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Antimalarial herbal remedies of Bukavu and Uvira areas in DR Congo: An ethnobotanical survey

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ARTICLE INFO

This article is dedicated to our close colleague Kisimba Kibuye, who died in 2017.

Keywords:
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South Kivu province
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ABSTRACT

Ethnopharmacological relevance: The main objective of the present study was to collect and gather information on herbal remedies traditionally used for the treatment of malaria in Bukavu and Uvira, two towns of the South Kivu province in DRC.

Material and methods: Direct interview with field enquiries allowed collecting ethnobotanical data; for each plant, a specimen was harvested in the presence of the interviewed traditional healers (THs). The recorded information included vernacular names, morphological parts of plants, methods of preparation and administration of remedies, dosage and treatment duration. Plants were identified with the help of botanists in the herbaria of INERA/KIPOPO (DRC) and the Botanic Garden of Meise (Belgium), where voucher specimens have been deposited. The results were analysed and discussed in the context of previous published data.

Results: Interviewees cited 45 plant species belonging to 41 genera and 21 families used for the treatment of malaria. These plants are used in the preparation of 52 recipes, including 25 multi-herbal recipes and 27 mono-herbal recipes. Apart of *Artemisia annua* L. (Asteraceae; % Citation frequency = 34%) and *Carica papaya* L. (Caricaceae; % Citation frequency = 34%), the study has highlighted that the most represented families are Asteraceae with 12 species (26%), followed by Fabaceae with 7 species (16%) and Rubiaceae with 4 species (9%). For a majority of plants, herbal medicines are prepared from the leaves in the form of decoction and administered by oral route.

Conclusion: Literature data indicate that part of cited species are already known (38%) and/or studied (30%) for antimalarial properties, which gives credit to the experience of Bukavu and Uvira interviewees and some level of confidence on collected information. The highly cited plants should be investigated in details for the isolation and identification of active ingredients, a contribution to the discovery of new possibly effective antimalarials.

1. Introduction

Malaria, a disease caused by hematozoa of the genus *Plasmodium*, is the leading cause of death in sub-Saharan Africa, particularly in the Democratic Republic of Congo (DRC) (Fidock et al., 2004; Colin, 2005; Ibrahima et al., 2012; Vishnoi et al., 2013; Memvanga et al., 2015; PNLP, 2016; WHO, 2018). Due to its high prevalence and morbidity, malaria represents a major public health problem and a hindrance to the development of poor countries (Garcia-Alvarez et al., 2013; Ngbolua et al., 2013; Chika and Bello, 2016; WHO, 2018). According to WHO estimates, 219 million cases of malaria were registered in the world in 2017 with 435,000 deaths, most of them being children under 5 years old from sub-Saharan Africa (WHO, 2018). The indirect adverse effects of malaria and its correlation with other diseases both contribute to severely impact its death toll (Rogers et al., 2002; Hay et al., 2004; Christopher et al., 2012). In DRC, malaria affects both rural and urban populations. As most of the country is hyperendemic, the disease accounts for 12% of the causes of death. It is estimated that 30–47% of

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hospitalizations are malaria-related (Mandoko et al., 2018) and that about 10–11 US dollars are needed to treat severe malaria (Tsakala et al., 2005; Bisimwa et al., 2014; PNLP, 2016), while the per capita income is less than 1 US dollar (President's Malaria Initiative, 2018). In particular, the South Kivu province is especially affected by the disease; in Bukavu, the capital city of the province, 2 million malaria cases were reported in 2013 (RZS, 2013).

Despite the progresses made in malaria prevention and control (Chika and Bello, 2016), its epidemiological situation in the world, and mostly in poor countries such as DRC, still depends on *Plasmodium* chemoresistance, on the reduced accessibility to quality antimalarials and on undesirable effects that reduce compliance (Ngbolua et al., 2013; Chika and Bello, 2016). Development of new effective antimalarials is consequently of profound importance and, in this undertaking, the study of herbal medicines is likely to play a key role (Willcox and Bodeker, 2004). Indeed, the isolation of new bioactive compounds from medicinal plants based on traditional use or from ethnobotanical data seems to be a very promising approach (Newman, 2008; Frausin et al., 2015; Memvanga et al., 2015).

Traditional medicines have been used to treat malaria for thousands of years and are the source of the two main groups (quinine and artemisinin derivatives) of modern antimalarial drugs (Willcox and Bodeker, 2004). In the same context, medicinal plants effective against malaria have been documented in many studies (e.g. Colin, 2005; Tabuti, 2008; Krettli, 2009; Asase et al., 2010; Nguta et al., 2010; Koudouvo et al., 2011; Dike et al., 2012; Traore et al., 2013; Yetein et al., 2013; Diarra et al., 2015): more than 1200 plant species belonging to 160 families are documented as being used against malaria and fever globally.

The DRC contains a large forest area with a flora rich in a wide variety of medicinal plants (Kalonda et al., 2014; Kasali et al., 2014a,b), a likely source for compounds that could lead to new antimalarial drugs. The use of these plants is associated with a diversity of traditional medicinal practices varying from one ethnic group to another (Kambu, 1990). As stated, malaria is a major public health problem in DRC and people living in endemic remote rural areas commonly use medicinal plants for treatment. Despite efforts in the ethnobotanical and ethnopharmacological documentation of Congolese antimalarial plants (Mabika, 1983; Bakana, 1984; Kambu, 1990; Biruniya, 1993; Defour, 1995; Kasuku et al., 1999; Chifundera, 2001; Muganza et al., 2012; Kasali et al., 2014a,b; Kalonda et al., 2014; Memvanga et al., 2015), many of these are still scientifically unknown; also, given ongoing deep sociological changes in the region (Godfraind, 2010), there is a definite risk of losing this traditional knowledge. In the South Kivu province of DRC, to our best knowledge, a single ethnobotanical survey was carried out on antimalarial medicinal plants, in the city of Bukavu (Kasali et al., 2014a,b) but not in the city of Uvira. As Bukavu and Uvira are two DRC cities with quite typical mountainous vegetations, the present study was conducted to compile an inventory of antimalarial plant species for leads warranting further pharmacological and phytochemical investigations.

2. Material and methods

2.1. Ethnomedicinal survey

2.1.1. Description of the research area

Bukavu (Fig. 1) is located in the Eastern part of DRC (S 2°26′-2°33′, E 28°49′-28°53′), on the Southern end of Lake Kivu. It is the highest part of DRC with an average altitude of 1600 m. This town is bounded on the West and South by the territory of Kabare, North by the Lake Kivu and East by the Ruzizi River, a natural border with Rwanda. The population of Bukavu is estimated to be around 807,000 people who mainly speak Swahili (Mangambu et al., 2015). The city is cosmopolitan; however, some ethnolinguistic groups are most represented, namely the Bashi and the Rega. Bukavu has a mountainous relief and a tropical mountain climate in two seasons, with a wet season from September to April and an average temperature of 20 °C (Ciza, 2015; Mangambu et al., 2015). Due to its humid climate, the vegetation of the city should be forested. Nevertheless, bio-indicator vegetation is marked by the presence in some places of relict species of seasonal deciduous forests (Kasali et al., 2014a,b).

Uvira is located at the Northern end of Lake Tanganyika (S 03°26′, E 29°08′), at 126 km from Bukavu (capital of South Kivu), 60 km from the Fizi Territory and 15 km from Bujumbura (capital of Burundi). Uvira has a population of about 217,000 people (Lumami et al., 2016). The city has a heterogeneous population, with a majority of indigenous people (Babembes, Bavira, Bafuliru and Banyamulenge). From this heterogeneity arise various languages and dialects but the most spoken is Swahili. The altitude varies between 180 and 900 m. It is bounded on the West by the chain of Mitumba and on the North by the Ruzizi plain. The city experiences two seasons, with a rainy season from mid-September to mid-May. The minimum temperatures are 20–30 °C in the Ruzizi plain and 15–25 °C in the high plateau. The vegetation is related to altitude and mainly consists of grassy savanna and forest trees used for farms and livestock pastures (Journaux and Alii, 1969).

In these two studied regions, communities are richly endowed with green floral vegetation and majority of the populace uses herbal medicines to treat several human diseases, including malaria.

2.1.2. Data collection

A survey of the population of the two areas, led through question-responses discussion with 192 inhabitants (62% women) selected randomly in the market in each locality, allowed to identify 32 highly popular traditional healers (THs; 17 from Bukavu and 15 from Uvira) who answered a pre-established guide questionnaire from May 2013 to December 2014. These 32 traditional healers were selected according to their frequency of citation by the 192 inhabitants which were greater than or equal to 10%. The objectives of the study were clearly explained, and the verbal consent of each TH was obtained.

Since malaria is a disease known in both study areas, no information was sought on THs' diagnostic criteria and questions mainly focused on the plants used to cure a pathology that is assumed to be malaria. Information was gathered about (1) the traditional healers interviewed and (2) the plants used in the control of malaria; this includes the vernacular names, the part(s) used, the preparation methods of the medicinal recipes, the association of plants in the recipes, the dosage, the route of administration, the duration of treatment but also the other diseases for which the plants are useful. The collection and use of personal data were conducted in accordance with the principles of anonymity as set out in the Helsinki Declaration (World Medical Association, 2013). All work conducted was carried out under the stipulations of the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity (United Nations, 2011).

2.1.3. Plant identification

The first identification was made by each plant, in the presence of the traditional healers and an agronomist of the Institute of the Environment and Agricultural Research (INERA-Mulungu) of Bukavu. Plant specimens were collected in triplicate for botanical authentication in the herbarium. A voucher sample was stored for each plant at the INERA-Kipopo Herbarium in Lubumbashi (DRC) where the identification was confirmed by comparison with *(i)* the existing samples in the Kipopo Herbarium; *(ii)* data from the literature (Troupin, 1978–1987); and *(iii)* the African Plant Database (CJB, 2012) and The Plant List (http://www.theplantlist.org). A set of the 35 identified plants was also deposited at the Herbarium of Meise Botanical Garden, Belgium.

2.1.4. Data processing

Microsoft Excel (2013) was used for the calculations and the histograms. The data obtained through the survey were analysed and

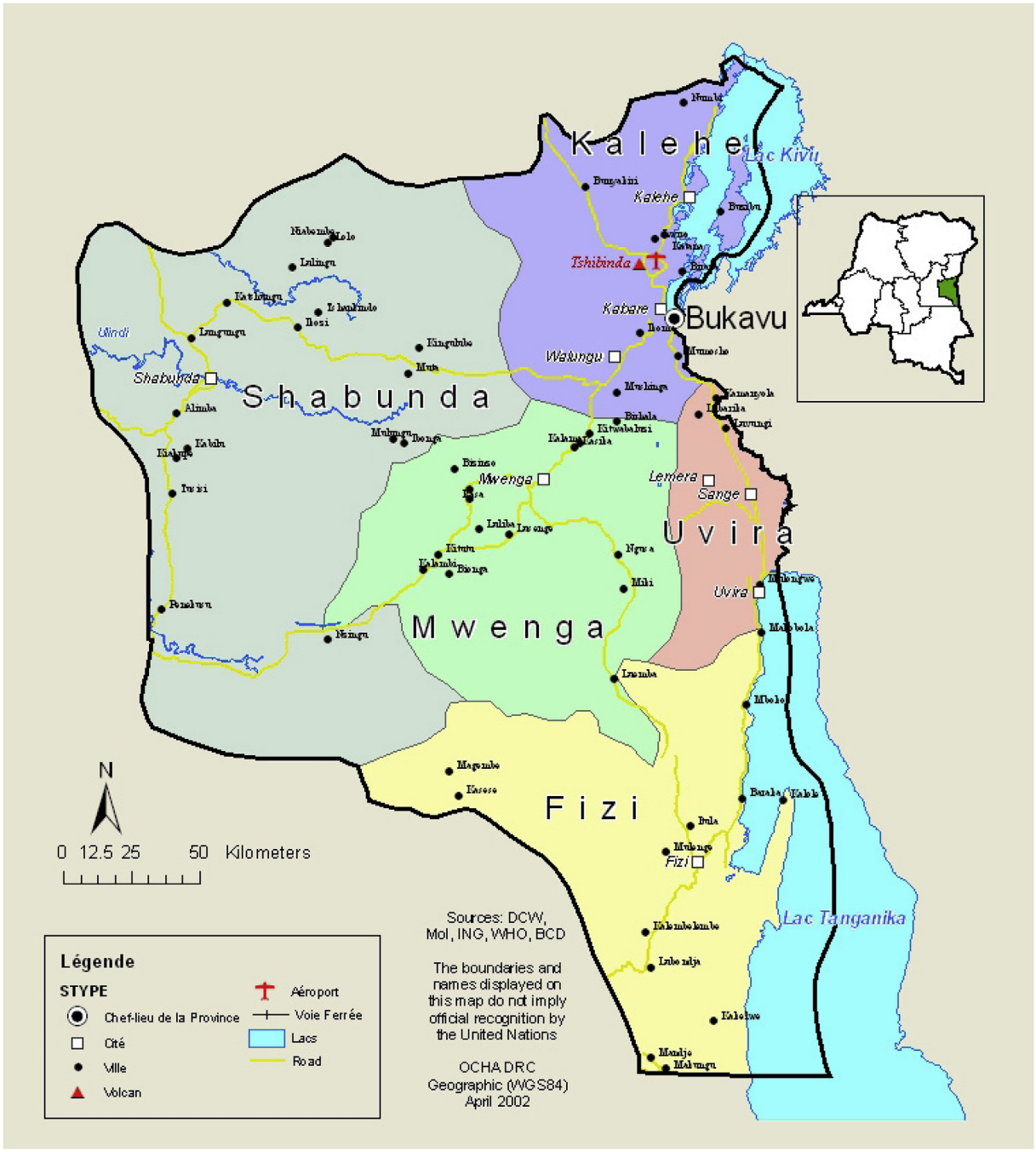

Fig. 1. Map of South Kivu province in DRC.

expressed as a percentage based on the taxonomic diversity, habitat and parts of the plant used to treat malaria. In addition, the relationships between recipes and herbs were graphed as an interaction network (Fig. 2) using the software Cytoscape 3.4.0 (http://cytoscape.org), with the layout *organic* (Shannon et al., 2003).

2.2. Review of literature

In order to compare our data with those of previous reports on cited antimalarial medicinal plants, a Google Scholar, HINARI, Medline/PubMed and ScienceDirect literature search was performed using keywords (antiplasmodial/antimalarial, ethnopharmacological survey, ethnomedicine, ethnobotany, herbal medicines, medicinal plants, traditional medicine, treatment of malaria and Congolese). To obtain information on species used in DRC, the word "Congolese" was combined with the different search terms. Additionally, the gray literature was also searched. Only studies published in English and French were considered.

3. Results

3.1. Ethnomedicinal survey

3.1.1. Socio-demographic profiles of the traditional healers and knowledge of malaria

Table 1 summarizes the socio-demographic profiles of the 32 interviewed THs, including 20 males and 12 females. These thirty-two THs belong to five ethnic groups, Shi, Fuliru, Rega, Bembe and Nande;

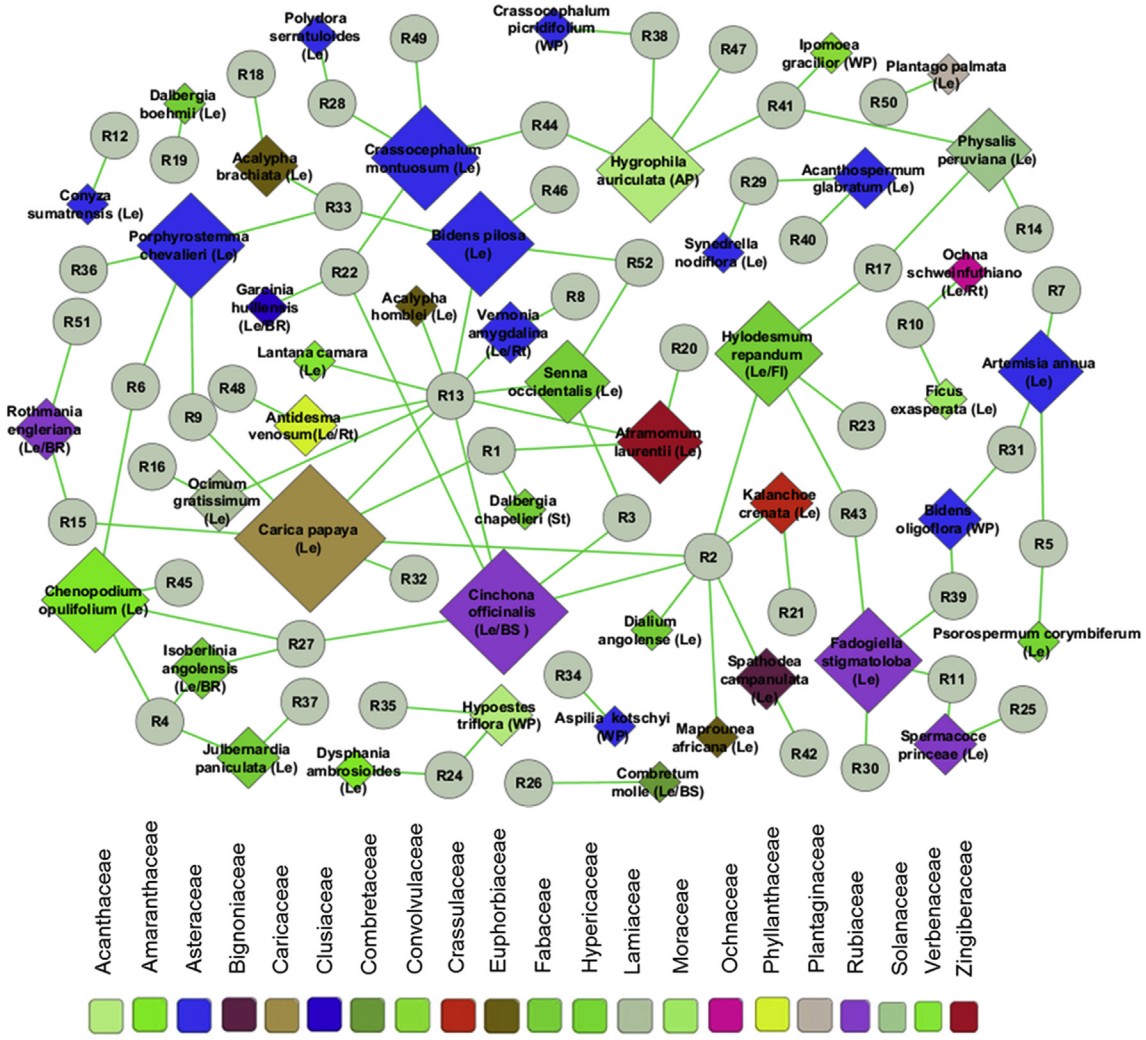

Fig. 2. Relationships between recipes and medicinal plants. Recipes are represented with circles, medicinal plants with diamonds; the size of the diamond is proportional to the frequency of citation of a medicinal plant. The colors of the diamonds correspond to the botanical family of the plant (Mukazayire et al., 2011) (AP, aerial part; BR, root bark; BS, stem bark; Fl, Flower; Le, Leaves; Rt, Roots; St, Steams; WP, Whole plant). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Table 1
Demographic data of the interviewed traditional healers (n = 32).

Parameters	Group	n	%
Gender	Male	20	62.5
	Female	12	37.5
Localization	Bukavu	17	53.1
	Uvira	15	46.9
Ethnic (self-stated)	Bembe	4	12.5
	Fuliru	7	21.9
	Nande	3	9.4
	Rega	6	18.7
	Shi	12	37.5
Age (years)	Less than 30	1	3.1
	30–40	3	9.4
	41–50	6	18.8
	51–60	8	25.0
	61–70	12	37.5
	More than 70	2	6.25
Experience	Less than 5 years	3	9.4
	5–10 years	5	15.6
	11–20 years	7	21.9
	More than 20 years	17	53.1
Profession	Traditional healers	32	100
Mode of acquisition of the knowledge	Inheritance	32	100

such ethnic diversity highlights the cultural richness of the studied areas. Their age varies between 29 and 79 years (mean age 55 ± 12 years), but most are in the ranges of 60–70 years and 30–50 years. All the THs have acquired their knowledge through family inheritance and practice traditional medicine as a main activity; more than 50% of them have more than 20 years of experience. During our investigations, we realized that all the interviewed THs have a knowledge about malaria and its symptoms. In most cases, they *"diagnose"* malaria using different signs and symptoms such as aches, fever and headaches. The interviewed THs also reported that some of their patients already know their health status from a prior medical examination in a hospital.

3.1.2. Medicinal plants used in malaria treatment

The ethnobotanical investigation revealed 45 plant species, belonging to 41 genera and 21 botanical families, have been reported to treat malaria (Table 2). Most of the medicinal plants used were herbs (55%), followed by shrubs (27%). In additional, more than 70% of them were collected in the wild, a likely problem for the sustainability of some species.

The Asteraceae (12 plant species), Fabaceae (7 species) and Rubiaceae (4 species) are the most important families, with 51% of all cited plants (Table 2). The species *Artemisia annua* L. (Asteraceae) and *Carica papaya* L. (Caricaceae) were the most frequently cited, claimed

Table 2
Herbal recipes (multi- and mono-) used in the treatment of malaria in Bukavu and Uvira areas.

Plant species (part used [a])/Voucher specimen number	Local name (Languages [b])	Main ailments (Recipes involved [c])	Mode of preparation/ Administration[d]	Use report (% Citation frequency)	Nature	Cultivated/Wild
Acanthaceae						
**Hygrophila auriculata* (Schumach.) Heine (AP) /BR0000020350000	Bugangabukali, Kanamafundwekazi (M); Bugangabukali (R)	Dermatoses (R47♦), Malaria (R38♣, R41, R44♣, R47♦)	Dec/OR; Ash/DA	3 (9%)	Shrub	Wild
**Hypoestes triflora* (Forssk) Roem. & Schult (WP) /BR0000020350048	Mageru, (M); Pindula (S); Ekina (N)	Anemia (R35♦), Dysentery (R35♦), Heart thrust (R35♦), Intestinal worms (R35♦), Liver deases (R35♦), Malaria (R24, R35♦), Schistosomiasis (R35♦)	Dec/OR	2 (6%)	Herb	Wild
Amaranthaceae						
**Chenopodium opulifolium* Schrad. ex W.D.J.Koch & Ziz (Le) /BR0000020350208	Mugombegombe (M); Mushafeza (S)	Dysentery (R45♦), Gastrointestinal disorders (R45♦), Hyperglobulinemia (R45♦), Intestinal worms (R45♦), Leukemia (R45♦), Malaria (R4♣, R6♣, R22, R27, R45♦), Measles (R45♦), Shrinkage of the vagina (R45♦)	Dec/OR; Mac/OR; Ov/VR	7 (22%)	Herb	Cultivated
♯Dysphania ambrosioides (L.) Mosyakin & Clemants. (Le) /BR0000020350284	Mugunduzimu (M); Kivunjahoma (S); Namahuma (F)	Malaria (R24♣)	Dec/OR	1 (3%)	Herb	Cultivated
Asteraceae						
**Acanthospermum glabratum* (DC.) Wild (Le)/ BR0000020350307	Senyi (R)	Asthenia (R40♦), Diarrhea (R40♦), Fever (R40♦), Joint pain (R40♦), Malaria (R29♣, R40♦)	Dec/OR	4 (12%)	Herb	Wild
Artemisia annua L. (Le) /MANYA KIP 02	Artemizia (M, S)	Bilharziasis (R7♦), Digestive candidiasis (R7♦), Loss of appetite (R7♦), Strengthening immunity (R7♦), Malaria (R5♣, R7♦, R31♣)	Inf/OR	11 (34%)	Herb	Cultivated
♯Aspilia kotschyi (Sch.Bip. ex Hochst.) Oliv. (WP) /BR0000020350321	Namafundo (F)	Bronchitis, Cholera, Malaria (R34♦)	Dec/OR	2 (6%)	Herb	Wild
♯Bidens oligoflora (Klatt) Wild (WP)/ BR0000020350291	Nyasa (S)	Malaria (R31, R39)	Dec/OR	2 (6%)	Herb	Wild
Bidens pilosa L. (Le) /MANYA KIP 05	Kashisha (F, M, S); Musonio (N)	Angina (R46♦), Malaria (R13, R33♣, R46♦ R52); Urinary infections, Verminoses (R46♦)	Dec/OR; Inf/OR; Sap/OR	9 (28%)	Herb	Wild
Conyza sumatrensis (S.F.Blake) Pruski & G.Sancho (Le) /MANYA KIP 06	Nyambula (M); Nakwakangi (F)	Fever, Malaria (R12♦)	Dec/OR	2 (6%)	Herb	Wild
Crassocephalum montuosum (S.Moore) Milne-Redh. (Le) /BR0000020350253	Cifula (M); Anyata na bupamba (B); Gifurandindi (F)	Dermatoses (R49♦), Food poisoning (R49♦), Malaria (R22, R28♣, R44, R49♦); Stimulation of uterine contractions during childbirth (R49♦)	Dec/OR; Ash/DA; Mac/ OR	5 (16%)	Herb	Wild
**Crassocephalum picridifolium* (DC.) S.Moore (WP)/BR0000020350277	Mfubwidi (M)	Malaria (R38)	Dec/OR	1 (3%)	Herb	Wild
♯Polydora serratuloides (DC.) H.Rob. (WP)/ BR0000020350109	Mtukutu (S); Mululuca (B)	Malaria (R28)	Dec/OR	1 (3%)	Herb	Wild
Porphyrostemma chevalieri (O.Hoffm.) Hutch. & Dalziel (Le)/BR0000020350116	Nakwangi (F), Lunandu (R)	Malaria (R6, R9, R33♣); Amoeba, Malaria (R36♦)	Dec/OR	3 (9%)	Herb	Wild
♯Synedrella nodiflora (L.) Gaertn. (Le)/ BR0000020350154	Ajunja (B)	Fever, Malaria, Joint pain (R29)	Dec/OR	1 (3%)	Herb	Wild
Vernonia amygdalina Delile (Le/Rt)/MANYA KIP 13	Mubirizi (M); Kilulukunju (S); Mubilishi (R); Mubiriri (N)	Malaria (R8♦, R13♣), Verminoses (R8♦)	Dec/OR; Inf/OR	6 (19%)	Shrub	Wild
Bignoniaceae						
Spathodea campanulata P.Beauv. (Le)/ BR0000020350086	Cifulafula (M, F); Musawe (S)	Malaria (R2, R42♦); Schistosomiasis (R42♦)	Dec/OR; Inf/OR	2 (6%)	Tree	Wild
Caricaceae						
Carica papaya L. (Le) /MANYA KIP 16	Ipapayi (M); Mpapayi (S); Papai (B, N, R); Mupapayi (F)	Intestinal worms (R32♦), Malaria (R1♣, R2, R9♣, R13, R15♣, R32♦)	Dec/OR; Inf/OR	11 (34%)	Tree	Cultivated
Clusiaceae						
♯Garcinia huillensis Welw. (Le/BR)/ BR0000020350192	Kitundambuga (F)	Malaria (R22)	Dec/OR	1 (3%)	Tree	Wild
Combretaceae						

(*continued on next page*)

Table 2 (*continued*)

Plant species (part used [a])/Voucher specimen number	Local name (Languages [b])	Main ailments (Recipes involved [c])	Mode of preparation/ Administration[d]	Use report (% Citation frequency)	Nature	Cultivated/Wild
[#]*Combretum molle* R. Br. ex G.Don (Le/BS)/ BR0000020350222	Nderalushaka (F)	Anemia, Malaria, Schistosomiasis (R26♦)	Dec/OR; Inf/OR	2 (6%)	Tree	Wild
Convolvulaceae						
[#]*Ipomoea indica* (Burm.) Merr. (WP)/ BR0000020350024	Ananda (B); Mujangajanga (F)	Malaria (R41)	Dec/OR	1 (3%)	Herb	Wild
Crassulaceae						
**Kalanchoe crenata* (Andrews) Haw. (Le)/ BR0000020350093	Mugembegembe (F)	Malaria (R2, R21♦); Otitis suppurativa (R21♦)	Dec/OR; Sap/Ins	3 (9%)	Herb	Cultivated
Euphorbiaceae						
Acalypha brachiata Krauss (Le)/ BR0000020350338	Mushindadunia (S)	Abdominal pain, Gonorrhea, Malaria (R18♦); Malaria (R33)	Dec/OR	3 (9%)	Herb	Wild
[#]*Acalypha homblei* De Wild. (Le)/ BR0000020350345	Ngwiki (F)	Malaria (R13)	Dec/OR	1 (3%)	Herb	Wild
[#]*Maprounea africana* Müll. Arg. (Le/BR)/ BR0000020350055	Musheusheu (B)	Malaria (R2)	Dec/OR	1 (3%)	Tree	Wild
Fabaceae						
[#]*Dalbergia boehmii* Taub. (Le)/ BR0000020350239	Mujimbehwe (F); Mungombe (S)	Malaria, Teeth ache (R19♦)	Mac/OR	2 (6%)	Shrub	Wild
[#]*Dalbergia chapelieri* Baill. (St)/ BR0000020350260	Munyereza (F)	Malaria (R1)	Inf/OR	1 (3%)	Shrub	Wild
[#]*Dialium angolense* Oliv (Le)/ BR0000020350031	Mulandege (S); Mbindula (F)	Malaria (R2)	Dec/OR	1 (3%)	Tree	Wild
[#]*Hylodesmum repandum* (Vahl) H.Ohashi & R.R.Mill (Le/Fl)/BR0000020350246	Irhuza (M); Kanyerekagoli (F)	Dysmenorrhea (R23♦), Female sterility (R23♦), Malaria (R2, R17♣, R43♣, R23♦); Newborn colic (R23♦)	Dec/OR; Inf/OR; Ex ju/ OR	4 (12%)	Shrub	Wild
[#]*Isoberlinia angolensis* (Welw. Ex Benth.) Hoyle & Brenan (Le/BR) /BR0000020350062	Mboza (S); Ndegabalume (F)	Malaria (R4, R27)	Dec/OR	2 (6%)	Shrub	Wild
[#]*Julbernardia paniculata* (Benth.) Troupin (Le)/ BR0000020350130	Ashindambuka (F)	Fever (R37♦), Malaria (R4, R37♦)	Dec/OR; Inf/OR	1 (3%)	Tree	Wild
[#]*Senna occidentalis* (L.) Link (Le)/MANYA KIP 34	Mujangajanga (F); Kashege (M)	Malaria (R3, R13, R52♦)	Dec/OR	5 (16%)	Herb	Wild
Hypericaceae						
[#]Psorospermum corymbiferum Hochr. (Le)/ BR0000020350079	Muhanga (S); Ngologosho (F)	Malaria (R5)	Inf/OR	1 (3%)	Shrub	Wild
Lamiaceae						
**Ocimum gratissimum* L. (Le) /MANYA KIP 35	Kabayirabashaka (M); Atundula (R); Nyenyeku(N)	Malaria (R13, R16♦)	Dec/OR	4 (12%)	Herb	Wild
Moraceae						
**Ficus exasperata* Vahl (Le) /BR0000020350161	Matudu (M); Mulumba (S); Moa (B); Lukenga (R); Mukimba, Mugumo (N)	Malaria (R10)	Mac/OR	1 (3%)	Shrub	Wild
Ochnaceae						
Ochna schweinfurthiana F.Hoffm. (Le/Rt)/ BR0000020350178	Mbatama (F); Lohoto (B)	Malaria (R10)	Mac/OR	1 (3%)	Shrub	Wild
Phyllanthaceae						
[#]*Antidesma venosum* E.Mey. ex Tul. (Le/Rt)/ BR0000020350215	Nalushushwa (F)	Malaria (R13); Abdominal pain, Diabetes, Diarrhea, Female sterility, Gonorrhea, Malaria (R48♦)	Dec/OR	2 (6%)	Shrub	Wild
Plantaginaceae						
Plantago palmata Hook.f. (Le)/MANYA KIP 39	Cibarhama (M)	Malaria (R50♦)	Dec/OR	2 (6%)	Herb	Cultivated
Rubiaceae						
**Cinchona officinalis* L. (Le/BS)/MANYA KIP 40	Kankina (M); Kenkina (S)	Malaria (R2♣, R3♣, R13♣, R22♣, R27♣)	Dec/OR	8 (25%)	Shrub	Cultivated

(*continued on next page*)

Table 2 (*continued*)

Plant species (part used [a])/Voucher specimen number	Local name (Languages [b])	Main ailments (Recipes involved [c])	Mode of preparation/ Administration[d]	Use report (% Citation frequency)	Nature	Cultivated/Wild
[#]*Fadogiella stigmatoloba* (K.Schum.) Robyns (Le) /BR0000020350017	Mukubashenfero (F)	Asthenia (R30♦), Fever (R30♦), Malaria (R11♣, R30♦, R39♣, R43); Sexual weakness (R30♦)	Dec/OR	3 (9%)	Herb	Wild
**Rothmannia engleriana* (K.Schum.) Keay (Le/ BR)/BR0000020350123	Yubure (M)	Female sterility (R51♦), Malaria (R15, R51♦), Tuberculosis (R51♦)	Dec/OR; Mac/OR	3 (9%)	Tree	Wild
**Spermacoce princeae* (K.Schum.) Verdc. (Le)/ BR0000020350185	Cumya (M); Mutasimba (N)	Cancer (R25♦), Conjunctivitis (R25♦), Gastric ulcers (R25♦), Loss of appetite (R25♦), Malaria (R11, R25♦), Sterility (R25♦)	Dec/OR; Sap/Ins	3 (9%)	Herb	Wild
Solanaceae						
**Physalis peruviana* L. (Le)/BR0000020350147	Imbuhu (M); Mbuma (S); Mbupuru (N)	Intestinal worms (R14♦), Splenomegaly (R14♦), Malaria (R14♦, R17, R41♣)	Dec/OR; Inf/OR	4 (12%)	Herb	Cultivated
Verbenaceae						
**Lantana camara* L. (Le) /MANYA KIP 44	Mwamuganga (M); Mavi ya kuku (S); Makereshe (N)	Malaria (R13)	Dec/OR	1 (3%)	Shrub	Wild
Zingiberaceae						
**Aframomum laurentii* (De Wild. & T.Durand) K.Schum. (Le) /BR0000020350314	Ntiru (M); Matungulu pori (R, S); Kitunguru (F)	Epistaxis (R20), Malaria (R1♣, R13)	Dec/OR; Inf/OR; Pow/TA	4 (12%)	Herb	Cultivated

[a] Parts of the plant used: AP, Aerial parts; BR: Bark roots; BS: Bark-stem; Fl: Flowers; Le: Leaves; Rt: Roots; St: Steams; WP: Whole plant.

[b] Languages: M, Mashi; N, Nande; S, Swahili; R, Rega; F, Fuliru; B, Bembe.

[c] Recipes involved: R followed by a number (e.g. R1) corresponds to a multi-herbal recipe, the complete composition of each recipe can be deduced from Fig. 2 (Cytoscape file: relationships between multi-herbal recipes and medicinal plants, supplementary data); R followed by a number with the sign ♦ (e.g. R7♦) corresponds to a mono-herbal recipe. The sign ♣ indicates that the plant is cited as a major ingredient in the recipe involved and can be used as mono-herbal recipe whenever THs cannot obtain the other plants of the recipe. Unless otherwise stated, recipes are composed of approximately equal amounts of each plant.

[d] Mode of preparation/Administration: Ash/DA, Ash and Dermal application; Dec/OR, Decoction and Oral route; Ext jus/OR, Extraction of juice and Oral route; Inf/OR, Infusion and Oral route; Mac/OR, Maceration and Oral route; Ov/VR, Ovule and Vaginal route; Pow/TA, Powder and Topical application; Sap/OR, Sap and Oral route; Sap/Ins, Sap and Instillation. All decoctions, infusion, and macerations operations are carried out with water as solvent and followed by filtration before use; most recipes are used as beverages.

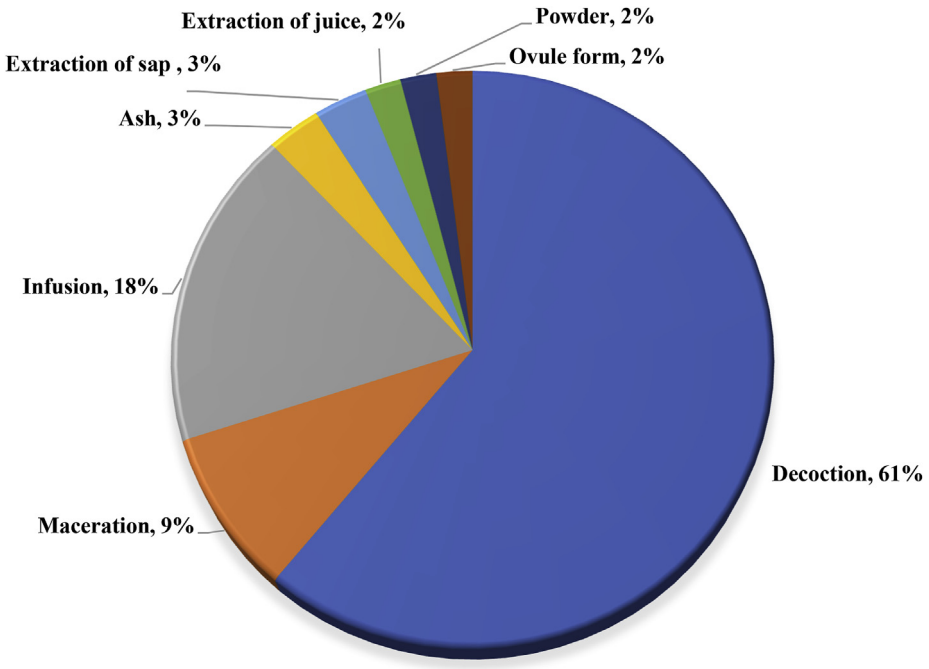

Fig. 3. Methods of preparation of remedies in the management of malaria.

by 11 (34%) traditional healers. *Bidens pilosa* L. (Asteraceae), *Cinchona officinalis* L. (Rubiaceae), *Chenopodium opulifolium* Schrad. ex W.D.J.Koch & Ziz (Amaranthaceae), *Vernonia amygdalina* Delile (Asteraceae) and *Senna occidentalis* (L.) Link (Fabaceae) were also reported by 9 (28%), 8 (25%), 7 (22%), 6 (19%) and 5 (16%) respondents, respectively. The use report for the rest of the species ranged from 4 (12%) to 1 (3%) (Table 2).

In the study area, the leaves (67%) were the most common parts used in the preparation of herbal remedies followed by the whole plant (11%), root barks (7%), roots (5%), stem barks (4%), aerial parts (2%), stems (2%) and flowers (2%).

The main method for remedies preparation is decoction (61%; Fig. 3). The administration of herbal remedies is essentially by oral route (91%). The interviewees state that they use handfuls, teaspoons, tablespoons, cups and bottles to adjust doses according to the age of the patient (child or adult) and/or her/his physiological state (e.g. pregnancy). By reference to the work of Chifundera (2001), we tried to estimate the quantities of solutions (volumes) and solids (powdered mass or parts of plants) when analyzing the results of this ethnobotany survey. According to our informants, the treatment of "malaria" lasts, in most cases, between 5 and 7 days.

3.1.3. Combination of herbs into recipes for the treatment of malaria

According to Fig. 2 and 27 single-herb preparations (51.9%) and 25 multi-herbal recipes (48.1%) were reported for the treatment of malaria, giving a total of 52 recipes made of 45 different herbs. Recipes are prepared either with 2 (32.7%) or 3 (11.5%) plant species, except for recipes R2 and R13 which are composed of 7 and 10 different plant species, respectively. Some species are involved in the preparation of several recipes, notably *Carica papaya* L. (6 recipes), *Cinchona officinalis* L. (5 recipes), *Hylodesmum repandum* (Vahl) H. Ohashi & R.R.Mill (4 recipes), *Chenopodium opulifolium* Schrad. ex W.D.J.Koch & Ziz (4 recipes), *Porphyrostemma chevalieri* (O.Hoffm.) Hutch. & Dalziel (4 recipes), *Fadogiella stigmatoloba* (K.Schum.) Robyns (4 recipes), *Bidens pilosa* L. (4 recipes), *Hygrophila auriculata* (Schumach.) Heine (4 recipes), *Crassocephalum montuosum* (S.Moore) Milne-Redh. (4 recipes), *Artemisia annua* L. (3 recipes), *Physalis peruviana* L. (3 recipes) and *Senna occidentalis* (L.) Link (3 recipes).

3.2. Literature review

A total of 194 medicinal plant species belonging to 69 families and 164 genera were previously reported to be used in the treatment of malaria and related symptoms in DR Congo (Table 3). The plant species most frequently cited in the literature are *Senna occidentalis* (L.) Link, *Carica papaya* L., *Morinda morindoides* (Baker) Milne-Redh., *Harungana madagascariensis* Lam. ex Poir, *Lantana camara* L. and *Vernonia amygdalina* Delile. In this reviewed literature, a variety of methods are used to prepare the drugs as single-herbs and multiple-herbs remedies, including crushing, infusion, decoction and maceration. Certain additives are frequently used to improve the acceptability of some remedies that are taken orally, notably honey, sugar, milk, local alcohol and butter.

3.3. Comparative analysis of the present survey with literature data

Comparison with plant species described as antimalarial in DR Congo

The comparison of antimalarial medicinal plants documented in the present ethnobotanical survey with literature data indicates that 38% of surveyed medicinal plants have been previously reported for this use. A degree of similarity was found with the studies conducted in the South-Kivu province (13 plants overlap) and Haut-Katanga province (6 plants overlap). The similarities between the survey and literature search with respect to the most frequently cited families and species indicates that Asteraceae and Fabaceae are dominantly represented families. *Carica papaya* L., *Vernonia amygdalina* Del., and *Senna occidentalis* (L.) Link are the most three frequently reported plant species in both survey and literature search. By contrast, 62% of the plant species identified in our ethnobotanical survey were not previously reported in Congo as antimalarial plants. These notably include *Aframomum laurentii* (De Wild. & T. Durand) K. Schum., *Fadogiella stigmatoloba* (K. Schum.) Robyns, *Hylodesmum repandum* (Vahl) H. Ohashi & R. R. Mill, *Kalanchoe crenata* (Andrews) Haw., *Porphyrostemma chevalieri* (O. Hoffm.) Hutch. & Dalziel and *Rothmannia engleriana* (K. Schum.) Keay.

Comparison with the general repartition of plant species in DR Congo

Table 3
Summary of Congolese antimalarial medicinal plants identified from the literature review.

Plant species	Family	Local name	Life form	Parts used	Number of citations	References
Acacia polyacantha Willd.	Fabaceae	Kibimbo, Hibomo (H); Kimungamunga (L); Kashia (S)	Tree	Rb	3	Lusakibanza (2012); Muya et al. (2014); Bashige et al. (2017)
Acacia sieberiana DC.	Fabaceae	Mugenge, Kashangala (M)	Tree	R	1	Defour et al. (1995)
Achillea millefolium L.	Asteraceae	–	Herb	L	1	Kasali et al. (2014b)
Afrostyrax lepidophyllus Mildbr.	Huaceae	Isiidza ya pembe	Shrub	Rb	1	Muganza et al. (2012)
Ageratum conyzoides L.	Asteraceae	Kahyorhe (M); Olupapali (N)	Herb	L	2	Kasali et al. (2014a); Kasali et al. (2014b)
Albizia adianthifolia (Schumach.) W. Wight	Fabaceae	Kamikaze (T); Kapela novo (B); Kapeta nzovu (L); Kampetanzevu (Ts)	Tree	Rb	2	Bashige et al. (2017); Lusakibanza (2012)
Albertisia villosa (Exell) Forman	Menispermaceae	–	Liana	R	1	Memvanga et al. (2015)
Alchornea cordifolia Mull.Arg.	Euphorbiaceae	Mbunza (O)	Shrub	L	3	Mesia (2009); Lusakibanza (2012); Memvanga et al. (2015)
Alchornea floribunda Müll. Arg.	Euphorbiaceae	Ononn (O)	Shrub	Rb	3	Mesia (2009); Lusakibanza (2012); Memvanga et al. (2015)
Allium sativum L.	Amaryllidaceae	Itunguru sumu (M); Litunguru Sumo (S); Ehayi (N)	Herb	B	2	Kasali et al. (2014a); Kasali et al. (2014b)
Aloe dawei A. Berger	Xanthrorrhoeaceae	Engaka (N)	Shrub	L	1	Kasali et al. (2014b)
Aloe lateritia Eng.	Xanthrorrhoeaceae	Cigaka (M)	Herb	L	1	Defour et al. (1995)
Aloe sp.	Xanthrorrhoeaceae	Kizimia muliro (M)	Herb	AP	1	Kasali et al. (2014a)
Alstonia boonei De Wild.	Apocynaceae	Bokuka	Tree	Sb	4	Mesia (2009); Lusakibanza (2012); Muganza et al. (2012); Memvanga et al. (2015)
Alstonia congensis Engl.	Apocynaceae	Okulu (O)	Tree	Sb	3	Mesia (2009); Lusakibanza (2012); Memvanga et al. (2015)
Alysicarpus rugorus (Wild.) DC.	Fabaceae	Ngandu (M)	Herb	WP	1	Defour (1995)
Amorphophallus angolensis (Welw. Ex Schott) N.E.Br.	Araceae	Mbandakabirimalaria (M)	Herb	T	1	Chifundera et al. (2001)
Amorphophallus bequaertii De Wild.	Araceae	Ikoma lya kabiri, Mbandakabiri (M)	Herb	T	2	Tshibangu et al., 2002; Memvanga et al. (2015)
Ananas cosmesus (L.) Merr.	Bromeliaceae	Nanasi (Swahili); Inanasi (M); Erinanasu (N)	Herb	L, Fr	2	Kasali et al. (2014a); Kasali et al. (2014b)
Anchomanes giganteus Engl.	Araceae	Ikoma lya kabiri (M)	Shrub	T	1	Chifundera et al. (2001)
Andropogon canaliculatus Schumach.	Poaceae	Mwehwe (M)	Herb	WP	1	Defour (1995)
Anisopappus chinensis (L.) Hook.f. & Arn.	Asteraceae	Umuretezo (Ny); Kasol-sol	Herb	L	3	Mutamba and Rwihaniza (1990); Lusakibanza (2012); Memvanga et al. (2015)
Anisophyllea boehmii Engl.	Anisophylleaceae	Fungo (Sa); Lufunga; (Ta) Mfongo (S), Mufungo (B)	Tree	L, S, R	1	Kalonda et al. (2014); Bashige et al., 2017
Annickia chlorantha (Oliv.) Setten & Maas	Annonaceae	Ikodzi konga	Tree	Sb	2	Muganza et al. (2012); Memvanga et al. (2015)
Annona muricata L.	Annonaceae	Mustafeli (M)	Tree	L	1	Defour (1995)
Anonidium mannii (Oliv.) Engl. & Diels	Annonaceae	–	Tree	Sb	1	Memvanga et al. (2015)
Antidesma venosum E.Mey. ex Tul.	Phyllanthaceae	–	Shrub	L	1	Kalonda et al. (2014)
Arachis hypogaea L.	Fabaceae	Kalanga (S); Kabemba (M); AKalanga(N)	Herb	S	2	Kasali et al. (2014a); Kasali et al. (2014b)
Aristolochia sp.	Aristolochiaceae	Amarinda, Ekyambe (N)	Herb	S	1	Kasali et al. (2014b)
Artemisia annua L.	Asteraceae	Artezia (M); Artemizia (S)	Herb	L	3	Balagizi et al. (2007); Kasali et al. (2014a); Kasali et al. (2014b)
Aspilia africana (Pers.) C. D. Adams	Asteraceae	Cambuba, Cumya (M)	Herb	WP	1	Defour (1995)
Anthemis nobilis L.	Asteraceae	–	Herb	F	1	Kasali et al. (2014a)
Autranella congolensis (De Wild.)A.Chev.	Sapotaceae	Bonyanga	Tree	Sb	2	Muganza et al. (2012); Memvanga et al. (2015)
Azadirachta indica A. Juss	Meliaceae	Arubaini (S); Dira (N); Mubanga (S) Nfwama (Sa)	Tree	L	2	Kasali et al. (2014b); Bashige et al. (2017)
Baccharoides adoensis var. mossambiquensis (Steetz) "Isawumi, El-Ghazaly & B.Nord."	Asteraceae	–	Herb	L	1	Muya et al. (2014)
Bauhinia reticulata DC.	Fabaceae	–	Shrub	L	1	Muya et al. (2014)
Bidens pilosa L.	Asteraceae	Kashisha (M, S); Nyassa (Le); Obukuto (N)	Herb	L	4	Balagizi et al. (2007); Kalonda et al. (2014); Kasali et al. (2014a); Kasali et al. (2014b)
Bobgunnia madagascariensis (Desv.) J.H.Kirkbr. & Wiersema	Fabaceae	Ndale, Mpampi (Ts); Kilonde, Kabi, Munienze (L)	Tree	L	1	Bashige et al. (2017)
Bridelia ferruginea Benth.	Phyllanthaceae	Mindu	Tree	L, Rb	1	Lusakibanza (2012)
Brucea javanica (L.) Merr.	Simaroubaceae	–	Shrub	S	2	Penge et al. (2013); Memvanga et al. (2015)
Cajanus cajan (L.) Huth	Fabaceae	Goliolio (L); Ngoliolio (Ta)	Shrub	L, Sb, S	2	Muya et al. (2014); Bashige et al. (2017)
Callistemon speciosus (Sims) D.C	Myrtaceae	–	Tree	L	1	Kasali et al. (2014b)
Caloncoba welwitshii Gilg.	Flacourtiaceae	Kembomo	Tree	L	1	Lusakibanza (2012)

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Table 3 (*continued*)

Plant species	Family	Local name	Life form	Parts used	Number of citations	References
Calycobolus sp.	Convolvulaceae	–	Tree	Sb	1	Memvanga et al. (2015)
Capsicum frutescens L.	Solanaceae	–	Tree	R, L	1	Kalonda et al. (2014)
Carica papaya L.	Caricaceae	Ipapayi (M); Mpapayi (S); Epayīpayī, Pai pai; Dilolo, Nlolo	Tree	F, B, Sb, R, L	8	Defour (1995); Balagizi et al. (2007); Lusakibanza (2012); Kalonda et al. (2014); Kasali et al. (2014a); Kasali et al. (2014b); Muya et al. (2014); Bashige et al. (2015)
Cassia floribunda Collad.	Fabaceae	–	Shrub	F, R, Rb	2	Mesia (2009); Lusakibanza (2012)
Catharanthus roseus (L.) G. Don	Apocyanaceae	Vinga (N); Vinka (S)	Sub shrub	Rb	3	Ngbolua et al. (2011); Kasali et al. (2014a); Kasali et al. (2014b)
Celosia trigyna L.	Amaranthaceae	Bukaragata, Mubalala (M)	Herb	Hp	2	Tshibangu et al., 2002; Memvanga et al. (2015)
Centella asiatica (L.) Urb.	Apiaceae	–	Herb	L, R	1	Kalonda et al. (2014)
Cinchona officinalis L.	Rubiaceae	Kankina (M); Kenkina (S)	Tree	L	1	Balagizi et al. (2007)
Cinchona calisaya Wedd.	Rubiaceae	Kankina (M); Kenkina (S)	Tree	B	2	Kasali et al. (2014a); Kasali et al. (2014b)
Cissampelos mucronata A.Rich.	Menispermaceae	Cibombwe, Kahulula (M)	Herb	F, R	2	Balagizi et al. (2007); Memvanga et al. (2015)
Cissampelos owariensis P.Beauv. ex DC.	Menispermaceae	–	Herb	Ep	1	Kalonda et al. (2014)
Citrus aurantiifolia (Christm.) Swingle	Rutaceae	Longmee (O)	Shrub	L	2	Mesia (2009); Lusakibanza (2012)
Citrus aurantium L.	Rutaceae	–	Shrub	L	1	Memvanga et al. (2015)
Citrus limon (L.) Burn.f.	Rutaceae	Ndimu (M, Li); Chunghwa kali (S)	Tree	L	3	Kasali et al. (2014a); Kasali et al. (2014b); Mbula et al., 2015
Combretum micranthum G.Don	Combretaceae	Muhara (M)	Shrub	L	1	Defour (1995)
Conyza sumatrensis (S.F.Blake) Pruski & G.Sancho	Asteraceae	Akabingande (N)	Herb	L	2	Balagizi et al. (2007); Kasali et al. (2014b)
Crassocephalum montuosum (S.Moore) Milne-Redh.	Asteraceae	Ekisulanindi (N)	Herb	L	1	Kasali et al. (2014b)
Crossopterix febrifuga (Afzel.) Benth	Rubiaceae	Mbinzo, mvala (O)	Tree	L	3	Mesia (2009); Lusakibanza (2012); Kalonda et al. (2014)
Croton mubango Müll. Arg	Euphorbiaceae	Omutsīkīlī (N)	Tree	B	2	Kasali et al. (2014b); Memvanga et al. (2015)
Cryptolepis sanguinolenta (Lindl.) Schlechter	Periplocaceae	–	Shrub	Rb	4	Cimanga et al. (1997); Mesia (2009); Lusakibanza (2012); Memvanga et al. (2015)
Curcuma longa L.	Zingiberaceae	–	Herb	L	1	Muya et al. (2014)
Cupressus lusitanica Mill.	Cupressaceae	Mashindano (S); Nsindani (M); Ekilau (N)	Tree	L	2	Kasali et al. (2014a); Kasali et al. (2014b)
Cymbopogon citratus (DC.) Stapf	Poaceae	Sinda (O); Ebitsayi (N); Matiti ma mputu	Herb	L	5	Mesia (2009); Lusakibanza (2012); Kasali et al. (2014a); Kasali et al. (2014b); Memvanga et al. (2015)
Cymbopogon densiflorus (Stend.) Stapf.	Poaceae	Musangu sangu (O)	Herb	L, Wp	4	Mesia (2009); Lusakibanza (2012); Muya et al. (2014); Memvanga et al. (2015)
Cynoglossum lanceolatum Forssk.	Boraginaceae	Ekituvā (N); Sukuma wuki (S)	Herb	L	1	Kasali et al. (2014b)
Dalbergia boehmii Taub.	Fabaceae	–	Tree	L, S	1	Kalonda et al. (2014)
Dalbergia nitidula Baker	Fabaceae	–	Shrub	L, S	1	Kalonda et al. (2014)
Dalhousiea africana S. Moore	Fabaceae	–	Shrub	L	1	Memvanga et al. (2015)
Dichostemma glaucescens Pierre	Euphorbiaceae	Ondenge (O)	Shrub	Sb	3	Mesia (2009); Lusakibanza (2012); Memvanga et al. (2015)
Drypetes gossweileri S. More	Putranjivaceae	Obele (O)	Tree	Sb	3	Mesia (2009); Lusakibanza (2012); Memvanga et al. (2015)
Dysphania ambrosioides (L.) Mosyakin & Clemants	Amaranthaceae	Mugunduzimu, Mugembye (M); Kivunjahoma (S); Omunduluma (N)	Herb	L	5	Defour (1995); Balagizi et al. (2007); Lusakibanza (2012); Kasali et al. (2014a); Kasali et al. (2014b)
Ekebergia benguelensis Welw. ex C.DC.	Meliaceae	–	Tree	L	1	Kalonda et al. (2014)
Entada abyssinica A.Rich.	Fabaceae	Tshitefu (Ts); Munike, Kipungu (Sa)	Shrub	R	1	Bashige et al. (2017)
Entandrophragma palustre Staner	Meliaceae	Pake	Tree	L, Sb	3	Lusakibanza (2012); Memvanga et al. (2015); Ngbolua et al. (2011)
Eremospatha haullevilleana De Wild.	Arecaceae	Akavu (O)	Tree	Wp	2	Mesia (2009); Lusakibanza (2012)
Erythrina abyssinica Lam. ex DC.	Fabaceae	Cigohwa (M); Omukohwa (K)	Tree	Sb	2	Defour (1995); Kasali et al. (2014a); Kqsqli et al., 2014b
Eucalyptus globulus Labill.	Myrtaceae	Omutusu we mbamba	Tree	L	2	Kasali et al. (2014a); Kasali et al. (2014b)
Eucalyptus sp.	Myrtaceae	–	Tree	S	1	Kasali et al. (2014b)
Euphorbia hirta L.	Euphorbiaceae	Madekere Gw'elwishi (M)	Herb	Wp, L, S	5	Defour (1995); Tona et al. (2004); Mesia (2009); Lusakibanza (2012); Kasali et al. (2014a); Memvanga et al. (2015)
Fleroya rubristipulata (K. Schum) Y. F. Deng	Rubiaceae	Muzibaziba (M)	Tree	R	1	Balagizi et al. (2007)

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Table 3 (*continued*)

Plant species	Family	Local name	Life form	Parts used	Number of citations	References
Garcinia kola Heckel	Clusiaceae	Ngadiadia, Ntende (O)	Tree	F	4	Tona et al. (2004); Mesia (2009); Lusakibanza (2012); Memvanga et al. (2015)
Gardenia ternifolia subsp. *jovis-tonantis* (Welw.) Verdc.	Rubiaceae	–	Shrub	L, Sb, R	1	Lusakibanza (2012)
Greenwayodendron suaveolens (Engl. & Diels) Verdc.	Anonaceae	Odjindja (O); Bodzinda	Tree	L, Rb, Sb	4	Mesia (2009); Lusakibanza (2012); Muganza et al. (2012); Memvanga et al. (2015)
Guibourtia demeusei (Harms) J. Léonard	Caesalpiniaceae	Okongo (O)	Tree	Sb	1	Mesia (2009)
Harungana madagascariensis Lam. ex Poir.	Hypericaeae	Mutunu, ntunu, Kadwamuko, Ndwamuko, mushombo (M); Ndura (S); Bontone	Tree	S, Rb, Sb	6	Defour (1995); Lusakibanza (2012); Muganza et al. (2012); Muya et al. (2014); Kasali et al. (2014a); Memvanga et al. (2015)
Hexalobus monopetalus (A.Rich.) Engl. & Diels	Annonaceae	–	Shrub	L, S	1	Kalonda et al. (2014)
Hygrophila auriculata (Schumach.) Heine	Acanthaceae	Bugangabukali, Kanamafundwekazi (M)	Herb	R	1	Balagizi et al. (2007)
Hymenocardia acida Tul.	Phyllanthaceae	Kigeti	Shrub	Sb, R	1	Lusakibanza (2012)
Hymenocallis littoralis (Jacq.) Salisb.	Amaryllidaceae	–	Herb	L	2	Mesia (2009); Memvanga et al. (2015)
Hymenodictyon floribundum (Hoscht & Steud) BL Rob	Rubiaceae	–	Shrub	R	1	Kalonda et al. (2014)
Indigofera arrecta Hochst. ex A. Rich	Fabaceae	Kasholoza, Kavunanfuka (M); abwebwe (Be); Musholotsi (H); Umwikokori (N)	Herb	R	2	Balagizi et al. (2007); Kasali et al. (2014a)
Ipomoea blepharophylla Hallier f.	Convolvulaceae	Gasakuza (Ny)	Herb	Rb	1	Mutamba and Rwihaniza (1990)
Isolona hexaloba Engl. &Diels	Annonaceae	Bodzungu	Tree	Sb	2	Muganza et al. (2012); Memvanga et al. (2015)
Jatropha curcas L.	Euphorbiaceae	Kitondomo (B); Ndolu	Shrub	L, R, Rb	4	Muganza et al. (2012); Kalonda et al. (2014); Bashige et al. (2015); Memvanga et al. (2015)
Khaya nyasica Stapf ex Baker f.	Meliaceae	–	Tree	Rb	1	Muya et al. (2014)
Laggera alata Nanth.	Asteraceae	Mfumu nseke (O)	Subshrub	L	1	Mesia (2009); Lusakibanza (2012)
Landolphia congolensis (Stapf) Pichon	Apocynaceae	–	Liana	L	1	Kalonda et al. (2014)
Landolphia kirkii Dyer	Apocynaceae	Mabungo (L, B, K)	Shrub	L	1	Bashige et al. (2017)
Landolphia owariensis P.Beauv.	Apocynaceae	Seka (O)	Tree	L	2	Mesia (2009); Memvanga et al. (2015)
Lantana camara L.	Verbenaceae	Kashubanshuha, Mwamuganga (M); Mavi ya kuku (S); Amakulumbe (N); Maka wabo (O)	Shrub	L	6	Balagizi et al. (2007); Mesia (2009); Lusakibanza (2012); Kasali et al. (2014a); Kasali et al. (2014b); Memvanga et al. (2015)
Leonotis martinicensis (Jacq.) J. C. Manning & Goldblatt	Lamiaceae	Akanya makundo kake (N); Kanyamafundo (M)	Herb	L	2	Balagizi et al. (2007); Kasali et al. (2014b)
Luffa cylindrica M. Roem.	Cucurbitaceae	Nsanu (O); Tseka	Herb	L	2	Mesia (2009); Lusakibanza (2012)
Mammea africana Sabine	Calophyllaceae	Okudi	Tree	Sb	3	Mesia (2009); Lusakibanza (2012); Memvanga et al. (2015)
Manniophyton fulvum Müll. Arg.	Euphorbiaceae	Lokosa	Shrub	L, Rb	2	Muganza et al. (2012); Memvanga et al. (2015)
Manotes expansa Sol. ex Planch.	Connaraceae	–	Shrub	Sb	2	Mesia (2009); Memvanga et al. (2015)
Maprounea africana Müll. Arg.	Euphorbiaceae	Mulubu lubu	Tree	L	1	Lusakibanza (2012)
Massularia acuminata (G.Don) Bullock ex Hoyle	Rubiaceae	Welo	Tree	Sb	2	Muganza et al. (2012); Memvanga et al. (2015)
Matricaria chamomilla L.	Asteraceae	–	Herb	L	2	Kasali et al. (2014a); Kasali et al. (2014b)
Melia azedarach L.	Meliaceae	Mwarubaini (S); marumaru (M); Kamura	Tree	L	2	Lusakibanza (2012); Kasali et al. (2014a)
Mentha piperita L.	Lamiaceae	Ehistsanyi	Herb	L	2	Kasali et al. (2014a); Kasali et al. (2014b)
Microdesmis puberula Hook.f. ex Planch.	Pandaceae	–	Shrub	L	3	Mesia (2009); Lusakibanza (2012); Memvanga et al. (2015)
Microglossa pyrifolia (Lam.) Kuntze	Asteraceae	Embatule (N); Kabeba mimba (S)	Tree	L	1	Kasali et al. (2014b)
Mikania cordata (Burm.f.) B.L.Rob.	Asteraceae	Engulapo	Liana	L	1	Kasali et al. (2014b)
Mirabilis jalapa L.	Nyctaginaceae	Kalifumo (M)	Herb	L	1	Kasali et al. (2014a)
Momordica charantia L.	Cucurbitaceae	Lumbusu (O)	Herb	Wp	3	Mesia (2009); Lusakibanza (2012); Memvanga et al. (2015)
Momordica foetida Schumach.	Cucurbitaceae	Lulali, muhu (M)	Herb	L	1	Kasali et al. (2014a)
Morinda citrifolia L.	Rubiaceae	Nsiki (O)	Shrub	Sb	3	Mesia (2009); Lusakibanza (2012); Memvanga et al. (2015)
Morinda lucida Benth.	Rubiaceae	–	Shrub	L, Sb, Rb	2	Cimanga et al. (2006); Memvanga et al. (2015)
Morinda morindoides (Baker) Milne-Redh.	Rubiaceae	Kongo bololo	Liana	L	7	Cimanga et al. (1994); Tona et al. (2004); Cimanga et al. (2008); Cimanga et al. (2009); Mesia (2009); Lusakibanza (2012); Memvanga et al. (2015)

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Table 3 (*continued*)

Plant species	Family	Local name	Life form	Parts used	Number of citations	References
Musanga cecropioides R.Br. ex Tedlie	Urticaceae	Botumbe	Tree	Sb	2	Muganza et al. (2012); Memvanga et al. (2015)
Myrianthus arboreus P.Beauv	Urticaceae	Byamba, Camba (M)	Shrub	B	2	Tshibangu et al., 2002; Memvanga et al. (2015)
Napoleona vogelii Hook.&Planch.	Lecythidaceae	Elenkete	Shrub	Sb	2	Muganza et al. (2012); Memvanga et al. (2015)
Ocimum gratissimum L.	Lamiaceae	Kaharajiji (M); Dikondi, mazulu, Luenyi, Lwenyi (S, Ts); Lwena (B, Ta); Ringishangish (R); Lumba lumba; Bonsonsolo	Shrub	L, Wp	5	Balagizi et al. (2007); Mesia (2009); Lusakibanza (2012); Muganza et al. (2012); Bashige et al. (2017)
Omphalocarpum agglomeratum De Wild.	Sapotaceae	Shanga sanga (O)	Shrub	Rb	2	Mesia (2009); Memvanga et al. (2015)
Ongokea gore (Hua) Pierre	Aptandraceae	Nsanu, oleko (O)	Tree	Sb	3	Mesia (2009); Lusakibanza (2012); Memvanga et al. (2015)
Oreosyce africana Hook.f.	Cucurbitaceae	Kungulira, Kungulira-nalima (M)	Herb	Wp	1	Chifundera (2001)
Otiophora pauciflora Baker	Rubiaceae	Lulerhalerha, Cifubula, Hinyangarha (M)	Herb	L	2	Chifundera (2001); Tshibangu et al., 2002
Paropsia brazzaeana Baill.	Passifloraceae	–	Shrub	Sb	1	Lusakibanza (2012)
Passiflora edulis Sims	Passifloraceae	Amarikucha (N); Maracuja (S)	Liana	L	1	Kasali et al. (2014b)
Passiflora foetida L.	Passifloraceae	–	Herb	L	1	Kasali et al. (2014a)
Penianthus longifolius Miers	Menispermaceae	Lopetu	Shrub	Rb	2	Muganza et al. (2012); Memvanga et al. (2015)
Pentaclethra eetveldeana De Wild. & T.Durand	Fabaceae	Mulu (O)	Tree	Rb	3	Mesia (2009); Lusakibanza (2012); Memvanga et al. (2015)
Pentaclethra macrophylla Benth.	Fabaceae	Ngansi, muwansi	Tree	L, Sb	1	Lusakibanza (2012)
Pentadiplandra brazzeana Baill.	Pentadiplandraceae	Musimi	Shrub	L, R	1	Lusakibanza (2012)
Persea americana Mill.	Lauraceae	Ivoka (M); Avokado (S); Efuka (N)	Tree	L, Sb	3	Chifundera (2001); Kasali et al. (2014a); Kasali et al. (2014b)
Phyllanthus muellerianus (Kuntze) Exell	Phyllanthaceae	Ludimba, lundimba, Kajimbajimba lujimba (L); Lulembalemba, Mulembalemba (H)	Shrub	L, Sb	1	Bashige et al. (2017)
Phyllanthus nituri L.	Euphorbiaceae	–	Herb	Wp	4	Tona et al. (2004); Cimanga et al. (2004); Mesia (2009); Lusakibanza (2012)
Physalis angulata L.	Solanaceae	Lumbundu, Ndimba Mbuma (M); Mbupuru, Embupuru (N)	Herb	Ap, F, L, Wp	4	Lusakibanza (2012); Kimpende et al. (2013); Memvanga et al. (2015)
Physalis peruviana L.	Solanaceae	Mbuma (M, S)	Herb	L	3	Bashige et al. (2017); Kasali et al. (2014a); Kasali et al. (2014b)
Phytolacca dodecandra L'Hér.	Phytolacaceae	Kenawiri, nkoy	Shrub	L	4	Mesia (2009); Lusakibanza (2012); Kasali et al. (2014a); Memvanga et al. (2015)
Picralima nitida (Stapf) T.Durand & H.Durand	Apocynaceae	Botolo	Tree	Sb	2	Muganza et al., 2012; Memvanga et al. (2015)
Piper guineense Schumach. & Thonn.	Piperaceae	Muborobondo (M); Boleleko	Liana	L, Rb, Sb, S	3	Kasali et al. (2014a); Muganza et al. (2012); Memvanga et al. (2015)
Piptadeniastrum africanum (Hook.f.) Brenan	Fabaceae	–	Tree	Sb	2	Mesia (2009); Memvanga et al. (2015)
Plantago palmata Hook.f.	Plantaginaceae	Cibarhama (M); Kibatama (S)	Herb	L	3	Defour (1995); Bashige et al. (2017); Kasali et al. (2014a)
Plectranthus barbatus var. grandis (L.H.Cramer) Lukhoba & A.J.Paton	Lamiaceae	–	Herb	L	1	Muya et al. (2014)
Plumbago zeylanica L.	Plumbaginaceae	–	Herb	L	3	Mesia (2009); Lusakibanza (2012); Memvanga et al. (2015)
Polyscias fulva (Hiern) Harms	Araliaceae	Ntonge, Lunga, Ndonyi	Tree	B	2	Tshibangu et al., 2002; Memvanga et al. (2015)
Psidium guajava L.	Myrtaceae	Mapera (S), Ipera (M); Amapera (N)	Tree	L	2	Kasali et al. (2014a); Kasali et al. (2014b)
Psorospermum febrifugum Spach	Hypericaceae	Soko soko (O)	Shrub	L	3	Mesia (2009); Lusakibanza (2012); Memvanga et al. (2015)
Psydrax palma (K. Schum.) Bridson	Rubiaceae	Oshuwi (O)	Shrub	Sb	3	Mesia (2009); Lusakibanza (2012); Memvanga et al. (2015)
Pterocarpus angolensis DC.	Fabaceae	Nzani lisolo (L); Mukula (T)	Tree	Sb	1	Bashige et al. (2017)
Pyrenacantha klaineana Pierre ex Exell & Mendonça	Icacinaceae	Nsemiandwa	Herb	L	2	Muganza et al. (2012); Memvanga et al. (2015)
Quassia africana (Baill.) Baill.	Simaroubaceae	Bomengia, Mupesi pesi	Shrub	L, Sb, Rb, R	3	Lusakibanza (2012); Muganza et al. (2012); Memvanga et al. (2015)
Ranunculus multifidus Forssk.	Ranunculaceae	Kivunja homa (S); Enyarubanda (N)	Herb	L	1	Kasali et al. (2014b)
Rauvolfia vomitoria Afzel.	Apocynaceae	Akatongo kube (N); Zumbu (O)	Shrub	L	4	Mesia (2009); Lusakibanza (2012); Kasali et al. (2014b); Memvanga et al. (2015)
Rubus rigidus Sm.	Rosaceae	Lukererhe, Ikangahwa (M)	Shrub	R	3	Tshibangu et al., 2002; Kasali et al. (2014b); Memvanga et al. (2015)
Rhynchosia insignis (O. Hoffm.) R.E.Fr.	Fabaceae	–	Herb	R	1	Muya et al. (2014)
Sambucus mexicana C.Presl ex DC.	Asteraceae	–	Tree	L	1	Kasali et al. (2014b)

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Table 3 (*continued*)

Plant species	Family	Local name	Life form	Parts used	Number of citations	References
Sarcocephalus latifolius (Sm.) E.A.Bruce	Rubiaceae	Kilolo kwango	Shrub	Rb, L	3	Mesia (2009); Lusakibanza (2012); Memvanga et al. (2015)
Sarcocephalus pobeguinii Pobeg.	Rubiaceae	–	Tree	Sb	3	Mesia (2009); Lusakibanza (2012); Memvanga et al. (2015)
Sclerocroton cornutus (Pax) Kruijt & Roebers	Euphorbiaceae	Okutshu (O)	Shrub	Sb	2	Mesia (2009); Memvanga et al. (2015)
Schrebera trichoclada Welw.	Oleaceae	–	Shrub	L, S	1	Kalonda et al. (2014)
Scorodophloeus zenkeri Harms	Caesalpiniaceae	Kubi (O)	Tree	Sb	1	Mesia (2009)
longipedunculata Fresen.	Polygalaceae	–	Tree	Sb	1	Muya et al. (2014)
Senna hirsuta (L.) H.S.Irwin & Barneby	Fabaceae	–	Herb	Rb	3	Mesia (2009); Lusakibanza (2012); Memvanga et al. (2015)
Senna occidentalis (L.) Link	Fabaceae	Kashangala, Mugenge, Mushegemanjoka (M); Omwita nzoka (N); Mwingajini (S); Lukunda banjani, Katshimenkele (Ts); Mufa nwa, Ngombe munianga (L); Ma nsambi usambi; Madezo ma sioto	Shrub	L, Sb, R	10	Defour (1995); Tona et al. (2004); Balagizi et al. (2007); Mesia (2009); Lusakibanza (2012); Ngbolua et al. (2011); Kasali et al. (2014a); Kasali et al. (2014b); Memvanga et al. (2015); Bashige et al. (2017)
Senna spectabilis (DC.) H. S. Irwin & Barneby	Fabaceae	–	Herb	L	1	Kasali et al. (2014a)
Solanum sysymbrifolium L.	Solanaceae	Lurhoborhobo, Ntobololo (M)	Herb	F	1	Chifundera et al. (2001)
Solanecio mannii (Hook.f.) C.Jeffrey	Asteraceae	Umutagara (Ny)	Shrub	L	1	Mutamba and Rwihaniza (1990)
Staudtia kamerunensis Warb.	Myristicaceae	Bokolombe	Tree	Sb	2	Muganza et al. (2012); Memvanga et al. (2015)
Strychnos cocculoides Baker	Loganiaceae	–	Shrub	L, R	1	Kalonda et al. (2014)
Strychnos icaja Baill.	Loganiaceae	Bondo bololo	Liana	Sb	1	Lusakibanza (2012)
Strychnos variabilis De Wild.	Loganiaceae		Tree	L	2	Mbenza et al. (2012); Memvanga et al. (2015)
Syzygium guineense (Willd) DC.	Myrtaceae	Omutusu (N)	Tree	B	1	Kasali et al. (2014b)
Tetracera alnifolia Willd.	Dilleniaceae	Onembo (O)	Shrub	L	1	Mesia (2009)
Tetracera poggei Gilg.	Dilleniaceae	–	Liana	L	2	Tona et al. (2004); Memvanga et al. (2015)
Tetradenia riparia (Hochst.) Codd	Lamiaceae	Mutizo gw'ebushi (M); Omutubya (N)	Shrub	L	3	Defour et al. (1995); Kasali et al. (2014a); Kasali et al. (2014b)
Tetrapleura tetraptera (Schumach. & Thonn.) Taub.	Fabaceae	Bolese	Tree	F, Sb	2	Muganza et al. (2012); Memvanga et al. (2015)
Thomandersia hensii De Wild. & T. Durand	Thomandersiaceae	Epapodzi	Shrub	L	2	Muganza et al. (2012); Memvanga et al. (2015)
Thomandersia laurifolia (T. Anderson ex Benth.) Baill.	Thomandersiaceae	–	Shrub	Sb	2	Mesia (2009); Memvanga et al. (2015)
Tithonia diversifolia (Hemsl.) A. Gray	Asteraceae	Cilula (M); Ekiwa (N)	Sub shrub	L	2	Kasali et al. (2014a); Kasali et al. (2014b)
Trema orientalis (L.) Blume	Cannabaceae	Wesen (O)	Tree	Rb	3	Mesia (2009); Lusakibanza (2012); Memvanga et al. (2015)
Trichilia gilgiana Harms	Meliaceae	Idjokondjo (O)	Tree	Sb	2	Mesia (2009); Lusakibanza (2012)
Triclisia gilletii (De Wild.) Staner	Meliaceae	Efili (O)	Tree	L, Sb, Rb	4	Mesia (2009); Kikueta et al., 2013; Lusakibanza (2012); Memvanga et al. (2015)
Triclisia dictyophylla Diels	Menispermaceae	Lomaloma Ya moindo	Liana	L	1	Muganza et al. (2012)
Tridax procumbens (L.) L.	Asteraceae	Otutula (O)	Herb	L	3	Mesia, 2009; Lusakibanza (2012); Memvanga et al. (2015)
Tropaeolum majus L.	Tropaeolaceae	–	Herb	Fr, L	2	Kasali et al. (2014a); Kasali et al. (2014b)
Vernonia amygdalina Delile	Asteraceae	Mubirizi (M); Kilulukunju (S); Omubīrīrī (N)	Shrub	L	6	Defour (1995); Tona et al. (2004); Balagizi et al. (2007); Kasali et al. (2014a); Kasali et al. (2014b); Kalonda et al. (2014)
Vitex madiensis Oliv.	Lamiaceae	–	Shrub	L	1	Kalonda et al. (2014)
Zebrina pendula Schnizl	Asteraceae	Endetsa ye rangi	Herb	L	1	Kasali et al. (2014b)
Ziziphus resinosa	Rhammaceae	Kankona (L, B, Sa)	Tree	R	1	Bashige et al. (2017)

Part useds: L: leaves; Rb, root bark; Sb: stem bark; WP: whole plant; B: Bulbs; Ap: Aerial part; Fr: Fruit; Hp: Herbal parts; T: Tuber; F: Flower; S: stem; Ep: external part.
Vernacular names: H: Hemba; S: Swahili; L: Luba; M: Mashi; N: nande; T: Tshokwe; B: Bemba; Ts: Tshiluba; O: Otetela; Yn: Kinyanulenge; Sa: Sanga; Le: Lega; Ta: Tabwa; Li: Lingala; Be: Bembe; H: Hemba; K: Kaonde; Rund: R.

In this study, we reported a total of 45 species, belonging to 21 families, used as antimalarial plants in Bukavu and Uvira cities. These plants represent about 2% of an estimated total of 2783[1] (in 187 families) species identified in the region (Table 4).

4. Discussion

4.1. Information on traditional healers

From the total of 32 traditional healers interviewed (aged between 30 and 70's), there were more males than females; the predominance of men in relation to women can probably be explained by a bias due to the interview period (probable absence of some women, due to farm work) and/or to the fact that parents usually prefer boys for the transmission of indigenous knowledge (Suleman et al., 2018). The predominance of a genus in the practice of traditional medicine varies according to the socio-cultural characteristics of studied populations; the art of healing can be held sometimes by women, sometimes by men (Longanga et al., 2000; Kamagaju et al., 2013; Kffuri et al., 2016; Ndob et al., 2016). According to the ages of the THs, the results obtained in this survey corroborate those obtained by others ethnobotanical investigations which attest that traditional medicine is mainly practiced by adults and elderly people (Traore et al., 2013; Dike et al., 2012; Ngarivhume et al., 2015; Kffuri et al., 2016). In Africa, family inheritance is the most widespread mode of acquisition of knowledge in traditional medicine (Adebo and Alfred, 2011; Keter and Mutiso, 2012), a fact confirmed by the present study.

4.2. Plants used in malaria treatment

Most of the medicinal plants mentioned by the respondents belong to the families of Asteraceae (12 species), Fabaceae (7 species) and Rubiaceae (4 species). In other surveys on medicinal plants, carried out at continental and national scales, the plant species of these three families are often reported to be used in phytotherapy for various diseases, including malaria (Mutabana and Mpulusi, 1990; Cos et al., 2002; Maregesi et al., 2007; Muganga et al., 2010; Yetein et al., 2013). In the present study, the predominance of Asteraceae corroborates with the results obtained by Kasali et al. (2014a,b) in his investigation of plants known as antimalarials in Bukavu. This is not surprising as Asteraceae is also one of the families presenting the highest number of species in the study area.

According to Table 2, more than half of the medicinal plants used were herbs, which is in fact in agreement with studies conducted in Kivu in DRC (Kasali et al., 2014a; 2014b), where most of the herbal remedies of antimalarial plants were obtained from the herbs. By contrast, studies in Katanga, DRC, have shown that most of the antimalarial medicinal plants of the region are trees (Kalonda et al., 2014; Bashige et al., 2017); a statement which corroborates studies released in Ethiopia (Suleman et al., 2018), Kenya (Muthaura et al., 2015), Namibia (Cheikhyoussef et al., 2011) and Nigeria (Odoh et al., 2018).

The 7 species most cited in our study, *Artemisia annua* L., *Carica papaya* L., *Bidens pilosa* L., *Cinchona officinalis* L., *Chenopodium opulifolium* Schrad. ex W.D.J.Koch & Ziz, *Vernonia amygdalina* Delile and *Senna occidentalis* (L.) Link., have already been reported as antimalarials in several ethnobotanical surveys (Neuwinger, 2000; Gurib-Fakim, 2006; Kvist et al., 2006; Tene et al., 2007; Hussain et al., 2010; Yetein et al., 2013; Adia et al., 2014; Kalonda et al., 2014; Kasali et al., 2014a,b; Oliveira et al., 2015; Muthaura et al., 2015; Galabuzi et al., 2016). As reported in Tables 2 and 5 of these plants treat, in addition to malaria, other diseases and symptoms, including bilharziasis, digestive candidiasis, loss of appetite, strengthening immunity (*Artemisia annua* L.), intestinal worms (*Carica papaya* L.), angina, urinary infections, verminoses (*Bidens pilosa* L., *Vernonia amygdalina* Delile), dysentery, gastrointestinal disorders, hyperglobulinemia, leukemia, measles and shrinkage of the vagina (*Chenopodium opulifolium* Schrad. ex W. D. J. Koch & Ziz). These species multiple uses confirm previous literature data review (Aiyeloja and Bello, 2006; Tene et al., 2007; de Wet et al., 2010; Lacroix et al., 2011; Namukobe et al., 2011; Mukazayire et al., 2011; Dolatkhahi et al., 2014; Ladoh-Yemeda et al., 2016; Iyamah and Idu, 2015; Tugume et al., 2016).

The high frequency of leaves use reported by the current study could be linked to their quasi permanent visibility and easiness in collecting; harvesting of leaves is generally less destructive than other morphological parts, ensuring biodiversity conservation (Odoh et al., 2018). Our present findings also revealed that most of the plants are obtained from the wild. These findings contrast with the previous research in Bukavu in which more than half of the medicinal species (52%) used to treat malaria were cultivated (Kasali et al., 2014a,b).

4.3. Preparations and administration route of antimalarial herbal medicines

It is striking that our survey on malaria therapy proposes so many single-herb preparations (52% of all herbal preparations recorded). Of note, previous studies in different fields have also reported many monocomponent recipes (Haddad et al., 2003; Kareru et al., 2007; Mukazayire et al., 2011; Ngezahayo et al., 2015); in fact, the purported advantages in combining several herbs (Dike et al., 2012), if any, has never been really investigated. Aware of the growth of resistance of *Plasmodium* to modern antimalarial drugs, polymedication in phytotherapy might be an interesting venue to further investigate.

In this study, medicinal recipes were commonly prepared by decoction and administered by oral route, which agrees with many other studies (Chifundera, 2001; Kasali et al., 2014a,b; Kalonda et al., 2014; Ngezahayo et al., 2015).

4.4. Comparative analysis of literature data

Comparison with plant species previously described as antimalarial

Our literature review indicates that a large numbers of medicinal species (n = 194) have been reported for malaria treatment *(i)* in DR Congo, the most frequently cited being *Senna occidentalis* (L.) Link, *Carica papaya* L., *Morinda morindoides* (Baker) Milne-Redh, *Harungana madagascariensis* Lam. ex Poir., *Lantana camara* L. and *Vernonia amygdalina* Delile; and *(ii)* in other parts of the world, notably *Senna occidentalis* (L.) Link. (Benin, Brazil, Kenya and Nigeria) (Milliken, 1997; Adebayoa and Krettli, 2011; Yetein et al., 2013; Mukungu et al., 2016), *Carica papaya* L. (Benin, Kenya, Ghana, Namibia, Nigeria, Zambia and Zimbabwe) (Iyamah and Idu, 2015; Chinsembu, 2015), *Vernonia amygdalina* Delile (Benin, Ghana, Kenya, Namibia, Nigeria, Uganda, Zambia) (Chinsembu, 2015), *Morinda morindoides* (Baker) Milne-Redh in Nigeria (Idowu et al., 2010), *Harungana madagascariensis* Lam. ex Poir in Guinea (Traore et al., 2013) and *Lantana camara* L. in Tanzania and Uganda (Tabuti, 2008; Nguta et al., 2010).

This comparison with literature data shows that 38% of medicinal plants documented in our survey have previously been reported as antimalarials. Though the highest similarity was observed with the survey conducted in part of our study area (Kasali et al., 2014a,b), a significant similarity is also marked with quite remote regions (Kalonda et al., 2014). This similarity could reflect environmental factors or study methodologies among communities under study (Houghton and Manby, 1985).

From the 28 identified species that were not hitherto locally recorded as antimalarials, most have been previously reported in previous ethnobotanical surveys from other countries (Neuwinger, 2000; Gurib-

[1] Note: the estimate number of 2783 species was found by compiling data from Troupin (1978–1987), Mutamba and Rwihaniza (1990), Bakenga et al. (2000), Chifundera (2001) and Kasali et al. (2014a,b), but it probably corresponds to an underestimation.

Table 4
Estimation of the proportion of plants used by THs compared to the number of plants that can be found in our study area.

Families of plants most represented in the region[a]		Families of medicinal plants reported in the present study
Number of species by family	Families[b]	Families[b]
Over 50	Acanthaceae (71), Asteraceae (231), Cyperaceae (110), Euphorbiaceae/Phyllanthaceae (77), Fabaceae (211), Lamiaceae (82), Myrtaceae (84), Orchidaceae (166), Poaceae (237), Rubiaceae (120)	Acanthaceae (2), Asteraceae (12), Euphorbiaceae (3), Fabaceae (7), Lamiaceae (1), Phyllanthaceae (1), Rubiaceae (4)
20–50	Amaranthaceae (35), Anacardiaceae (21), Apiaceae/Umbelliferae (25), Asclepiadaceae (41), Brassicaceae (20), Caesalpiniaceae (30), Commelinaceae (39), Convolvulaceae (33), Cucurbitaceae (27), Liliaceae (34), Malvaceae (39), Melastomataceae (21), Mimosaceae (27), Moraceae (33), Proteaceae (46), Scrophulariaceae (40), Solanaceae (34), Urticaceae (22), Verbenaceae (30)	Amaranthaceae (2), Convolvulaceae (1), Moraceae (1), Solanaceae (1), Verbenaceae (1)
11–19	Apocynaceae (17), Araceae (17), Balsaminaceae (17), Begoniaceae (12), Boraginaceae (19), Capparaceae (14), Caryophyllaceae (15), Clusiaceae (12), Crassulaceae (12), Flacourtiaceae (11), Gentianaceae (11), Loganiaceae (11), Loranthaceae (14), Lythraceae (11), Menispermaceae (11), Oleaceae (13), Polygalaceae (15), Polygonaceae (15), Ranunculaceae (11), Rosaceae (17), Rutaceae (17), Sapindaceae (14), Sterculiaceae (12), Tiliaceae (15), Vitaceae (18)	Clusiaceae (1), Crassulaceae (1)
7–10	Bignoniaceae (8), Campanulaceae (8), Celastraceae (10), Chenopodiaceae (7), Cupressaceae (9), Dioscoreaceae (7), Ericaceae (7), Geraniaceae (8), Iridaceae (8), Lauraceae (8), Lemnaceae (8), Lobeliaceae (10), Marantaceae (8), Meliaceae (10), Musaceae (10), Myrsinaceae (8), Nyctaginaceae (8), Onagraceae (9), Oxalidaceae (8), Portulacaceae (9), Rhamnaceae (9), Sapotaceae (7), Thymelaeaceae (7)	Bignoniaceae (1)
5–6	Agavaceae (6), Amaryllidaceae (5), Annonaceae (5), Araliaceae (6), Bromeliaceae (6), Combretaceae (6), Hippocrateaceae (5), Juncaceae (6), Ochnaceae (6), Passifloraceae (5), Piperaceae (6)	Ochnaceae (1), Combretaceae (1)
4	Alismataceae, Casuarinaceae, Hydrocharitaceae, Molluginaceae, Pittosporaceae, Potamogetonaceae, Primulaceae, Rhizophoraceae, Theaceae, Ulmaceae, Violaceae, Zingiberaceae	Zingiberaceae (1)
3	Aizoaceae, Amygdalaceae, Aponogetonaceae, Araucariaceae, Aristolochiaceae, Cactaceae, Chrysobalanaceae, Dipsacaceae, Ebenaceae, Gesneriaceae, Hypoxidaceae, Myricaceae, Nymphaeaceae, Pinaceae, Plumbaginaceae, Trapaceae, Turneraceae, Typhaceae	–
2	Arecaceae, Bombacaceae, Burseraceae, Callitrichaceae, Caprifoliaceae, Caricaceae, Connaraceae, Cuscutaceae, Cycadaceae, Droseraceae, Fumariaceae, Haloragaceae, Malpighiaceae, Najadaceae, Olacaceae, Papaveraceae, Pedaliaceae, Plantaginaceae, Podocarpaceae, Pontederiaceae, Santalaceae, Simaroubaceae, Xyridaceae	Caricaceae (1), Plantaginaceae (1)
1	Alliaceae, Alangiaceae, Aloeaceae, Aquifoliaceae, Araceae, Balanitaceae, Balanophoraceae, Basellaceae, Burmanniaceae, Cabombaceae, Cannabaceae, Canellaceae, Cannaceae, Cappartidaceae, Ceratophyllaceae, Cornaceae, Dichapetalaceae, Ericaceae, Eriocaulaceae, Escalloniaceae, Hamamelidaceae, Hydrangeaceae, Hydnoraceae, Hypericaceae, Icacinaceae, Linaceae, Malaceae, Melianthaceae, Monimiaceae, Oliniaceae, Opiliaceae, Orobanchaceae, Phytolaccaceae, Podostemaceae, Punicaceae, Resedaceae, Salicaceae, Salvadoraceae, Smilacaceae, Sinopteridaceae, Sphenocleaceae, Taccaceae, Tropaeolaceae, Xanthrorrhoeaceae, Zygophyllaceae	Hypericaceae (1)
Total	2783	21

[a] Data compiled from Troupin (1978–1987), Mutamba and Rwihaniza (1990), Bakenga et al. (2000), Chifundera (2001) and Kasali et al. (2014a,b).
[b] Number in brackets corresponds to the number of species in the family.

Fakim, 2006; Kvist et al., 2006; Tene et al., 2007; Hussain et al., 2010; Yetein et al., 2013; Adia et al., 2014; Oliveira et al., 2015; Muthaura et al., 2015; Galabuzi et al., 2016), except for *Aframomum laurentii* De Wild. & T. Durand) K. Schum., *Fadogiella stigmatoloba* (K.Schum.) Robyns, *Hylodesmum repandum* (Vahl) H. Ohashi & R.R.Mill, *Kalanchoe crenata* (Andrews) Haw., *Porphyrostemma chevalieri* (O.Hoffm.) Hutch. & Dalziel and *Rothmannia engleriana* (K.Schum.) Keay.

These species are reported here for the first time as antimalarials; three of them namely *Aframomum, Fadogiella* and *Porphyrostemma*, are not yet included in the database Medicinal Plant Names Services of the Kew Royal Botanic Gardens.

Comparison with plant species previously investigated for antimalarial properties

At least 30% of the plants we identified have been previously investigated (*in vitro* and/or *in vivo*) for antimalarial activity (Table 5). A total of 38 compounds (Table 5, Fig. 4) have been isolated from 10 of the recorded plants and tested for antimalarial potential (Table 5).

This gives credit to the experience of Bukavu and Uvira interviewees and some level of confidence on collected information.

5. Conclusion

The present survey documented 45 medicinal plants used by traditional healers for the treatment of malaria in the South-Kivu cities of Bukavu and Uvira. These plants are divided into 21 families and participate in the formulation of 25 multi- and 27 mono-herbal recipes. According to the literature, some of these plants have few or no studies dealing with their antimalarial activity; i.e. *Acalypha brachiata* Krauss, *Hygrophylla auricula* (Schumach.) Heine, *Hylodesmum repandum* (Vahl) H. Ohashi & R.R.Mill, *Fadogiella stigmatoloba* (K. Schum.) Robyns, *Kalanchoe crenata* (Andrews) Haw. *Porphyrostemma chevalieri* (O. Hoffm.) Hutch. & Dalziel and *Rothmania engleriana* (K. Schum.) Verdc. These cited plants should be investigated in details for the isolation and identification of active ingredients, a contribution to the discovery of new possibly effective antimalarials.

Authors contributions

Henry Manya Mboni prepared the study, obtained and analysed survey data, collected and participated to the identification of the plants species and took part in writing the paper. Flore Keymeulen, Jérémie Ngezahayo, Salvius Bakari Amuri and Joh Kahumba Byanga

Table 5
Scientific investigations previously reported on the plants identified in the present study.

S/N	Plants	Anti-malarial or anti-plasmodial activities of extracts	Anti-malarial or anti-plasmodial activities of isolated compounds
1	*Acalypha brachiata* Krauss	No report	No report
2	*Acalypha homblei* De Wild.	No report	No report
3	*Acanthospermum glabratum* (DC.) Wild	No report	No report
4	*Aframomum laurentii* (De Wild. & T.Durand) K.Schum.	No report	No report
5	*Antidesma venosum* E.Mey. ex Tul.	No report	No report
6	*Artemisia annua* L.	*In vitro* (Tawfiq et al., 1989; Chen Liu et al., 1992; Willcox, 2009; Ramazani et al., 2010; De Donno et al., 2012) and *in vivo* (Mueller et al., 2000; Ramazani et al., 2010)	Artemisinin (**1**) (Kohler et al., 1997; Willcox, 2009); Artemetin (**2**), Casticin (**3**), Chrysoplenetin (**4**), Chrysosplsrtol-D (**5**), Cirsilmeol (**6**), Eupatorin (**7**): *in vitro* (Chen Liu et al., 1992; Ferreira et al., 2010)
7	*Aspilia kotschyi* (Sch.Bip.ex Hochst.) Oliv.	No report	No report
8	*Bidens oligoflora* (Klatt) Wild	No report	No report
9	*Bidens pilosa* L.	*In vitro* (Clarkson et al., 2004; Oliveira et al., 2004; Lacroix et al., 2011); *in vivo* (Brandão et al., 1997; Andrade-Neto et al., 2004; Krettli et al., 2001; Krettli, 2009)	1-phenyl-hepta-1,3,5-triyne (**8**): *in vitro*, (R)-1,2-dihydroxytrideca-3,5,7,9,11-pentayne (**9**): *in vitro* and in *vivo*, 2-β-D-glycopyrasyloxy-1-hydroxytrideca-3,5,7,9,11-pentayne (**10**); flavonoids (**11, 12**), Phenylacetylene (**13**), Phenylheptatriyne (**14**): *in vitro* (Krettli et al., 2001; Tobinaga et al., 2009; Nogueira and Lopes, 2011)
10	*Carica papaya* L.	*In vitro* (Bhat and Surolia, 2001; Julianti et al., 2014; Chinsembu, 2015); *in vivo* (Okpe et al., 2016)	(1S-11R-13S–14S-24R–26S)-13,26-Dimethyl-2,15-dioxa-12,25-dia- zatricyclo [22.2.2.211,14]triacontane-3,16-dione ((þ)-carpaine (**15**), 6-(8-Methoxy-8-oxooctyl)-2-methylpiperidin-3-yl8-(5-hydroxy-6-methylpiperidin-2-yl) octanoate (**16**), 13,26-Dimethyl-2,15-dioxa-12,25-diazatricyclo [22.2.2.211,14] triacontane-3,16-dione (**17**): active *in vitro* (Suleman et al., 2018)
11	*Chenopodium opulifolium* Schrad. ex W.D.J.Koch & Ziz	No report	No report
12	*Cinchona officinalis* L.	*In vivo* (Rajan and Bagai, 2012)	Cinchonidine (**18**), quinine (**19**) (Geerlings et al., 1999; Cragg and Newman, 2005)
13	*Combretum molle* R. Br. ex G.Don	*In vitro* (Asres et al., 2001; Prozesky et al., 2001; Traoré-Coulibaly et al., 2013)	Punicalagin (**20**): *in vitro* (Asres et al., 2001)
14	*Conyza sumatrensis* (S.F.Blake) Pruski & G.Sancho	*In vitro* (Boniface et al., 2015), *In vivo* (Boniface and Pal, 2013; Boniface et al., 2015)	(2S)-1,2-di-O-[(9Z)-octadeca-9-enoyl]-3-O-β-D-galactopyranosyl glycerol (**21**), (2S)-1,2-di-O-[(9Z,12Z,15Z)-octadeca-9,12,15-trienoyl]-3-O-(6-sulpho-α-D) quinovopyranosyl glycerol (**22**), 1-O-β-D-glucopyranosyl- (2S,3R,8E)-2-[(2′R)-2-hydroxy palmitoylamino]-8-octadecene-1,3-diol (**23**), 3-O-β-D-glucopyranosyl-3,4dihydroxybenzoic acid (**24**): *in vitro* (Boniface et al., 2015)
15	*Crassocephalum montuosum* (S.Moore) Milne-Redh.	No report	No report
16	*Crassocephalum picridifolium* (DC.) S.Moore	No report	No report
17	*Dalbergia boehmii* Taub.	No report	No report
18	*Dalbergia chapelieri* Baill.	No report	No report
19	*Dialium angolense* Oliv	No report	No report
20	*Dysphania ambrosioides* (L.) Mosyakin & Clemants.	*In vitro* (Pollack et al., 1990)	Ascaridole (**25**) (Pollack et al., 1990)
21	*Fadogiella stigmatoloba* (K.Schum.) Robyns	No reference	No report
22	*Ficus exasperata* Vahl	*In vitro* (Ndjonka et al., 2012)	No report

(*continued on next page*)

Table 5 (*continued*)

S/N	Plants	Anti-malarial or anti-plasmodial activities of extracts	Anti-malarial or anti-plasmodial activities of isolated compounds
23	*Garcinia huillensis* Welw.	No report	No report
24	*Hygrophila auriculata* (Schumach.) Heine	No report	No report
25	*Hylodesmum repandum* H. Ohashi & R.R.Mill	No report	No report
26	*Hypoestes triflora* (Forssk) Roem. & Schult	No report	No report
27	*Ipomoea indica* (Burm.) Merr.	No report	No report
28	*Isoberlinia angolensis* (Welw. Ex Benth.) Hoyle & Brenan	No report	No report
29	*Julbernardia paniculate* (Benth.) Troupin	No report	No report
30	*Kalanchoe crenata* (Andrews) Haw.	No report	No report
31	*Lantana camara* L.	*In vitro* (Clarkson et al., 2004; Kamaraj et al., 2012; Mesia et al., 2008; Jonville et al., 2008), *in vivo* (Jonville et al., 2008)	Quinine like alkaloid, lantanine (Nguta et al., 2010)
32	*Maprounea africana* Müll.	*In vitro* (Mesia et al., 2008)	No report
33	*Ochna schweinfurthiana* F.Hoffm.	*In vitro* (Messi et al., 2016; Omoniwa et al., 2017)	4‴-methoxylophirone (**26**); 4, 4′,4‴–trimethoxylophirone A (**27**); (4E; 7Z)-3,8-dicar-boxy-1-(O-b-D-glucopyranosyl-(1 → 6)-O-b-D-glucopyranosyl-2,9-dihydroxyhexeicosa-4,7-diene (**28**), Calodenone (**29**), Calodenine B (**30**), Lophirone A (**31**), α16,17-Gerontoisoflavone, dihydroxy-ent-kauran-19-oic acid (**32**) and 3ß-O-D-glucopyranosyl-ß-sitosterol (**33**): *in vitro* (Messi et al., 2016)
34	*Ocimum gratissimum* L.	*In vitro* (Kaou et al., 2008; Mesia et al., 2008; Muganza et al., 2012; Muthaura et al., 2015; Bashige et al., 2017); *in vivo* (Tchoumbougnang et al., 2005)	Essential oils (Tchoumbougnang et al., 2005)
35	*Physalis peruviana* L.	No report	No report
36	*Plantago palmata* Hook.f.	No report	No report
37	*Polydora serratuloides* (DC.) H.Rob.	No report	No report
38	*Porphyrostemma chevalieri* (O.Hoffm.) Hutch. & Dalziel	No report	No report
39	*Psorospermum corymbiferum* Hochr.	No report	No report
40	*Rothmannia engleriana* (K.Schum.) Keay	No report	No report
41	*Senna occidentalis* (L.) Link	*In vitro* (El-Tahir et al., 1999; Tona et al., 1999, 2004; Ménan et al., 2006; Kaou et al., 2008; Muthaura et al., 2015), *in vivo* (Tona and Mesia, 2001)	Quinones: *in vitro* (Kayembe et al., 2010)
42	*Spathodea campanulata* P.Beauv.	*In vitro* (Rangasamy et al., 2008), *in vivo* (Titanji et al., 2008),	Lapachol (**34**), ursolic acid (**35**): *in vitro* (Titanji et al., 2008; Ntie-Kang et al., 2014)
43	*Spermacoce princeae* (K.Schum.) Verdc.	*In vitro* (Muregi et al., 2003; Jeruto et al., 2015)	No report
44	*Synedrella nodiflora* (L.) Gaertn.	No report	No report
45	*Vernonia amygdalina* Delile	*In vitro* (Muthaura et al., 2015); *in vivo* (Abosi and	Vernolide (**36**), vernodalin (**37**), vernodalol (**38**): *in vitro* (Onguén et al., 2013; Mukungu et al., 2016; Suleman et al., 2018)

(*continued on next page*)

Table 5 (*continued*)

S/N	Plants	Anti-malarial or anti-plasmodial activities of extracts	Anti-malarial or anti-plasmodial activities of isolated compounds
		Raseroka, 2003; Okpe et al., 2016)	

revised the paper. Emery Kalonda Mutombo participated to botanical identification. Pierre Duez, Caroline Stévigny and Jean-Baptiste Lumbu Simbi supervised the study, analysed the survey and botanical data and took part in writing the paper.

Declaration of competing interest

We report no declaration of interests.

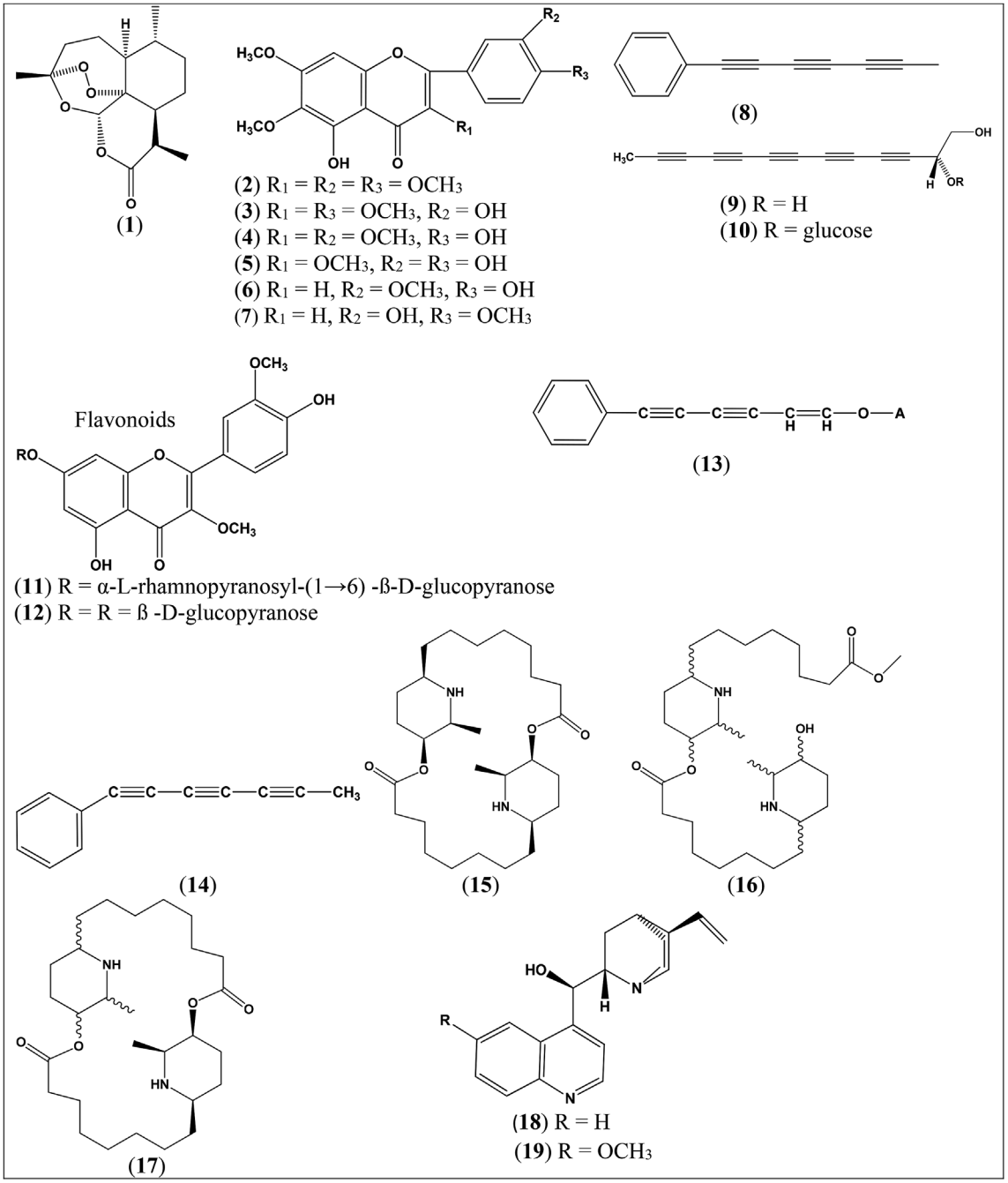
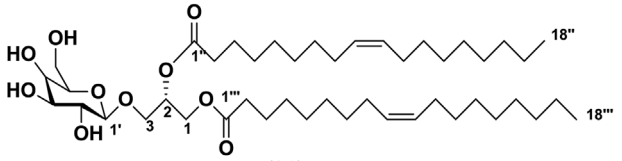


Fig. 4. Chemical structures of anti-malarial compounds isolated from the plant species repertoried in our study (The compounds names as well as the references are mentioned in Table 5).



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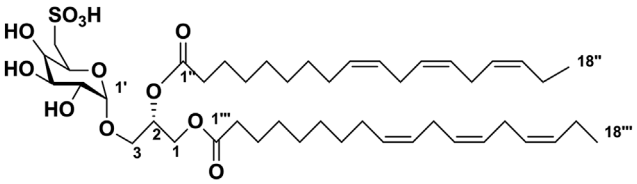

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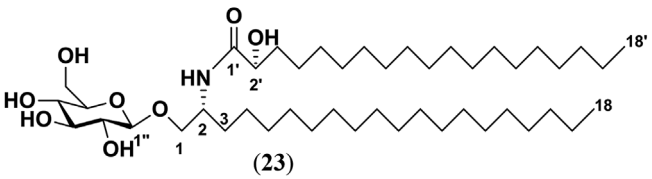

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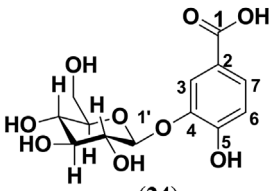

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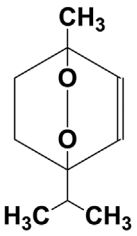

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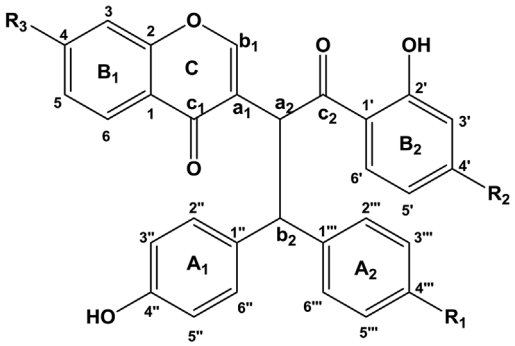
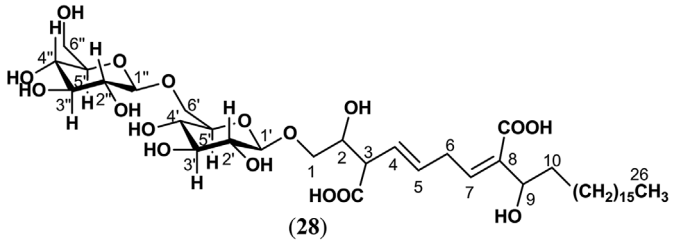


(26) R1 = OMe, R2 = R3 = OH

(27) R1 = R2 = R3 = OMe



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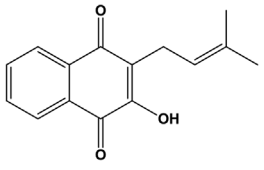

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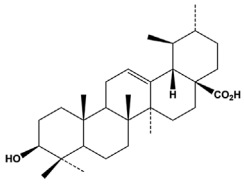

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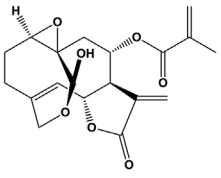

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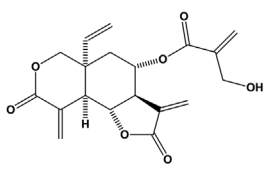

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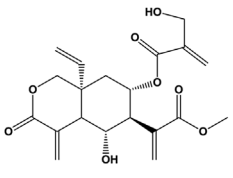

(38)

Fig. 4. (*continued*)

Acknowledgments

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Appendix 1. Main characteristics of studies (n = 26) included in this literature search

N°	Author, Year	Place of study	Year of study	Sample size	Type of respondents	Number of medicinal plants reported for malaria
1	Balagizi et al. (2007)	South Kivu-DRC	NA	124	TH	17
2	Bashige et al. (2015)	Lubumbashi (DRC)	2013	14	TH	2
3	Bashige et al. (2017)	Kenya commune (Lubumbashi-DRC)	2011–2013	13	TH	13
4	Chifundera et al. (2001)	Bushi area	1980–1990	170	TH	6
5	Cimanga et al. (1994)	NA	NA	1	NA	1
6	Cimanga et al. (1997)	NA	NA	1	NA	1
7	Cimanga et al. (2004)	NA	NA	1	NA	1
8	Cimanga et al. (2006)	NA	NA	1	NA	1
9	Cimanga et al. (2008)	NA	NA	1	NA	1
10	Cimanga et al. (2009)	NA	NA	1	NA	1
11	Defour et al. (1995)	Bushi area	NA	400	TH	16
12	Kalonda et al. (2014)	Lubumbashi-DRC	2011–2012	19	TH	19
13	Kasali et al. (2014a)	Bukavu City -DRC	2011–2012	39	TH	39
14	Kasali et al. (2014b)	Butembo City	2010–2011	46	TH	46
15	Kimpende et al. (2013)	NA	NA	1	NA	1
16	Lusakibanza (2012)	Bandundu, Bas-Congo, Equateur, Kasaï-Oriental, Katanga, Kinshasa et Maniema	2000–2002	132	TH, GI	60
17	Mbenza et al. (2012)	NA	NA	1	NA	1
18	Memvanga et al. (2015)	NA	NA	97	NA	75
19	Mesia (2009)	Bandundu, Bas-Congo and Kinshasa	2000–2002	50	TH	50
20	Muganza et al. (2012)	Bandundu province	2008	37	NA	22
21	Muya et al. (2014)	Lubumbashi and surroundings	2011	61	TH	12
22	Ngbolua et al. (2011)	NA	NA	3	NA	3
23	Mutamba and Rwihaniza (1990)	Fizi in DRC	1985	87	TH	3
24	Penge et al. (2013)	NA	NA	1	NA	1
25	Tona et al. (2004)	NA	NA	7	NA	7

GI = General Informant, NA = not available; TH = Traditional healer.

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