rumonge	Rare
Sesbania sesban (L.) Merr.	Forests with little disturbance, Fields, gardens, fallow land	Indigeneous	Ngozi	Rare
			Bujumbura	Rare
			Kirundo	Less abundant
			Muramvya	Abundant
Tetradenia urticifolia (Baker) Phillipson	Fields, fallows, gardens	Indigeneous	Ngozi	Abundant
			Bujumbura	Rare
			Bubanza	Abundant
			Cankuzo	Rare
			Kirundo	Abundant
			Rumonge	Less abundant
Erigeron sumatrensis (S.F. Blake) Pruski & G.Sancho	Fallows, fields, gardens	Indigeneous	Bubanza	Less abundant
			Cankuzo	Less abundant
			Muramvya	Rare
			Rumonge	Less abundant
Dodonaea viscosa Jacq.	Forests with little disturbance, savannas, aging fallows	Indigeneous	Bujumbura	Rare, Almost impossible to find
			Bubanza	Less abundant
			Cankuzo	Less abundant
			Kirundo	Less abundant
			Muramvya	Abundant
Markhamia lutea (Benth.) K. Schum.	Forests with little disturbance, fields	Indigeneous	Bujumbura	Less abundant, Rare
			Kirundo	Abundant
Solanecio mannii (Hook.f.) C.Jeffrey	Fields, fallows, gardens	Indigeneous	Cankuzo	Abundant
			Muramvya	Very Abundant

			Rumonge	Less abundant
Baccharoides lasiopus (O. Hoffm.) H. Rob	Forests with little disturbance, savannas, Gardens, fields	Indigeneous	Cankuzo	Less abundant
			Bubanza	Abundant
			Kirundo	Less abundant
			Muramvya	Less abundant
Mangifera indica L.	Gardens, fallows, fields	Exotic	Ngozi	Abundant
			Bujumbura	Abundant
			Bubanza	Very Abundant
			Cankuzo	Abundant
			Muramvya	Abundant
			Rumonge	Abundant
Gutenbergia cordifolia Benth. ex Oliv.	Marshland	Indigeneous	Muramvya	Very Abundant
Cenchrus purpureus (Schumach.) Morrone	Forests with little disturbance, Gardens, fields	Exotic	Kirundo	Abundant
			Muramvya	Very Abundant
			Rumonge	Abundant
Digitaria abyssinica (Hochst. ex A.Rich.) Stapf	Fields, fallows, marshland, gardens	Indigeneous	Ngozi	Very Abundant
			Bujumbura	Abundant
			Kirundo	Abundant

N.B: Garden means here the green space laid out in and around the fence of the houses to embellish or green but not primarily agricultural.

CHAPTER IV. DISCUSSION OF THE RESULTS

IV.1. Importance of the listed plant families

Our study shows that the families of the species in our inventory are the Asteraceae family, the Fabaceae family, the Lamiaceae family and the Poaceae family. These results are consistent with other research (Dénou et al., 2017; Kouadio et al., 2016; Rhattas et al., 2016) that has reported the importance of these families in traditional medicine.

The importance of Poaceae and Asteraceae has been reported in Côte d'Ivoire (Kouadio et al., 2016), in an ethnobotanical study of medicinal plants used in the Transua department, Zanzan district. The Fabaceae family has been reported in Cameroon as the most represented among the families of plants used in the treatment of malaria (Dénou et al., 2017). The Lamiaceae family is also important in traditional medicine. The inventory carried out in Talassemtane National Park (Morocco) concluded that the Lamiaceae family is the most represented (Rhattas et al., 2016).

The importance of the Fabaceae family and those of the Poaceae could be explained by the fact that they are among the richest families in terms of species. Therefore, the chance of abundance of species for medicinal use may be greater.

IV.2. Anti-malaria" plants identified

The results of our study allowed us to inventory 42 species of plants known as "anti-malaria" by the Burundian population. Although some of these species have low informant consensus indices, most of them have already been the subject of ethnobotanical and/or phytochemical studies and the results confirmed the importance of some of them in the treatment of malaria and many other diseases.

Some species in our inventory are cited for the first time as "anti-malaria" species. These are *Plectranthus esculentus* L., *Solanum terminale* Forssk., *Lantana trifolia* L., *Euphorbia grantii* Oliv., *Eucalyptus globulus* subsp. *maidenii* (F. Muell.) Kirkp. and *Solanecio mannii* (Hook.f.) C. Jeffrey.

Indeed, the results of our study rank *Eucalyptus globulus* subsp. *maidenii* (F. Muell.) Kirkp. among the species known as "anti-malaria" in Burundi. This being the case, we could not find any other results that concur with those of our study. This species is rather known to treat chest pain and cough (Amri & Kisangau, 2012). In addition, it is known to treat whooping cough (Rwangabo, 1993), fever, cough, muscle aches and pains, and external relaxation through bathing (Aston Philander, 2011). However, other studies have reported the antibacterial and antioxidant effect of *Eucalyptus globulus leaf* essential oil (Ghalem & Mohamed, 2008; Hafsa et al., 2016; Harkat-Madouri et al., 2015). We believe that its recognition as "anti-malaria" in Burundi could be explained by its importance in the treatment of fever, one of the first symptoms of malaria.

Although known as an "anti-malaria" species in Burundi, *Lantana trifolia* L. is known in Rwanda to treat angina, gonorrhoea and hepatitis (Rwangabo, 1993). It is from this species that *Umuhengerine*, a flavonoid with strong antimicrobial activity, was first isolated (Rwangabo et al., 1988). It is also reported to treat gonorrhoea, wounds and sores, and hepatitis etiopatosplenomegaly (Rwangabo, 1993).

It also appears from our work that the species *Solanecio mannii* (Hook.f.) C. Jeffrey, treats malaria by Leafs expression. Other studies have rather shown that bathing a decoction of Leafs *Solanecio mannii* (Hook.f.) C. Jeffrey with a decoction of Leafs. Jeffrey, mixed with those of *Gymnanthemum amygdalinum* (Delile) Sch. Bip. ex Walp and S. *oleracius*, would cure fever (Namukobe et al., 2011). The species is not known against malaria but a species of the same genus (C. *monthuosum*) is reported against malaria in the Democratic Republic of Congo (Kasali et al., 2014).

The roots and exudate of *Euphorbia grantii* Oliv. treat epilepsy, toothache, and snake bites by external application or nasal application (Augustino et al., 2011). It also treats gonorrhoea (Rwangabo, 1993) and is known to be a good luck charm by drinking a young shoot decoction (Ssegawa & Kasenene, 2007).

Plectranthus esculentus is attributed for its effectiveness against poor digestion (purple belly, nausea, vomiting, diarrhea). It is also used as a purgative, anthelmintic, and carminative (Lukhoba et al., 2006).

Although it is cited in this study as an "anti-malarial" species, *Solanum terminale* is not known for its action against malaria. Rather, it is thought to be used to induce labour in parturient women (Kamatenesi-Mugisha & Oryem-Origa, 2007). It is also used to treat asthma (Tomani et al. 2018) and is believed to treat kwashiorkor (Lawal *et al*., 2010).

Other species in our inventory are poorly reported as "anti-malaria" or even their efficacy against malaria has been questioned. We mention here the species Gutenbergia cordifolia Benth. ex Oliv, Chenopodium ugandae (Aellen) Aellen and Aloe sp.

Although known as an anti-malarial in Burundi, the species Gutenbergia cordifolia Benth. ex Oliv. has been reported to have no anti-malarial activity despite the interest of the Maasai in this species in relation to its usefulness in the treatment of malaria (Koch et al., 2005). It is also reported to control ticks, giardiasis and cough (Chifundera, 2001; Nanyingi et al., 2008).

Reported as anti-malaria only in Rwanda by Rwangabo (1993), Chenopodium ugandae is also an antifungal and antibacterial species (Cos et al., 2002) particularly against abdominal colic, stomach aches, amoebic dysentery and "ubuganga" (Rwangabo, 1993). It would also be effective as a voluntary skin depigmentation agent (Kamagaju et al., 2013).

Aloe sp. is cited among the species used in the treatment of malaria, but we could not find any studies that revealed this claim. *Aloe vera*, which has been a traditional and widely used medicinal plant for millennia (Michayewicz, 2013), has not yet been studied for its antimalarial properties. On the other hand, several research studies have shown that it is rather toxic despite its moisturizing, anti-inflammatory and healing activities (Kemper & Chiou, 1999). Nevertheless, for Africans and Zulus, *Aloe vera* is considered as the plant that heals everything (Michayewicz, 2013), which could justify the importance given to this species by the Burundian population in the fight against malaria.

IV.3. Mosquito repellent" plants identified

This study identified 8 species used by the Burundian population in the fight against the malaria vector (Mosquito repellent). These species have low consensus indices, but previous research work has shown the interest of some of them in the fight against malaria in general and its vector in particular.

For example, the species *Cymbopogon citratus* is known to be a leaf fumigant (L. N. Bonkian et al., 2017), but its efficacy has been questioned. Nevertheless, the use of this plant would have risks based on the skin-irritating compounds it contains (Maia & Moore, 2011).

The evaluation of the chemical composition of the essential oil of *Eucalyptus globulus* leaf has led to the conclusion that this plant has good insecticidal activity against the housefly, *Musca domestica L*. (Kumar et al., 2012). This argument could justify the fact that the plant is known by the Burundian population to be a mosquito repellent.

The species *Azadirachta indica* A. *Juss*. has been frequently cited as a mosquito repellent plant in the Longido district of Tanzania (Innocent et al., 2016). This species also has biologically active components that show insecticidal activity (Rachid & Ahmad, 2013).

The results of our investigation show that leaf's decoction of *Ocimum gratissimum* L. var. *gratissimum* treats malaria. These results also show that the suspension of the plant or its leafs in the house contributes to mosquito repulsion. Our results are therefore consistent with those of the survey conducted by (J. Chogo & Crank, 1982) which showed that the oil of *Ocimum gratissimum* L. var. *gratissimum* is a good mosquito repellent and antimicrobial, with eugenol as the active component. This has led to the use of the plant as an insect repellent and its use in the treatment of skin, eye, ear and stomach ailments (J. B. Chogo & Crank, 1982). The species *Ocimum gratissimum* L. var. *gratissimum* has also revealed its antiplasmodial, anti-mosquito and anti-larval role (Kiraithe et al., 2016) thanks to its extracts or the suspension of the plant or its leafs in the house (L. N. Bonkian et al., 2017).

Essential oils from the bark of *Casuarina equisetifolia* are effective against mosquitoes (Adeosun et al., 2016). However, another study suggested that C. *equisetifolia* would favor disease-carrying insects (Reiskind et al., 2010). The zest and juice of the fruit of *Citrus limon* in water have been reported to control mosquitoes (Shaalan et al., 2005; Bonkian et al., 2017; Youmsi et al., 2017).

On the other hand, although *Cupressus* sp. is recognized in our work as a "Mosquito repellent" plant, we could not find any research that proved this finding. In addition, there are species of this genus that are of interest in the treatment of malaria. For example, C. *lusitanica* is known to be anti-malarial in the Democratic Republic of Congo through leafs decoction (Kasali et al., 2014). Further studies are needed to investigate the species of the genus *Cupressus* as a mosquito repellent.

IV.4. Parties, method of preparing revenue and its administration

The results of our inventory reveal that leaf and bark are the most commonly used parts of the "anti-malaria" and "Mosquito repellent" plants found in Burundi. Leaf has been reported in other research as the most commonly used part of plants used in the treatment of malaria (Bla et al. 2015; Mpiana et al. 2014; Sylla et al. 2018; Yetein et al. 2013). Although leaf is reported as the most commonly used part, other work has shown that the leafy stem is the most commonly used part of most plants used in the treatment of malaria (Dénou et al., 2017).

With regard to the modes of preparation of medicines, our inventory shows that the expression is the most used mode of preparation of the medicinal recipe, i.e. in 52% of cases. Other methods used are decoction (31%), burning in the house (7%), infusion (5%), followed by planting the species near the house (3%) and hanging the plant in the house (2%). Although plant expression is described in this work as the most widely used method, other researchers have found that decoction is the most widely used (Nzuki, 2016; Sylla et al., 2018; Yetein et al., 2013). Decoction and expression are the most widely used main preparation methods. The use of decoction can be justified on the basis of its advantages of promoting extraction and releasing volatile toxins (Bashige et al., 2017). Unfortunately, decoction also has the risk of denaturing heat-sensitive active ingredients.

Finally, this study shows that most of the herbal medicines are administered, for the most part, orally. Other modes of drug administration are vapor bath, smoke expansion, expansion of volatile compounds, skin application and smoke expansion. These results are consistent with other studies that have reported that the oral route is the most commonly used route of administration (Bashige et al., 2017).

The use of the oral route in most cases may be explained by the fact that oral ingestion of bioactive ingredients involves a much faster and more efficient metabolic process than the dermal (brushing, ablution) and aeropharyngeal routes such as nasal instillation and vapor bath (Bla et al., 2015).

IV.5. Vulnerability of plants depending on the parts collected, habitats and morphological types

The use of leaf in most of the "anti-malaria" and "Mosquito repellent" species recorded in Burundi could provide information on the degree of vulnerability of these species. Intensive harvesting of leaf does not present a danger to the plant. Ouattara (2006) in (Bla et al., 2015) showed that the removal of 50% of the leafs from a tree does not significantly affect its survival. On the other hand, the removal of bark or whole of the plant may have adverse effects on the survival of the species, especially when the species concerned is not abundant in its environment.

In addition, this work shows that the most dominant morphological type among the "anti-malaria" and "Mosquito repellent" species recorded in Burundi are shrubs, trees and herbaceous plants. The morphological types of the species in our inventory can provide information on their vulnerability and thus inform decision making in case of conservation. Research work has led to the conclusion that a species is much more vulnerable when it occurs in the form of a tree than when it occurs in a herbaceous form (S. Sibomana et al., 2012).

Using Raunkier's (1966) classification, the morphological types of anti-malarial and Mosquito repellent plants recorded in Burundi are grouped into two main categories: phanerophytes (Trees, shrubs) and chamephytes (herbaceous).

As our inventory is mainly composed of phanerophytes (Trees, shrubs), we admit that the anti-malaria and mosquito repellent species recorded in Burundi are vulnerable. However, we believe that plant vulnerability parameters are not limited to morphological types.

In relation to habitats, most of the species in our inventory are found in forests that have been disturbed. However, research has shown that disturbed forest species are vulnerable compared to fallow or rangeland species (S. Sibomana et al., 2012). Indigenous species reported in this work are not equally immune to this degradation.

Vulnerability factors of "anti-malaria" and "Mosquito repellent" species recorded in Burundi as described in this work include the harvesting mode (parts collected) and the morphological type and habitat. However, the implications for conservation should take into account all these vulnerability factors. The "anti-malaria" and "mosquito repellent" plants recorded in Burundi are vulnerable and that their conservation is very necessary on the one hand for their protection and for the conservation of the goods and services they offer on the other hand. In the future, in-depth studies should be carried out to establish conservation priorities for these species. Species at risk of extinction should normally be given priority in the case of in-situ and/or ex-situ conservation programmes. The implications for the conservation of malaria and mosquito repellent plants identified in Burundi could make good sustainable management practices, including the use of these plants in agroforestry.

IV.6. A look at the relationship between anti-malarial plants and Covid-19 prevention

Some anti-malaria species in our inventory are used to prevent Covid-19. Since the announcement of the first positive test cases, plants such as *Eucalyptus globulus subsp. maidenii (F. Muell.) Kirkp., Tetradenia urticifolia* (Baker) Phillipson, *Artemisia annua* L. and *Azadirachta indica* A. have tested positive for Covid-19. Juss. are sold in the streets of the economic capital of Burundi. In addition to these plants, the fruits of Citrus limon (L.) Burm. f. are also sought after for their interest in preventing this pandemic.

However, according to the WHO, traditional medicine has many benefits but scientific rigor must prevail in the steps taken. It is therefore essential to conduct rigorous clinical trials before establishing the efficacy of herbal remedies and determining their adverse effects (WHO, 2020).

For example, "Covid-Organics", an herbal tea based on *Artemisia annua* L., is sold in Madagascar. It is used in prevention, but clinical observations have shown a trend towards its curative effectiveness (Larcher, 2020). *Azadirachta indica* leaf suspension would provide oxygen and previous studies have already mentioned that it has antimicrobial, anti-inflammatory, antifungal, antipyretic and immunostimulant effects (Desai et al., 2020). Eucalyptol (1,8 cineole), a molecule present in the essential oil *Eucalyptus globulus subsp. maidenii* (F. Muell.) Kirkp. has an interest in controlling Covid-19. However, further research is still needed to consider its medical use (Sharma & Kaur, 2020).

Although the users of these plants in Burundi attribute to them all the qualities to clear the respiratory tract after a vapor bath, further phytochemical studies are needed to assess the efficacy of anti-malarial plants that are of particular interest in the treatment or prevention of Covid-19. As these plants are in high demand by the population, domestication programmes are needed to avoid depletion of this resource.

GENERAL CONCLUSION

Malaria is a public health problem at the international level in general and more particularly in the African context where the disease is endemic. In Burundi, the incidence of malaria also remains a reality. The use of insecticides to control the malaria vector has contributed to the reduction of the incidence of this disease, but it has been threatened by the resistance developed by the vector. The resistance of Plasmodium to antimalarial drugs is also a threat to the fight against this disease.

This study was thus conducted in Burundi with the aim of providing an information base for the search for new molecules with anti-malarial and/or mosquito repellent potential. The results show that the Burundian population has knowledge related to "anti-malaria" and "mosquito repellent" plants. The very low values of the consensus indices of the informants made it possible to admit that the Burundian population has very little knowledge of mosquito repellent species compared to knowledge of "anti-malaria" plants.

Certain species such as *Plectranthus esculentus* L., *Solanum terminale* Forssk., *Lantana trifolia* L., *Euphorbia grantii* Oliv. and *Eucalyptus globulus subsp. maidenii* (F. Muell.) Kirkp. and *Solanecio mannii* (Hook.f.) C. Jeffrey are cited for the first time as species of interest against malaria. Others such as *Gutenbergia cordifolia* Benth. ex Oliv., *Chenopodium ugandae* (Aellen) Aellen and Aloe sp. are little reported as "anti-malaria" or even their efficacy against malaria has been questioned. Further phytochemical analyses are needed to assess their phytotherapeutic efficacy.

The study showed that the "anti-malaria" and "Mosquito repellent" species recorded in Burundi are essentially prepared by expression and administered orally. Leaf is the most exploited organ, which presents a low risk to plants. Trees and shrubs are the most dominant morphological types, which presents a high risk of vulnerability for these plants. The study also showed that the "anti-malaria" and "mosquito repellent" species recorded in Burundi are not all indigenous. They are found in ruderal environments or those that have undergone disturbances such as forests with little disturbance, fallows, fields and gardens, which also presents a high risk of vulnerability for them.

Finally, in order to conserve the "anti-malaria" and "mosquito repellent" plants identified in Burundi as well as the goods and services they offer, several actions should be carried out in the future. The future prospects proposed in this work include the development of in-depth studies to establish conservation priorities for these species. Thus, in-situ and/or ex-situ conservation programmes should target, as far as possible, species at risk of vulnerability. Good practices of sustainable plant management including their use in agroforestry could be one of the approaches for the conservation of "anti-malaria" and "mosquito repellent" plants in Burundi. Anti-malaria or mosquito repellent plants used for the treatment or prevention of Covid-19 should be conserved through the implementation of domestication programmes.

REFERENCES

Adeosun, C., Bamidele, I., Salau, B., & Ayorinde, A. (2016). Essential oil from the stem bark of Casuarina equisetifolia exhibits mosquitocidal potential. *Journal of Phytopathology and Pest Management*, *3*, 53–62.

Agbodeka, K., Gbekley, H. E., Karou, S. D., Anani, K., & Simpore, J. (2017). Activité antiplasmodiale des plantes médicinales d ' Afrique de l ' Ouest : Revue de la littérature. *International Journal of Innovation and Scientific Research*, *28*(2), 121–129. https://www.researchgate.net/publication/311912390

Amri, E., & Kisangau, D. P. (2012). Ethnomedicinal study of plants used in villages around Kimboza forest reserve in Morogoro, Tanzania. *Journal of Ethnobiology and Ethnomedicine*, *8*(1), 9. https://doi.org/10.1186/1746-4269-8-1

Aouinty, B., Oufara, S., Mellouki, F., & Mahari, S. (2006). Évaluation préliminaire de l'activité larvicide des extraits aqueux des Leafs du ricin (Ricinus communis L.) et du bois de thuya (Tetraclinis articulata (Vahl) Mast.) sur les larves de quatre moustiques culicidés : Culex pipiens (Linné), Aedes caspius . *Biotechnologie, Agronomie, Société et Environnement*, *10*(2), 67–71. https://www.researchgate.net/publication/26433487

Asase, A., & Oppong-Mensah, G. (2009). Traditional antimalarial phytotherapy remedies in herbal markets in southern Ghana. *Journal of Ethnopharmacology*, *126*(3), 492–499. https://doi.org/10.1016/j.jep.2009.09.008

Asase, A., Oteng-Yeboah, A. A., Odamtten, G. T., & Simmonds, M. S. J. (2005). Ethnobotanical study of some Ghanaian anti-malarial plants. *Journal of Ethnopharmacology*, *99*, 273–279. https://doi.org/10.1016/j.jep.2005.02.020

Aston Philander, L. (2011). An ethnobotany of Western Cape Rasta bush medicine. *Journal of Ethnopharmacology*, *138*(2), 578–594. https://doi.org/10.1016/j.jep.2011.10.004

Augustino, S., Hall, J. B., Makonda, S. B. F., & Ishengoma, R. C. (2011). Medicinal resources of the miombo woodlands of Urumwa, Tanzania: plants and its uses. *Journal of Medicinal Plants Research*, *5*(27), 6352–6372. https://doi.org/10.5897/jmpr10.517

Bashige, C. V, Bakari, A. S., Mbuyi, K. S., Kahumba, B. J., Duez, P., & Lumbu, S. J. . (2017). Étude ethnobotanique , phytochimique et évaluation de l ' activité antiplasmodiale de 13 plantes réputées antipaludéennes dans la commune du Kenya (Lubumbashi , RDC). *Phytothérapie*, 10. https://doi.org/10.1007/s10298-017-1152-x

Bla, K., Trebissou, J., Bidie, A., Assi, Y., Zihiri-Guede, N., & Djaman, A. (2015). Étude ethnopharmacologique des plantes antipaludiques utilisées chez les Baoulé- N'Gban de Toumodi dans le Centre de la Côte d'Ivoire. *Journal of Applied Biosciences*, *85*(1), 7775. https://doi.org/10.4314/jab.v85i1.4

Bonkian, L. N., Yerbanga, R. S., Coulibaly, M. T., Lefevre, T., Sangaré, I., Ouédraogo, T., Traoré, O., Ouédraogo, J. B., Guiguemdé, T. R., & Dabiré, K. R. (2017). Plants against Malaria and Mosquitoes in Sahel region of Burkina Faso : An Ethno-botanical survey. *International Journal of Herbal Medicine*, *5*(3), 82–87.

Bonkian, L., Yerbanga, R., Traoré Coulibaly, M., Lefevre, T., Sangaré, I., Ouédraogo, T., Traoré, O., Ouédraogo, J., Guiguemdé, T., & Dabiré, K. (2017). Plants against Malaria and Mosquitoes in Sahel region of Burkina Faso : An Ethno-botanical survey. *International Journal of Herbal Medicine*, *5*(3), 82–87. https://hal.archives-ouvertes.fr/hal-02411013

Chandre, F., Darrier L, M., Akogbeto, M., O, F., Jean, M., & P, G. (1999). Situation de la résistance aux pyréthrinoïdes chez Anopheles gambiae sensu lato. *Bulletin of the World Health Oganization*, 230–234.

Chantal, S. (2016). *Les plantes médicinales de la région montagneuse de Kahuzi-Biega en République démocratique du Congo : utilisation , accessibilité et consensus des tradipraticiens*. *December 2015*.

Chardon, P.-A. (1981). Méthodes pratiques de dépouillement de questionnaires. *Université de Neuchâtel*, 1–136. http://doc.rero.ch/lm.php?url=1000,40,4,20051227102903-ES/2_these_ChardonPA.pdf

Chifundera, K. (2001). Contribution to the inventory of medicinal plants from the Bushi area, South Kivu Province, Democratic Republic of Congo. *Fitoterapia*, *72*(4), 351–368. https://doi.org/10.1016/S0367-326X(00)00294-X

Chogo, J. B., & Crank, G. (1982). Chemical composition and biological activity of the tanzanian plant Ocimum suave. *Journal of Natural Products*, 308–311. https://doi.org/https://doi.org/10.1021/np50015a012

Chogo, J., & Crank, G. (1982). Essential oil and leaf constituents of Lippia ukambensis from Tanzania. *Journal of Natural Products*, *45*(2), 186–188. https://doi.org/https://doi.org/10.1021/np50020a013

Cos, P., Hermans, N., De Bruyne, T., Apers, S., Sindambiwe, J. B., Vanden Berghe, D., Pieters, L., & Vlietinck, A. J. (2002). Further evaluation of Rwandan medicinal plant extracts for their antimicrobial and antiviral activities. *Journal of Ethnopharmacology*, *79*, 155–163. https://doi.org/10.1016/S0378-8741(01)00362-2

Danis, M. (2019). Proposition d ' un traitement du paludisme par des Leafs d ' Artemisia ҂ , ҂҂ About treatment of malaria with Artemisia leaves. *Bulletin de l'Académie Nationale de Médecine*, *203*(3–4), 122–123. https://doi.org/10.1016/j.banm.2019.04.004

Dénou, A., Koudouvo, K., Togola, A., Haïdara, M., Dembélé, S. M., Ballo, F. N., Sanogo, R., & Diallo, D. (2017). *Savoir traditionnel sur les plantes antipaludiques à propriétés analgésiques , utilisées dans le district de Bamako (Mali)*. 10985–10995.

Desai, A., Desai, C., Desai, H., Mansuri, A., & Desai, J. (2020). Possible role of medicinal plants in Covid19 - A brief review. *International Journal of Scientific Development and Research*, *5*(4), 205–209.

Durand, M., & Loup, C. (2007). *L'avenir des Herbiers de Montpellier*. 25.

Gakuya, D. W., Itonga, S. M., Mbaria, J. M., Muthee, J. K., & Musau, J. K. (2013). Ethnobotanical survey of biopesticides and other medicinal plants traditionally used in Meru central district of Kenya. *Journal of Ethnopharmacology*, *145*(2), 547–553. https://doi.org/10.1016/J.JEP.2012.11.028

Gassita, J. (1995). La Nouvelle Pharmacopée Pragmatique Africaine (N.P.P.A), justification scientifique et applications industrielles. *Pharm. Méd. Trad. Afr.*, 95–100.

Ghalem, B. R., & Mohamed, B. (2008). Antibacterial activity of leaf essential oils of Eucalyptus globulus and Eucalyptus camaldulensis. *African Journal of Pharmacy and Pharmacology*, *2*(10), 211–215.

Hafsa, J., Smach, M. ali, Ben Khedher, M. R., Charfeddine, B., Limem, K., Majdoub, H., & Rouatbi, S. (2016). Physical, antioxidant and antimicrobial properties of chitosan films containing Eucalyptus globulus essential oil. *LWT - Food Science and Technology*, *68*, 356–364. https://doi.org/10.1016/j.lwt.2015.12.050

Harkat-Madouri, L., Asma, B., Madani, K., Bey-Ould Si Said, Z., Rigou, P., Grenier, D., Allalou, H., Remini, H., Adjaoud, A., & Boulekbache-Makhlouf, L. (2015). Chemical composition, antibacterial and antioxidant activities of essential oil of Eucalyptus globulus from Algeria. *Industrial Crops and Products*, *78*, 148–153. https://doi.org/10.1016/j.indcrop.2015.10.015

Innocent, E., Augustino, S., & Kisinza, W. (2016). Plants Used to Control Mosquitoes and Treat Mosquito Related Diseases in Plants Used to Control Mosquitoes and Treat Mosquito Related Diseases in Maasai-land of Longido District , Tanzania. *European Journal of Medicinal Plants*, *January*. https://doi.org/10.9734/EJMP/2016/23214

Innocent, E., Hassanali, A., Kisinza, W. N. W., Mutalemwa, P. P. P., Magesa, S., & Kayombo, E. (2014). Anti-mosquito plants as an alternative or incremental method for malaria vector control among rural communities of Bagamoyo District, Tanzania. *Journal of Ethnobiology and Ethnomedicine*, *10*(1), 11. https://doi.org/10.1186/1746-4269-10-56

Jansen, O., Frédérich1, M., Tits, M., Angenot, L., Cousineau, S., Bessot, L., Crunet, C., & Nicolas, J.-P. (2008). Ethnopharmacologie et paludisme au Burkina-Faso : sélection de 13 espèces à potentialités antiplasmodiales méconnues. *Ethnopharmacologia*, *41*, 12.

Kamagaju, L., Bizuru, E., Minani, V., Morandini, R., Stévigny, C., Ghanem, G., & Duez, P. (2013). An ethnobotanical survey of medicinal plants used in Rwanda for voluntary depigmentation. *Journal of Ethnopharmacology*, *150*(2), 708–717. https://doi.org/10.1016/j.jep.2013.09.031

Kasali, F. M., Mahano, A. O., Nyakabwa, D. S., Kadima, N. J., Misakabu, F. M., Tshibangu, D. S. T., Ngbolua, K. N., & Mpiana, P. T. (2014). Ethnopharmacological survey of medicinal plants used against malaria in Bukavu city (D.R. Congo). *European Journal of Medicinal Plants*, *4*(1), 29–44. https://doi.org/10.9734/ejmp/2014/5766

Kemper, K. J., & Chiou, V. (1999). Aloe vera (Aloe vera). *Http://Www.Longwoodherbal.Org/*, 1–24. http://www.longwoodherbal.org/aloe/aloe.pdf

Kiraithe, M. N., Nguta, J. M., Mbaria, J. M., & Kiama, S. G. (2016). Evaluation of the use of Ocimum suave Willd. (Lamiaceae), Plectranthus barbatus Andrews (Lamiaceae) and Zanthoxylum chalybeum Engl. (Rutaceae) as antimalarial remedies in Kenyan folk medicine. *Journal of Ethnopharmacology*, *178*, 266–271. https://doi.org/10.1016/j.jep.2015.12.013

Koch, A., Tamez, P., Pezzuto, J., & Soejarto, D. (2005). Evaluation of plants used for antimalarial treatment by the Maasai of Kenya. *Journal of Ethnopharmacology*, *101*(1–3), 95–99. https://doi.org/10.1016/j.jep.2005.03.011

Koné, D. (2018). Enquête ethnobotanique de six plantes médicinales maliennes : extraction , identification d ? alcaloïdes - caractérisation , quantification de polyphénols : étude de leur activité antioxydante. In *HALL* (p. 189).

Kouadio, B., Djeneb, C., Guessan, F. N., Yvette, B., & Noël, Z. G. (2016). *Étude ethnobotanique des plantes médicinales utilisées dans le Département de Transua , District du Zanzan (Côte d ' Ivoire)*. *27*(2), 4230–4250.

Kumar, P., Mishra, S., Malik, A., & Satya, S. (2012). Compositional analysis and insecticidal activity of Eucalyptus globulus (family: Myrtaceae) essential oil against housefly (Musca domestica). *Acta Tropica*, *122*(2), 212–218. https://doi.org/10.1016/j.actatropica.2012.01.015

Lapenna, S., Bergonzi, M. C., Vincieri, F. F., & Bilia, A. R. (2008). *Natural Product Communications Comparative Analysis of Antimalarial Principles in Artemisia annua L . Herbal Drugs from East Africa*.

Larcher, L. (2020). *Contre le Covid-19, Madagascar parie sur l'artemisia*. https://www.la-croix.com/Monde/Afrique/Contre-Covid-19-Madagascar-parie-lartemisia-2020-04-22-1201090597

Lukhoba, C. W., Simmonds, M. S. J., & Paton, A. J. (2006). Plectranthus: A review of ethnobotanical uses. *Journal of Ethnopharmacology*, *103*, 1–24. https://doi.org/10.1016/j.jep.2005.09.011

Maia, M. F., & Moore, S. J. (2011). Plant-based insect repellents: A review of their efficacy, development and testing. *Malaria Journal*, *10*(SUPPL. 1), 1–14. https://doi.org/10.1186/1475-2875-10-S1-S11

MEEATU. (2016). *Stratégie Nationale et Plan d'Action en matière d'accès aux ressources génétiques et de partage des avantages découlant de leur utilisation au Burundi* (OBPE (ed.); p. 51). http://bi.chm-cbd.net.

Mergeai, G. (2014). Artemisia annua, un espoir pour contrôler les principales maladies parasitaires en Afrique subsaharienne. *Tropicultura*, *32*(1), 1–2.

Michayewicz, N. (2013). *L ' Aloe vera , plante médicinale traditionnellement et largement utilisée depuis des millénaires , aux nombreuses propriétés thérapeutiques . Plante miracle ?* https://hal.univ-lorraine.fr/hal-01731937

Mpiana, P. ., Kalonda, E. M., Mbayo, M. K., Muhume, S. K., Kasereka, M., Mulamba, J. ., Manya, H. ., Lumbu, J. B. ., Misakabu, F. ., & Kasali, M. (2014). Ethnopharmacological survey of plants used against malaria in Lubumbashi city (D.R. Congo). *Journal of Advanced Botany and Zoology*, *1*(2). https://doi.org/10.15297/jabz.v1i2.02

MSPLS. (2009). *Plan stratégique de lutte contre le paludismen au burundi (2008-2012)*. 0–50.

N'Guessan, K., Trabi, FH., Kone, M. (2009). Etude ethnopharmacologique de plantes utilisées en médecine traditionnelle ches les Abbey et Krobou d'Agboville (Côte d'Ivoire). *Ethnopharmacologia*, *44*, 42–50.

Namukobe, J., Kasenene, J. M., Kiremire, B. T., Byamukama, R., Kamatenesi-Mugisha, M., Krief, S., Dumontet, V., & Kabasa, J. D. (2011). Traditional plants used for medicinal purposes by local communities around the Northern sector of Kibale National Park, Uganda. *Journal of Ethnopharmacology*, *136*, 236–245. https://doi.org/10.1016/j.jep.2011.04.044

Nanyingi, M. O., Mbaria, J. M., Lanyasunya, A. L., Wagate, C. G., Koros, K. B., Kaburia, H. F., Munenge, R. W., & Ogara, W. O. (2008). Ethnopharmacological survey of Samburu district, Kenya. *Journal of Ethnobiology and Ethnomedicine*, *4*, 1–12. https://doi.org/10.1186/1746-4269-4-14

Ndabirorere, S. (1999). *Données statistiques des produits forestiers non-ligneux du Burundi* (p. 34). FAO. www.fao.org/3/X6698F/X6698F00.pdf

Nzigidahera, B, Mbarushimana, D., Habonimana, B., & Habiyaremye, F. (2016). *Habitats du Parc National de la Ruvubu au Burundi. Guide sur la flore pour le suivi de la dynamique des habitats du PNR*.

Nzigidahera, Benoît. (2012). *Description du Burundi : Aspects physiques*. MINEAGRIE, ex. MINAGRIE.

Nzigidahera, Benoît. (2017). *Droit d'usages des ressources biologiques des aires protégées et d'autres milieux naturels*.

Nzuki, B. F. (2016). *Recherches ethnobotaniques sur les plantes médicinales dans la Région de Mbanza- Ngungu, RDC*.

OMS. (1978). *Rapport de la Conférence internationale sur les soins de santé primaires* (p. 88). https://www.who.int/topics/primary_health_care/alma_ata_declaration/fr/ Visité le 25 juin 2019

OMS. (2002). *Stratégie de l'OMS pour la Médecine Traditionnelle pour 2002-2005 Organisation mondiale de la Santé Genève*. http://apps.who.int/iris/bitstream/handle/10665/67313/WHO_EDM_TRM_2002.1_fre.pdf?sequence=1

OMS. (2013). *Renforcement du rôle de la médecine traditionnelle dans les systèmes de santé : une stratégie pour la région africaine : rapport du secrétariat. OMS. Bureau régional de l'Afrique. 14*. https://doi.org/10.1017/CBO9781107415324.004

Ousset, J. L. P. (2006). *Politiques nationales PLACE DES MÉDICAMENTS TRADITIONNELS EN AFRIQUE*. 606–609.

Pradines, B., Dormoi, J., Briolant, S., Bogreau, H., & Rogier, C. (2010). La résistance aux antipaludiques. *Revue Francophone Des Laboratoires*, *2010*(422), 51–62. https://doi.org/10.1016/s1773-035x(10)70510-4

Rachid, M., & Ahmad, A. (2013). The Effect of Neem (Azadirachta indica) Leaves Extract on the Ecdysis and Mortality of Immature Stages of Common House Mosquito Culex pipiens fatigans. *Biologia (Pakistan)*, *59*(2).

Reiskind, M. H., Zarrabi, A. A., & Lounibos, L. P. (2010). Invasive leaf resources alleviate density dependence in the invasive mosquito, Aedes albopictus. *Biological Invasions*, *12*(7), 2319–2328. https://doi.org/10.1007/s10530-009-9646-6

Rhattas, M., Douira, A., & Zidane, L. (2016). *Étude ethnobotanique des plantes médicinales dans le Parc National de Talassemtane (Rif occidental du Maroc). 9211*, 9187–9211.

Rodrigo, L., Gazzaneo, S., Farias, R., Lucena, P. De, & Albuquerque, U. P. De. (2005). *Knowledge and use of medicinal plants by local specialists in an region of Atlantic Forest in the state of Pernambuco (Northeastern*. *8*, 1–8. https://doi.org/10.1186/1746-4269-1-9

Rokia, S. (2013). *Le rôle des pharmacopées traditionnelles dans la lutte contre le paludisme*. 1–5. http://www.doc-developpement-durable.org/file/sante-hygiene-medecine/Maladies/paludisme-malaria/rôle des pharmacopées traditionnelles dans la lutte contre le paludisme.pdf Visité le 02 juillet 2019

Rubert, A., Guillon-Grammatico, L., Chandenier, J., Dimier-Poisson, I., & Desoubeaux, G. (2016). Insecticide resistance in anopheles mosquitoes: Additional obstacles in the battle against malaria. *Medecine et Sante Tropicales*, *26*(4), 423–431. https://doi.org/10.1684/mst.2016.0634

Rwangabo, P. C. (1993). *La médecine traditionnelle au Rwanda. KARTHALA Editions.* (Karthala &).

Rwangabo, P. C., Claeys, M., Pieters, L., Corthout, J., Vanden Berghe, D. A., & Vlietinck, A. J. (1988). Umuhengerin, a new antimicrobially active flavonoid from lantana trifolia. *Journal of Natural Products*, *51*, 966–968. https://doi.org/10.1021/np50059a026

Sani, Y. (2013). *Le paludisme : repères historiques, climatiques et anthropiques* (Vol. 9, Issue 2004). https://www.ruor.uottawa.ca/bitstream/10393/24125/3/Yaya_Sanni_2013_Le_paludisme_repères_historiques_climatiques_et_anthropiques.pdf Visité le 05 juillet 2019

Shaalan, E. A. S., Canyon, D., Younes, M. W. F., Abdel-Wahab, H., & Mansour, A. H. (2005). A review of botanical phytochemicals with mosquitocidal potential. *Environment International*, *31*, 1149–1166. https://doi.org/10.1016/j.envint.2005.03.003

Sharma, A. D., & Kaur, I. (2020). *Eucalyptol (1,8 cineole) from eucalyptus essential oil a potential inhibitor of COVID 19 corona virus infection by Molecular docking studies*. *March*. https://doi.org/10.20944/preprints202003.0455.v1

Sibomana, R., Bukobero, L., Hariyongabo, H., & Niyonkuru, D. (2017). Effet de la cataire non transformée sur la répulsion des moustiques. *Université Populaire Haguruka*, 1–4.

Sibomana, S., Nshimba, S.-M., Koffi, K. J., Robbrecht, E., Lejoly, J., Habonimana, B., & Bogaert, J. (2012). *Identification des plantes menacées du Burundi par l'analyse de la vulnérabilité*. *85*(2008), 77–85.

Sinzinkayo, D. (2018). *Etat des lieux de la malaria au Burundi*. http://www.ub.edu.bi/wp-content/uploads/2018/05/EtatdeslieuxdelaMalariaauBurundi.pdf Visité le 05 Août 2019

Soh, P. N. (2008). *Recherche de nouveaux composés à activité antipaludique à partir de différentes pharmacopées traditionnelles*. 167.

Ssegawa, P., & Kasenene, J. M. (2007). Medicinal plant diversity and uses in the Sango bay area, Southern Uganda. *Journal of Ethnopharmacology*, *113*(3), 521–540. https://doi.org/10.1016/j.jep.2007.07.014

Sylla, Y., Silue, D. K., Ouattara, K., & Kone, M. W. (2018). Etude ethnobotanique des plantes utilisées contre le paludisme par les tradithérapeutes et herboristes dans le district d'Abidjan (Côte d'Ivoire). *International Journal of Biological and Chemical Sciences*, *12*(3), 1380. https://doi.org/10.4314/ijbcs.v12i3.25

Treyvaud, V., Arnason, J. T., Maquin, P., Cal, V., Belize, S., Amiguet, V. T., Arnason, J. T., Maquin, P., Cal, V., Vindas, P. S., & Poveda, L. (2016). *A Consensus Ethnobotany of the Q ' eqchi ' Maya of Southern Belize Pablo Sanchez Vindas and Luis Poveda Published by : Springer on behalf of New York Botanical Garden Press Stable URL : http://www.jstor.org/stable/4256933 REFERENCES Linked references are* . *59*(1), 29–42.

WHO. (2014). WHO Malaria Report 2014. *Lancet*, *365*(9469), 1487–1498. https://doi.org/10.1016/S0140-6736(05)66420-3

WHO. (2018). *World Malaria Report 2018 Isbn 978 92 4 156565 3*. www.who.int/malaria

WHO. (2019). *World malaria report 2019*. www.who.int/malaria

WHO. (2020). *L'OMS soutient une médecine traditionnelle reposant sur des éléments scientifiques probants*. 2. https://www.afro.who.int/fr/news/loms-soutient-une-medecine-traditionnelle-reposant-sur-des-elements-scientifiques-probants

Yerbanga, R. S., Rayaisse, J. B., Vantaux, A., Salou, E., Mouline, K., Hien, F., Habluetzel, A., Dabiré, R. K., Ouédraogo, J. B., Solano, P., & Lefèvre, T. (2016). Neemazal ® as a possible alternative control tool for malaria and African trypanosomiasis? *Parasites and Vectors*, *9*(1), 1–14. https://doi.org/10.1186/s13071-016-1538-x

Yetein, M. H., Houessou, L. G., Lougbégnon, T. O., Teka, O., & Tente, B. (2013). Ethnobotanical study of medicinal plants used for the treatment of malaria in plateau of Allada, Benin (West Africa). *Journal of Ethnopharmacology*, *146*(1), 154–163. https://doi.org/10.1016/j.jep.2012.12.022

Youmsi, R. D. F., Fokou, P. V. T., Menkem, E. Z., Bakarnga-Via, I., Keumoe, R., Nana, V., & Boyom, F. F. (2017). Ethnobotanical survey of medicinal plants used as insects repellents in six malaria endemic localities of Cameroon. *Journal of Ethnobiology and Ethnomedicine*, *13*, 1–14. https://doi.org/10.1186/s13002-017-0155-x

APPENDIX

Appendix 1. Survey Questionnaire

Cible : Populations and traditional practitioners **Date :**

I. IDENTIFICATION OF THE RESPONDENT

Name : ……

Surname : ……

Sheet Nº : ……

Age :

Sex : ☐ Male ☐ Female

Marital status : ☐ Single ☐ Married ☐ widow (er) ☐ Divorced

Level of education : ☐ None ☐ Primary ☐ Secondary ☐ University

Profession : ……

Religion: ☐ Muslims ☐ Pentecost
☐ Catholics ☐ Jehovah's Witnesses
☐ Protestants ☐ Evangelical churches
☐ Adventists ☐ Others (to be specified)

Province : ……

Commune : ……

Colline : ……

Sub-colline : ……

II. KNOWLEDGE OF MOSQUITO REPELLENT AND ANTI-MALARIA PLANTS AND THEIR PROPERTIES

1) Have you ever heard of Mosquito repellent and/or anti-malaria plants?

YES ☐ NO ☐

2) Do you know of any plant species used to control mosquitoes and/or malaria in your locality?

YES ☐ NO ☐

If the answer is no, the investigation stops.

If yes, what species ?

Nº	*Vernacular name*	*Scientific name*	*Common Name*
1	……	……	……
2	……	……	……
3	……	……	……
4	……	……	……
5	……	……	……
6	……	……	……

3) What are the relative "anti-malaria" properties of each species in relation to mosquito repulsion and/or elimination?

Features / **Name of the species**	***Insect repellent***	***Insecticide***	***Anti-malaria***
1.			
2.			
3.			
4.			
5.			
6.			

4) What part(s) of the plant(s) is (are) used in the fight against mosquitoes and malaria?

Fresh plant ☐ ***Dried plant*** ☐

Stems ☐ Flowers ☐ Bark ☐

Roots ☐ Grains ☐ Essential oils ☐

Leafs ☐ Fruits ☐ Ohers. (to be specified) ☐

5) How do you prepare the plant for use?

Method of preparation	***Species 1***	***Species 2***	***Species 3***	***Species 4***	***Species 5***	***Species 6***
Powder						
Decoction						
Infusion						

Cataplasm						

6) Among the plant species used in the fight against mosquitoes and/or malaria that you know of, which ones are native?

1……. 4…….

2……. 5…….

3……. 6…….

III. DISTRIBUTION AND ECOLOGY OF MOSQUITO REPELLENT AND ANTI-MALARIA PLANTS

1) What are the habitats where you encounter the species listed?

Habitat / **Name of species**	***Forest***	***Fallow***	***Garden***	***Fields***	***Marshland***	***Savannas***
1.						
2.						
3.						
4.						
5.						
6.						

2) Do you have any information on the presence of each species in other natural regions or provinces of Burundi?

Species ***Natural Region or Province***

1. …….. *(1)* …… *(2)* …… *(3)* ……

2. …….. *(1)* …… *(2)* …… *(3)* ……

3. …….. *(1)* …… *(2)* …… *(3)* ……

4. …….. *(1)* …… *(2)* …… *(3)* ……

5. …….. *(1)* …… *(2)* …… *(3)* ……

6. …….. *(1)* …… *(2)* …… *(3)* ……

3) Are the species with Mosquito repellent and anti-malaria properties that you know planted or grow naturally?

☐ Planted

- ☐ Grows naturally
- ☐ Planted but can grow naturally

4) Which species are planted and how is the planting done?

Plantation / **Name of species**	***Sowing the seeds***	***Cuttings by roots***	***Stem cuttings***	***Cuttings by leafs***	***Others (to be precised)***
1.					
2.					
3.					
4.					
5.					
6.					

Appendix 2. Illustration of some species of the Lamiaceae family

Ocimum gratissimum

Plectranthus barbatus

Tetradenia urticifolia

Appendix 3. Illustration of some species of the Asteraceae family

Solanecio manii

Gutenbergia cordifolia

Baccharoides lasiopus

Gymnanthemum amygdalinum

Tithonia diversifolia

Erigeron sumatrensis

Appendix 4. Illustration of some species of the Fabaceae family

Cajanus cajan

Sesbania sesban

Senna didymobotrya

Appendix 5. Illustration of some species of the families of Chenopodiaceae, Myrtaceae, Rubiaceae and Bignoniaceae

Chenopodium ugandae

Eucalyptus globulus* subsp. *Maidenii

Psidium guajava

Cinchona officinalis

Rubia cordifolia

Markhamia lutea

h

Appendix 6. Illustration of some species of the families of Solanaceae, Verbenaceae, Casuarinaceae and Cupressaceae

Physalis angulata

Solanum terminale

Lantana camara

Lantana trifolia

Casuarina equisetifolia

***Cupressus* sp.**

Appendix 7. Illustration of some species of the families of Euphorbiaceae, Meliaceae, Phytolacaceae and Sapindaceae

Euphorbia grantii

Azadirachta indica

Phytolacca dodecandra

Dodonaea viscosa