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Ethnobotanical study of plants used by traditional healers in Lubumbashi (Democratic Republic of Congo) in the management of typhoid fever

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Abstract

No documented study reports the ethnobotanical knowledge of the medicinal plants involved in the management of typhoid fever in Lubumbashi. This study aims to identify plants and recipes used by traditional medicine practitioners (TMPs) in Lubumbashi to manage typhoid fever. The cross-sectional descriptive survey was carried out on TMPs through a direct interview, making it possible to collect ethnobotanical data. Fifty TMPs consulted (sex ratio M / F = 2.5, age = 45 ± 11 years, experience: 20 ± 13 years) made it possible to list 57 plants. These taxa are mostly shrubs (52%), Microphanerophytes (52%), endemic to tropical Africa (32%), belonging to 28 botanical families dominated by Fabaceae and indicated in 47 other causes of consultation for which diarrhea comes first position. From these 57 plants derived, 67 anti-typhoid recipes were administered orally. The stem bark was the most used part (33%), and the decoction (72%) was the most common preparation method. This study reports for the first time the ethnobotanical anti-typhoidal use of 25 species, among which *Ficus sur* Forssk. (0.22), and *Monotes katangensis* DeWild (0.18) has the highest consensus indexes (CI) and *Diplorhynchus condylocarpon* (Müll.Arg.) Pichona (UVp = 0.19) followed by *Albizia antunesiana* Harmsa (0.17), the highest usual values (UVp). TMPs use several plants in Lubumbashi to treat typhoid fever. Some are specific to the ecological environment, and others are used in other regions of the continent. Pharmacological studies are underway to assess the therapeutic efficacy of lesser-known plants among those listed.

Keywords: Typhoid fever; Medicinal plants; Traditional Medicine; Lubumbashi; Traditional medicine practitioners (TMPs).

1. Introduction

Typhoid fever is a severe food poisoning caused by a gram-negative bacterium, *Salmonella enterica subsp. enterica* serovar Typhi, present in water and food contaminated with faeces [1, 2]. The acute form of the pathology is characterized by prolonged fever, headaches, fatigue, and digestive disorders, including nausea, constipation, or diarrhea. Severe complications of typhoid fever occur in 10-15% of hospitalized patients, usually after 2-3 weeks of

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illness, and can include life-threatening gastrointestinal bleeding, intestinal perforation, and encephalopathy [3, 4]. This infectious pathology mainly occurs in developing countries where hygiene conditions are precarious [5, 6].

Every year, typhoid fever affects between 11 and 20.6 million people worldwide and causes more than 223, 000 deaths [7]. In sub-Saharan Africa, typhoid fever is more than 100 per 100, 000 people per year, and the number of annual deaths due to the disease is estimated at 33, 490 [6, 7]. Data on the prevalence of the disease at the national level are not accessible. However, 40 to 60% of prevalences are reported in certain regions of the country, particularly in Kikwit [5, 8] and Goma [9]. In Lubumbashi, indirect studies have reported prevalence estimated at 38.4%, n= 203 [10] and 62 %, n=510 [11].

In the past, chloramphenicol was used as the treatment of choice for typhoid fever. Still, as soon as multi-drug strains resistant to chloramphenicol, ampicillin and co-trimoxazole appeared, fluoroquinolones (ciprofloxacin and ofloxacin) became a more serious alternative. Although fluoroquinolones are superior to cephalosporins, the diffusion of strains less sensitive to ciprofloxacin has limited their effectiveness, especially in Asia. Thus, extended-spectrum cephalosporins (ceftriaxone and cefixime) and azithromycin remained suitable alternatives for S. Typhi less susceptible to fluoroquinolones. Increasingly combinations of cephalosporin and azithromycin are used frequently to treat patients who have not responded quickly [12]. Although there are models of anti-typhoid vaccines, which can strengthen the axis of prevention, their effectiveness-accessibility-risk ratio significantly reduces their performance in the fight against typhoid fever [13]. Despite all these alternatives for managing typhoid fever, the fact remains that cases of resistance in the most affected countries are increasingly alarming, and the number of new cases is increasing.

In the absence of accessibility to the drug, as mentioned earlier, associated with low efficiency and socio-cultural habits, 80% of the population, which does not have access to primary health care or drinking water, is exposed to infectious pathologies, especially typhoid fever, and resorts to traditional medicine. Some plants like *Annona senegalensis* Pers (Annonaceae), *Euphorbia hirta* L. (Euphorbiaceae) or *Piliostigma thonningii* (Schumach.) Milne-Redh. (Fabaceae) are claimed in traditional African medicine both in Nigeria [14] and Cameroon [15] in the treatment of typhoid fever and have also shown efficacy against S. Typhi *in vitro* [16–18]. In DR Congo, some plants are reported to be used in traditional medicine in some cities against typhoid fever. This is particularly the case of *Cymbopogon citratus* (DC.) Stapf (Poaceae) in Lubero [19], *Crassocephalum monthuosum* (S. Moore) Milme-Redh (Asteraceae) in Butembo [20], *Dialium angolense* Welw. Ex Oliv (Fabaceae) in Bukavu [21], *Morinda morindoides* (Baker) Milne-Redh. (Rubiaceae) in Kinshasa [22] and, *Cymbopogon densiflorus* (Steud.) Stapf (Poaceae) in Lubumbashi [23]; However, no study has been devoted to collecting plants against typhoid fever in Lubumbashi, despite the danger presented by the disease and the effective use of medicinal plants observed within the target population.

This study aims to list the plants and recipes used in Lubumbashi by traditional medicine practitioners (PMTs) to manage typhoid fever to draw up an ethnomedicinal profile.

2. Material and methods

2.1. Study period and site

This descriptive ethnobotanical study was conducted between September 2020 and June 2021 in the city of Lubumbashi, in the province of Haut-Katanga, in the Democratic Republic of Congo (Figure 1).

The city of Lubumbashi is located between 11°26'- 11°55′ south latitude and 27°15′ – 27°40′ east longitude at an altitude of 1230 meters. The climate is tropical, with an average annual temperature of 22.4°C and an average yearly precipitation of 512.7 mm^3. The rainy season (from November to April) is shorter in two seasons. The characteristic vegetation is dominated by the Miyombo forest [24].

2.2. Ethnobotanical data Collection

Ethnobotanical data were collected between September 2020 and June 2021 from PMTs in the city of Lubumbashi by direct interview using a guide questionnaire with 18 questions. These questions mainly focused on information relating to the plants and recipes used to treat typhoid fever in Lubumbashi. However, elements relating to the socio-demographic characteristics of TMPs were also collected. The sampling of PMTs was carried out in a snowballing fashion from an initial core of PMTs constituted based on information from the population of each municipality or other PMTs of their posters. The investigations were carried out in all 7 communes of Lubumbashi city of (Figure 1). The plants identified with the PMTs were harvested with the help of the PMTs. During the harvest, a herbarium was created and deposited at the Kipopo herbarium, where the plant's identity was determined.

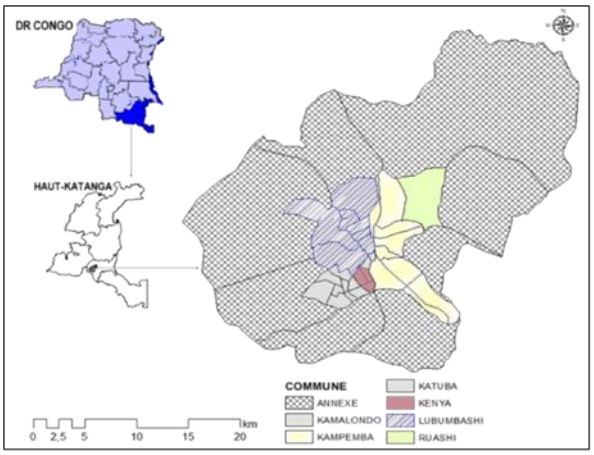

Figure 1 Map of the city of Lubumbashi.

The geographic types were determined based on data from the database « *African Plant Database* ». The botanical names of the species have been formatted based on the information contained in the databases, *African Plant Database* (https://africanplantdatabase.ch/), *Plants of the World Online* (https://powo.science.kew.org/), or *World Flora Online* (http://www.worldfloraonline.org/).

2.3. Data analysis

The relative frequency of citation (Fi = n*100/N) was used to assess the socio-cultural characteristics of informants as well as the floristic and ethnobotanical characteristics of the plants after processing by the Excel version 2016 software. Three ethnobotanical indices were calculated to assess the significant species: The use value (UV =∑Ui/N), the fidelity index (IF=np/N), and the consensus index (IC =nr/Np) where n= number of times the characteristic is mentioned and N= number of informants, Ui=Number of uses mentioned by informant i, Np=number of informants who mentioned a species for use p.

In this study, UV: makes it possible to assess the medicinal importance of a plant in the study environment, IC: makes it possible to identify the level of consensus of a species as to its anti-typhoidal use; IF: makes it possible to establish an agreement of informants around an anti-typhoidal recipe.

3. Results

3.1. Ethnobotanical characteristics of plants collected from PMTs

This study identified fifty-seven plants used in Lubumbashi to manage typhoid fever (Table 1) which are named in 13 languages of the Democratic Republic of Congo with a predominance of Bemba: Fi= 40.4% and Luba: Fi=28.1% (Figure 2). These plant species belong to 28 botanical families dominated by the Fabaceae (Fi= 28.1%). Apart from this predominant family, 3 other families, Euphorbiaceae, Lamiaceae, and Phyllanthaceae, share second place with Fi =5.3% each (Figure 3).

Table 1 Ethnobotanical profile of listed plants

	Plant species	Family	Appellation	Uat	Al	Herbarium code
1	*Acalypha villicaulis* Hochst. ex A.Rich.	Euphorbiaceae	Kabobo[a]	RAS	RAS	KIP452120000
2	*Albizia antunesiana* Harms	Fabaceae	Musase[b]	RAS	RAS	KIP462025883
3	*Albizia versicolor* Welw. ex Oliv	Fabaceae	Musase[l]	RAS	RAS	KIP452120001
4	*Aloe vera* (L.) Burm.f.	Asphodelaceae	Musula[b]	Uo, p	[37]	KIP452120002

	Plant species	Family	Appellation	Uat	Al	Herbarium code
5	*Ananas comosus* (L.) Merr.	Bromeliaceae	Inanasi [f]	Uo, p	RAS	KIP203550072
6	*Annona senegalensis* Pers.	Annonaceae	Mulolo[a]	Uo	[17]	KIP452120003
7	*Antidesma venosum* E. Mey. ex Tul.	Phyllanthaceae	Kifubiab Itompo[a]	Uo	[38]	KIP418175142
8	*Arachis hypogaea* L	Fabaceae	Mbaa[a]	Uo	RAS	KIP309272041
9	*Asparagus bequaertii* De Wild.	Asparagaceae	Mukoma wa Kanyegele[b]	RAS	RAS	KIP350524510
10	*Bidens pilosa* L	Asteraceae	Sokontwe [h]	Uo, p	[39]	KIP452120004
11	*Bobgunia madagascariensis* (Desv.) J.H. Kirkbr.	Fabaceae	Munienze[b]	RAS	[40]	KIP452120005
12	*Brachystegia allenii* Hutch. & Burtt Davy	Fabaceae	Musamba [a]	RAS	RAS	KIP452120006
13	*Brachystegia taxifolia* Harms	Fabaceae	Musamb[c]	RAS	RAS	KIP452120007
14	*Bulbostylis scabricaulis* Cherm	Cyperaceae	Msiki[b]	RAS	RAS	KIP452120008
15	*Cajanus cajan* (L.) Huth	Fabaceae	Goliolio[b]	Up	[41]	KIP223105500
16	*Carica papaya* L	Caricaceae	Ipapayi [g]	Up	[42]	KIP452120009
17	*Cassia abbreviata* Oliv.	Fabaceae	Kafungunasha [a]	Up	[43]	KIP452120010
18	*Celosia trigyna* L.	Amaranthaceae	Katuni[a]	RAS	[44]	KIP452120011
19	*Citrus × limon* (L.) Osbeck	Rutaceae	Chungwa [a]	Uo, p	[45]	KIP452120012
20	*Combretum celastroides* Welw. ex M. A. Lawson	Combretaceae	Kibobo [a]	RAS	RAS	KIP452120013
21	*Crossandra leucodonta* Vollesen	Acanthaceae	Misafwa [a]	RAS	RAS	KIP452120014
22	*Cryptolepis oblongifolia* (Meisn.) Schltr.	Apocynaceae	Kalembelembe [a]	RAS	RAS	KIP452120015
23	*Cymbopogon citratus* (DC.) Stapf	Poaceae	Kiyombomputu[b]	Uo, p	[46]	KIP178804459
24	*Cymbopogon densiflorus* (Steud.) Stapf	Poaceae	Bikochi[e]	RAS	[47]	KIP472716179
25	*Dalbergia boehmi* Taub. Subsp	Fabaceae	Msuati[b]	RAS	RAS	KIP452120016
26	*Diplorhynchus condylocarpon* (Müll.Arg.) Pichon	Apocynaceae	Mburi [a]	RAS	RAS	KIP361753009
27	*Dysphania ambrosioides* (L.) Mosyakin & Clemants	Amaranthaceae	Lufianyoka [a]	RAS	RAS	KIP231226246
28	*Euphorbia hirta* L.	Euphorbiaceae	Kavudji[b]	Up	[16]	KIP501400542
29	*Euphorbia ingens* E. Mey. ex Boiss.	Euphorbiaceae	Ntul a mend[c]	RAS	RAS	KIP452120017
30	*Ficus sur* Forssk.	Moraceae	Mukuyu[b]	RAS	RAS	KIP539378804

	Plant species	**Family**	**Appellation**	**Uat**	**Al**	**Herbarium code**
31	*Ficus sycomorus* L.	Moraceae	Tshikuyi[b]	RAS	[48]	KIP452120018
32	*Julbernardia paniculata* (Benth.) Troupin	Fabaceae	Mutando [a]	RAS	RAS	KIP452120019
33	*Lannea acida* A. Rich	Anacardiaceae	Muheti [j]	Up	[49]	KIP452120020
34	*Lantana camara* L	Verbenaceae	Makereshe [k]	Uo	[50]	KIP452120021
35	*Monotes katangensis* De Wild.	Dipterocarpaceae	Chimpampa [a]	RAS	RAS	KIP452120022
36	*Moringa oleifera* Lam	Moringaceae	Moringa [b]	Up	[51]	KIP318101663
37	*Ochna afzelii* R.Br. ex Oliv.	Ochnaceae	Munyahu[b]	Up	RAS	KIP452120023
38	*Ocimum americanum* L.	Lamiaceae	Lueni [a]	RAS	RAS	KIP452120024
39	*Parinari alvimii* Prance	Chrysobalanaceae	Pundu[d]		RAS	KIP452120025
40	*Pericopsis angolensis* (Baker) Meeuwen	Fabaceae	Mubanga [a]	Up	RAS	KIP452120026
41	*Phragmanthera capitata* (Spreng.)	Loranthaceae	Kwapata [i]	Up	[52]	KIP452120027
42	*Phragmanthera leonensis* (Sprague) Balle	Loranthaceae	Mupela [a]	RAS	RAS	KIP452120028
43	*Phyllanthus amarus* Schumach. & Thonn.	Phyllanthaceae	Kivumbwa[d]	Up	[53]	KIP256901169
44	*Phyllanthus muellerianus* (Kuntze) Exell	Phyllanthaceae	Mupetwalupe [a]		RAS	KIP277202454
45	*Piliostigma thonningii* (Schumach.) Milne-Redh.	Fabaceae	Kifumbe[e]	RAS	[54]	KIP452120029
46	*Sclerocarya birrea* (A. Rich.) Hochst.	Anacardiaceae	Muongo[b]		[55]	KIP452120030
47	*Senna occidentalis* (L.) Link	Fabaceae	Kimbayeshi [m]	Up	[56]	KIP231974463
48	*Senna sophera* (L.) Roxb	Fabaceae	Day[c]	RAS	RAS	KIP452120031
49	*Senna spectabilis* (DC.) H.S. Irwin & Barneby	Fabaceae	Kifunfu[b]	RAS	[57]	KIP523712350
50	*Solanum aethiopicum* L.	Solanaceae	Mutete [g]	RAS	[58]	KIP452120032
51	*Strychnos spinosa* Lam.	Loganiaceae	Kisongole [a]	RAS	[59]	KIP221873302
52	*Terminalia mollis* M.A. Lawson	Combretaceae	Kibobo [a]	Uo	[60]	KIP452120033
53	*Tetradenia riparia* (Hochst.) Codd	Lamiaceae	Mutuzo [a]	RAS	[61]	KIP370001297
54	*Tithonia diversifolia* (Hemsl.) A. Gray	Asteraceae	Kilulukunja [h]	Up	[62]	KIP452120034
55	*Turraea floribunda* Hochst	Meliaceae	Wapinga [a]	RAS	RAS	KIP452120035
56	*Vachellia hockii* (De Wild.) Seigler & Ebinger	Fabaceae	Lungole[b]	RAS	RAS	KIP203066812
57	*Vitex madiensis* Oliv.	Lamiaceae	Mafutu [a]	RAS	RAS	KIP452120036

[a]: Bemba name, [b]: Luba name, [c]: Rund name, [d]: Hemba name, [e]: Lamba name, [f]: Shi name, [g]: Swahili name, [h]: Tabwa name, [i]: Lingala name, [j]: Mbala name, [k]: Nande name, [l]: Sanga name, [m]: Tetela name, Uo: ethnobotanical use in DR Congo, Up: ethnobotanical use outside the country, RAS: Nothing to report.

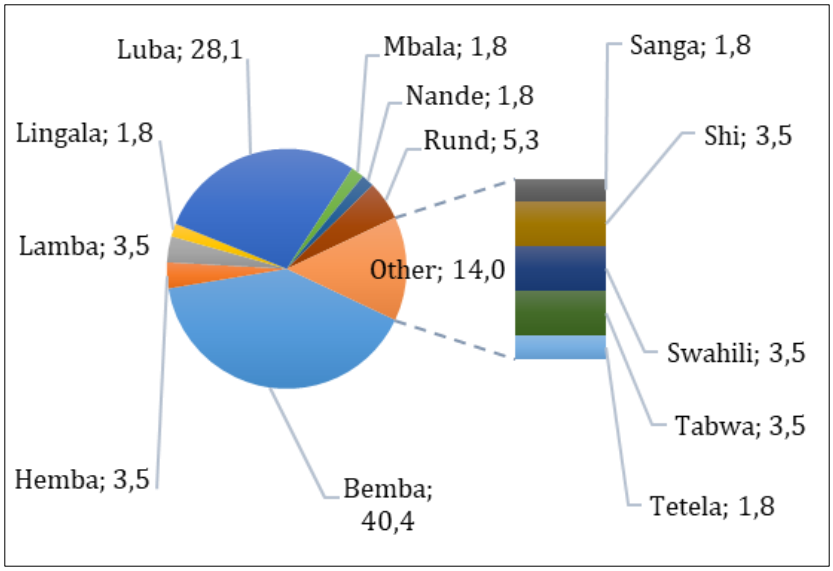

Figure 2 Language of the naming of listed plants (n= 57).

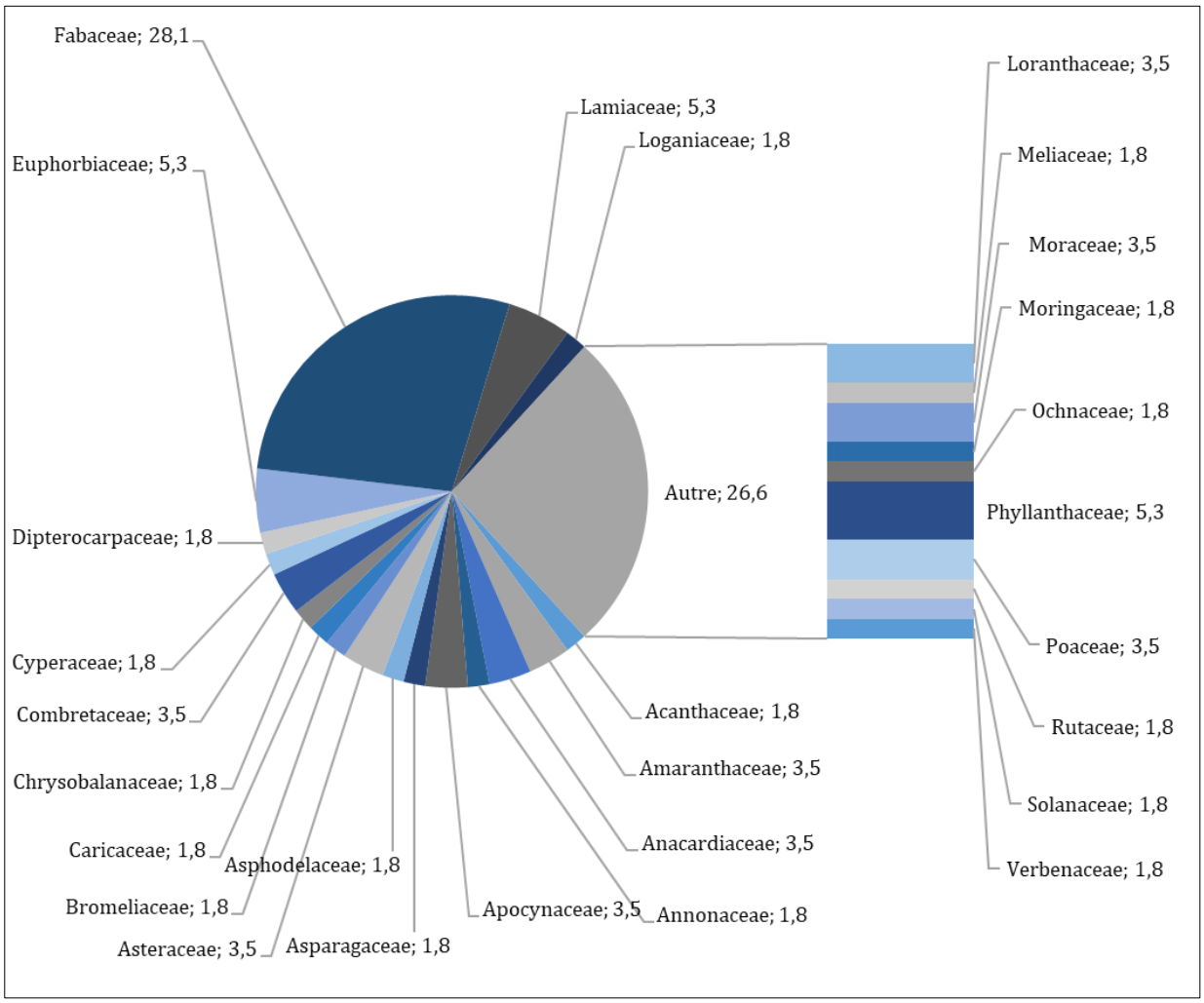

Figure 3 Botanical families of listed species (n=57)

The plant species inventoried during this study present 3 morphological types, where the shrub represents the most dominant morphology (60%). It is followed by grass with Fi = 30%. These taxa also present 3 biological types, where the McPh type (60%) comes first, followed by the MePh type (30%). Three sites, Kamalubwe, Kashamata, and Mimbulu, served as collection locations, and 50% of the taxa were collected from Kamalubwe. These species have 11 geographical types with a 75% predominance of 2 types: the tropical type: TA (Fi= 32%), and the Australo-tropical type: SA-TA, Fi= 23% (Figure 4).

According to data from the available literature, the plants inventoried (Table 1) can be grouped into 4 classes where most of the plants (43.9%) are unknown both from the point of view of anti-typhoidal activity and from the point of view of for use in the management of typhoid fever. However, among the 57 plants, those reported and proven as active plants on *S. Typhi* represent 31.6% (Figure 4).

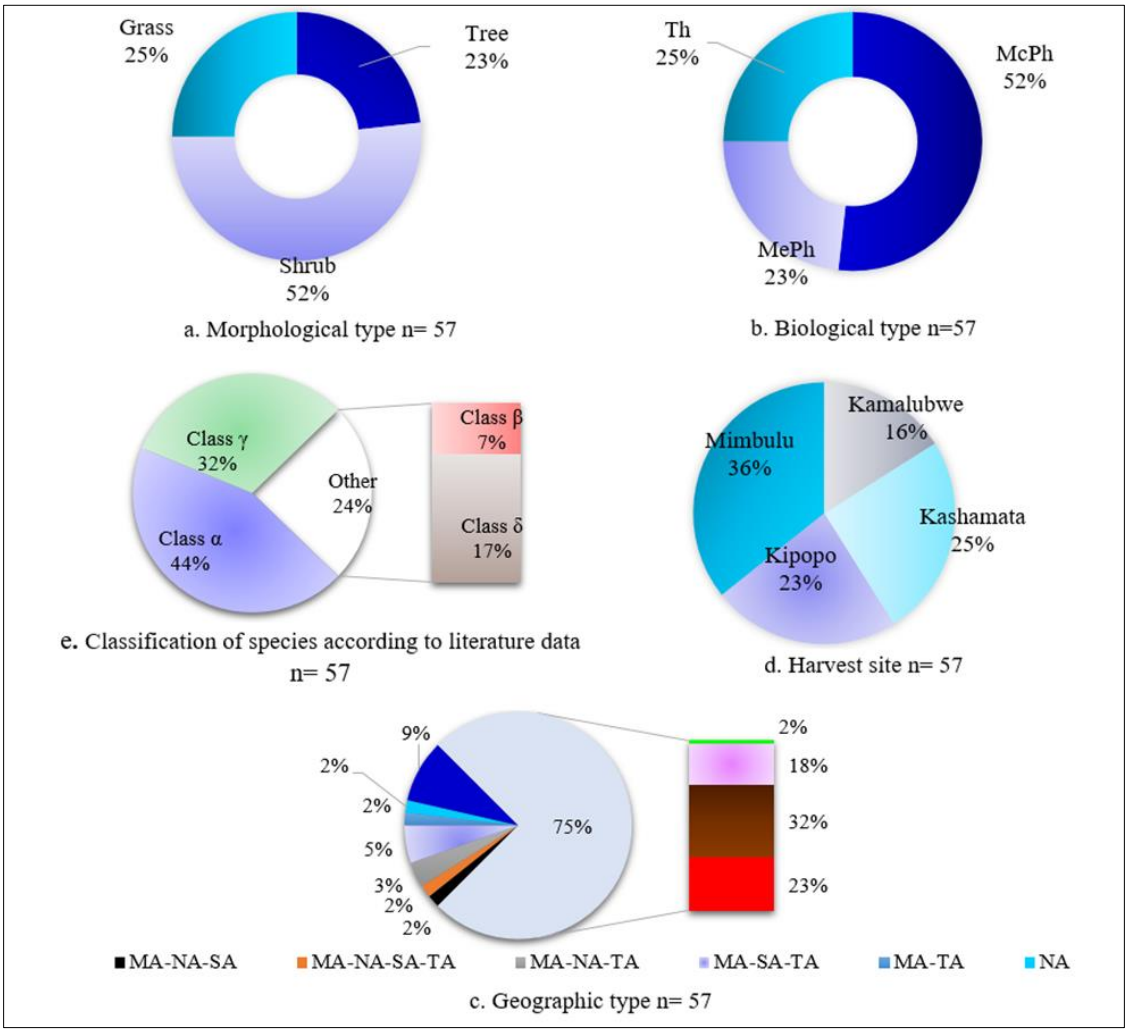

Figure 4 Morphological, biological and geographical types and classification of species

Ethnobotanical use anti-typhoidal (-) anti-typhoidal activity (-) previous: Class α, Ethnobotanical use anti-typhoidal (+) anti-typhoidal activity (-) previous: Class β, Ethnobotanical use anti-typhoidal (+) activity anti -typhoidal anterior (+): Class γ, Ethnobotanical use anti-typhoidal (-) anti-typhoidal activity anterior (+): Class δ. (-): absent, (+): present. MePh: Mesophanerophytes, McPh: Microphanerophytes, NPh: Nanophanerophytes, Th: Therophytes, TA: tropical Africa, SA: southern Africa, MA: Madagascar, NA: North Africa.

3.2. Ethnomedicinal profile of the plants collected from the PMTs consulted

From 57 listed plants, derive 65 anti-typhoidal recipes, which all use a single plant and for which only *Strychnos spinosa* has 3 anti-typhoidal recipes (R56-58). It is followed by 6 other species, *Albizia antunesiana*$^{\alpha}$, *Antidesma venosum*$^{\gamma}$, *Asparagus bequaertii*$^{\alpha}$, *Piliostigma thonningii*.$^{\delta}$, *Senna sophera*$^{\alpha}$, and *Vitex madiensis*$^{\alpha}$ which each have 2 anti-typhoid recipes. The balance is made up of one-recipe plants (Table 2).

Table 2 Anti-typhoid recipes and other indications

Plant species	Anti-typhoid recipe	IC (n=50)	IF	PU	Other indications	UVp (n=48)	UVo (n=48)
Acalypha villicaulis Hochst. ex A. Rich.α	R1: Decoction for 15 minutes of a handful of root bark in 2 liters of water. Drink 200 mL twice a day for 5 days.	0.04	1	R	Diarrhea and Typhoid Fever.	0.06	0.06
Albizia antunesiana Harms α	R2: Decoction for 15 minutes of a handful of root bark in 2 liters of water. Drink 200 mL twice a day for 5 days.	0.06	0.6	ER	Tonsillitis, Diabetes, Typhoid fever, Gonorrhoea, Peptic ulcer disease, Tuberculosis.	0.17	0.13
	R3: Decoction for 15 minutes 5 handfuls of fruit in 2 liters of water. Drink 200 mL twice a day for 5 days.	0.04	0.4	Fr	Diabetes, Typhoid Fever & STI.		0.06
Albizia versicolor Welw. ex Olivα	R4: Decoction for 15 minutes of a handful of root bark in 2 liters of water. Drink 200 mL twice a day for 5 days.	0.02	1	ER	Intestinal worms, Fever, typhoid, Gastrointestinal disorders.	0.06	0.06
Aloe vera (L.) Burm.f.γ	R5: Decoction for 45 minutes of a handful of fresh leaves in 1 L of water. Drink 150 Ml twice a day for 5 days.	0.02	1	F	Acnes, Diarrhoea, Typhoid fever.	0.06	0.06
Ananas comosus (L.) Merr.β	R6: Decoction for 15 minutes of the whole fruit in 1 litter of water. Drink 100ml twice a day for 5 days.	0.04	1	Fr	Constipation, Gastrointestinal disorders, Typhoid fever, Malaria, Intestinal worms.	0.10	0.10
Annona senegalensis Pers.γ	R7: Decoction for 30 minutes of a handful of fresh leaves in 1L of water. Drink 100 mL twice a day for 5 days.	0.02	1	F	Intestinal pain, typhoid fever, HIV.	0.10	0.06
Antidesma venosum E. Mey. ex Tul.γ	R8: Decoction for 30 minutes of a handful of root bark in 1.5 liters of water. Drink 100 mL twice a day for 7 days.	0.1	0.5	ER	Anemia, Diarrhoea, Typhoid fever, Gastrointestinal disorders.	0.15	0.08
	R9: Decoction for 30 minutes of a handful of stem bark decoction in 1.5 liters of water. Drink	0.1	0.5	ET	Urogenital Tract Infections, Gastrointestinal Disorders,		0.08

Plant species	Anti-typhoid recipe	IC (n=50)	IF	PU	Other indications	UVp (n=48)	UVo (n=48)
	100 mL twice a day for 7 days.				Typhoid Fever & HIV		
Arachis hypogaea L[β]	R10: Decoction for 45 minutes of a handful of fresh leaves in 1 L of water. Drink 150 mL twice a day for 5 days.	0.04	1	F	Cancer, Constipation, Fever, typhoid, wounds, Insomnia, Prostatitis.	0.15	0.15
Asparagus bequaertii De Wild.[α]	R11: Decoction for 30 minutes of one of the roots in 1.5 liters of water. Drink 100 mL twice a day for 5 days.	0.02	0.5	R	Malaria, Typhoid fever.	0.06	0.04
	R12: Decoction for 30 minutes of a handful of stem bark in 1.5 liters of water. Drink 100 mL twice a day for 5 days.	0.02	0.5	ET	Diarrhoea, Typhoid fever.		0.04
Bidens pilosa L[γ]	R13: Decoction for 30 minutes of a handful of stem bark in 1.5 liters of water. Drink 100 mL twice a day for 5 days.	0.02	1	ET	Intestinal worms, Hepatitis, Typhoid fever, Peptic ulcer disease, Gastrointestinal disorders.	0.10	0.10
Bobgunia madagascariensis (Desv.) J.H. Kirkbr.[δ]	R14: Decoction for 30 minutes of a handful of stem bark in 1.5 liters of water. Drink 100 mL twice a day for 5 days.	0.02	1	ET	Gastrointestinal disorders, peptic ulcer disease, Diabetes, Typhoid fever.	0.08	0.08
Brachystegia allenii Hutch. & Burtt Davy[α]	R15: Decoction for 30 minutes of a handful of stem bark in 1.5 liters of water. Drink 100 mL twice a day for 5 days.	0.1	0.5	ET	Gastrointestinal disorders, peptic ulcer disease, diabetes, typhoid fever.	0.08	0.08
Brachystegia taxifolia Harms[α]	R16: Maceration for 72 hours of 5 handfuls of root bark in 1 litter of water. Drink 100 mL three times a day for 3 days.	0.1	0.5	ER	Diarrhoea, typhoid fever, cough.	0.06	0.06
Bulbostylis scabricaulis Cherm [α]	R17: Decoction for 30 minutes of a handful of stem bark in 1.5 liters of water. Drink 100 mL twice a day for 5 days.	0.02	1	ET	Typhoid fever	0.02	0.02

Plant species	Anti-typhoid recipe	IC (n=50)	IF	PU	Other indications	UVp (n=48)	UVo (n=48)
Cajanus cajan (L.) Huth[γ]	R18: Decoction for 30 minutes of a handful of fresh leaves in 1L of water. Drink 100 mL twice a day for 5 days.	0.04	1	F	Elephantiasis, Influenza, Typhoid fever, Gingivitis, Hepatitis.	0.10	0.10
Carica papaya L[γ]	R19: Decoction for 30 minutes of a handful of leaves in 1L of water. Drink 100 mL twice a day for 5 days.	0.1	1	F	Asthma, Beriberi, Typhoid fever, wounds.	0.08	0.08
Cassia abbreviata Oliv.[γ]	R20: Maceration for 72 hours of 5 handfuls of root bark in 1 litter of water. Drink 100 mL three times a day for 3 days.	0.06	1	ER	Diarrhoea, Typhoid fever, Malaria, Peptic ulcer disease.	0.08	0.08
Celosia trigyna L.[δ]	R21: Infusion for 30 minutes of a handful of leaves in 2 liters of water. Drink 200 mL twice a day for 5 days.	0.06	1	F	Gastrointestinal disorders, Typhoid fever, Intestinal worms.	0.06	0.06
Citrus × limon (L.) Osbeck[γ]	R22: Decoction for 30 minutes of two handfuls of fresh leaves in 1L of water. Drink 100 mL twice a day for 5 days.	0.1	1	F	Angina, typhoid fever.	0.04	0.04
Combretum celastroides Welw. ex M. A. Lawson[α]	R23: Decoction for 15 minutes of a handful of root bark in 2 liters of water. Drink 200 mL twice a day for 5 days.	0.02	1	ER	Conjunctivitis, Joint pain, Typhoid fever.	0.06	0.06
Crossandra leucodonta Vollesen[α]	R24: Decoction for 15 minutes of a handful of root bark in 2 liters of water. Drink 200 mL twice a day for 5 days.	0.02	1	ER	Amoebas & Typhoid Fever.	0.04	0.04
Cryptolepis oblongifolia (Meisn.) Schltr[α]	R25: Decoction for 15 minutes of a handful of root bark in 2 liters of water. Drink 200 mL twice a day for 5 days.	0.02	1	ER	Diarrhoea, Typhoid fever, Gastro-duodenal ulcer, Cough.	0.08	0.08
Cymbopogon citratus (DC.) Stapf[γ]	R26: Infusion for 30 minutes of a handful of stem bark in 2 liters of water. Drink 200 mL twice a day for 5 days.	0.02	1	ET	Bronchitis, wounds, rheumatism, typhoid fever, tuberculosis.	0.10	0.10
Cymbopogon densiflorus (Steud.) Stapf[δ]	R27: Infusion for 15 minutes of a handful of roots in 1 litter of water. Drink 150 mL once a day for 5 days.	0.04	1	R	Asthma, Epilepsy, Typhoid fever, Colds.	0.08	0.08

Plant species	Anti-typhoid recipe	IC (n=50)	IF	PU	Other indications	UVp (n=48)	UVo (n=48)
Dalbergia boehmi Taub. Subsp [α]	R28: Maceration for 72 hours of 5 handfuls of stem bark in 1 litter of water. Drink 100 mL three times a day for 3 days.	0.12	1	ET	Diarrhoea, Dysentery, Typhoid fever, Period pain, Gingivitis.	0.10	0.10
Diplorhynchus condylocarpon (Müll.Arg.) Pichon [α]	R29: Infusion for 30 minutes of a handful of roots in 1 litter of water. Drink 100 mL three times a day for 3 days.	0.02	1	R	Constipation, Diabetes, Dysentery, Typhoid fever, Hepatitis, Acnes, Hepatitis, Wounds, Measles.	0.19	0.19
Dysphania ambrosioides (L.) Mosyakin & Clemants [α]	R30: Decoction for 15 minutes of a handful of the roots in 2 liters of water. Drink 150 mL three times a day for 5 days.	0.04	0.5	R	Diabetes and Typhoid Fever, STI.	0.06	0.06
Euphorbia hirta L.[γ]	R31: Decoction for 15 minutes 5 handfuls of the leaves in 2 liters of water. Drink 150 mL twice a day for 7 days.	0.04	0.5	F	Asthma, Bronchitis, Typhoid fever, Colds.	0.08	0.08
Euphorbia ingens E. Mey. ex Boiss [α]	R32: Maceration for 72 hours of 5 handfuls of stem bark in 1 litter of water. Drink 100 mL three times a day for 3 days	0.02	1	ET	Diarrhoea, Dysentery, Typhoid fever Gastrointestinal disorders.	0.08	0.08
Ficus sur Forssk[α]	R33: Decoction for 1 hour of a handful of stem bark in 2 liters of water. Drink 200 mL twice a day for 7 days.	0.22	1	ET	Anemia, Diarrhoea, Typhoid fever, Peptic ulcer disease, Infertility, Oedema, Rheumatism.	0.15	0.15
Ficus sycomorus L[γ]	R34: Decoction for 1 hour of a handful of stem bark in 2 liters of water. Drink 200 mL, twice a day for 7 days.	0.1	1	ET	Typhoid fever & Tuberculosis.	0.04	0.04
Julbernardia paniculata (Benth.) Troupin [α]	R35: Decoction for 15 minutes of a handful of root bark in 2 liters of water. Drink 200 mL twice a day for 5 days.	0.04	1	ER	Malaria, Typhoid fever.	0.04	0.04

Plant species	Anti-typhoid recipe	IC (n=50)	IF	PU	Other indications	UVp (n=48)	UVo (n=48)
Lannea acida A. Rich[γ]	R36: Maceration for 72 hours of 5 handfuls of stem bark in 1 liter of water. Drink 100 mL three times a day for 3 days.	0.04	1	ET	Diarrhoea, Dysentery & Typhoid Fever.	0.06	0.06
Lantana camara L[γ]	R37: Infusion for 45 minutes of a handful of leaves in 1 L of water. Drink 150 mL twice a day for 5 days.	0.04	1	F	Typhoid fever, Rheumatism, Peptic ulcer disease, Cough.	0.08	0.08
Monotes katangensis De Wild α	R38: Maceration for 72 hours of 5 handfuls of stem bark in 1 litter of water. Drink 100 mL three times a day for 3 days.	0.18	1	ET	Cough, Diarrhoea & Typhoid Fever.	0.06	0.06
Moringa oleifera Lamc	R39: Decoction for 30 minutes of a handful of stem bark in 1.5 liters of water. Drink 150 mL twice a day for 5 days.	0.02	1	ET	Typhoid fever, Malaria, Gastrointestinal disorders.	0.06	0.06
Ochna afzelii R.Br. ex Oliv.[β]	R40: Decoction for 15 minutes of a handful of root bark in 2 liters of water. Drink 200 mL twice a day for 5 days.	0.06	1	ER	Peptic ulcer & Typhoid fever.	0.04	0.04
Ocimum americanum L α	R41: Decoction for 30 minutes of a handful of the roots in 3 liters of water. Drink 150 mL twice a day for 7 days.	0.02	1	R	Diabetes, Gingivitis & Typhoid Fever.	0.06	0.06
Parinari alvimii Prance α	R42: Decoction for 15 minutes of a handful of root bark in 2 liters of water. Drink 200 mL twice a day for 5 days.	0.06	1	ER	Typhoid fever.	0.02	0.02
Pericopsis angolensis (Baker) Meeuwen[β]	R43: Infusion for 45 minutes of a handful of leaves in 1 L of water. Drink 150 mL twice a day for 5 days.	0.1	1	F	Convulsions, Typhoid Fever & Malaria	0.06	0.06
Phragmanthera capitata (Spreng.) c	R44: Maceration for 72 hours of 5 handfuls of stem bark in 1 liter of water. Drink 100 mL three times a day for 3 days.	0.04	1	ET	Acne, Diarrhoea, Typhoid fever.	0.06	0.06
Phragmanthera leonensis (Sprague) Balle[α]	R45: Infusion for 45 minutes of a handful of leaves in 1 L of water.	0.04	1	F	Typhoid fever.	0.02	0.02

Plant species	Anti-typhoid recipe	IC (n=50)	IF	PU	Other indications	UVp (n=48)	UVo (n=48)
	Drink 150 mL twice a day for 5 days.						
Phyllanthus amarus Schumach. & Thonn.ɣ	R46: Infusion for 45 minutes of a handful of fresh leaves in 1 L of water. Drink 150 mL twice a day for 5 days.	0.1	1	F	Asthma, Diabetes, Typhoid fever, Hepatitis, Bronchial infections, peptic ulcer disease	0.13	0.13
Phyllanthus muellerianus (Kuntze) Exell α	R47: Infusion for 45 minutes of a handful of fresh leaves in 2 liters of water. Drink 150 mL twice a day for 7 days.	0.04	1	F	Wounds, Difficulty giving birth, Typhoid fever, Influenza, Malaria, Snake bite, Intestinal worms.	0.15	0.15
Piliostigma thonningii (Schumach.) Milne-Redh.δ	R48: Maceration for 72 hours of 5 handfuls of stem bark in 1 litter of water. Drink 100 mL three times a day for 3 days.	0.02	0.5	ET	Typhoid fever, gastritis, haemorrhoid, cough.	0.06	0.06
	R49: Decoction for 15 minutes of a handful of root bark in 2 liters of water. Drink 200 mL twice a day for 5 days.	0.02	0.5	ER	Typhoid fever, STI.	0.04	0.04
Sclerocarya birrea (A. Rich.) Hochst.δ	R50: Maceration for 72 hours of 5 handfuls of stem bark in 1 liter of water. Drink 100 mL three times a day for 3 days.	0.02	1	ET	Typhoid fever.	0.04	0.02
Senna occidentalis (L.) Link ɣ	R51: Decoction for 15 minutes of a handful of root bark in 2 liters of water. Drink 200 mL twice a day for 5 days.	0.04	0.5	ER	Constipation, Diabetes, Typhoid fever, Malaria, Intestinal worms.	0.10	0.10
Senna sophera (L.) Roxb α	R52: Decoction for 30 minutes of a handful of fresh leaves in 1L of water. Drink 100ml twice a day for 5 days.	0.04	1	F	Diabetes & Typhoid Fever.		0.04
	R53: Decoction for 15 minutes of a handful of root bark in 2 liters of water. Drink 200 mL twice a day for 5 days.	0.02		ER	Typhoid fever.		0.02

Plant species	Anti-typhoid recipe	IC (n=50)	IF	PU	Other indications	UVp (n=48)	UVo (n=48)
Senna spectabilis (DC.) H.S. Irwin & Barneby δ	R54: Decoction for 15 minutes of a handful of root bark in 2 liters of water. Drink 200 mL twice a day for 5 days.	0.06	1	ER	STI, Typhoid fever, Tuberculosis.	0.02	0.06
Solanum aethiopicum L.δ	R55: Decoction for 30 minutes of a handful of fresh leaves in 1L of water. Drink 100ml twice a day for 5 days.	0.02		F	Typhoid fever and high blood pressure.	0.04	0.04
Strychnos spinosa Lam.δ	R56: Decoction for 30 minutes of a handful of leaves in 1L of water. Drink 100ml twice a day for 5 days.	0.04	0.7	F	Diarrhoea, Typhoid fever, Miscarriage, Gastritis, Haemorrhoids, Urogenital tract infections, Toothache, Tuberculosis.	0.25	0.17
	R57: Decoction for 15 minutes of a handful of stem bark in 1.5 liters of water. Drink 100 mL twice a day for 5 days.	0.02	0.3	ET	Diarrhoea, Typhoid fever, Intestinal worms.		0.06
	R58: Decoction for 15 minutes of a handful of root bark in 2 liters of water. Drink 200 mL twice a day for 5 days.	0.02	0.3	ER	STIs, typhoid fever, gastrointestinal disorders, ringworms, intestinal worms.		0.10
Terminalia mollis M.A. Lawsonγ	R59: Decoction for 15 minutes of a handful of root bark in 2 liters of water. Drink 200 mL twice a day for 5 days.	0.02	1	ER	Diabetes, Diarrhoea, Gastrointestinal disorders, Typhoid fever.	0.08	0.08
Tetradenia riparia (Hochst.) Coddδ	R60: Decoction for 15 minutes of a handful of leaves in 1.5 liters of water. Drink 100 mL twice a day for 5 days.	0.1	0.5	ET	Angina, sores, typhoid fever, gastrointestinal disorders.	0.17	0.08
Tithonia diversifolia (Hemsl.) A. Gray c	R61: Decoction for 30 minutes 3 handfuls of leaves in 1L of water. Drink 100ml twice a day for 5 days.	0.04	0.7	F	Diabetes, Amoeba, Cancer, Typhoid Fever & Intestinal Worms.		0.10
Turraea floribunda Hochstα	R62: Decoction for 15 minutes 2 handfuls of stem bark in 1.5 liters of	0.02	0.3	ET	Typhoid fever.	0.02	0.02

Plant species	Anti-typhoid recipe	IC (n=50)	IF	PU	Other indications	UVp (n=48)	UVo (n=48)
	water. Drink 100 mL twice a day for 5 days.						
Vachellia hockii (De Wild.) Seigler & Ebinger[α]	R63: Decoction for 30 minutes of a handful of the roots in 3 liters of water. Drink 150 mL twice a day for 7 days.	0.02	1	R	Epilepsy, Typhoid fever, Gastrointestinal disorders.	0.06	0.06
Vitex madiensis Oliv [α]	R64: Decoction for 15 minutes 2 handfuls of stem bark in 1.5 litters of water. Drink 100 mL twice a day for 5 days.	0.04	0.7	ET	Malaria, Typhoid fever	0.08	0.04
	R65: Decoction for 15 minutes 2 handfuls of root bark in 2 liters of water. Drink 200 mL twice a day for 5 days.	0.02	0.3	ER	Diabetes, Typhoid Fever & Gastrointestinal Disorders		0.06

IC= Consensus index (IC=n /N), IF: fidelity index (nr/Np: the number of people who cited the recipe out of the number of people who cited the plant); UV: usual value (UV=∑Ui /U the set of uses of an organ (Uo), of a plant (Up) out of all the uses identified in the study). F: Leaves, ET: Stem bark; ER: root bark, R: roots; Fr: Fruit.

A third of anti-typhoidal recipes (33%) are made from stem bark, but the use of leaves and root bark occurs with the same frequency (Fi= 27%), occupying the second position. Although rarely used, fruits are only used at 3% (Figure 5).

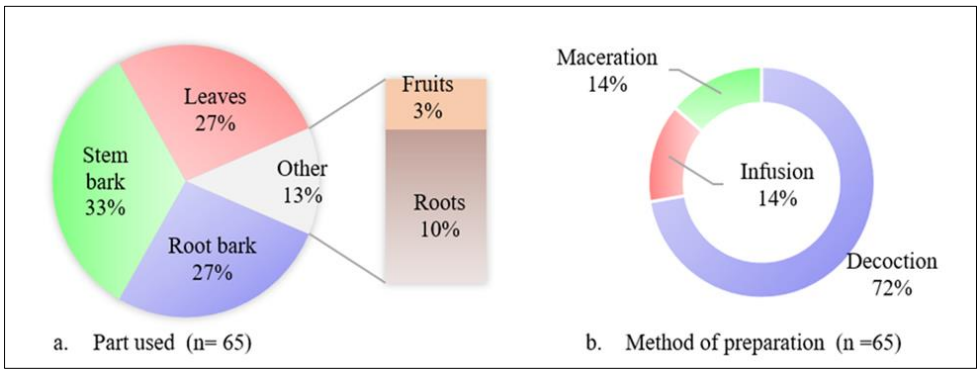

Figure 5 Parts used and ways of preparing anti-typhoid recipes

The consensus indices of different species vary between 0.02 and 0.22, and those of fidelity range from 0.3 to 1. The recipes R33, R28 (CI= 0.12) and R38 present respectively the highest consensus indexes (CI = 0.22, CI= 0.12 and CI= 0.18) and reliability If (IF = 1). These 3 recipes are respectively those based on taxa, *Ficus sur* Forssk[α], *Dalbergia boehmi*[α] and *Monotes katangensis*[α] However, it is the taxa *Strychnos spinosa* [δ] (UVp =0.25), *Diplorhynchus condylocarpon* [α] (UVp = 0.19) and *Albizia antunesiana*[α] have the 3 highest usual values, which vary between 0.02 and 0.22 (Table 2).

Apart from typhoid fever, these 57 plants are implicated in 47 other causes of consultation, where diarrhea (34%), gastrointestinal disorders (29.8%), diabetes (27.7%), and gastroduodenal ulcers (25, 5%) constitute the first 3 indications (Figure 6).

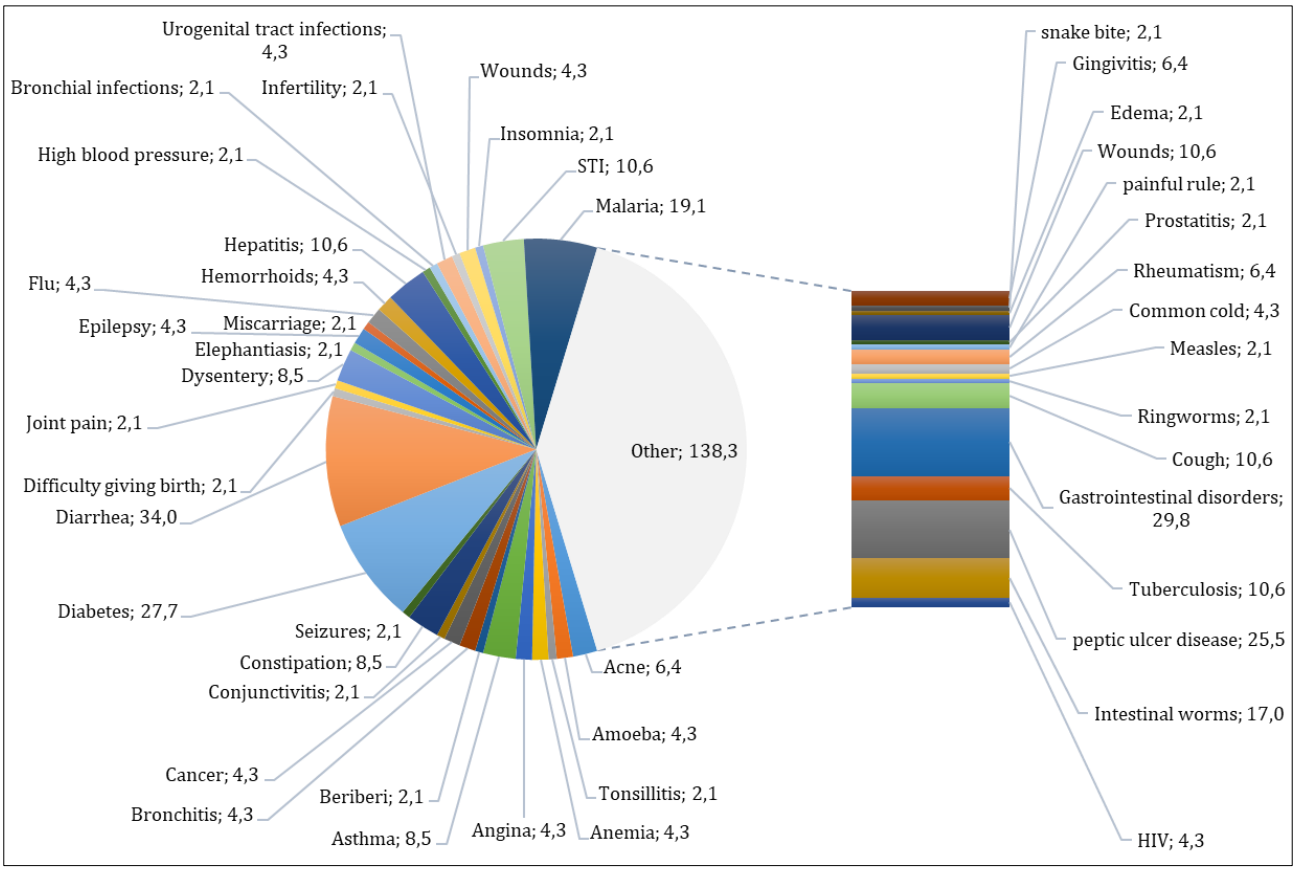

Figure 6 Other indications of the 57 listed anti-typhoidal plants

3.3. Socio-demographic characteristics of traditional medicine practitioners (TMPs) consulted

This study was made possible thanks to the participation of 50 PMTs (sex ratio M-F = 2.5, the average age of 30 years; extremes: 25 and 65 years, the average experience of practice in traditional medicine 20 years - extremes: 5 and 30 years). These PMTs have acquired knowledge from their ancestors (90%). Although the majority are Luba from Katanga (38%), Luba from Kasai (36%), and Bemba (18%), all speak Swahili (Table 3).

Table 3 Socio-demographic characteristics of the PTMs

Class	Subclass	Ei	Fi (n=50)
Age	20 – 30	3	6
	30 – 40	20	40
	40 – 50	9	18
	50 – 60	16	32
	> 60	2	4
Experience (year)	44682	8	16
	5 – 10	21	42
	42278	8	16
	15 - 20	7	14
	20 - 25	6	12
Sex	Women	14	28

Class	Subclass	Ei	Fi (n=50)
	Man	36	72
Level of studies	State diploma	30	60
	Third cycle	3	6
	Primary	13	26
	No Instructions	0	0
	Secondary	2	4
	Professional	2	4
Spoken languages	Bemba	9	18
	French	40	80
	Luba	19	38
	Swahili	50	100
Ethnic group	Bemba	9	18
	Luba of Kasaï	18	36
	Luba of Katanga	19	38
	Hemba	4	8

Ei = counts, Fi: Relative frequency of citations.

4. Discussion

This study has just identified for the first time 57 plant species used by the PMTs of Lubumbashi in the management of typhoid fever. Most of these taxa belong to the Fabaceae family 28.1% (Figure 3). The preponderance of Fabaceae reflects the importance of this family in traditional medicine for the management of several pathologies, as reported in various ethnobotanical studies carried out in the Lubumbashi region. This is particularly the case of the survey carried out on the plants used in the management of sexual dysfunction [21], or that carried out on plants known to be antimalarial [23] or diabetes [25], or against tooth decay [26], against schistosomiasis [27] or for diarrhea [28]. The preponderance of Fabaceae during this study can be linked to the fact that it constitutes the most prominent family of trees in the tropical and dry forests of Africa [29], mainly from Lubumbashi [30].

This study reports for the first time, 25 species as usual plants against typhoid fever in Lubumbashi (Figure 4). These taxa have never been the subject of a previous biological study on *S. typhi.* Those are: *Acalypha villicaulis*, *Albizia antunesiana*, *Albizia versicolor*, *Asparagus bequaertii*, *Brachystegia allenii*, *Brachystegia taxifolia*, *Bulbostylis scabricaulis*, *Combretum celastroides*, *Crossandra leucodonta*, *Cryptolepis oblongifolia*, *Dalbergia boehmi*, *Diplorhynchus condylocarpon*, *Dysphania ambrosioides*, *Euphorbia ingens*, *Ficus sur*, *Julbernardia paniculata*, *Monotes katangensis*, *Ocimum americanum* , *Parinari alvimii*, *Phragmanthera leonensis*, *Phyllanthus muellerianus*, *Senna sophera*, *Turraea floribunda*, *Vachellia hockii*, and *Vitex madiensis*. Among these 25 species, no accessible ethnopharmacological information are reported on nine taxa: *Albizia versicolor*, *Asparagus bequaertii*, *Brachystegia allenii*, *Brachystegia taxifolia*, *Bulbostylis scabricaulis*, *Crossandra leucodonta*, *Ficus sur*, *Monotes katangensis*, *Phragmanthera leonensis*. This study therefore reports for the first time the ethnopharmacological knowledge of these 9 plant species. Subsequent investigations must be carried out as a priority on these 9 plants to confirm their uses against typhoid fever, especially since they emerge as rare and endemic to the region. The order of importance in studying these plants can be based on their ethnobotanical indexes. In this case, concerning the consensus index, *Ficus sur* (Ic = 0.22) and *Monotes katangensis* (Ic = 0.18) may take precedence; however, if we refer to their usual value, *Monotes katangensis* (UVp = 0.15) and *Brachystegia allenii* (UVp = 0.8) occupy the first two places. If we consider the two indices concomitantly (IC and UVp), *Monotes katangensis* takes precedence, followed by these 3 other species mentioned above.

This study also shows that the plants listed are primarily named in Bemba: 40% (Figure 2) but that most of the PMTs consulted are from the Luba ethnic group of Katanga (38%) (Table 3). This disparity can be justified by the fact that the PMTs are not necessarily the harvesters, so they know the plants that is not of their ethnicity. Another variable that could explain this disparity would be the fact of a cultural mix which means that the knowledge of the PMT of

Lubumbashi exceeds that acquired from its ancestors; However, it should be noted that the various ethnobotanical studies carried out in the region [23, 25, 27, 31] show that the practice of traditional medicine is dominated by the Bemba and the Luba. They would probably constitute the majority ethnic groups of the region.

Furthermore, the fact that 38.6% of plant species under examination have been previously reported as anti-typhoids and that among them 31.6% have already been studied on *S. typhi* (Figure 5) suggests some credibility to be accorded to the information resulting from the investigations. Thus it is probable to find among the plants not studied but informed during the present study those active on *S. Typhi*.

This study lists from 57 plants, 65 anti-typhoidal recipes for which the stem bark constitutes the most used part (Fi= 33%) and the decoction (Fi=72%) the mode of preparation of the recipes, the most used (Figure 5). Although these results are similar to those encountered in the various ethnobotanical surveys carried out in the region about decoction [23, 25–27, 31, 32], there is a disparity regarding the most used part. The leaf is more used in some studies of the region [23, 26, 32], while in others [25, 27, 31], it is the root that is the most used part. In the present study, the stem bark is the most used. In certain ethnobotanical studies targeted towards anti-typhoidal use, in particular, those carried out in Benin [4], Nigeria [33], and Cameroon [15], the decoction (50 -100%) and the leaf (34.2 - 68%) constitute the method of preparation and the most used organ. It is, therefore, possible to identify a trend of consensus on decoction as the preferred mode of use of plants for anti-typhoidal use, unlike the organ. However, this hypothesis is considered very modestly given the few studies mentioned.

Nevertheless, it would be interesting to review the literature on the plants used in the management of typhoid fever at the national and continental levels to have a clear-cut point of view. The use of leaves offers lower stability of constancy in the activity than stem bark. Indeed, the leaf being generally the organ of synthesis, depending on whether the leaf is harvested young or at maturity, its composition can easily change, unlike the harvesting of stem bark which constitutes the storage places where the design should be slightly affected by the synthesis of metabolites.

In previous ethnobotanical studies carried out in Lubumbashi on medicinal plants [23, 25–27, 31], as in the present study (Table 3), men over the age of 40 old were the most encountered during the survey, unlike women, and their level of education was deficient. On the other hand, in particular, in works carried out in North Africa [34–36], women predominate in traditional medicine. One of the reasons that could justify this situation would be that in Lushoise society, the woman is mainly occupied with housework, leaving the man to look for food for the household. However, suppose the traditional medicine practice is regarded as a profession in the region; in that case, the probability of meeting men in its practice seems higher than that of meeting women.

5. Conclusion

This study reports 57 plants used in 65 anti-typhoid recipes by TMPs in Lubumbashi. Pharmacological investigations of eighteen 57 plants, including *Annona senegalensis*, have already been registered from different parts of Africa as potential medicinal herbs to manage typhoid fever. Their studies on *S. typhi* have shown them to be active. Twenty-five other species, such as *Monotes katangensis* or *Ficus sur* are reported for the first time and have a high medicinal use value in Lubumbashi. In addition to treating typhoid fever, these plants also treat several other pathologies, such as diabetes. These results suggest that further work is needed to establish the scientific basis for the anti-typhoidal use of these plants in traditional medicine and possibly identify the compounds likely to justify this activity.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that might appear to influence the work reported in this article.

Author contributions

Data collection: Kasongo Ilunga Pierre; Project design, formal analysis, statistical data processing, and writing of the draft article: Bashige Chiribagula Valentin; Supervision - revision and editing of the project: Mboni Manya Henri, Félicien Mushagalusa Kasali, Okusa Ndjolo Philippe, Lumbu Simbi Jean-Baptiste.

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