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Medicinal plants with antimicrobial, larvicidal, and repellent properties: An ethnopharmacological survey from the Democratic Republic of the Congo

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ABSTRACT

Introduction

Infectious diseases (IDs) constitute a real public health problem in the Democratic Republic of the Congo (DRC).

Purpose

This survey aimed to gather more information about the plants used in the DRC for anti-infective, larvicidal, or repellent treatments.

Methods

The study spanned 4 months (from April 1 to July 31, 2022) within 11 provinces in the DRC and was conducted among 20 traditional healers (TH), 105 vegetable growers (VG), and 953 other plant users (OU) of traditional plants scattered across the country. The survey consisted of a simple interview with an inventory of the plants used.

Results

The results showed that the average age of the respondents was between 39 and 43 years old. The VG were mainly illiterate. As for TH and OU, literacy rates up to the primary level were 60% and 78%, respectively. The knowledge of the use of plants by the various actors of traditional medicine in this survey emanates from the cultural heritage. For this study, 132 plant species (104 identified and 28 unidentified based on their botanical name or family) were reported. 33 antimicrobial species and 7 larvicidal species belonging to 22 botanical families have been reported among TH, while 1 and 75 antimicrobial species, 6 and 16 larvicidal species, and 13 and 30 repellent species were respectively identified among VG and OU. This study identified *Morinda morindoides*, *Cymbopogon citratus*, and *Boswellia sacra* as the plant species most used by the individuals surveyed for anti-infective, larvicidal, and repellent treatments, respectively, by their citation frequencies, which were the highest. Additionally, the leaves represented the plant parts most used by the respondents.

Conclusion

This ethnobotanical analysis revealed that most herbal antimicrobial recipes are used to treat malaria. This study confirms the richness of the Congolese flora concerning anti-infective, larvicidal, and repellent treatments.

INTRODUCTION

Infectious diseases (IDs) include all pathologies caused by the invasion of organisms by pathogens (e.g., bacteria and parasites) and have been a global burden of mortality and morbidity for decades. IDs are the second leading cause of death worldwide and the third leading cause of death in developed countries (Gajdács et al., 2021).

Bacteria are the main culprits of IDs, implicated in more than 70% of mortality cases (Ismahene, 2022). Antibiotics undeniably pushed back their emergence during the 20th century. However, they have gradually lost their bactericidal or bacteriostatic activity due to their increasing and sometimes inappropriate use. Many bacterial strains have started to adapt and develop resistance in their presence (Baran et al., 2023; Kaur et al., 2021).

Antimicrobial resistance (AMR) has been identified as a fundamental threat to global health security and international development (Dhingra et al., 2020). The World Health Organization (WHO) reports on global AMR surveillance highlighted the risk of entering a post-antibiotic era, where common infections could pose a danger of death due to the progressive loss of effective treatment (Sartorius et al., 2023). Annual AMR deaths are estimated to reach 10 million worldwide by 2050 (Grooters et al., 2024).

Compared to other regions, sub-Saharan Africa has been reported to have the highest mortality rates related to antibiotic resistance, with 99 deaths per 100,000 population, far exceeding previous global projections of 700,000 annual AMR-related deaths (Kariuki et al., 2022). In the DRC, only estimated data on AMR are available. This is due to the lack of appropriate service dealing with the collection and compilation of data on AMR (Akilimali et al., 2023; Lupande-Mwenebitu et al., 2020). Nevertheless, it has been reported that the level of resistance to commonly prescribed antibiotics (methicillin, third generation of cephalosporin, fluoroquinolone, etc.) is very significant in the DRC (Murray et al., 2022). The analysis of the pharmaceutical sector in the DRC highlights several weaknesses, including the uncontrolled use of antibiotics (Birindwa et al., 2021).

Authors claim that much of the available data on AMR in Africa is based on poor databases, with significant gaps in health, laboratory, and surveillance systems (Okolie et al., 2023). The inability of laboratories in Africa to routinely test bacteria for resistance translates into substandard care (Gulumbe et al., 2022).

Given the spread of the resistance phenomenon and the limited number of antibiotics under development, discovering new antibacterial molecules has become more than essential (Miethke et al., 2021). To be innovative and circumvent the mechanisms of bacterial resistance, tomorrow's antibiotics will have to target new active action targets (Mehrjou et al., 2023).

On the other hand, the world is generally threatened by the devastating effects of malaria. This infectious disease affects approximately 229 million people each year, 94% of whom are recorded in tropical regions (World Health Organization, 2021). Part of the WHO African region, the DRC is home to more than 10% of the global malaria burden (Kayiba et al., 2024; World Health Organization, 2024). Of 233 million cases noted in the WHO African Region in 2022, 12% of them were recorded in the RDC (World Health Organization, 2024).

Malaria is caused by the parasite of the genus *Plasmodium*, transmitted by female mosquitoes of the genus *Anopheles*. Although the current use of chemical larvicides and repellents against the malaria vector is widely accepted in several countries, and they have even received authorization from the Environmental Protection Agency (EPA), environmental risks and health are frequently postponed (Gunathilaka et al., 2021; Runge et al., 2021; Wong et al., 2019). We also observe today an increased resistance of mosquitoes to these products in the DRC and the world (Hubbard & Murillo, 2024; Matubi et al., 2020; Nguiffo-Nguete et al., 2023; Wat'senga et al., 2020).

In addition, the high cost for populations living in developing countries also represents another disadvantage. This cost becomes exorbitant especially when the areas to be treated are constantly flooded with water, and the anopheles population explodes, or when the products used are not very powerful. There is, therefore, a need to develop new larvicidal and repellent agents that are more effective, less toxic, respectful of the environment, and more financially accessible (Gunathilaka et al., 2021; Runge et al., 2021; Wong et al., 2019).

There are many avenues of research, but the exploration of natural resources appears to be one of the most promising because they constitute, due to their biodiversity, the largest reserve of active substances (Miethke et al., 2021). Since the beginning of time, man has turned to plants to find the essentials of food, medicine, and survival (Singh et al., 2016). Phytotherapy is an ancient medical discipline of traditional medicine based on using medicinal plants to treat many diseases. It is still relevant, with ever-increasing popularity in recent years (Ullah et al., 2010). Work stipulates that in developing countries of Asia, Africa, and Latin America, medicinal plants constitute precious resources for most rural populations, more than 80% of whom use them to provide their healthcare. This preference is explained by the proximity and accessibility of this type of care, at an affordable cost and primarily due to the lack of access to modern medicine for these populations (Ullah et al., 2010). These plants reflect the main health concerns and the importance of traditional medicine for local people (Pathy et al., 2021).

The DRC is characterized by its richness and the diversity of the origin of its flora. It constitutes a veritable phylogenetic reservoir, enabling it to occupy a privileged place among countries with a long medical tradition and traditional know-how based on medicinal plants (Tchicaillat-Landou et al., 2018). However, the medicinal flora of this country remains so far known mainly empirically. Several desires converge to preserve and enhance it. Ethnobotanical surveys contribute, on their part, to gathering and constituting a precious source of information ready to be exploited scientifically (Kimpouni et al., 2019b).

This study, an ethnobotanical survey in the DRC, was conducted among traditional healers (TH), vegetable growers (VG), and other users of conventional plants in households (OU). Its objective was to gather more information about the plants used by these players in traditional medicine either to treat infectious diseases, to prevent the development of insect larvae in water, or to repel certain insects harmful to crops and water. This is done to promote these plants with a view to sustainable exploitation.

METHODS

Study material

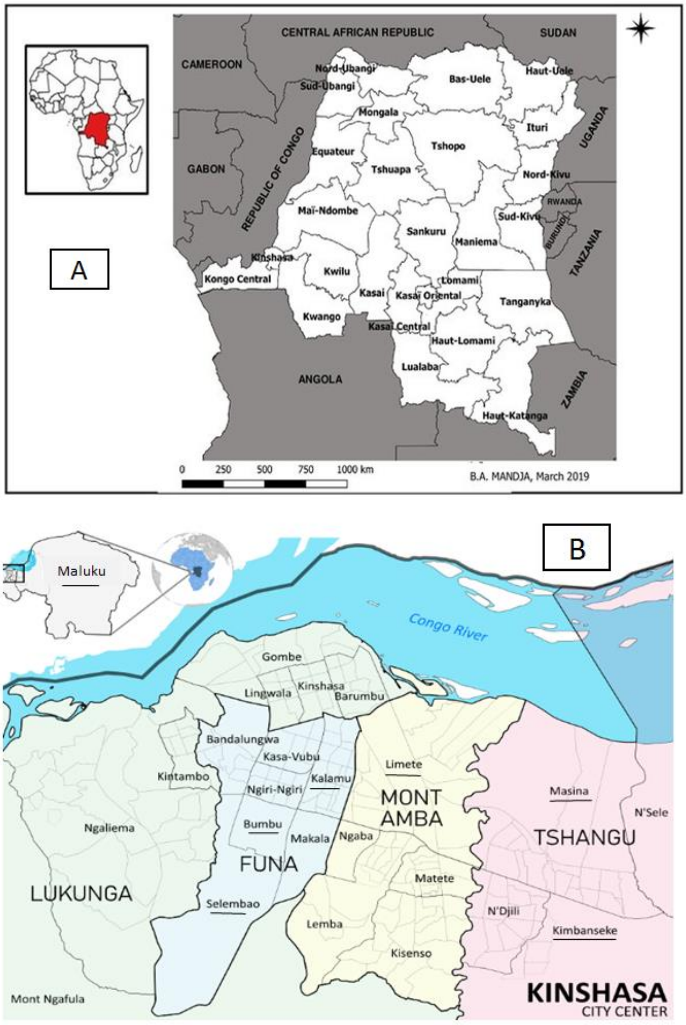
This ethnobotanical study was carried out through a series of surveys using a pre-established questionnaire in the French language, completed either online or during visits to the study-chosen sites. The survey questionnaire was designed and validated following guidelines proposed by Ranganathanet et al. (2023). Briefly, the questionnaire was written in French and then submitted to a pilot group of respondents for preliminary validation to avoid any confusion in the questions asked. Then, the questionnaire was rewritten and submitted to a group of internal experts for validation. The validated questionnaire was submitted to the internal ethics committee of the University of Kinshasa. The respondent signs at the bottom of the form acknowledging having given their consent and freely responding to the questionnaire proposed to them. The survey questionnaire included sociodemographic data, displaying the identity of the respondent (sex, age, level of education, origin of knowledge) and ethnobotanical data on anti-infective, larvicidal, or repellent plants (vernacular name, parts used, indications, mode of preparation, mode, and route of administration, etc.).

Study area

This study was carried out in the DRC, an African country that covers an area of 2 345 000 Km^2 and possesses land and liquid boundaries representing a total length of 10 340 Km. As shown in Figure 1A (Mandja et al., 2019), the DRC is bordered by nine countries. The DRC generally enjoys a tropical climate and has a great diversity of soils and vegetation. The capital, Kinshasa, is located on the Congo River, which is the country's main drainage system. The DRC relief goes from the plains to the mountains, passing by low and high plateaus. It is interrupted by two estuaries and is situated between 5°46' and 6°03' South latitude and 12° 12' and 12° 22' East longitude. This coastline is linked to the continent by the chain of Mounts Bangu (Karume et al., 2022). From a geological point of view, the coastline consists of a sedimentary basin of Cretaceous age which contains detrital deposits of marine origin and continental. The coast's soil is sandy, clay-sandstone, ferritic, and hydromorphic. The coastal vegetation is also varied and dominated by the forest of mangroves. Ocean water's

temperature varies from 25°C at the surface to 10°C at 300 m deep (Lateef et al., 2010).

Figure 1:
(A) Map of 26 provinces and bordering countries of DRC (Mandja et al., 2019), (B) Map of 24 municipalities of Kinshasa (Masamba et al., 2023)



Sample size and selection of sources

This cross-sectional survey was conducted through different DRC's provinces. Firstly, the survey was launched to the VG present in Kimwenza station, Premonstratensian monastery, and Sendwe Boulevard sites in the city province of Kinshasa. These three sites were chosen because they constitute reference sites for the sale of plant-based products in Kinshasa. Among VG who work in these well-known and highly reputable sites, 105 VG (53 women and 52 men) responded to the survey.

Secondly, the survey was also carried out among TH located in reputed markets or sites in Kinshasa related to the treatment with traditional medicine. 20 TH (12 women and 8 men) from these sites in Kinshasa agreed to participate in the survey. These TH provide information on the anti-infective plants they use, which have been registered, identified, and chosen according to their reputation within the population.

Thirdly, 7 of the 24 municipalities of Kinshasa were also consulted door-to-door or online, with the overall participation of 910 households due to 130 households distributed in different neighborhoods of each municipality. These are the municipalities of Maluku (Ma), Bumbu (Bu), Selembao (Se), Masina (Mas), Kimbanseke (Ki), Kalamu (Ka), and Limete (Lu), shown in Figure 1B. Unpublished data from the National Malaria Control Program (NMCP) made it possible to select these municipalities, given that they are classified among those with high malaria prevalence in Kinshasa city.

The online survey was completed in the other provinces of the DRC, without Kinshasa. However, only 10 provinces responded to the survey. In all, 43 residents registered in 10 of the DRC's 26 provinces (Kongo Central 16, Kasai 2, Tshopo 4, Sud-Kivu 4, Tshuapa 2, Nord-Kivu 10, Tanganyika 1, Sankuru 1, Kasaï oriental 2, Haut Katanga 1) took part in the online survey. All these residents of Kinshasa (Ma, Bu, Se, Mas, Ki, Ka, and Lm) and those of other provinces (PR) represent in this survey the group called "other plant users (OU)".

Collection of information and conduct of the investigation

This survey was spanned for 4 months (1st April to 31st July 2022) in the DRC. It encouraged the participants to reveal information on the plants they use to fight the various infectious diseases that affect this region, prevent the development of insect larvae in water, or repel certain insects harmful to crops and water.

Data processing and analysis

In addition to the data collected on the survey sheets, botanical documents made it possible to determine the scientific names and families of the plants. Qualitative data were translated into quantitative data in a database, then processed and analyzed statistically using Excel 2019 and GraphPad software. A descriptive statistical method using frequencies and percentages was used to analyze the sociodemographic data of the respondents, and the results

of the ethnobotanical survey were analyzed using citation frequencies. To assess the distribution of botanical families, plant species, plant parts, and various antimicrobial properties of the identified medicinal plants, the citation frequency (CF) of each of these parameters was calculated as follows:

$$CF = \frac{NCP}{NCT} x\ 100$$

where NCP represents the number of citations for the parameter considered and NCT is the total number of citations of this parameter (Rehman et al., 2023).

RESULTS

Sociodemographic data

20 TH, 105 VG, and 953 OU took part in the survey. The average age of TH, VG, and OU was 43, 41, and 39 years, respectively **(Table 1)**. There were no TH or VG in the 20-30, 61-70, or over-70 age groups. TH and VG were only present in a small proportion of the 31-40 and 51-60 years and in a large proportion of the 41-50 years. No OU over 70 years old was enrolled in the survey. A significant number of OU from various other age groups participated in the survey, with a high proportion in the 41-50 age group. This survey recruited more male TH than females and more females than males among VG and OU **(Table 1)**.

Moreover, the VG were mainly illiterate. As for TH and OU, the literacy rates were 60% and 78%, respectively. Several TH, VG, and OU claimed to have inherited knowledge of the use of medicinal plants from their cultures. The detailed data are placed in **Table 1** below.

Table 1:
Socio-demographic profile of the respondents

Factors	Category	Percentage (%)		
		TH	VG	OU
Sex	Male	60	49	36
	Female	40	51	64
Age (years old)	20-30	0	0	18
	31-40	15	27	22
	41-50	60	43	34
	51-60	25	30	17
	61-70	0	0	9
	Over 70	0	0	0
Education level	Literate	60	28	78
	Illiterate	40	72	22
Origin of phytotherapy initiation	Cultural heritage	70	95	42
	Revelation	30	0	0
	Family	0	5	20
	School	0	0	11
	University	0	0	13
	Media	0	0	14

Legend: TH (Traditional healer), VG (Vegetable grower), OU (Other plant users)

Ethnobotanical data

The ethnobotanical data of anti-infectious, larvicidal, and repellent plants inventoried by TH, VG, and OU of traditional medicine are given in **Tables 2** and **3** below.

Table 2:
Medicinal plants used as antimicrobial, larvicide, and repellent in the DRC

Plant species	Vernacular and common names	Family	Part used	Properties	Source	Traditional use	NCP
Acacia ssp.	Acacia (F, Li)	Fabaceae	Leaves	Repellent	OU (PR)	Repellent	2
Aframomum alboviolaceum (Ridl.) K.Schum.	Ntundulu (Kk), Ditundu (L), Ntondolo (Li)	Zingiberaceae	Leaves, fruits	Antimicrobial	OU (Ma, Bu, Se)	Conjunctivitis, measles, urinary tract infectious	7
Agave sisalana Perrine	Tshisegesege (Kk)	Asparagaceae	Roots	Antimicrobial	OU (Ma)	Scabies	1
Albizia lebbeck (L.) Benth	Langue de femme (F)	Fabaceae	Leaves	Antimicrobial	OU (PR)	Malaria	1
Alchornea cordifolia (Schumach. & Thonn.)	Mbuzi mbuzi (Kk)	Euphorbiaceae	Leaves, roots	Antimicrobial	OU (Ma, Se, Ka, Lm)	Flu, malaria, vaginal pruritus	29

Allium cepa L.	Oignon (F), Bola (Kk), Litungulu (Li), Ditungulu (L)	Amaryllidaceae	Bulb	Antimicrobial	TH OU (Ma) OU (PR)	Respiratory infections	7
Allium sativum L.	Ail (F), ayi (Li)	Amaryllidaceae	Bulb	Antimicrobial	TH OU (Ma, Bu, Se, Mas, Ka, Lm) OU (PR)	Urinary tract, respiratory infections, amoebiasis, flu, tooth decay, infected wounds	37
Aloe vera (L.) Burm.f.	Badinseki (Kk)	Asphodelaceae	Leaves	Antimicrobial	OU (Ma, Bu) OU (PR)	Rashes, skin infections	8
Annona reticulate Sieber ex A.DC.	Coeur de boeuf (F), Kalabefu (L)	Annonaceae	Leaves	Antimicrobial	OU (Ka)	Flu	2
Artemisia afra Jacq. ex Willd.	Armoise africaine (F) Atemizia (Li)	Asteraceae	Leaves	Antimicrobial	OU (PR)	Malaria	6
Artemisia annua L.	Armoise chinoise (F), Atemizia (Li)	Asteraceae	Leaves	Antimicrobial	OU (PR)	Malaria	3
Averrhoa carambola L.	Carambole (F), Paka paka (Li, Kk), Mitotu (L)	Oxalidaceae	Fruits	Antimicrobial	OU (Bu, Mas)	Angina	6
Azadirachta indica A.Juss.	Neem (F), Nim (Li)	Meliaceae	Leaves	Antimicrobial	OU (PR)	Covid-19, skin infections	1
			Roots	Repellent	OU (PR)	Repellent	1
			Roots	Larvicidal	OU (PR)	Larvicide	1
Bambusa vulgaris Scrad ex Wendl.	Bambou de chine (F), Nshiba (L), Matutu (Kk)	Poaceae	Roots	Antimicrobial	OU (Ka)	Malaria	1
Bidens pilosa L.	Nsolokoto (Kk), kimana-ngansi (Kk), Mpotshia ya mbua (L), Kankanga (L), herbe aiguille (F)	Asteraceae	Leaves	Antimicrobial	OU (PR)	Sexually transmitted infections	1
Boswellia sacra Flück.	Encens (F), Kamonia (L)	Burseraceae	Leaves	Larvicidal	TH OU (Ka) VG (Bu, Se, Ki, Ka)	Larvicide	2
			Stem	Repellent	OU (Bu, Se, Ki, Ka)	Repellent	28
Bridelia ferruginea Benth.	Kimwindu (Kk), Tshinkunku (L), Mujimwika (L)	Phyllan Thaceae	Leaves	Antimicrobial	TH	Sexually transmitted infections	1
Brillantaisia patula T.Anderson	Lemba lemba (Li)	Acanthaceae	Leaves	Antimicrobial	OU (Bu, Se, Mas, Ki)	Shingles, urinary tract infections, measles, buruli ulcer	28
Bryophyllum pinnatum (Lam.) Oken	Hébreu (F), Luyuki (Kk)	Crassulaceae	Leaves	Antimicrobial	OU (Se, Ki)	Otitis	8
Calendula officinalis L.	Souci (F) Susi (Li)	Asteraceae	Leaves	Repellent	OU (Ki)	Repellent	1
Canarium schweinfurthii Engl.	Mbidi (Kk)	Burseraceae	Leaves	Antimicrobial	TH	Skin infections	1
Cannabis sativa L.	Cannabis (F) Diamba (Kk) (L), Bangi (Li)	Cannabaceae	Seeds	Antimicrobial	OU (Bu)	Bronchitis	2
Capsicum frutescens L.	Piment (F), Pili-pili (Li), Ndunga (L)	Solanaceae	Leaves	Repellent	VG	Repellent	1
Carica papaya L.	Papaye (F), Payipayi (Li), Tshinguenda (L), Dipapayi (Kk)	Caricaceae	Roots, leaves	Antimicrobial	TH OU (Ma, Bu, Se, Mas, Ka, Lm) OU (PR)	Ringworms, flu, tooth decay, amoebiasis, scabies, urinary tract infections, sexually transmitted infections	38
			Leaves	Larvicidal	TH	Larvicide	1
			Leaves	Repellent	VG	Repellent	1
Centella asiatica (L.) Urb.	Lilembetene (L)	Apiaceae	Leaves	Antimicrobial	OU (PR)	Urinary tract infections	1
Chenopodium ambrosioides L.	Nkasa kindongo (Kk), Dinkanga bakishi (L)	Chenopodiacea e	Leaves	Antimicrobial	OU (Se)	Genital infections	2
Cinchona officinalis L.	Quinquina (F), Kinkina (Li)	Rubiaceae	Roots	Antimicrobial	OU (PR)	Malaria	1
Citrus x limon (L.) Osbeck	Citronnier (F), Lala ma nsa (Kk) Bimuma bia mpusu (L)	Rutaceae	Leaves	Antimicrobial	TH OU (Ma) OU (PR)	Flu, angina, malaria	16
			Roots	Repellent	OU (Bu, Se)	Repellent	5
			Whole plant	Larvicidal	OU (PR)	Larvicide	1

Citrus medica L.	Malala ma ngayi (Kk)	Rutaceae	Leaves	Repellent	OU (PR)	Repellent	2
Citrus x sinensis (L.) Osbeck	Oranger (F), lala dinzenzo (Kk)	Rutaceae	Leaves	Repellent	OU (Bu, Se, Ki, Ka)	Repellent	8
			Fruits	Larvicidal	OU (Bu, Lm)	Larvicidal	6
Coffea arabica L.	Café (F), kafé (Li)	Rubiaceae	Leaves	Larvicidal	TH	Larvicidal	1
Cola acuminata (P.Beauv.) Schott & Endl.	Likasu (L), Nkasu (Kk)	Malvaceae	Leaves	Repellent	VG	Repellent	5
Colletoecema dewevrei (De Wild.) Petit	Nsunda (Kk)	Rubiaceae	Leaves	Antimicrobial	TH	Skin infections	2
Conyza sumatrensis (Retz.) E.Walker	Mfumu zi matebu (Kk), Fumu di kiula (Kk), Kabangabanga (L)	Asteraceae	Leaves	Antimicrobial	OU (PR)	Ringworms	2
Costus afer Ker Gawl.	Minkeni (Kk)	Costaceae	Leaves	Repellent	VG	Repellent	1
Crossopteryx febrifuga (Afzel. ex G.Don) Benth.	Mumpala mbaki (Kk), Mbizo (Li)	Rubiaceae	Leaves	Antimicrobial	OU (Lm)	Sexually transmitted infections	1
Cupressus lusitanica Mill.	Ekilau (K)	Cupressaceae	Nuts	Antimicrobial	OU (PR)	Ear, nose and throat infections	1
			Nuts	Repellent	OU (PR)	Repellent	2
Cymbopogon citratus (DC.) Stapf	Citronnelle (F), Sinda (Li), Disela diamputu (L) Sinda dimputu (Kk)	Poaceae	Leaves	Larvicidal	VG OU (Bu) OU (PR)	Larvicide	14
			Leaves	Repellent	VG OU (Ma, Bu, Ki) OU (PR)	Repellent	16
			Leaves	Antimicrobial	OU (Ka)	Malaria, flu, respiratory infections	4
Cymbopogon densiflorus (Steud.) Stapf	Musangu sangu (Kk), Kindongo (Kk), Tshikota (L)	Poaceae	Leaves	Repellent	OU (Bu, Ki, Ka, Lm) OU (PR)	Repellent	15
			Leaves	Antimicrobial	OU (Se)	Urogenital infections	4
Cyperus esculentus L.	Tomboka (Li)	Cyperaceae	Nuts	Repellent	VG	Repellent	2
Dacryodes edulis (G.Don) H.J.Lam	Safoutier (F), Nsafu (Kk), Safu (Li)	Burseraceae	Leaves	Larvicidal	VG	Larvicide	1
			Leaves	Antimicrobial	OU (Ki) OU (PR)	Tooth decay, urinary tract infections	4
Elaeis guineensis Jacq.	Palmier à huile (F), Ba di nsamba (Kk), Dibwe (L), Mbila (Li)	Arecaceae	Leaves, nuts	Repellent	VG OU (Ma, Bu, Mas, Ka) OU (PR)	Repellent	14
			Leaves	Larvicidal	OU (Ma, Lm)	Larvicide	5
Eucalyptus globulus Labill.	Eucalyptus (F), Bikali (Li)	Myrtaceae	Leaves	Larvicidal	VG OU (Ki) OU (PR)	Larvicide	3
			Leaves	Antimicrobial	OU (Ma) OU (PR)	Flu, tuberculosis	8
			Leaves	Repellent	OU (Bu, Se, Ka, Lm) OU (PR)	Repellent	18
Euphorbia hirta L.	Kandundu (L), Kikula ntedi (Kk), Kabudimbwa (L)	Euphorbiaceae	Leaves	Antimicrobial	OU (PR)	Urinary tract infections	1
Garcinia huillensis Welw. ex Oliv.	Kisima (Kk)	Clusiaceae	Leaves	Antimicrobial	TH	Respiratory infections, sexually transmitted infections	1
Garcinia kola Heckel	Ngadiadia (Kk), (Li)	Clusiaceae	Nuts	Repellent	VG	Repellent	12
			Nuts	Antimicrobial	OU (Bu, Ka)	Malaria	10
Garcinia huilensis Welw. ex Oliv.	Kisima (Kk)	Clusiaceae	Roots	Antimicrobial	OU (PR)	Sexually transmitted infections	1
Gardenia ternifolia Welw. ex Baker	Kilemba nzau (Kk), Laurier d'Afrique (F)	Rubiaceae	Roots	Antimicrobial	TH	Respiratory infections	2

Gymnanthemum amygdalinum (Delile) Sch.Bip. ex Walp.	Malulu (Kk)	Asteraceae	Leaves	Antimicrobial	OU (Lm)	Chickenpox	1
Heinsia crinita (Wennberg) G.Taylor	Kinkete (Kk), Mpumbu mutsi (L)	Rubiaceae	Leaves	Antimicrobial	TH	Flu	1
Helichrysum mechowianum	Ludimi lu mbwa (Kk)	Asteraceae	Roots	Antimicrobial	OU (PR)	Urinary tract infections	1
Hibiscus esculentus L.	Dongo dongo (Li), Gombo (F), Mulembua (L)	Malvaceae	Fruits	Antimicrobial	OU (Bu)	Flu	3
Hyptis suaveolens Poit.	Nkama-nsongo (Kk)	Lamiaceae	Fruits	Repellent	OU (PR)	Repellent	1
Ipomoea batatas (L.) Lam.	Matembele (Li), Mvunguta (Kk), Patate douce (F), Tshilunga (L)	Convolvulaceae	Leaves	Antimicrobial	OU (Ki)	Amoebiasis	2
Lannea antiscorbutica (Hiern) Engl	Kalombo (L)	Anacardiaceae	Leaves, bark	Antimicrobial	TH	Tooth decay, infectious diarrhea, helminthiasis	1
Lantana camara L.	Landani (Kk), Lantana (F)	Verbenaceae	Leaves	Repellent	OU (PR)	Repellent	1
Laurus nobilis L.	Laurier (F), Feyi ya laurier (Li)	Lauraceae	Leaves	Antimicrobial	OU (PR)	Tooth decay	1
Lippia multiflora Moldenke	Bulukutu (Li), Thé de Gambie (F)	Verbenaceae	Leaves	Antimicrobial	OU (Bu)	Covid-19	8
			Leaves	Repellent	OU (Mas)	Repellent	5
Malus domestica (Suckow) Borkh.	Pomme (F, Li)	Rosaceae	Leaves	Antimicrobial	OU (Ka, Lm)	Malaria	4
Manihot esculenta Crantz	Manioc (F), Pondu (Li), Dioko (Kk), Kaleji (L)	Euphorbiaceae	Tubers, leaves	Antimicrobial	TH OU (Bu, Se, Mal, Ki, Ka, Lm) OU (PR)	Smallpox, chickenpox, varicella, measles, skin infections	48
Mangifera indica L.	Manguier (F), Manga (Kk) (Li), Dingeya (L)	Anacardiaceae	Roots	Larvicidal	VG OU (Ka)	Larvicide	2
			Leaves	Repellent	VG OU (Mas)	Repellent	3
			Fruits	Antimicrobial	TH OU (Ma, Bu, Mas, Ki, Ka, Lm) OU (PR)	Urinary tract infections, malaria, amoebiasis, sinusitis	48
Millettia versicolor Welw. ex Baker	Mbota (Kk), Bois d'or (F)	Fabaceae	Leaves	Antimicrobial	TH	Sexually transmitted infections	1
Mitracarpus hirtus (L.) DC.	Banda nzazi (Kk), Kugwa nkusu (L)	Rubiaceae	Leaves	Antimicrobial	OU (PR)	Skin infections	1
Mondia whitei (Hook.f.) Skeels	Kimbiolongo (Li), Ntubungu (Kk)	Apocynaceae	Roots	Antimicrobial	TH	Urinary tract infections	4
Monodora myristica (Gaertn.) Dunal	Mpeya (Kk), Muscadier d'Afrique (F)	Myristicaceae	Seeds	Antimicrobial	TH	Sexually transmitted infections	1
Moringa oleifera Lam.	Ben ailé (F), Moringa (Li)	Moringaceae	Leaves	Antimicrobial	TH OU (Se, Ki)	Malaria, angina	23
			Leaves	Repellent	OU (PR)	Repellent	3
			Leaves	Larvicidal	OU (PR)	Larvicide	1
Morinda morindoides (Baker) Milne-Redh.	Kongo bololo (Li), Nkonga bululu (L), Meso nkama (Kk)	Rubiaceae	Bulb	Antimicrobial	TH OU (Ma, Mas, Bu, Ki, Ka, Lm)	Malaria, flu, amoebiasis, tooth decay, urinary tract, respiratory infections, Covid-19	82
			Leaves	Larvicidal	TH	Larvicide	1
Musa paradisiaca L.	Bananier (F) Mankondo, Bitiba (Kk), Makemba (Li), Bibota (L)	Musaceae	Fruits	Repellent	OU (Mas)	Repellent	2
Newbouldia laewis	Mumpese mpese (Kk), Mupeshipeshi (Li)	Bignoniaceae	Leaves, stem	Antimicrobial	TH	Malaria, conjunctivitis	2
Nicotiana tabacum L.	Tabac (F), Tumbako (Li), Fumu (Kk)	Solanaceae	Leaves	Larvicidal	VG	Larvicide	1
Nymphaea alba L.	Nénuphar blanc (F), Longa longa di masa (Kk)	Nymphaeaceae	Leaves	Antimicrobial	OU (PR)	Flu	1

Ocimum gratissimum L.	Lumbalumba (L), Tshilua benyi (L), Baumier (F)	Lamiaceae	Leaves	Antimicrobial	OU (Ma, Mas, Ki, Ka, Lm) OU (PR)	Infected wounds, flu, respiratory infections, malaria, rashes	56
			Roots	Repellent	OU (Bu, Mas, Lm), VG	Repellent	15
Pentaclethra macrophylla Benth.	Ngansi (Kk), Arbre à semelles (F)	Fabaceae	Leaves	Antimicrobial	TH	Infectious diarrhea	1
Pentadiplandra brazzeana Baill.	Lisoka (Li), Nkenge kiasa (Kk)	Pentadiplandraceae	Leaves	Larvicidal	OU (Ka)	Larvicide	1
			Leaves	Antimicrobial	TH	Urogenital infections	1
Pentas lanceolata (Forssk.) Deflers	Bouquet d'étoiles (F)	Rubiaceae	Roots	Antimicrobial	OU (PR)	Urinary tract infections	1
Persea americana Mill.	Avocatier (F), Savoka (Li), Divoka (Kk)	Lauraceae	Leaves	Antimicrobial	TH OU (Bu, Mas, Ki)	Ringworms, skin infectious, malaria	12
			Leaves	Repellent	OU (Mas)	Repellent	2
Physalis angulata L.	Opa (Li)	Solanaceae	Leaves	Antimicrobial	OU (PR)	Skin infections	1
Pinus spp.	Pin (F, Li)	Pinaceae	Roots	Repellent	OU (Ma, Bu, Ka, Lm) OU (PR)	Repellent	8
			Leaves	Larvicidal	OU (PR)	Larvicide	1
Piper umbellantum L.	Dilombolombo (L), Lembe ki makongo (Kk)	Piperaceae	Leaves	Antimicrobial	TH	Urogenital infections	1
Plukenetia conophora	Makasu ya bololo (Li), Makasu nsinga (Kk)	Euphorbiaceae	Leaves	Antimicrobial	VG	Urinary tract infections	1
Psidium guajava L.	Mapela (Li) Tshinkalafi (L)	Myrtaceae	Leaves	Antimicrobial	OU (Bu, Ki) OU (PR)	Tooth decay, amoebiasis, infectious diarrhea	12
Quassia africana (Baill.) Baill.	Yombo (Kk), Ekbetema (Li)	Simaroubaceae	Bark, roots, stem, leaves	Antimicrobial	OU (Ma, Bu, Ka, Lm) TH	Typhoid fever, malaria, urinary tract infections	28
Rauvolfia vomitoria Afze	Kapanda panda (L), Kilungu, Kilungwa (Kk), Ndokolo (Li)	Apocynaceae	Leaves	Antimicrobial	OU (Lm)	Vaginal infections	1
Saccharum officinarum L.	Canne à sucre (F), Mukuku (Kk), Muenga (L)	Poaceae	Leaves	Antimicrobial	OU (Ka)	Buruli ulcer	1
Sarcocephalus latifolius (Sm.) E.A.Bruce	Kienga (Kk), Pêcher africain (F)	Rubiaceae	Leaves	Antimicrobial	TH	Infected wounds	1
Securidaca longepedunculata Fresen.	Likalakonki (Kk)	Polygalaceae	Roots	Antimicrobial	TH	Skin infections, respiratory infections	1
Senna alata (L.) Roxb.	Dartrier (F), Mutshi wa diota (L), Bawu bawu (Kk)	Fabaceae	Leaves	Antimicrobial	OU (PR)	Skin infections	1
Senna occidentalis L.	Kanioka nyoka (Kk), Lukunde ba jangi (L)	Fabaceae	Leaves	Repellent	OU (Ki)	Repellent	1
			Leaves	Antimicrobial	OU (Ka)	Amoebiasis	3
Sida acuta Burn.f.	Tumfumfu (Kk), Mimvumvu (L)	Malvaceae	Leaves	Antimicrobial	OU (PR)	Malaria	1
Solanum aethiopicum L.	Bilolo (Li), Muteta (L), Musoso (Kk)	Solanaceae	Leaves	Repellent	VG	Repellent	1
Solanum lycopersicum L.	Tomate (F), Lumantu (Kk), Tumata (L)	Solanaceae	Leaves	Antimicrobial	OU (Ki, Ka, Lm)	Amoebiasis, rashes	8
Strychnos cocculoides Baker	Mampuya (Kk)	Gentianaceae	Leaves	Antimicrobial	TH	Urinary tract infections	2
Syzygium guineense subsp. Guineense	Kikulu (Kk)	Myrtaceae	Nuts	Antimicrobial	OU (PR)	Urinary tract infections	1
Tanacetum cinerariifolium (Trevis.) Sch.Bip	Pyrèthre (F)	Asteraceae	Leaves	Repellent	OU (PR)	Repellent	1
Tephrosia spp	Bwalu (Kk)	Fabaceae	Leaves	Larvicidal	OU (PR)	Larvicide	1
Tephrosia vogelii Hook. f.	Mbaka (Kk)	Fabaceae	Leaves	Larvicidal	OU (Ka)	Larvicide	1
Tetradenia riparia (Hochst.) Codd	Mutozo (Li)	Lamiaceae	Leaves	Antimicrobial	OU (Ma, Se, Mas, Ki, Ka, Lm), OU (PR)	Sinusitis, measles, otitis, tooth decay, scabies, skin infectious, mycosis	71
			Leaves	Repellent	OU (PR)	Repellent	1

Tithonia diversifolia (Hemsl.) A. Gray	Makasa ya bololo (Kk), Minsumbululu (L)	Asteraceae	Leaves	Antimicrobial	OU (PR)	Flu	1
Triumfetta tomentosa Bojer	Tshikolokoso (L), Mokonge (Li)	Tiliaceae	Leaves	Antimicrobial	OU (Se)	Angina	1
Urena lobata L.	Mpunga (Kk), Jute congolais (F)	Malvaceae	Leaves	Larvicidal	VG	Larvicide	3
Urtica dioica L.	Grande ortie (F), Ekpakpa (Li)	Urticaceae	Leaves	Repellent	OU (PR)	Repellent	1
Uvaria scabrida Oliv.	Kalombo (L)	Annonaceae	Leaves	Antimicrobial	TH	Skin infections	2
Vernonia amygdalina Delile.	Mundudi nduddi (Kk), Mosungu bululu (L)	Asteraceae	Leaves	Antimicrobial	OU (PR)	Malaria, helminthiasis	2
Zingiber officinale Roscoe	Gingembre (F), Tangawisi (Kk)	Zingiberaceae	Rhizome	Antimicrobial	TH OU (Bu) OU (PR)	Urinary tract infections, sinusitis	8

Legend: Bu (Bumbu), E (English), F (French), Ka (Kalamu), Kk (Kikongo), Ki (Kimbanseke), L (Luba), Li (Lingala), Lm (Limete), Ma (Maluku), Mas (Masina), NCP (number of citation for the plant considered), OU (Other plant users), PR (Province), Se (Selembao), TH (Traditional healer), VG (Vegetable grower).

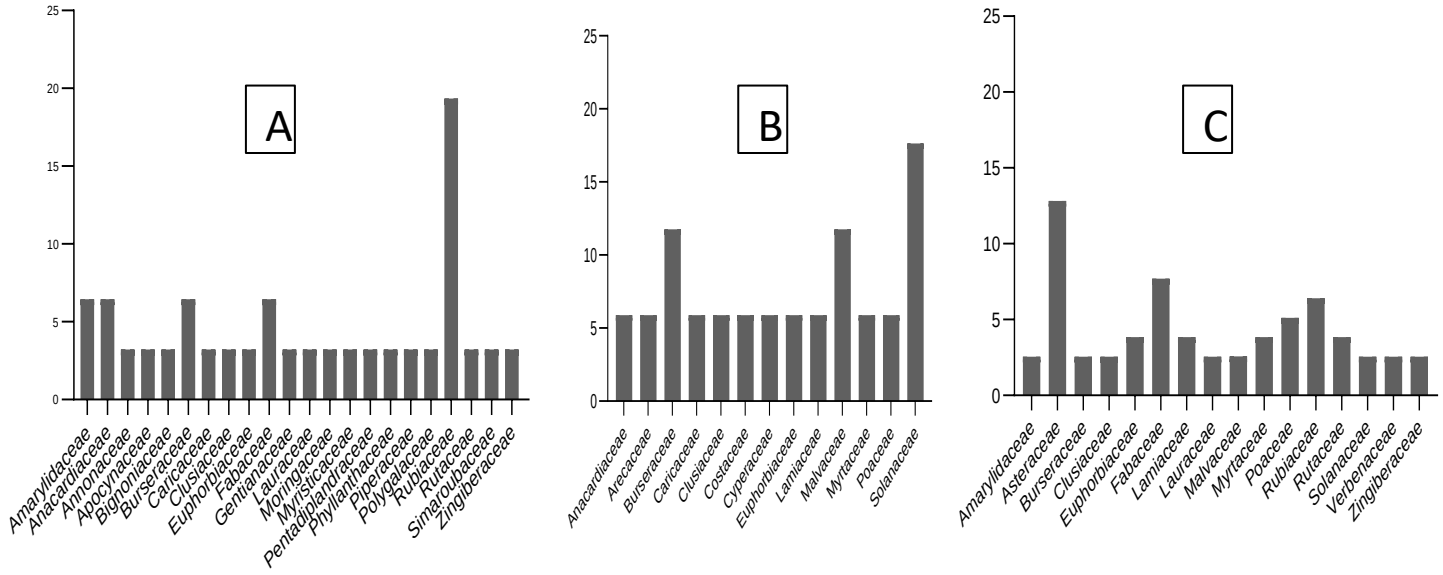
Table 3:
Other medicinal plants used as antimicrobial, larvicide, and repellent in the DRC

Plants species*	Vernacular names	Family	Part used	Properties	Source	Traditional use	NCP
NI	Kikwadi (-)	NI	Fruits	Antimicrobial	OU (Se)	Scabies, ringworms	2
NI	Bopilo (-)	NI	Leaves	Repellent	VG	Repellent	1
NI	Kifua (Kk)	NI	Leaves	Larvicidal	TH	Larvicide	1
NI	Kaja (Kk)	NI	Leaves	Larvicidal	TH	Larvicide	1
NI	Manipetume (Kk)	NI	Leaves	Larvicidal	TH	Larvicide	1
NI	Mushini (L)	NI	Leaves	Antimicrobial	TH	Skin infections	1
NI	Kieba (L)	NI	Leaves	Antimicrobial	TH	Genital infections	1
NI	Budiatondu (L)	NI	Leaves	Antimicrobial	TH	Mycosis	1
NI	Musumbala (-)	NI	Leaves	Antimicrobial	TH	Skin infections	1
NI	Dukula kula (-)	NI	Fruits	Repellent	OU (Ma)	Repellent	1
NI	Kasuku ou Musuku (-)	NI	Leaves	Repellent	OU (Ma)	Repellent	1
NI	Luntila ntila (-)	NI	Leaves	Antimicrobial	OU (Se)	Genital infections	4
NI	Gbanzinga (-)	NI	Leaves	Antimicrobial	OU (Se)	Skin infectious	1
NI	Djokota (-)	NI	Leaves	Antimicrobial	OU (Se)	Scabies, ringworms	1
NI	Nlakasa (-)	NI	Leaves	Antimicrobial	OU (Mas)	Conjunctivitis	2
NI	Mupelepele (Kk)	NI	Leaves	Antimicrobial	OU (Mas)	Angina, paronychia	2
NI	Mvuzi mvuzi (Kk)	NI	Leaves	Antimicrobial	OU (Mas)	Typhoid fever	6
NI	Ebaka (Li)	NI	Leaves	Antimicrobial	OU (Ka)	Amoebiasis	1
NI	Kibulakale (-)	NI	Leaves	Antimicrobial	OU (Ka)	Skin infections	1
NI	Bolombo (-)	NI	Leaves	Larvicidal	OU (Ka)	Larvicide	1
NI	Kikwata (-)	NI	Leaves	Antimicrobial	OU (Lm)	Mycosis	1
NI	Manioka nioka (-)	NI	Leaves	Repellent	OU (Lm)	Repellent	2
NI	Ngote ngote (-)	NI	Roots	Antimicrobial	OU (PR)	Mycosis	1
NI	Mikalangani (-)	NI	Leaves	Antimicrobial	OU (PR)	Urinary tract infections	1
NI	Ciprin (-)	NI	Leaves	Repellent	OU (PR)	Repellent	1
NI	Ibuwe (-)	NI	Leaves	Repellent	OU (PR)	Repellent	1
NI	Kabozo (-)	NI	Leaves	Larvicidal	OU (PR)	Larvicide	1
NI	Asseng (-)	NI	Leaves	Larvicidal	OU (PR)	Larvicide	1

Legend: - (unspecified vernacular language), Bu (Bumbu), Ka (Kalamu), Kk (Kikongo), L (Luba), Li (Lingala), Lm (Limete), Ma (Maluku), Mas (Masina), NCP (number of citation for the plant considered), NI (Not identified), OU (Other plant users), PR (Province), Se (Selembao), TH (Traditional healer), VG (Vegetable grower).

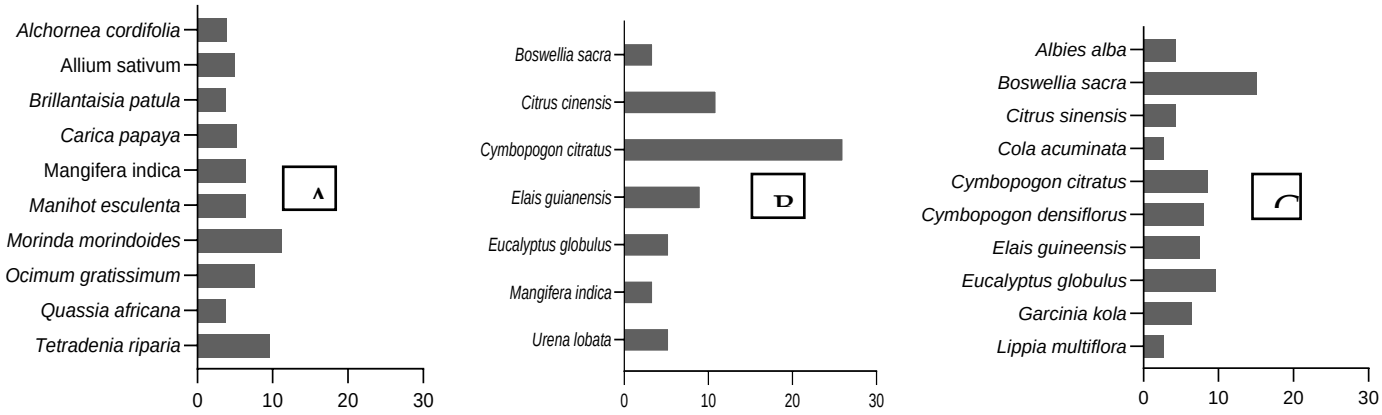
For this study, 132 plant species (104 identified and 28 unidentified based on their botanical name or family) were reported. The survey of TH made it possible to list 33 antimicrobial and 7 larvicidal species of plants belonging to 22 known botanical families, the most represented of which is the Rubiaceae (19.35%). TH did not cite any repellent species. Among VG, the 1 antimicrobial, 6 larvicidal, and 13 repellent species of identified plants belonged to 13 families, the most represented of which is the Solanaceae (17.64%). Among OU, 75 antimicrobial, 16 larvicidal, and 30 repellent species belonging to 41 known botanical families have been listed. The Asteraceae (12.82%) remained the most cited family. Other families may have been added to the data presented in **Figure 2**, as we were unable to identify 28 plant species cited by OU (20), VG (1), and TH (7) presented in **Table 3** above.

Figure 2:
Citation frequency of botanical families used by traditional healers (A), vegetable growers (B), and other plant users (C)



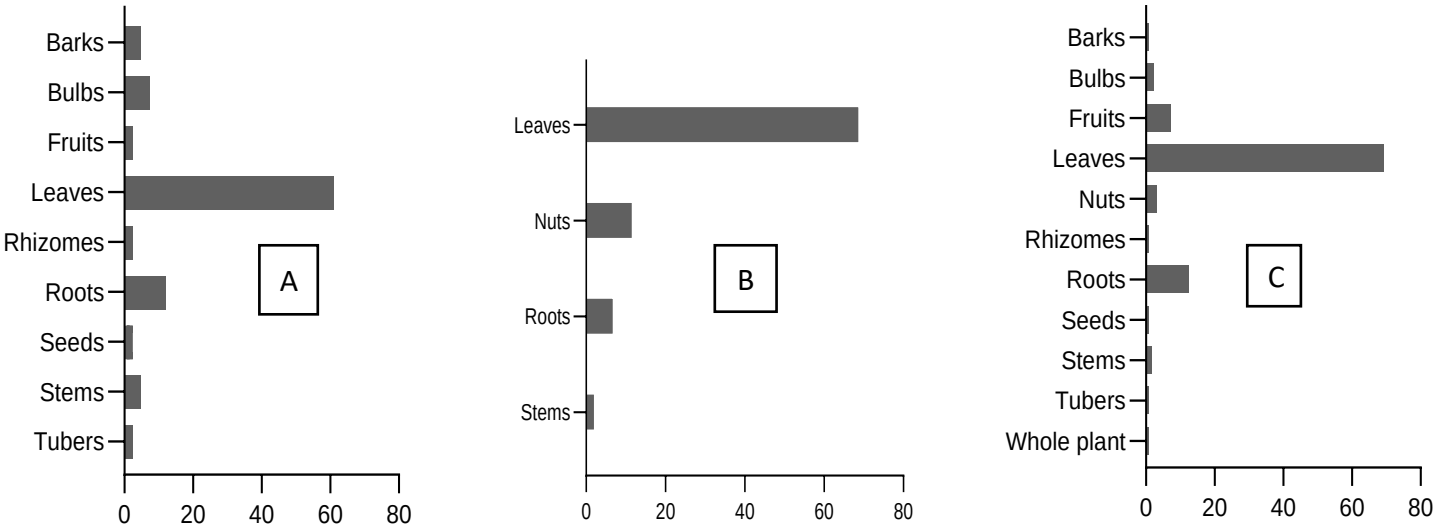
Morinda morindoides is the most cited antimicrobial species (11.26%) by TH, VG, and OU out of a total of 728 citations of the listed antimicrobial plant species (Figure 3A). The most cited larvicidal species out of the 53 taken up by these users of medicinal plants is *Cymbopogon citratus* (26.41%) **(Figure 3B)**. *Boswellia sacra* is the most cited repellent species (15.05%) among the 186 identified by VG and OU of medicinal plants interviewed in households **(Figure 3C)**.

Figure 3:
Citation frequency of (A) antimicrobial, (B) larvicidal and (C) repellent plant species



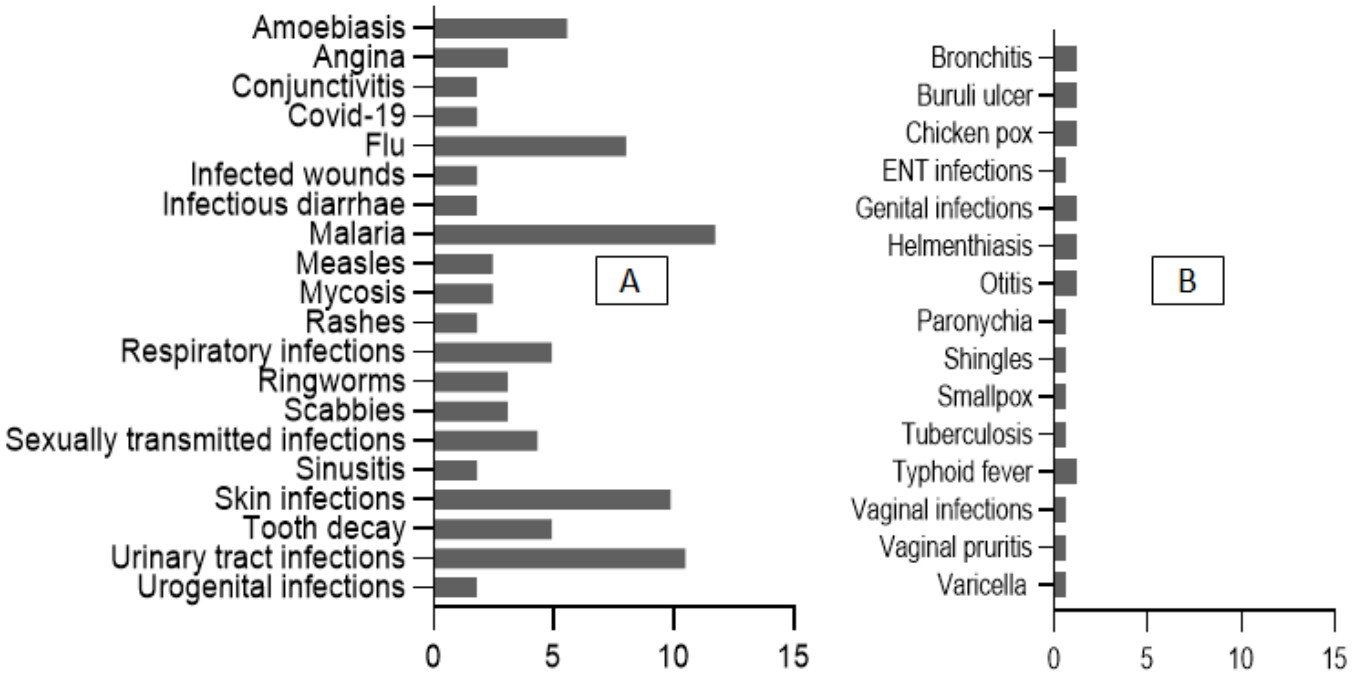
Leaves are the plant parts most used by TH (60.97%), VG (66.66%), and OU (69.29%) **(Figure 4)**.

Figure 4:
Citation frequency relative to different parts of plants used by traditional healers (A), vegetable growers (B), and other plant users (C)



TH, VG, and OU have reported many indications of medicinal plants used to treat infectious diseases. These properties are reported in **Figure 5 (A and B)**. 80% of the antimicrobial properties of identified plants are recognized in traditional African pharmacopoeias. 20% of the indications are additional information gathered during the survey.

Figure 5:
Citation frequency of antimicrobial properties of identified medicinal plants



DISCUSSION

The DRC continues to face multiple health problems (Maketa et al., 2013). As access to conventional medicine is limited for a significant proportion of the population, traditional medicine is a good alternative (Mutombo et al., 2022). Integrating the use of plants into modern medicine is not only sparking renewed interest in ancestral knowledge (Niazi & Monib, 2024), but also paving the way for innovative treatments that respect both the body and the environment (Chaachouay & Zidane, 2024). This promising symbiosis between tradition and modernity represents a major asset for the future of public health (Anand et al., 2019).

Traditional knowledge can therefore be integrated with modern medicine to support global health and the safe and effective treatment of pathologies (Negahban et al., 2018). The WHO advocates its recognition and modernization for primary healthcare. It has already given a favourable opinion on the integration of traditional medicine into modern healthcare practices. For this purpose, WHO has developed a strategy with several objectives, including the appropriate integration of traditional medicine into national healthcare systems. This strategy aims to implement traditional medicine policies and programs to promote the evaluation of the safety, efficacy, and quality of herbal medicines; improving the availability and accessibility of traditional medicine, and to increase the availability and accessibility of traditional medicine (World Health Organization, 2022).

Previous studies have also reported the use of plants for the management of IDs in the DRC (Manya et al., 2020; Masengo et al., 2023; Mbayo et al., 2016). Unfortunately, these studies are limited to a specific province and do not cover the entire extent of the DRC. To overcome this limitation, we carried out the study in several provinces of the DRC. Interestingly, this study shows the importance of traditional plants in Congolese community life. It was initiated with 20 TH, 105 VG, and 953 OU scattered in several provinces of the DRC. The public rejection to participate in the survey, especially among the TH, is the greatest limitation of this study. Despite all the explanations provided concerning the survey's objectives, which relate to the valorization of Congolese culture, some did not stop assimilating it to a competitive analysis, which led to several unsuccessful visits and the inability to interview more than 20 TH. Others agreed to be interviewed but did not readily give or confess to keeping some information about the plants. Although the survey was also done online, it could not be carried out on TH and VG in provinces other than Kinshasa. In addition, the number of online respondents is not sufficient given the size of the DRC. This also represents a weakness of this study.

In Africa, traditional medicine knowledge is undeniably precious and carefully guarded by the holders. Indeed, ritual practices require an adult age generally over 40 years old, and physical vigor to be initiated (Mahomoodally, 2013). This could explain the non-use or the low rate of use of medicinal plants observed in the 20-30 age group. Nevertheless, the presence of TH, VG, and OU aged 31-40 could underline the effort of young people in the search for knowledge in standard therapy in recent years. In addition, nowadays, health problems affect many people, making many people learn medicine recipes that enter health care. In addition, the predominance of adults over 40 shows that people of advanced age generally practice traditional therapy. This indicates the consistency of the information collected. Based on the information collected, we dare to believe that the number of plants provided is sufficient and confirms the interest that young people have in the use of plants by contacting older people to receive information. Several studies have also reported similar results concerning the involvement of older people (Kimpouni et al., 2019a; Mandjo et al., 2021).

The predominance of male TH observed in the population surveyed testifies to the first place they generally have in the exercise of professions within African societies, women being instead occupied with other tasks. Ashande et al. have also reported the predominance of men in traditional medicine (Ashande et al., 2023). However, the study reveals that women mainly own the market gardening sector. This strong presence of the fairer sex is explained by the fact that short-cycle income-generating activities attract women to meet family needs. These results coincide with those of Haug *et al.* (Haug et al., 2021), who observe a certain feminization of market gardening, although men are also interested in it. Among OU scattered throughout the country, a strong presence of women is also reported. This

is also explained by current health problems encouraging them to be interested in herbal medicinal recipes.

Indeed, in Africa, knowledge of medicinal plants' uses, and properties is generally acquired following a long experience transmitted from one generation to another. Learning about medicinal plants comes typically from the family, which shows the importance of the respectful transmission of knowledge in African customs (Mandjo et al., 2021) and justifies that the origins of knowledge most represented in this survey are cultural heritage.

The TH interviewed in this survey have at least reached the primary school level. These results are in agreement with those found by Kibungu et al., showing the ability of TH to transmit knowledge about medicinal plants (Pathy et al., 2021). The VG were mainly illiterate. These results confirm those of Angwafo and Bime (Angwafo & Eric Bime, 2020) in a study among VG who justify the non-literacy of these actors by the fact that market gardening is reserved for people in difficult financial conditions. OU are also mostly educated. Compared to TH and VG, OU with a high literacy rate is interested in the use of plants because they know how to read and therefore have the possibility of searching for information in the literature (books, papers, internet, etc.) on the use of medicinal plants beyond information received orally. Unlike illiterate TH and VG, OU with high literacy also have the possibility of verifying the conformity between the data in the literature and those received orally from their elders. This offers the possibility of unearthing errors that may come from elders but also of finding additional indications that a plant may have. These results show that using plants is increasingly popularized and is no longer the business of illiterates (Mandjo et al., 2021).

The study of botanical data reveals that the families of Rubiaceae, Solanaceae, and Asteraceae are the most used among TH, VG, and OU considered in the survey. Plants of these different families are widespread in the Congolese flora, with several species in a good number of genera. They are thus widely used for their properties in several fields (Da Cruz et al., 2022; Van Wyk, 2020). The Rubiaceae family has been the subject of several studies that have shown several species' antimicrobial properties (Roy et al., 2023; Wong et al., 2015). Solanaceae is one of the families containing a wide range of aromatic plants. The prominent biological properties exhibited by its members are antibacterial, antifungal, insecticidal, and larvicidal (Afroz et al., 2020; Chowański et al., 2016). In comparison, those of Asteraceae demonstrate antibacterial and wound-healing properties.

For unidentified botanical families, it's important to point out that it was difficult to obtain more information on these different plants presented under their vernacular names, especially from TH who thought it was a market survey for future competitors.

This study identified *Morinda morindoides*, *Cymbopogon citratus,* and *Boswellia sacra* as the plant species most used by the surveyed individuals for anti-infective, larvicidal, and repellent treatments, respectively, by their citation frequencies, which were the highest. The *Morinda morindoides* species is widely used in the Congolese traditional pharmacopeia to treat diseases such as malaria, diabetes, skin rashes, and pruritus (Cimanga et al., 2021; Kasali et al., 2021; Ngbolua et al., 2016). Studies have proven that lemongrass essential oil, composed mainly of citral, shows larvicidal effects against several mosquito species (Luker, 2024; Mariam et al., 2021). Numerous studies have also reported using *Boswellia sacra* as a repellent (Khalifa et al., 2023; Rajan et al., 2018). It should also be noted that the inability to find, in botanical documents, the scientific name of some species mentioned by the participants under their vernacular or common names can lead to two or more unidentified plants representing the same plant species.

The leaves are the organs of the species most used in treating infectious diseases, larvicides, and repellents. Numerous studies conducted in various countries also pointed out the everyday use of leaves (Amjad et al., 2015; Azam et al., 2014) as they are less destructive to the plant (Asiimwe et al., 2021). The high frequency of use of leaves can also be explained by the ease and speed of harvesting (Lara Reimers et al., 2018), but also by the fact that the leaves are the site of photosynthesis and storage of secondary metabolites responsible for the biological properties of the plants (Asiimwe et al., 2021).

This ethnobotanical analysis revealed that most plant antimicrobial recipes are used to treat malaria. The majority of plant indications were found in traditional African pharmacopoeias (African Union Scientific, 2014; Oscar,

2008). The other indications obtained as additional information during the survey are valuable elements that deserve further studies to be confirmed.

To promote the findings of ethnobotanical studies, a program aiming to develop traditional medicines prepared from locally grown or harvested plants has already been implemented (Pirintsos et al., 2022). However, *in vitro*, preclinical, and clinical studies must be done rigorously to evaluate the efficacy and safety of identified plants. It will be therefore interesting for future ethnobotanical studies to open the door to ethnopharmacology, which will lead to the identification of new active principles, probably promising pharmacological substances for biomedical research and therapeutics (Chaachouay et al., 2019).

The study will also serve as a basis for providing the necessary support to the Congolese people in their quest to achieve sustainable development. In this sense, it will be interesting to form a network of medicinal plants and traditional medicine in the country, which will bring together different actors (TH, VG, researchers, development partners, and governments) to facilitate the dissemination of research results and the recognition of traditional medicine, and thus integrate the sustainable, safe, and effective use of medicinal plants into public health services.

This knowledge is part of a community's identity and adaptation to its environment and contributes to the conservation of biological diversity (Nemogá et al., 2022). The loss of traditional knowledge could contribute to the abandonment of traditional ways of life that are still necessary today. Conversely, protecting this knowledge will help to ensure the cultural vitality of communities and promote the use of traditional knowledge for community healthcare and drug development (Reyes-García et al., 2013).

The current wave of acculturation in Africa in general, and in DR Congo in particular, makes it urgent to accurately document traditional knowledge, especially that related to plants (Peschard et al., 2023). This documentation must include all information on plants: vernacular or common and scientific names, medicinal uses, harvesting, distribution, conservation of medicinal plants, etc. This documented knowledge will describe a variety of rich local experiences. It can be integrated into local biodiversity management and conservation programs and used to guide plant selection and pharmacological testing for drug development (Raven, 2019; Wekundah, 2012).

CONCLUSIONS

This ethnobotanical survey conducted in the DRC confirms that it is possible to highlight the important place of traditional phytotherapy. It underlined the endogenous know-how of the actors of Congolese traditional medicine (TH, VG, and OU) by describing the plants they use as anti-infective, larvicidal, and repellent treatments, which will ultimately enhance biodiversity and contribute to the development and well-being of the population throughout the country.

The sociodemographic data of the respondents revealed that men and women have a shared medicinal knowledge, with an advantage going to women, especially those in the 41-50 age group. The lowdown on using plants by these actors of traditional medicine comes from the cultural heritage. The results also show that using plants is increasingly popularized and does not only concern illiterate people. The ethnobotanical data from this survey identified a wide variety of plants used by TH, VG, and OU in the Congolese population, belonging to various botanical families, the most represented of which are Rubiaceae, Solanaceae, and Asteraceae. This study identified *Morinda morindoides*, *Cymbopogon citratus*, and *Boswellia sacra* as the plant species most used by the surveyed individuals for anti-infective, larvicidal, and repellent treatments, respectively, by their citation frequencies, which were the highest. It also showed that several parts of the plant are used for therapeutic purposes by this population, with the leaves representing the most used parts. Most antimicrobial species have been used primarily for the treatment of malaria. Traditional knowledge deserves to be protected to ensure the security of local culture. The results obtained are an invaluable source of information for the country's various regions. They could also serve as a database for further research in the fields of phytochemistry and pharmacology, to identify new natural substances.

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