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Ethnobotanical study of selected medicinal plants traditionally used in the rural Greater Mpigi region of Uganda

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ABSTRACT

Ethnopharmacological relevance: This study provides the first report on selected traditional medicinal plant use, including parts used and methods of preparation, in the Greater Mpigi region of Uganda. This data supports the conservation of local traditional ecological knowledge and will facilitate future drug discovery research.
Aim of the study: Our study aimed to conserve culturally and scientifically-valuable medical knowledge of 16 plant species traditionally used in the Greater Mpigi region in Uganda, namely *Albizia coriaria*, *Cassine buchananii*, *Combretum molle*, *Erythrina abyssinica*, *Ficus saussureana*, *Harungana madagascariensis*, *Leucas calostachys*, *Microgramma lycopodioides*, *Morella kandtiana*, *Plectranthus hadiensis*, *Securidaca longipedunculata*, *Sesamum calycinum subsp. angustifolium*, *Solanum aculeastrum*, *Toddalia asiatica*, *Warburgia ugandensis* and *Zanthoxylum chalybeum*. An additional objective of the study was an ethnological investigation of the socio-cultural background and medical understanding of diseases treated by traditional healers in the study area.
Materials and methods: A pilot survey in the study area revealed that 16 plant species were frequently used in treatment of a variety of medical disorders. In order to obtain more complete information, we conducted a broader ethnobotanical survey using structured interviews with 39 traditional healers from 29 villages, specifically asking about the traditional uses of these 16 medicinal species.
Results: Results of the survey confirmed a high level of traditional use of these species in the Greater Mpigi region. In addition, various other traditional uses and methods of preparation were recorded, most of them for the first time. In total, 75 different medical disorders treated with the plants were documented.
Conclusions: Conservation of traditional knowledge for future generations is vital, as loss has already been recorded due to multiple causes. The need for novel and more effective drugs derived from natural products is more important than ever, making future studies on herbal remedies both justified and urgently required. The traditional healers surveyed in this project also have expectations of the research – they would like to be updated about any resulting studies into the pharmacological efficacy of medicinal plants so that the research findings can inform their confidence in each herbal remedy.

1. Introduction

Plants have been used traditionally as a source of medicine and natural remedies throughout history by humans across the globe and medicinal plant use is still the predominant form of healthcare services in East and Central Africa (Bussmann et al., 2018; Kigen et al., 2019). In Uganda, four out of five people primarily seek care from traditional healers and previous studies report that there is at least one traditional healer per village (Abbo, 2011; THETA, 2001). Subsequently, Uganda has been reported to have many more indigenous traditional healers than Western-trained doctors. The traditional healer-to-population ratio in Uganda is 1:200 compared to 1:20,000 for Western-trained physicians (Abbo, 2011; King, 2002; Tuck and Green, 1997), thus resulting in 100 times as many traditional healers as Western-trained physicians. Especially in rural areas, these Western-trained physicians are absent, although the WHO recommends a ratio of at least 1 physician to 1000 people (WHO, 2016). On the other hand, traditional healers meet the healthcare needs of most Ugandans in a culturally appropriate manner.

Uganda has a very rich biological diversity deriving from its unique bio-geographical location despite its small size (Kalema and Bukenya-Ziraba, 2005). The East African country boasts seven of Africa's 18 phytogeographical regions (Davenport and Matthews, 1995). This tally is higher than that of any other African country (White, 1983). Its biodiversity includes more than 5000 species of higher plants in the indigenous flora (Hamilton et al., 2016).

Roughly 86% of Uganda's population are predominantly farmers who rely on subsistence agriculture and live in rural areas (Turyahabwe et al., 2013). These farmers are generally poor and 40% live on less than

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a US dollar per day, which is below the global poverty line (Turyahabwe et al., 2013). Previous studies amongst the traditional medicine practitioners in our study region indicate they generally have very low levels of literacy and schooling (Adia et al., 2014; Nyamukuru et al., 2017).

Practices of African traditional medicine and application of medicinal plants vary between different cultures, geographic and climatic regions, and even between neighboring villages. In most parts of Africa, including Uganda, traditional knowledge of healing using plants is transferred orally from one generation to the other and is often never documented (Adia et al., 2014; Nyamukuru et al., 2017). Unfortunately, much of this traditional knowledge on the medicinal application of plants has already been lost due to deforestation, economic drift to the cities (rural-urban migration), or Western influence in general (Bussmann et al., 2018). Thus, this first documentation of traditional knowledge concerning the use of selected medicinal plants in the Greater Mpigi region is vital for the conservation of traditional knowledge for future generations.

The aims of this study were two-fold: 1) To document the traditional use of selected medicinal plant species from tropical Uganda, specifically in the Greater Mpigi region; and 2) To undertake an ethnological assessment of the socio-cultural background and medical understanding of diseases treated by traditional healers in the study area.

2. Materials and methods

2.1. Study area

The study was conducted with traditional healers in the Greater Mpigi region of central Uganda–a tropical country located on the northern shores of Lake Victoria, bordered by Kenya to the east, South Sudan to the north, the Democratic Republic of Congo to the west, and Rwanda and Tanzania in the south. Apart from the high biodiversity, Uganda is also characterized by its diversity in terms of ethnic groups (> 50) and languages (Brockerhoff and Hewett, 2000).

The Greater Mpigi region consists of Mpigi, Butambala and Gomba districts. Butambala and Gomba were originally counties within Mpigi district, but were elevated to district status in 2010 (Mpigi-Local-Government, 2019; UBOS, 2012). Mpigi District is located 0.2274° N, 32.3249° E, whereas Butambala is located at 0° 8′ 16 N and 32° 13′ 5 E and Gomba is 0° 12′ 0 N and 31° 45′ 0 E. The population of Mpigi, Butambala and Gomba districts is 273,900, 105,400 and 169,000 respectively, according to the Uganda Bureau of Statistics (UBOS, 2018). The study area lies between 1182–1341 m above sea level and receives heavy rainfall in the range of 1513 mm per annum. The main ethnic group here are the Buganda and the main language spoken is Luganda (UBOS, 2012). The local vegetation is characterized as a tropical, moist evergreen forest/savanna mosaic (Barbour et al., 1987; Howard, 1991).

A total of 39 traditional healers from 29 different villages were interviewed. The locations of the villages are shown in Fig. 1. The perimeter in which the 29 villages are located adds up to an estimated total study area of 715 km^2. People living in this remote area are highly dependent on medicinal plants and local traditional healers to cover their primary healthcare needs.

Most of the traditional healers visited and interviewed belonged to the Buyijja Traditional Healers Association (BUTHGA), which is affiliated with an international NGO called PROMETRA that has a branch in Uganda (www.prometraug.com). The PROMETRA Uganda headquarters is located within the study area in Buwama-Buyija, 67 km from Kampala along Masaka road. The institution is situated on more than 100 acres of forested land. Through the platform created by PROMETRA, traditional healers meet once a week to share ideas, remedies and learn from each other during workshops.

2.2. Collection of ethnopharmacological data

During preceding pilot study field research expeditions in 2015 and 2016, 16 different medicinal plant species were collected, identified and the traditional use was recorded through three informants, accompanied by a thorough literature review. All of these 16 species were verbally reported to be highly used medicinally in the rural Greater Mpigi region. In 2018, ethnobotanical interviews were conducted in the study area with 39 informants. The three traditional healers from the pilot study were not among these 39 informants, but all informants were local practicing traditional healers in their respective home villages. The ethnopharmacological survey questionnaires were specifically designed to collect in-depth data on each species (use, parts used, methods of preparation) because for many of these species, this would be the first report of their medicinal use in this particular region of Uganda.

Our research group specializes in ethnopharmacological fieldwork in Africa and subsequent evaluation of traditional use through pharmacological bioassays. Therefore, the questionnaires were designed to:

a) collect specific information on the traditional use in treatment of those diseases where our *in vitro* model expertise lies, namely malaria, bacterial infections, antiinflammatory disorders and cancer. This strategy will guide towards further selection and prioritization of medicinal plants for future pharmacological studies through the ethnobotanical approach;
b) gather data on the totality of ethnopharmacological uses of the studied plants within the study area;
c) assess the general knowledge regarding Western Medicine of the traditional healers in the study area, including understanding of infectious diseases, the concept of microbial pathogens, and cancer. Listing known infectious diseases contributed to the identification of the culturally most-important diseases;
d) identify the traditional healers' needs and future expectations of our research endeavor and collaboration.

The methodological standards of the survey and the questionnaires were evaluated prior to the field research according to established recommendations (Heinrich et al., 2009; Weckerle et al., 2018). Before undertaking the survey, written prior informed consent was obtained from all traditional healers participating in the study after explaining to them the study aims and what would be involved in obtaining the data. The questionnaires were in the English and Luganda language (Appendix A and B Supplementary data). Interviews were conducted in the Luganda language by GA.

2.3. Collection of plant material and identification of specimens

Linking local plant names with collected plant samples is one of the major challenges of ethnopharmacological field research (Bennett and Balick, 2014; Rivera et al., 2014). The 16 selected plant specimens were collected with representative morphological features under guidance of the traditional healers. The collection was conducted following the standard collection procedures (Martin, 2004).

The methodology for plant identification and assignment of scientific names was adapted from Weckerle et al. (2018) in terms of collecting specimens for herbarium vouchers, linking plant names given during interviews to plants collected for herbarium voucher preparation, as well as exhaustive collection of plant material and application of visual aids for identification (KEW database). Scientific names were cross-checked with http://www.theplantlist.org on August 11th, 2019 and family assignments follow The Angiosperm Phylogeny Group IV guidance (The Angiosperm Phylogeny, 2016). Voucher specimens of all species collected were deposited at Makerere University Herbarium in

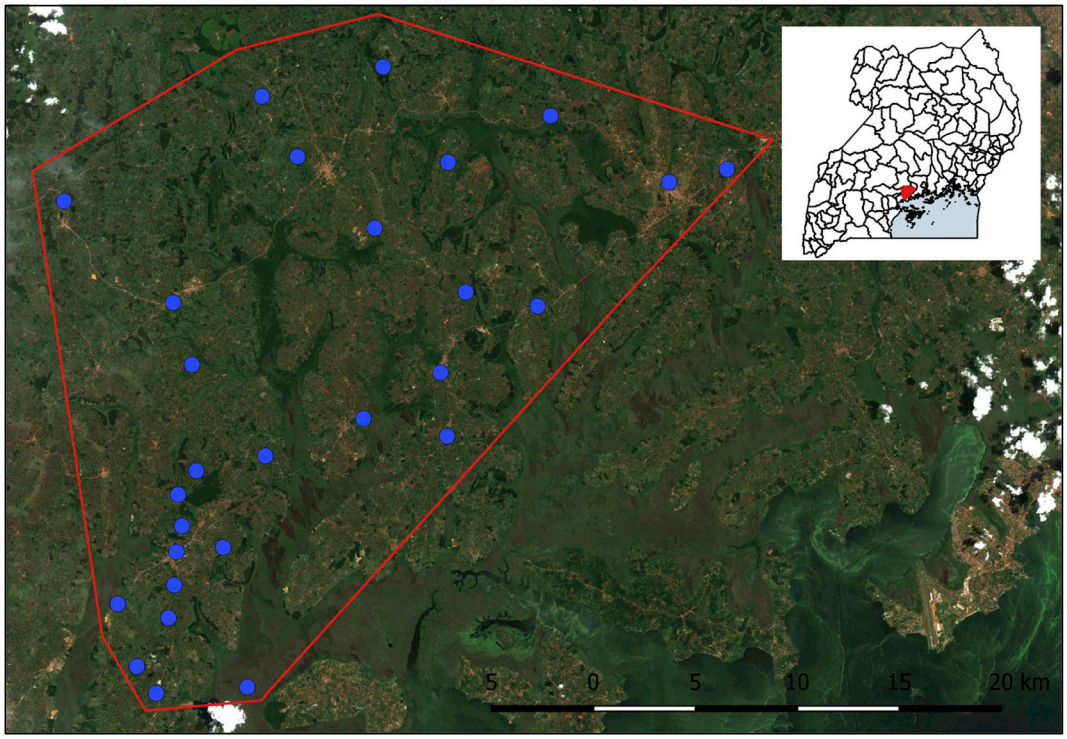

Fig. 1. Map of the study area in the Greater Mpigi region (715 km^2), illustrating the 29 villages where the ethnobotanical survey was conducted (Satellite Data: Copernicus Sentinel, 2019; processed by the European Space Agency).

Kampala, Uganda and select specimens were also deposited at Emory University Herbarium (GEO) in Atlanta, GA, USA and digitized specimens are available for viewing through the SERNEC portal at http://sernecportal.org/portal/.

2.4. Data analysis

Following completion of fieldwork, all questionnaires were processed for data analysis, e.g. scanned and data transferred to Excel sheets. All parameters, such as methods of preparation, information on herbal drug administration, number of citations of a species for a specific traditional use or demographic data, were analyzed through descriptive statistics, described below.

2.4.1. FC

Transparency of this study is mainly conferred through information on the Frequency of Citation (FC), making the study comparable with other studies in the region and resulting in a reliable assessment of the cultural use of a plant species (Heinrich et al., 2009). The FC expresses the absolute number of informants interviewed that use a certain plant species for a specific event (non-specified medicinal use/specified medicinal condition or disease). For a single event, it varies from 0 (none of the informants uses this plant species in a specific event) to 39 (maximum number of informants use this plant species in a specific event; $n = 39$). The ethnobotanical index FC_{event} represents the number of use reports of a medicinal plant mentioned in each previously defined event ("malaria", "inflammatory disorders", "treatment of symptoms of general infections", "skin infections", "tuberculosis", "cancer"). If set into relation with the total number of informants, this absolute value serves as a parameter for prioritizing the selected plant species for our future evaluation of pharmacological effects through *in vitro* models. The event "total" and the FC_{total} describe the total sum of all use reports for treatment of all medical conditions combined.

3. Results and discussion

3.1. Demographic data

Thirty-nine informants participated in the study; all were rural traditional healers. The demographic data of these informants is reported in Table 1. The majority were female (24, 61.5%), whereas 15 male traditional healers (38.5%) were interviewed. The age of the informants ranged from 23 to 74 years. The age groups 36–45 (28.2%), 46–55 (23.1%) and 56–65 years (23.1%) were more represented than younger informants from the age groups 25–35 years (10.3%) or younger (2.6%). The distribution of traditional knowledge among elder generations, without passage of knowledge to younger generations has been exacerbated by economic drift to the cities and Western influence. This gap in traditional knowledge between the older and younger generations is more pronounced in neighboring districts, because traditional medicine is already being taught in organized sessions by the BUTHGA and the PROMETRA network in the study area. Informants older than 65 years (12.8%) were also less represented, reflecting that

Table 1
Demographic data of the informants (n = 39).

	Group	*n*	%
Gender	Female	24	61.5
	Male	15	38.5
Age	Younger than 25 years	1	2.6
	25–35 years	4	10.3
	36–45 years	11	28.2
	46–55 years	9	23.1
	56–65 years	9	23.1
	Older than 65 years	5	12.8
Tribe	Baganda	33	84.6
	Bakiga	2	5.1
	Banyankole	2	5.1
	Bagwere	1	2.6
	Banyarwanda	1	2.6

Table 2
Locations of practice of interviewed traditional healers in rural Central Uganda (n = 39).

Village	*n*	%	Approx. coordinates	
			latitude	longitude
Buwama	4	10.3	0.06424	32.10788
Buwere	2	5.1	0.08945	32.10866
Buyijja	2	5.1	0.10659	32.14712
Gombe	2	5.1	0.25657	32.27275
Kamengo	2	5.1	0.1433	32.22426
Kibanga	2	5.1	0.23616	32.2276
Kibibi	2	5.1	0.23859	32.16125
Mpigi	2	5.1	0.22735	32.32492
Nsangwa	2	5.1	0.1	32.11666
Bunjako Island	1	2.6	0.00454	32.13912
Busolo	1	2.6	0.26527	32.14555
Butambala	1	2.6	0.17425	32.10646
Kabira	1	2.6	0.17263	32.26706
Kalamba	1	2.6	0.27824	32.19894
Kibissi-Mawokota	1	2.6	0.04958	32.10692
Kisubi	1	2.6	0.01368	32.09051
Kyabadaza	1	2.6	0.12299	32.1903
Lungala	1	2.6	0.23308	32.35043
Magejjo	1	2.6	0.17883	32.23543
Magya	1	2.6	0.06617	32.12849
Mbizzi Nnya	1	2.6	0.04126	32.08208
Mitala Maria	1	2.6	0.0756	32.11034
Mpenja	1	2.6	0.21894	32.05835
Ntolomwe	1	2.6	0.14685	32.11476
Nvule	1	2.6	0.00179	32.09894
Ssango	1	2.6	0.0351	32.1044
Ssenero	1	2.6	0.11527	32.22715
Ssenge	1	2.6	0.20705	32.19522

depth of traditional knowledge is vanishing due to the death of rural elderly people. Most of the informants were members of the Baganda tribe (33, 84.6%). Other ethnic groups stated include two informants each from the Bakiga (2) and the Banyankole (5.1%) tribes, as well as one informant each from the Bagwere (2.6%) and Banyarwanda tribes (2.6%).

The informants live and practice traditional medicine in a total of 29 different villages, small towns or communities within the study area. The names of all locations and their approximate coordinates are given in Table 2. The highest proportion of informants (10.3%) reside in Buwama, one of the smaller towns along Kampala-Masaka Road, which is the major road connecting the capital Kampala with the South-Western parts of the country. Apart from Mpigi town, most of the other communities are very small, sometimes remote villages and communities that cannot be reached during heavy rain due to muddy dirt roads. One community, Bunjako Island, is interestingly located on a small island in the swamps of Lake Victoria.

3.2. Background of traditional healers

Interviews began with collection of background information on each healer. This included questioning the traditional healers about their experience in practicing their profession, about the number of patients each healer treats per month and about the source of their botanical and medical knowledge. Results are listed in Table 3.

The level of experience of the survey participants ranged from 2 to 40 years of practicing. This discrepancy is largely due to the variation of age of the traditional healers, described in subsection 3.1. The largest part of the informants (41.0%) had practiced medicinal plant use and healing for 11–20 years in their individual local communities at the time of the survey. Table 3 also shows the monthly numbers of patients treated, which ranged from 1 to 40 patients per month.

The source of traditional knowledge varied between the informants: 12.8% of the respondents stated that they acquired their medicinal knowledge from their parents and 15.4% from their grandparents, resulting in a total of 28.2% of the traditional practitioners where traditional knowledge was solely transferred from one generation to another within the family. Ten percent of the respondents mentioned their knowledge of botanical medicine was obtained via apprenticeship under other traditional healers. However, with 51.3% the majority of respondents claimed to have acquired their traditional knowledge by participating in the BUTHGA platform and the associated PROMETRA network, reflecting the important work and gain in conservation of traditional ethnobotanical knowledge performed by these associations in the region. Of the survey participants, 10.3% reported that their source of traditional knowledge can be described by a combination of the traditional knowledge transfer within the family and the modern BUTHGA/PROMETRA approach.

Table 3
Information on the background of the interviewed traditional healers (n = 39).

	Group	*n*	%
Experience as traditional healer	Less than 5 years	7	17.9
	5–10 years	11	28.2
	11–20 years	16	41.0
	More than 20 years	5	12.8
No. of patients per month	Less than 4	3	7.7
	5–9	14	35.9
	10–14	9	23.1
	15–19	2	5.1
	20–24	8	20.5
	25–29	0	0.0
	30–34	2	5.1
	35–39	0	0.0
	More than 40	1	2.6
Origin of traditional knowledge	Parents	5	12.8
	Grandparents	6	15.4
	Other traditional healer	4	10.3
	Buyijja Traditional Healers Association (BUTHGA)	20	51.3
	Combination of above	4	10.3

Another aspect of documenting the background of the traditional healers was learning more about their awareness and conception of infectious diseases, as well as their understanding of cancer. During interviews, healers were asked about the general concept of infectious diseases and were asked to state three infectious diseases they know about. According to their own statements, this general concept, such as that diseases are caused by very tiny organisms invisible to the naked eye, was clear to them (100% confirmation). However, results indicate that the Western concept of pathogenic microbiology generally or at least the differentiation between cancer and infectious diseases is not fully understood (Table 4). Nearly one third of participants (30.8%) listed “cancer” as an infectious disease. Other non-infectious diseases stated were sickle cell disease (5.1%), diabetes (2.6%) and asthma (2.6%). Malaria (41.0%), HIV/AIDS (33.3%), syphilis (28.2%) and tuberculosis (15.4%) were the infectious diseases most prominently mentioned. Of note, 25.6% of the traditional healers failed to name more than two infectious diseases/conditions and one healer (2.6%) was only able to state one such disorder. All participants could name at least one infectious disease/condition.

All of the 39 informants were aware of diseases summarized under the general term “cancer”. Following this, they were asked to define ‘cancer’. Results are shown in Table 5. The greatest proportion of the traditional healers defined cancer as “wounds that are not healing” (28.2%) or “increased, uncontrolled or abnormal growth of cells” (20.5%). Cancer was generally referred to as “Kookolo”, which is the condition of cancer within the body in Luganda, the most common local language. Some of the answers of informants were related to individual experiences and hearsay, e.g. “Cancer is caused by eating food sprayed with pesticides”, “Cancer can be caused by having teeth removed” or “Some menstruating women develop cervical cancer because of using dirty sanitary pads”.

Table 4
Knowledge of traditional healers regarding the connection between diseases and contagiousness through microorganisms (n = 39).

	Group	*n*	%
Knowledge about infectious diseases and microorganisms	Yes	39	100.0
	No	0	0
If yes, which three infectious diseases were named	Malaria	16	41.0
	HIV/AIDS	13	33.3
	Syphilis	11	28.2
	Tuberculosis	6	15.4
	Typhoid fever	5	12.8
	STDs	5	12.8
	Candidiasis	4	10.3
	Gonorrhea	4	10.3
	Ringworms	2	5.1
	Measles	2	5.1
	Skin rashes	2	5.1
	Flu	2	5.1
	Mumps	1	2.6
	Skin infections	1	2.6
	Fungal infections	1	2.6
	Bacterial infections	1	2.6
	Potentially infectious conditions stated instead:		
	Stomachache/vomitting	3	7.7
	Fever	2	5.1
	Cough	2	5.1
	Non-infectious diseases stated:		
	Cancer	12	30.8
	Sickle Cell Disease	2	5.1
	Diabetes	1	2.6
	Asthma	1	2.6
	Inability to name three diseases:		
	Just two diseases/ conditions stated	10	25.6
	Just one disease/condition stated	1	2.6
	No diseases/condition stated	0	0.0

3.3. Collection of plant species

In total, 16 medicinal plants were collected in the Greater Mpigi region. Table 6 lists these selected plant species, along with their plant families, life forms, voucher specimen details and local names in Luganda. Some of these species are highly understudied, whereas others are known to be incorporated in the African traditional medicine system inter-regionally.

Voucher specimens of all 16 selected species were deposited at the Makerere University Herbarium in Kampala, Uganda. Additional voucher specimens of *Leucas calostachys, Sesamum calycinum* subsp. *angustifolium*, *Morella kandtiana*, *Harungana madagascariensis* and *Warburgia ugandensis* were deposited at the Emory University Herbarium in Atlanta, GA, USA and made available as part of the digitized collection in the SERNEC portal (SERNEC, 2019). Herbarium voucher numbers are provided in Table 6.

3.4. Relative importance of medicinal plants

The majority of the 16 plant species focused on in this study have recently been reported to be used medicinally in Uganda, the East African region or different parts of the continent, demonstrating their relative significance in African traditional medicine (Alebie et al., 2017; Bunalema et al., 2014; Jima and Megersa, 2018; Katumba et al., 2004; Kibuuka and Anywar, 2015; Lamorde et al., 2010; Lukhoba et al., 2006; Malan et al., 2015; Maroyi, 2013; Mongalo and Makhafola, 2018; Moshi et al., 2012; Muazu and Kaita, 2008; Mukungu et al., 2016; Nyamukuru et al., 2017; Ochwang'i et al., 2014; Orwa et al., 2008; Shaheen et al., 2017; Ssegawa and Kasenene, 2007; Tabuti, 2008; Tabuti et al., 2003; Tariq et al., 2017; Tuasha et al., 2018; Tugume et al., 2016; Vanga et al., 2018; Wambugu et al., 2011).

Taking the Greater Mpigi region into account, the selection of medicinal plant species as study objects was done prior to the survey and based on pilot study interviews with three traditional healers from the study area. Plant species were chosen because they were cited as playing a significant role in the local traditional medicine system, although the majority of these species are still understudied in a laboratory setting. Results of the survey show that this pre-assessment was accurate, as all of the 16 selected medicinal plant species were

Table 5
View of interviewed traditional healers on cancer (n = 39).

	Group	*n*	%
Knowledge about cancer	Yes	39	100.0
	No	0	0.0
If yes, how would you define of cancer	External or internal wounds that are not healing result in cancer.	11	28.2
	Cancer is a malignant disease caused by overproliferation/increased, uncontrolled or abnormal growth of body cells.	8	20.5
	When cells and body parts die and refuse to leave the body, they form “Kookolo” known as cancer.	4	10.3
	Cancer is a disease resulting in spoilt/destroyed cells in the body.	3	7.7
	Cancer is a disease that is incurable.	3	7.7
	Cancer is a prolonged body disorder/sickness.	3	7.7
	Cancer is an internal wound that does not heal and is infected by bacteria.	2	5.1
	Cancer is a disease caused by heavy metals.	2	5.1
	Cancer is an abnormal functioning of the body.	2	5.1
	Wounds/conditions that are not treated results in cancerous cells.	2	5.1
	Cancer is a non-contagious disease.	1	2.6
	Cancer are wounds that affect the uterus, lungs and liver.	1	2.6
	Cancer are wounds that are internal and destroy the bones.	1	2.6
	Cancer is a disease that cannot easily be treated.	1	2.6
	Cancer attacks the breast.	1	2.6
	Cancer needs Western diagnosis unless it is skin cancer.	1	2.6
	Cancer is caused by eating food sprayed with pesticides.	1	2.6
	Cancer is when white blood cells begin functioning abnormally and rebel against the body system.	1	2.6
	Cancer is an infection for example of the breast, uterus, or wounds (Candida causes uterus cancer).	1	2.6
	Some menstruating women develop cervical cancer because of using dirty sanitary pads.	1	2.6
	Cancer is a disease caused by diet or change of behavior.	1	2.6
	Cancer can be caused by having teeth removed.	1	2.6

Table 6
Medicinal plants selected for the ethnobotanical survey and related FCs, confirming general knowledge and high traditional use of the selected species in the study area (n = 39).

Botanical name	Family	Local name (Luganda)	Life form	Voucher specimen no.	FC
Albizia coriaria Oliv.	Fabaceae	Mugavu	Tree	AG203[a]	39
Cassine buchananii Loes.	Celastraceae	Mbaluka	Shrub/small tree	AG198[a]	24
Combretum molle R.Br. ex G.Don	Combretaceae	Ndagi	Shrub/small tree	AG191[a]	35
Erythrina abyssinica DC.	Fabaceae	Jjirikiti	Shrub/small tree	AG199[a]	39
Ficus saussureana DC.	Moraceae	Omuwo	Strangler/tree	AG219[a]	37
Harungana madagascariensis Lam. ex Poir.	Hypericaceae	Mukabiiransiko	Shrub/small tree	AG230[a] 23180[b]	38
Leucas calostachys Oliv.	Lamiaceae	Kakuba musulo	Herb	AG195[a] 23175[b]	17
Microgramma lycopodioides (L.) Copel.	Polypodiaceae	Kukumba	Fern	AG639[a]	17
Morella kandtiana (Engl.) Verdc. & Polhill	Myricaceae	Mukikimbo	Shrub	AG201[a] 23174[b]	34
Plectranthus hadiensis (Forssk.) Schweinf. ex Sprenger	Lamiaceae	Kibwankulata	Herb	AG210[a]	38
Securidaca longipedunculata Fresen.	Polygalaceae	Omukondwe	Tree	AG196[a]	15
Sesamum calycinum subsp. *angustifolium* (Oliv.) Ihlenf. & Seidenst.	Pedaliaceae	Lutungotungo	Herb	AG205[a] 23173[b]	34
Solanum aculeastrum Dunal	Solanaceae	Ekitengo	Shrub/small tree	AG193[a]	28
Toddalia asiatica (L.) Lam.	Rutaceae	Kawule	Shrub	AG190[a]	38
Warburgia ugandensis Sprague	Canellaceae	Abasi	Tree	AG220[a] 23181[b]	36
Zanthoxylum chalybeum Engl.	Rutaceae	Ntaleyaddungu	Shrub/tree	AG204[a]	18

[a] deposited at Makerere University herbarium
[b] deposited at Emory University herbarium

confirmed to be frequently used as medicines in the study area. Table 6 reports the number of survey participants (FCs) that claim to use a particular species at all, verifying the general knowledge of the selected medicinal plant species and their traditional use.

Albizia coriaria and *Erythrina abyssinica* are the two species that are used medicinally by all participants. In total, 10 out of 16 of the selected plant species were mentioned by at least 87.2% or more of the survey participants. Only *Zanthoxylum chalybeum*, *Leucas calostachys*, *Microgramma lycopodioides* and *Securidaca longipedunculata* were recorded by less than half of the traditional healers interviewed. Still, these plant species are also regarded as being widely used in the local traditional health system as 18 informants, 17, 17 and 15 respectively, claimed to utilize these species regularly.

By determining the information whether a specific plant is used in this particular study area in the Greater Mpigi region (FC), our research sought to establish a comparable relationship between local traditional use and traditional use within the East African region. Our following assessment on the total use reports not only takes the five predefined medical conditions into account ("malaria", "inflammatory disorders", "skin infections", "tuberculosis", "cancer"), but also every single individual medicinal use stated in the questionnaire category "other" (FC_{total} = sum of all use reports in the survey). Calculated FC_{total} values are shown in Fig. 2.

A. coriaria, Warburgia ugandensis and *E. abyssinica* were the predominant species that exhibited the highest number of use reports in the study area, followed by *Plectranthus hadiensis*, *Ficus saussureana* and *Toddalia asiatica*. These plants reflect a high use in the treatment of a large variety of diseases and medical disorders. The lowest numbers of use reports were calculated for *M. lycopodioides*, *L. calostachys* and *S. longipedunculata*. The low number of use reports was as expected for *L. calostachys* and *M. lycopodioides,* as these are understudied species. However, in case of *S. longipedunculata,* the low number of use reports was surprising as it grows and is used medicinally all over the African continent (Mongalo et al., 2015; Okoli et al., 2005).

3.5. Specification of traditional use

Selection of medicinal plants was based on previous pilot ethnobotanical studies within the study area. Particular emphasis was placed on questioning the survey participants about their traditional use of plants in treatment of malaria, inflammatory disorders, treatment of symptoms of general infections, skin infections, tuberculosis and cancer. Apart from plants described in the treatment of a certain disease or medical condition, information about the methods of preparation, administration and the plant parts used were also recorded. Plant parts used medicinally and therefore mentioned in the survey were bark (B), leaves (L), roots (R), root bark (RB), seeds (S), stem (ST), stem bark (STB). fruits (FR), flowers (F) and the whole plant (WP).

The following subsections provide summaries of the results for each of these medical conditions and their treatment with the selected plants.

3.5.1. Malaria

Forty-one percent of the traditional healers interviewed mentioned malaria among the three infectious diseases that came first to their mind (see Table 4). In Uganda, malaria still kills more than 200 children daily (Sub-Saharan Africa > 1200), making research on botanical antimalarial treatments and the discovery of "novel" natural remedies a high priority (Chinsembu, 2015). In the African traditional medicine system, medicinal plants for treatment of malaria are well established, yet many species remain unknown to scientists, undocumented, or at least have never been investigated for antimalarial activity and efficacy in the lab (Onguéné et al., 2013; Titanji et al., 2008).

The traditional use of plants in treatment of malaria, plant parts used and methods of preparation and administration are summarized in Table 7. As indicated in our initial pilot study, all 16 plant species were confirmed to be used against malaria in traditional medicine within the Greater Mpigi region. *W. ugandensis* (27), *A. coriaria* (26), *T. asiatica* (25) and *E. abyssinica* (25) were the species most often mentioned and reached the highest numbers of malaria-specific use reports. Species with low $FCs_{malaria}$ within the study area are *M. lycopodioides* (4), *L. calostachys* (7) and *S. longipedunculata* (7). Eight out of the nine plant species with high $FC_{malaria}$ (> 14) were previously described in the ethnobotanical literature for their traditional use in malaria treatment in Mpigi District, Uganda, which is a part of the Greater Mpigi region (Adia et al., 2014). Our study therefore confirms and extends the list of plants used against malaria in the study area.

For the vast majority of plant species, the stem bark, the leaves, or both are used in traditional medicine within the study area. Often, the whole plant, meaning multiple plant parts at once, are also boiled and

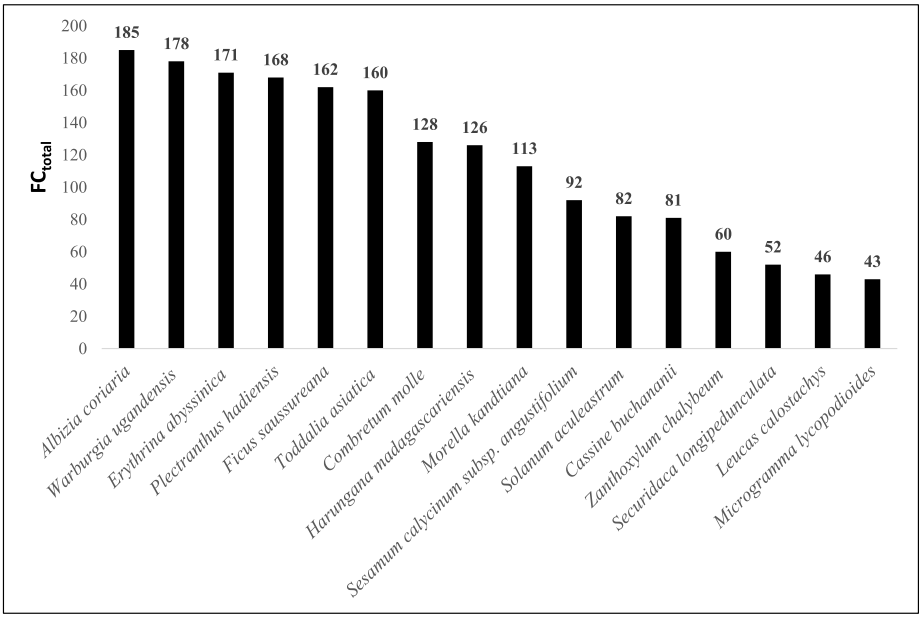

Fig. 2. Total number of use reports (FC_{total}) of the selected medicinal plant species in the study area.

Table 7
Results of analysis of traditional use of selected plant species in treatment of malaria (n = 39); FCs for total specific use and for the sum of FCs for mode of preparations/administrations per species might differ due to participants mentioning multiple parts used and/or methods.

Plant species	$FC_{malaria}$	Parts used	Mode of preparation and administration (FC)
Albizia coriaria	26	STB	boiled (20); powdered into water (5); pounded and boiled (1), taken orally
Cassine buchananii	11	B	boiled (7), taken orally
		L	boiled (3); powdered into tea (2), taken orally
		STB	mixed with other herbs, boiled (1), taken orally
Combretum molle	19	STB	boiled (12); powdered into water (2); mixed with other herbs, boiled (1), taken orally
		L	boiled (7), taken orally
Erythrina abyssinica	25	STB	boiled (18); powdered into water (6), taken orally
		L	boiled (2), taken orally
		F	boiled (1), taken orally
Ficus saussureana	19	STB	boiled (13); powdered into water (6), taken orally
Harungana madagascariensis	14	STB	boiled (12); powdered into water (5), taken orally
		L	boiled (3); powdered into tea (1), taken orally
		S	boiled (1), taken orally
		WP	boiled (1), taken orally
Leucas calostachys	7	L	boiled (5); powdered into tea (1), taken orally
		WP	boiled (1), taken orally
Microgramma lycopodioides	4	L	boiled (3); powdered into tea (2), taken orally
		R	boiled (1), taken orally
Morella kandtiana	16	RB	boiled (2); powdered into cold water (1), taken orally
		L	boiled (2); fresh leaves chewed (1); powdered, then licked (1), taken orally
		R	boiled (6); powdered, boiled (4), taken orally
		WP	boiled (2); steamed (1), taken orally
Plectranthus hadiensis	23	L	boiled (19); powdered into tea (1); cold pressed, boiled (1); mixed with other herbs, boiled (1), taken orally
		R	boiled (1), taken orally
		ST	boiled (1), taken orally
		WP	boiled (1), taken orally
Securidaca longipedunculata	7	B	boiled (5), taken orally
		L	boiled (1), taken orally
		R	powdered, boiled (1), taken orally
Sesamum calycinum subsp. *angustifolium*	11	L	boiled (8); powdered into tea (1), taken orally
		WP	boiled (2), taken orally
Solanum aculeastrum	11	STB	boiled (1), taken orally
		L	boiled (2), taken orally
		R	boiled (8); powdered, boiled (1), taken orally
Toddalia asiatica	25	STB	boiled (1); powdered into cold water (2), taken orally
		L	boiled (7), taken orally
		R	boiled (11); powdered, boiled (9), taken orally
Warburgia ugandensis	27	STB	boiled (15); powdered into tea (5); fresh bark chewed (1); taken orally
		L	boiled (8); powdered into tea (2), taken orally
Zanthoxylum chalybeum	12	STB	boiled (3), taken orally
		L	boiled (4); powdered into tea (1); mixed with other herbs, boiled (1), taken orally
		R	boiled (3), taken orally

key: B = bark, L = leaves, R = roots, RB = root bark, S = seeds, ST = stem, STB = stem bark, FR = fruits, F = flowers, WP = whole plant

consumed for treatment. In addition, other plant parts prepared and administered, but less often cited, include stems, seeds, flowers and roots. The predominant mode of preparation is as aqueous decoction. Some plant parts are also combined with tea leaves when preparing tea (e.g. *Cassine buchananii* leaves, *W. ugandensis* stem bark and leaves, *M. lycopodioides* leaves), chewed (*M. kandtiana* leaves, *W. ugandensis* stem bark) or licked (*M. kandtiana* leaves). The method of drug delivery for treatment of malaria with the plants of interest is always oral administration.

3.5.2. Inflammatory disorders

Inflammation is one of the most important human host defense mechanisms, as it is the immune system's reaction to injury and invading pathogens. Although these mechanisms are essential for life, in some cases acute or chronic inflammation may lead to tissue damage and lethal failure of vital organs (George et al., 2014; Ricciotti and FitzGerald, 2011). In recent years, more studies have focused on discovery of novel antiinflammatory herbal remedies, following ethnobotanical leads. Prior to these endeavors, the traditional use of medicinal plants to treat inflammatory disorders in different cultures needed to be thoroughly preserved and documented. In our survey, we sought to investigate treatment of inflammation in the study area and the cardinal signs of acute inflammation, i.e. pain, swelling, heat, redness and wound infection/healing were combined in the category "inflammatory disorders". Results are reported in Table 8.

W. ugandensis (19), *A. coriaria* (16) and *T. asiatica* (13), *H. madagascariensis* (12), and *E. abyssinica* (12) showed the highest numbers of use reports ($FC_{inflammation}$). Subsequently, these species were most often associated with treatment of inflammatory disorders among the selection of medicinal plants investigated in this study. Plant species less used to treat inflammatory disorders in the study region are *L. calostachys* (2), *S. longipedunculata* (2) and *M. lycopodioides* (5). Generally, plant parts mostly used are stem bark, roots, root bark and leaves. Some exceptions are *S. aculeastrum* fruits and seeds, and *A. coriaria* seeds.

The modes of administration differed depending on the area of inflammatory disorder and the type of symptoms. In most instances, plant parts, powders or aqueous decoctions are taken orally as an analgesic. Another common method is applying processed plant parts, decoctions or powders incorporated in petroleum jelly directly on wounds or swollen body parts. Wounds are sometimes treated by pressing leaves directly against the wounds, e.g. *C. buchananii* (fresh leaves), *Sesamum calycinum* subsp. *angustifolium* (boiled leaves) and *Leucas calostachys* (boiled leaves). Some more rare modes of preparation and administration include sniffing *M. kandtiana* root powder, warming *P. hadiensis* leaves over the fire and application on the inflamed body part, and burning dry fruits from *S. aculeastrum* prior to the ashes being added to petroleum jelly and subsequent smearing onto the inflamed body area.

In some cases, traditional uses in pain management of certain body areas and corresponding FCs were additionally recorded: a) headache, b) joint pain, c) back pain, d) chest pain, e) bone pain, and f) labor pain. In our study, we also requested information on the herbal treatment of toothache. Four of the 16 plant species investigated are traditionally used for toothache in the study area. Here, aqueous decoctions of *A. coriaria* stem bark, *P. hadiensis* leaves or *Z. chalybeum* roots are used to rinse the mouth without swallowing. Fresh *P. hadiensis* leaves are also chewed on the site of the toothache. One informant stated that he prescribes *C. buchananii* root powder as a painkiller, which is then sniffed in the case of toothache.

3.5.3. Treatment of symptoms of general infections

In traditional medicine practices, identification of pathogenesis is also often based on holism, including spiritual, philosophical and sociocultural conceptions, as well as the character and emotions of the patient. Unlike Western medicine and the pharmaceutical industry, where accurate extractions of plants or selective synthesis of pure active molecules are performed according to established protocols, in traditional medicine on the community level, plants or plant parts are mostly used with individually varying methods of preparations, e.g. as decoctions, pills, juices or fresh (Firenzuoli and Gori, 2007). As reported in other studies, indigenous peoples often do not clinically diagnose a particular disease, but rather prescribe herbal drug mixtures to treat the totality of symptoms that are mentioned by the patient (Vandebroek et al., 2008; Wachtel-Galor and Benzie, 2011). As all of the 16 selected medicinal plants are widely used against an array of diseases and medical conditions in the Greater Mpigi region, this subsection elaborates on their use for treatment of symptoms that indicate contagion with an infectious disease. This disease might be of more serious nature, such as tuberculosis, malaria, typhus or cholera, but also of less harmful nature, e.g. the common cold.

Symptoms categorized in this subsection were sore throat, fever, stomachache/gastrointestinal tract (GI) disorder, nausea and cough. The FCs for the traditional use of these symptoms are reported in Fig. 3. *F. saussureana*, *T. asiatica, P. hadiensis* and *S. longipedunculata* are the species most often cited in treatment of sore throat. Considering our previous results on the general knowledge and traditional use of the selected plant species among the participants (Table 6), it is surprising that *S. longipedunculata* was mentioned amongst the highly used species. This is because 61.5% of the informants claimed that they do not use *S. longipedunculata* at all, making it the least used and least known plant species among the 16 species investigated. Thus, this species reveals a high specialization in treatment of sore throats within the study area. In the literature, mainly the roots and bark are cited for treatment of different conditions in African traditional medicine (Borokini et al., 2013; Okoli et al., 2005; Semenya et al., 2013; Sobiecki, 2008). In our study area, an aqueous decoction of the leaves of *S. longipedunculata*, combined with a few drops of lemon juice, is used for treatment of sore throat. To the best of our knowledge, this specific use of the leaves against sore throats is reported for the first time. Only four ethnobotanical studies report use of the roots for flu symptoms, such as cough in Nigeria (Motlhanka and Nthoiwa, 2013; Mustapha, 2013), influenza in the Ugandan Bulamogi county (Tabuti et al., 2003) or cough and oral sores for treatment of opportunistic infections among people living with HIV/AIDS in Uganda (Anywar et al., 2020). One paper from 1962 mentions the use of the leaves in treatment of skin wounds and sores in Eastern Tanzania (Watt and Breyer-Brandwijk, 1962). When it comes to results of pharmacological assays published, most studies also investigate the roots. However, one study reported certain antibacterial and antifungal properties of a crude extract made from *S. longipedunculata* leaves, supporting the traditional application of the leaves in the Greater Mpigi region (Karou et al., 2012). Interestingly, *T. asiatica* is used by the Keiyo Community in the Kenyan Elgeyo Marakwet County to treat common colds (chewed leaves and bark) and a disease called "Koroitab mokto" that translates to "Disease of the Throat" (Kigen et al., 2014). After documenting a description of the symptoms by local herbalists, the research team concluded that the symptoms were similar to those of throat cancer. Here, an aqueous concoction of the roots along with a combination of other plant roots is prepared and administered orally.

Plants most often referred to for treatment of fever were *T. asiatica, P. hadiensis*, *W. ugandensis* and *E. abyssinica*. These four species were also among those most often used for treatment of inflammatory disorders. This overlap may be explained by the generalized molecular mechanism of action of non-steroidal antiinflammatory drug molecules (NSAIDs). NSAIDs achieve their pharmacological activity by inhibition of cyclooxygenase-2 (COX-2) in the prostaglandin H2 (PGH2) signaling pathway, therefore relieving pain and reducing fever non-selectively (Ho et al., 2018; Simmons et al., 2000; Steinmeyer, 2000). *P. hadiensis* is used in Ayurvedic formulations to treat any type of carcinoma and chronic inflammation, and showed promising antiinflammatory and cytotoxic properties in two pharmacological studies by an Indian research group (Menon et al., 2011, 2014). Moreover, a total of 15 species of the genus *Plectranthus* are known to be used for treatment of fever

Table 8
Medicinal use of the study species in treatment of inflammatory disorders, such as pain, redness, heat, swelling and wound treatment in the Greater Mpigi region (n = 39); FCs for total specific use and for the sum of FCs for mode of preparations/administrations per species might differ due to participants mentioning multiple parts used and/or methods.

Plant species	$FC_{inflammation}$	Parts used	Mode of preparation and administration (FC)
Albizia coriaria	16	STB	boiled (9), taken orally; powdered in petroleum jelly, then smeared on body part (5); powdered on wound (1), applied topically
		S	broken and then smeared on wound/swollen body part (1), applied topically
Cassine buchananii	7	B	boiled (5), taken orally; powdered in petroleum jelly, then smeared on body part/wound (1), applied topically
		L	boiled (1), taken orally; boiled, then pressed on wound/swollen body part (1), applied topically
		R	powdered and sniffed (1), nasal administration
Combretum molle	10	STB	boiled (7), taken orally; powdered in petroleum jelly, then smeared on body part/wound (1), applied topically
		L	boiled (3), taken orally; boiled, then pressed on wound/swollen body part/wound (1), applied topically
Erythrina abyssinica	12	STB	boiled (7); mixed with other herbs, boiled and decoction is drunk (2), taken orally; powdered in petroleum jelly, then smeared on body part/wound (2); mixed with other herbs, boiled in petroleum jelly and then pressed against wound/swollen body part (1), applied topically
		F	boiled (1), taken orally; boiled, pressed around the pain area (1), applied topically
Ficus saussureana	11	STB	boiled (6); powdered into tea (2), taken orally; boiled and used for cleaning wound (1), applied topically
		L	boiled (1), taken orally; juice extracted from fresh leaves and smeared on the affected area (1); fresh leaves directly put on swollen wound (1); boiled and used for cleaning wound (1), applied topically
Harungana madagascariensis	12	STB	boiled (8), taken orally; powdered in petroleum jelly, then smeared on body part/wound (1); mixed with other herbs, boiled in petroleum jelly and then pressed against wound/swollen body part (2), applied topically
		L	boiled (1), taken orally
		RB	boiled (1), taken orally
Leucas calostachys	2	L	boiled (1), taken orally; boiled, then pressed on wound/swollen body part (1); juice extracted from fresh leaves and smeared on the affected area (1), applied topically
Microgramma lycopodioides	5	L	boiled (2); powdered into water (1); squeezed into cold water and drunk (1), taken orally; boiled, then pressed on wound/swollen body part (1); juice extracted from fresh leaves and smeared on the affected area (1), applied topically
		R	boiled (1), taken orally
Morella kandtiana	8	RB	mixed with other herbs, boiled and decoction is drunk (1), taken orally; powdered in petroleum jelly, then smeared on body part/wound (1), applied topically
		L	powdered, then licked (1), taken orally
		R	boiled (3); crushed, boiled (1), taken orally; powdered, sniffed (1), nasal administration
Plectranthus hadiensis	11	L	boiled (6); fresh leaves chewed near location of toothache (3), taken orally; boiled, then pressed on wound/swollen body part (2); powdered in petroleum jelly, then smeared on body part/wound (1); juice extracted from fresh leaves and smeared on the affected area (2); warmed over fire, applied on inflamed part (2), applied topically
Securidaca longipedunculata	2	B	boiled (2), taken orally
Sesamum calycinum subsp. *angustifolium*	10	L	boiled (4); powdered into cold water (1), taken orally; juice extracted from fresh leaves and smeared on the affected area (1); boiled, then pressed on wound/swollen body part (3), applied topically
		WP	mixed (fresh) with other herbs, then put on a swollen wound (1), applied topically
Solanum aculeastrum	9	L	powdered in petroleum jelly, then smeared on body part/wound (1), applied topically
		R	boiled (3); crushed, boiled (1), taken orally
		FR	mixed with petroleum jelly, rubbed on swollen body part (1); dry fruits burned to ash, ash added to petroleum jelly, then smeared onto inflamed area (1), applied topically
		S	crushed, then smeared on swollen body part/wound (2), applied topically
Toddalia asiatica	13	STB	powdered in petroleum jelly, then smeared on body part/wound (2), applied topically
		L	boiled (3), taken orally
		R	boiled (6); crushed, boiled (3), taken orally
		RB	mixed with other herbs, boiled and decoction is drunk (1), taken orally
Warburgia ugandensis	19	STB	boiled (11); powdered into tea (1), taken orally; powdered in petroleum jelly, then smeared on body part/wound (3), applied topically
		L	boiled (5), taken orally; powdered in petroleum jelly, then smeared on body part (3); juice extracted from fresh leaves and smeared on the affected area (1), applied topically
		R	boiled (1), taken orally
Zanthoxylum chalybeum	7	STB	boiled (1), taken orally; powdered in petroleum jelly, then smeared on body part/wound (1), applied topically
		L	boiled (2), taken orally; boiled, then pressed on wound/swollen body part (1), applied topically
		R	boiled (3), taken orally

key: B = bark, L = leaves, R = roots, RB= root bark, S = seeds, ST = stem, STB = stem bark, FR = fruits, F = flowers, WP = whole plant

and infections (Lukhoba et al., 2006). However, according to data obtained from our literature assessment, the use of *P. hadiensis* against fever is now reported for the first time. *W. ugandensis* has previously been reported as an anti-fever remedy in Kenya (Jeruto et al., 2008). In other Ugandan regions, e.g. in Butebo County in the Eastern part of the country, *E. abyssinica* is used against fever, among other traditional uses (Anywar et al., 2020; Philip et al., 2017).

In terms of treatment of stomachache or GI tract related disorders, *T. asiatica, A. coriaria* and *F. saussureana* were most often cited. Generally, most of the selected plants were used to treat symptoms of this category, as 13 of the 16 plant species were cited by 5 informants or more.

E. abyssinica was most often named when participants were questioned about herbal medication against nausea, followed by *P. hadiensis*, *T. asiatica, W. ugandensis* and *M. kandtiana*. The sap of *E. abyssinica* was previously described to be used to prevent vomiting (Chitopo et al., 2019).

Almost half of the traditional healers questioned stated that they

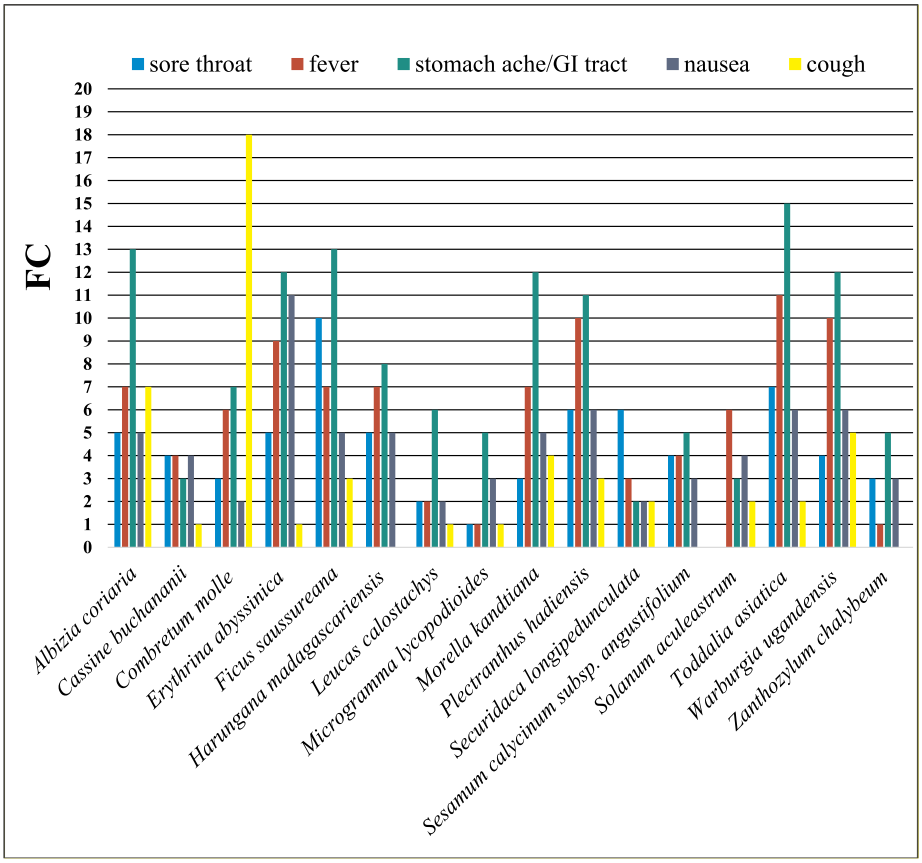

Fig. 3. FCs of plants used in treatment of individual symptoms of general infections (n = 39).

prescribe *C. molle* for treatment of cough. Other often-cited plants in this category were *A. coriaria*, *W. ugandensis* and *M. kandtiana*. According to a book published in 1976, *C. molle* is taken to treat chest conditions in Kenya (Kokwaro, 1976).

The calculated $FCs_{symptoms}$ combine the total use of the five individual, symptom-specific FCs per species and are shown in Table 9, along with the plant parts used, and modes of preparation and administration.

3.5.4. Skin infections

Skin and soft tissue infections (SSTIs) are frequently encountered by medical staff and traditional healers in Uganda and worldwide. The human skin is characterized by a notable ecological diversity of microorganisms that could cause infection, if unbalanced or disturbed. SSTIs encompass a broad set of conditions, and pathogenesis may range from simple infections, e.g. subcutaneous abscesses or pyoderma, to life-threatening infections, e.g. necrotizing fasciitis (Dryden, 2009; Ki and Rotstein, 2008). Bacterial strains involved in pathogenesis are of limited number, but possess unique virulence and transmissibility factors that account for the majority of SSTIs (Gorwitz, 2008). Amongst these are *Staphylococcus aureus*, a leading cause of SSTIs that is also implicated in atopic dermatitis, *Acinetobacter baumannii*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Streptococcus pyogenes* and *Cutibacterium acnes*. As antibiotic resistance has been reported in these strains in recent years, herbal remedies used by traditional healers and herbalists are increasingly frequently being investigated for their pharmacological efficacy and could be leveraged as starting points for future anti-infective drug development (Salam and Quave, 2018).

Part of our survey aimed to investigate traditional plant use against skin infections. Results are shown in Table 10. Generally, "skin infections" was the category with the lowest number of use reports compared to the other categories. According to our informants, 11 of the 16 plant species are used in treatment of skin infections in the Greater Mpigi region. *C. buchananii*, *M. kandtiana*, *S. longipedunculata*, *S. aculeastrum* and *Z. chalybeum* are not utilized medicinally at all, while *M. lycopodioides* roots, *C. molle* stem bark and *L. calostachys* leaves/whole plant were only cited by one or two informants. The species and plant parts most often stated to be used to treat skin infections were *H. madagascariensis* stem bark, leaves and fruits, *A. coriaria* stem bark and leaves, and *S. calycinum* subsp. *angustifolium* leaves. In Mawokota county, which is part of the Greater Mpigi region in Central Uganda, *A. coriaria* bark has previously been described by Adia et al. (2014) as a natural remedy against skin disorders. Another plant cited is *P. hadiensis,* which has previously only been reported to be used in treatment of wounds in the Malabar region of Kerala in India where leaves are rubbed onto the wound (Deepthy and Ramashree, 2014). The modes of preparation and administration differed considerably compared to the other categories of traditional use. This was mainly due to the need for topical application in most cases. The predominant method of preparation was bathing the affected skin or soft tissue body part in an herbal aqueous decoction. Another way of preparation regularly cited was boiling plant parts in petroleum jelly, which is then smeared onto the infected skin.

3.5.5. Tuberculosis

This category of traditional use focuses on the application of the selected species in treatment of tuberculosis (TB). TB has co-evolved with humans over thousands of years, and it is one of the most ancient diseases of humanity (Sandhu, 2011). Molecular evidence of the disease was found in human remains from the Stone Age, recovered 9000 years later from Neolithic settlement in the Eastern Mediterranean (Hershkovitz et al., 2008). Along with HIV/AIDS, TB remains the top cause of death from a single infectious agent worldwide, accounting for more than 10 million infections and 1.6 million deaths in 2017 (WHO,

Table 9
$FCs_{symptoms}$, plant parts used and modes of preparation and administration in treatment of symptoms of general infections (n = 39); $FCs_{symptoms}$ combine the total use of the five individual, symptom-specific FCs per species.

Plant species	$FC_{symptoms}$	Parts used	Mode of preparation and administration
Albizia coriaria	37	STB	aqueous decoction; powdered into tea, taken orally
Cassine buchananii	16	B	aqueous decoction, taken orally
		L	aqueous decoction, taken orally
Combretum molle	36	STB	aqueous decoction; powdered into tea; powdered and licked, taken orally
		L	aqueous decoction; fresh leaves chewed; dried leaves powdered and licked, taken orally
		R	aqueous decoction, taken orally
Erythrina abyssinica	38	STB	aqueous decoction; powdered into tea; fresh bark powdered in cold water; powdered bark licked; sliced bark chewed, taken orally
		L	aqueous decoction, taken orally
		F	aqueous decoction, taken orally
Ficus saussureana	38	STB	aqueous decoction; powdered into tea, taken orally
		L	aqueous decoction; dried leaves powdered and licked, taken orally
Harungana madagascariensis	25	STB	aqueous decoction; powdered into tea, taken orally
		L	aqueous decoction; powdered into tea, taken orally
		R	aqueous decoction, taken orally
		P	aqueous decoction; dried, powdered and licked, taken orally
		WP	aqueous decoction, taken orally
Leucas calostachys	13	L	aqueous decoction; fresh leaves chewed; burned to ashes, then licked, taken orally
		WP	aqueous decoction, taken orally
Microgramma lycopodioides	11	R	aqueous decoction, taken orally
		L	aqueous decoction; crushed into fruit juice, taken orally
		WP	aqueous decoction, taken orally
Morella kandtiana	31	RB	aqueous decoction; powdered into tea, taken orally
		L	aqueous decoction; powdered and licked, taken orally
		R	aqueous decoction; powdered into tea, powdered and licked, taken orally; powdered and sniffed; steam bath, nasal administration
		STB	aqueous decoction, taken orally
Plectranthus hadiensis	36	L	aqueous decoction; fresh leaves chewed; powdered into tea; powdered, mixed into milk; crushed into fruit juice, taken orally
Securidaca longipedunculata	15	L	aqueous decoction; lemon juice added to decoction, taken orally
Sesamum calycinum subsp. *angustifolium*	16	L	aqueous decoction; powdered into tea; fresh leaves chewed; crushed into fruit juice, taken orally; decoction mixed with salt to rinse the mouth
		WP	aqueous decoction, taken orally
Solanum aculeastrum	15	L	aqueous decoction, taken orally
		FR	fruits squeezed, juice then taken orally
		R	burned, then ashes mixed with salt; roots chewed, taken orally
		S	burned, then ashes mixed with salt, licked, taken orally
Toddalia asiatica	41	STB	aqueous decoction; powdered and licked; bark sliced and chewed, taken orally
		L	aqueous decoction; fresh leaves chewed, taken orally
		R	aqueous decoction, powdered into tea; roots chewed, taken orally
		P	aqueous decoction, taken orally
Warburgia ugandensis	37	STB	aqueous decoction; powdered into tea; powdered and licked, taken orally
		L	aqueous decoction; powdered and licked, taken orally
Zanthoxylum chalybeum	12	STB	aqueous decoction; powdered into tea, taken orally
		L	aqueous decoction; powdered into tea, taken orally
		R	aqueous decoction, taken orally

key: B = bark, L = leaves, R = roots, RB = root bark, S = seeds, ST = stem, STB = stem bark, FR = fruits, F = flowers, WP = whole plant.

2018). Patients cured from the disease can still suffer substantial reduction in quality of life due to lifetime sequelae, such as parenchymal, airway, vascular, mediastinal, pleural and chest wall lesions (Glaziou et al., 2015; Kim et al., 2001; Miller et al., 2009). TB is mainly caused by *Mycobacterium tuberculosis* and it is most commonly transmitted from people with infectious pulmonary TB to others via droplet infection, e.g. through sneezing, coughing and speaking (Glaziou et al., 2015; Nardell, 2016). A previous study by Bunalema et al. (2014) investigated the tuberculosis health situation in the Greater Mpigi region. This study showed that the majority of the local traditional healers closely associate TB with HIV/AIDS, substantiated by the fact that 50% of TB patients are infected with HIV and that 30% of all AIDS-related deaths are attributed to TB.

Africa harbors the Cradle of Humanity (Dirks and Berger, 2013). Since TB co-evolved with humans, traditional cultural knowledge of medicinal plants used to counteract TB also co-evolved with the ancient African traditional medicine system. This is also true of local herbal medicine use in the Greater Mpigi region, where, according to our ethnobotanical survey, all of the 16 plant species are used alone or in herbal mixtures to treat TB (Table 11). Plant species displaying the highest TB-specific numbers of use reports are *A. coriaria* (25), *W. ugandensis* (24), *C. molle* (21) and *E. abyssinica* (21). There was high consensus regarding these species, as more than half of the traditional healers interviewed stated they use these plants in treatment of TB. The lowest TB-specific numbers of use reports were recorded for *L. calostachys* leaves and the whole plant and *M. lycopodioides* roots and leaves which were named by only two and three of the informants respectively. Plant parts used and methods of preparation/administration are generally similar to those already described in the traditional use category "malaria" (subsection 3.5.1). For the majority of interviews and plants, these are aqueous decoctions that are drunk as medication. Another regularly mentioned mode of preparation is mixing leaves into tea. Other methods recorded include licking powdered stem bark or powdered roots, and chewing raw stem bark. Two of the sources mentioned that they steam fresh *P. hadiensis* leaves over the fire, which they then give to their patients to chew. According to our literature review, use of *P. hadiensis* in treatment of tuberculosis is reported for the first time. One study of another species of the genus *Plectranthus, P. amboinicus*, that grows in Puerto Rico, showed low antibacterial properties against growth of *M. tuberculosis* (Frame et al., 1998). One

Table 10
Results of analysis of traditional use of selected plant species in treatment of SSTIs (n = 39); FCs for total specific use and for the sum of FCs for mode of preparations/administrations per species might differ due to participants mentioning multiple parts used and/or methods.

Plant species	$FC_{skin\_infections}$	Parts used	Mode of preparation and administration (FC)
Albizia coriaria	8	STB	boiled, herbal bath (3); boiled in petroleum jelly (1) or powdered and mixed in petroleum jelly (3), then smeared on skin, applied topically
		L	boiled (1), herbal bath
Cassine buchananii	–	–	–
Combretum molle	1	STB	pounded and mixed with petroleum jelly (1), then smeared on skin, applied topically
Erythrina abyssinica	3	STB	boiled in petroleum jelly (3), then smeared on skin, applied topically; boiled, filtered and then the infected skin part is bathed in (1), herbal bath
Ficus saussureana	5	STB	boiled in petroleum jelly (4) or powdered and mixed in petroleum jelly (1), then smeared on skin, applied topically
Harungana madagascariensis	12	STB	boiled, herbal bath (2); boiled in petroleum jelly (2) or powdered and mixed in petroleum jelly (6), then smeared on skin, applied topically
		L	powdered and mixed in petroleum jelly (1), then smeared on skin, applied topically
		FR	powdered and mixed in petroleum jelly (1), then smeared on skin, applied topically
Leucas calostachys	2	L	powdered and mixed in petroleum jelly (1), then smeared on skin, applied topically
		WP	boiled (1), herbal bath
Microgramma lycopodioides	1	R	boiled in petroleum jelly (1), then smeared on skin, applied topically
Morella kandtiana	–	–	–
Plectranthus hadiensis	5	ST	boiled in petroleum jelly (1) or powdered and mixed in petroleum jelly (1), then smeared on skin, applied topically
		L	boiled (3), herbal bath
Securidaca longipedunculata	–	–	–
Sesamum calycinum subsp. *angustifolium*	6	L	boiled (2), herbal bath; powdered and mixed in petroleum jelly (4), then smeared on skin, applied topically
Solanum aculeastrum	–	–	–
Toddalia asiatica	3	STB	boiled in petroleum jelly (1), then smeared on skin, applied topically
		R	boiled (1), herbal bath; chewing of roots (1), taken orally
Warburgia ugandensis	4	STB	boiled in petroleum jelly (1) or powdered and mixed in petroleum jelly (2), then smeared on skin, applied topically
		L	boiled (1), herbal bath
Zanthoxylum chalybeum	–	–	–

key: B = bark, L = leaves, R = roots, RB= root bark, S = seeds, ST = stem, STB = stem bark, FR = fruits, F = flowers, WP = whole plant

traditional healer stated that dried, powdered fruits of *S. aculeastrum* are added to cold water and then consumed orally. The use of *S. aculeastrum* in treatment of tuberculosis has also not been reported before.

3.5.6. Cancer

Although nowadays cancer is not a rare disease in tropical Africa, it continues to be a low priority for health care services. The reason is undoubtedly the overwhelming burden of communicable diseases, as reflected by the high number of deaths suffered from malaria, tuberculosis, HIV/AIDS, amongst others (Jemal et al., 2012; Sitas et al., 2006). Epidemiological data on cancer in Uganda is still insufficient and scarce (Jemal et al., 2012). This is mostly due to absence of modern Western clinical facilities for cancer diagnosis in many regions, resulting in a high estimated number of unknown/undetected cases. This lack of modern facilities and technologies means that Ugandan patients being treated in hospitals using Western medicine, experience much lower survival rates than patients in other, non-African developing countries (Gondos et al., 2005). In Uganda, according to the authors' knowledge, there is insufficient data on survival rates of patients treated by traditional healers with medicinal plants and/or witchcraft, making assessment of efficacy of these treatments extremely difficult.

The selected 16 medicinal plant species are also widely used for treatment of a broad array of types of cancer in the study area. Regarding the types of cancer mentioned by the traditional healers, the calculated FCs_{cancer} show that some species are used more regularly than others. Beginning with the highest number of use reports against cancer, in general: *A. coriaria* (31), *F. saussureana* (30), *P. hadiensis* (26), *H. madagascariensis* (22), *T. asiatica* (22), *E. abyssinica* (0.51), *W. ugandensis* (18), *C. molle* (16), *M. kandtiana* (12), *S. calycinum* subsp. *angustifolium* (12), *S. longipedunculata* (10), *S. aculeastrum* (9), *L. calostachys* (8), *C. buchananii* (7), *M. lycopodioides* (6) and *Z. chalybeum* (6). Table 12 shows the types of cancer named by the informants in the survey, as well as those plant species used for treatment and cure of these specific cancer variants.

In our study, we also wanted to investigate how particular types of cancer can be specifically treated with medicinal plants in the absence of clinical diagnosis available in Ugandan traditional medicine, especially in the remote parts of the Greater Mpigi region. How do our informants know about these different types of cancer while living in remote villages, far away from hospitals which use Western medical techniques? Another question was how this relatively new knowledge can be described as "traditional and transferred orally over generations". The answer to these questions is that, as when HIV/AIDS was a new disease in the early 1980's, traditional healers treat cancers based on the similarity of symptoms. A small number of patients may have the possibility to travel and can afford a Western-medicine hospital diagnosis. After receiving a cancer diagnosis, these patients report to their traditional healer in the village. The traditional healers treat their patients for the symptoms they have, such as pain, swelling, visible tumor growth, etc. Consequently, they connect the symptoms and medicinal plants used with the previously obtained specific cancer diagnosis from the hospital. Cases of patients reporting to the traditional healers from the hospital may be very rare in the Greater Mpigi region, but new information about a patient with a certain type of cancer being treated with a certain plant, resulting in a positive change in pathogenesis, can spread fast at the community level among traditional medicine colleagues.

3.5.7. Other traditional medicinal uses recorded

With our questionnaires, we also sought to document all other traditional uses that do not fall in one of the six categories above. These "other" traditional uses, corresponding plant parts used and the respective FCs are shown in Table 13. Results of the full range of traditional uses of the selected medicinal plant species were diverse and numerous. A total of 141 "other" traditional uses for the 16 selected species were recorded, describing their use in the treatment of 44 different diseases and (medical) conditions. The informants responded in many different ways, e.g. they referred to *Z. chalybeum* and *M.*

Table 11
Traditional use of selected plant species in treatment of tuberculosis (n = 39); FCs for total specific use and for the sum of FCs for mode of preparations/administrations per species might differ due to participants mentioning multiple parts used and/or methods.

Plant species	$FC_{tuberculosis}$	Parts used	Mode of preparation and administration (FC)
Albizia coriaria	25	STB	boiled (19) or powdered, then boiled (5); powdered and licked (1), taken orally
Cassine buchananii	11	B	boiled (8) or powdered, then boiled (1); powdered in tea, (1), taken orally
		L	powdered into tea (1), taken orally
Combretum molle	21	STB	boiled (17) or powdered, then boiled (3); chewed raw (1), taken orally
		L	boiled (4), taken orally
		R	boiled (1), taken orally
Erythrina abyssinica	21	STB	boiled (17) or powdered, then boiled (4), taken orally
		L	boiled (1), taken orally
		F	boiled (1), taken orally
Ficus saussureana	15	STB	boiled (9) or powdered, then boiled (6), taken orally
Harungana madagascariensis	10	STB	boiled (8), taken orally
		L	boiled (1); powdered into tea (1), taken orally
		WP	boiled (1), taken orally
Leucas calostachys	2	L	boiled (2), taken orally
		WP	boiled (1), taken orally
Microgramma lycopodioides	3	R	boiled (1), taken orally
		L	boiled (1); powdered into tea (1), taken orally
Morella kandtiana	12	RB	powdered, then boiled (1); powdered and licked (1), taken orally
		L	powdered into tea (1); powdered and licked (1), taken orally
		R	boiled (4) or powdered, then boiled (4); powdered and licked (1), taken orally
		WP	boiled (1), taken orally
Plectranthus hadiensis	16	L	boiled (8); dried leaves powdered into tea (2); fresh leaves cold pressed, boiled (2); steamed over fire, then chewed (2), taken orally
		ST	boiled (1), taken orally
		WP	boiled (2), taken orally
Securidaca longipedunculata	6	B	boiled (3), taken orally
		L	boiled (1), taken orally
		R	boiled (2), taken orally
		FR	boiled (1), taken orally
Sesamum calycinum subsp. *angustifolium*	9	L	boiled (5); powdered into tea (1), taken orally
		WP	boiled (3), taken orally
Solanum aculeastrum	10	L	boiled (1), taken orally
		R	boiled (7) or powdered, then boiled (1), taken orally
		FR	dried, powdered and mixed with cold water (1), taken orally
Toddalia asiatica	18	STB	boiled, taken orally (2); powdered and licked (1), taken orally rally
		L	boiled (2), taken orally
		R	boiled (6) or powdered, then boiled (7), taken orally
Warburgia ugandensis	24	STB	boiled (14) or powdered, then boiled (2); powdered and licked (2); chewed raw (1), taken orally
		L	boiled (7); powdered into tea (2), taken orally
Zanthoxylum chalybeum	9	STB	boiled (3), taken orally
		L	boiled (3); powdered into tea (1); powdered and licked (1), taken orally
		R	boiled (2), taken orally

key: B = bark, L = leaves, R = roots, RB= root bark, S = seeds, ST = stem, STB = stem bark, FR = fruits, F = flowers, WP = whole plant

kandtiana use with the Luganda word "Bulalu". Literally translated this means "madness", which is why we classified it as traditional use in treatment of psychosis. The term "madness" as a disease/medical condition has previously been described and literally translated from local languages in other East African countries and ethnic groups, such as the Jo-Luo and the Kakwa in South Sudan, the Sebei in southeast Uganda, the Pokot and Kamba in Kenya, the Hehe in Tanzania, the Tutsi and Hutu in Burundi and the Wanande in the Democratic Republic of the Congo (Edgerton, 1966; Ventevogel et al., 2013). The local conception of mental illnesses and the generalized East African definition of "madness" relate to all conditions of severe behavioral disturbances, ranging from chaotic behavior (collecting rubbish, walking aimlessly or naked), talking nonsense, conversing with oneself, doing things considered foolish, and types of interpersonal violence to posttraumatic stress disorders and major depression (Ventevogel et al., 2013).

Some traditional uses cited deal with sexual performance and reproduction, e.g. plants as aphrodisiacs, for vaginal dryness, as a birth control agent, or against infertility and importance in men. Moreover, some plants are highly used in treatment of erectile dysfunction within the study area, e.g. *C. buchananii*, *S. aculeastrum* and *S. calycinum subsp. angustifolium*.

As mentioned before, traditional medicine in Uganda is holistic, taking both the physical and the psycho-spiritual condition of a patient into account. Therefore, medicinal plants may be prescribed to appease the spirits, or to remove charms or spells of witchcraft. This treatment might be more expensive than others, e.g. treatment of physical illnesses, and sacrifice of animals and mob justice might also be involved (Allen and Reid, 2015; Tabuti et al., 2003). *M. lycopodioides* and *Z. chalybeum* leaves were both cited to be used to cure bewitchment and chase away evil spirits. Here, the mention of the polypodiaceous fern *M. lycopodioides* is of high interest because, this plant has only been documented for its traditional use as a medicinal plant for treatment of diseases in two publications so far. Just as in our study in the Greater Mpigi region, it has previously been reported to be used to treat anemia in Tanzania, and additionally for removal of lice in South Africa (Maroyi, 2017). More interestingly, in 1988, Dr. Philip A. Dennis published a paper on herbal medicine among the Zambo-Miskito of Eastern Nicaragua, in which he also described the use of *M. lycopodioides* against witchcraft attacks (Dennis, 1988). Surprisingly, although the territory of the Miskito Indians in Nicaragua and the Greater Mpigi region are separated by more than 12,800 km, both ethnic groups seem to utilize the same plant spiritually against witchcraft and sorcery.

M. lycopodioides naturally occurs in South and Central America, Sub-Saharan Africa and in the Caribbean (Mucunguzi, 2007; Pereira et al., 2013; Steege and Cornelissen, 1989; Walker, 1973). It is likely that a shipwrecked African slave ship on the shallow-water coast of Nicaragua

Table 12
Types of cancer mentioned in the survey and plant species used for individual treatment (n = 39).

Type of cancer	Plant species used and their specific FCs
abdominal cancer	*Albizia coriaria* (4), *Combretum molle* (1), *Erythrina abyssinica* (2), *Ficus saussureana* (1), *Plectranthus hadiensis* (1), *Sesamum calycinum* subsp. *angustifolium* (1)
blood cancer/leukemia	*Albizia coriaria (1), Cassine buchananii (2), Combretum molle (2), Erythrina abyssinica (2), Ficus saussureana (2), Harungana madagascariensis (2), Leucas calostachys (1), Microgramma lycopodioides (1), Plectranthus hadiensis (1), Securidaca longipedunculata (1), Solanum aculeastrum (1), Toddalia asiatica (3), Warburgia ugandensis (3)*
bone cancer	*Combretum molle* (1), *Ficus saussureana* (2), *Leucas calostachys* (2)
bone marrow cancer	*Albizia coriaria* (1), *Securidaca longipedunculata* (1)
brain cancer	*Ficus saussureana* (1), *Morella kandtiana* (1), *Plectranthus hadiensis* (1)
breast cancer	*Microgramma lycopodioides (1), Morella kandtiana (1), Plectranthus hadiensis (1), Securidaca longipedunculata (1), Sesamum calycinum* subsp. *angustifolium (2), Toddalia asiatica (3), Warburgia ugandensis (1)*
cervical cancer	*Albizia coriaria* (5.1), *Cassine buchananii (1), Combretum molle* (1), *Erythrina abyssinica* (1), *Ficus saussureana* (3), *Harungana madagascariensis* (1), *Morella kandtiana* (2), *Securidaca longipedunculata* (1), *Toddalia asiatica* (1), *Warburgia ugandensis* (1)
intestinal cancer	*Albizia coriaria* (6), *Cassine buchananii (3), Combretum molle* (5), *Erythrina abyssinica* (3), *Ficus saussureana* (4), *Harungana madagascariensis* (4), *Leucas calostachys* (3), *Morella kandtiana* (3), *Plectranthus hadiensis* (4), *Sesamum calycinum* subsp. *angustifolium* (3), *Solanum aculeastrum* (1), *Toddalia asiatica* (7), *Warburgia ugandensis* (6), *Zanthoxylum chalybeum* (1)
liver cancer	*Combretum molle (2), Ficus saussureana (2), Harungana madagascariensis (1), Microgramma lycopodioides (1), Morella kandtiana (1), Securidaca longipedunculata (2), Solanum aculeastrum (1), Zanthoxylum chalybeum (1)*
lung cancer	*Cassine buchananii* (1), *Erythrina abyssinica* (1), *Morella kandtiana* (2), *Plectranthus hadiensis* (1), *Solanum aculeastrum* (1)
prostate cancer	*Albizia coriaria* (2), *Erythrina abyssinica* (1), *Ficus saussureana* (1), *Plectranthus hadiensis* (1), *Securidaca longipedunculata* (1), *Toddalia asiatica* (1), *Warburgia ugandensis* (1)
skin cancer	*Albizia coriaria (14), Combretum molle (3), Erythrina abyssinica (10), Ficus saussureana (13), Harungana madagascariensis (14), Leucas calostachys (2), Microgramma lycopodioides (2), Morella kandtiana (1), Plectranthus hadiensis (14), Securidaca longipedunculata (3), Sesamum calycinum* subsp. *angustifolium (5), Solanum aculeastrum (4), Toddalia asiatica (5), Warburgia ugandensis (5), Zanthoxylum chalybeum (4)*
stomach cancer	*Morella kandtiana* (1)
throat cancer	*Albizia coriaria (1), Combretum molle (1), Ficus saussureana (1), Microgramma lycopodioides (1), Plectranthus hadiensis (1), Sesamum calycinum* subsp. *angustifolium (1), Solanum aculeastrum (1), Toddalia asiatica (2), Warburgia ugandensis (1),*
uterine cancer	*Plectranthus hadiensis* (1)

in 1641 facilitated the intercontinental transfer of spiritual knowledge about *M. lycopodioides* from Africa to America. In 1711, the bishop of Nicaragua, Benito Garret y Arlovi, wrote a letter to the King of Spain, in which he described the events of 1641, when about a third of the Africans who survived the shipwreck escaped and hid in the forest, then violently fought and defeated the local Amerindian groups, reproducing with the Amerindian women by intermarriage, ultimately followed by peaceful communal life (Arlovi, 1711; Cwik, 2019). These events, especially the intermarriage, are considered to be the birth and fundament of the Zambo-Miskito culture, which is therefore an ethnic group originally composed of Amerindians and former African slaves (Arlovi, 1711; Dennis and Olien, 1984; Iglesias, 2012). Similar traditional use of *M. lycopodioides* against witchcraft in both regions can therefore be logically explained by this historical context and the power

Table 13
Other traditional uses recorded for the 16 selected medicinal plant species (n = 39).

Plant species	Other traditional uses recorded (parts used, FCs)
Albizia coriaria	aphrodisiac (L, 1), fibroids (STB, 3), heart diseases (STB, 1), hernia (STB, 2), HIV/AIDS (STB, 3), STIs (STB, 1), syphilis (STB, 4), typhoid fever (STB, 1), ulcers (STB, 1), vaginal dryness (STB, 3)
Combretum molle	aphrodisiac (STB, 1), diarrhea (STB, 1), hemorrhoids (L, 1), HIV/AIDS (STB, 1), kidney failure (STB, 1), syphilis (STB, 2; L, 1; R, 1), ulcers (P, 1)
Cassine buchananii	erectile dysfunction (STB, 8; R, 3), flu (R, 1), HIV/AIDS (B, 3), kidney failure (B, 1), liver disease (1), sinusitis (S, 1), syphilis (B, 2), yellow fever (B, 1)
Erythrina abyssinica	anemia (STB, 3), birth control (F, 1), brain disorders (L, 1), dehydration (STB, 2), diabetes (STB, 1), diarrhea (STB, 1), eye dryness (L, 1), fallopian tube blockage (STB, 1), fibroids (1), HIV/AIDS (STB, 3), STIs (STB, 1), syphilis (STB, 10)
Ficus saussureana	diabetes (STB, 1; L, 1), fallopian tube blockage (STB, 2), HIV/AIDS (STB, 2), infertility in men (STB, 1), STIs (STB, 1), syphilis (STB, 7; L, 1; R, 1), typhoid fever (STB, 1), ulcers (L, 1; R, 2)
Harungana madagascariensis	anemia (L, 1), diarrhea (STB, 1), hernia (STSB, 1), syphilis (STB, 4; L, 2), typhoid fever (S, 1), ulcers (STB, 1; L, 1), worms (STB, 1)
Leucas calostachys	anemia (L, 1), bed-wetting (1), candidiasis (L, 1), hemorrhoids (L, 1), hernia (R, 1), HIV/AIDS (L, 1), vaginal dryness (L, 2)
Microgramma lycopodioides	anemia (L, 1; R, 1), chasing away evil spirits (L, 1), flu (L, 1), heart diseases (WP, 1), HIV/AIDS (R, 1)
Morella kandtiana	anemia (R, 1), diarrhea (WP, 1), epilepsy (RB, 1), fallopian tube blockage (R, 1), influenza (L, 3; R, 3), fungal infections (L, 1), HIV/AIDS (R, 2), psychosis (RB, 1), sinusitis (RB, 3; R, 2), typhoid fever (R, 1)
Plectranthus hadiensis	diarrhea (L, 2), eye diseases (L, 3), fallopian tube blockage (L, 2), flu (L, 1), fibroids (L, 1), gonorrhea (ST, 1), HIV/AIDS (L, 1), infertility in men (ST, 1), kidney failure (ST, 1), measles (L, 2), psychosis (ST, 1), syphilis (L, 3), typhoid fever (1), ulcers (L, 5),
Securidaca longipedunculata	diarrhea (B, 1; L, 1), liver disease (1), syphilis (B, 1), ulcers (B, 1)
Sesamum calycinum subsp. *angustifolium*	anemia (L, 1), erectile dysfunction (L, 3; WP, 2), bed-wetting (L, 1), dehydration (WP, 1), diarrhea (L, 1), vaginal dryness (WP, 1), impotence/infertility (WP, 2), prolapsed rectum (L, 1), syphilis (L, 1), typhoid fever (L, 2), vaginal dryness (L, 4)
Solanum aculeastrum	erectile dysfunction (STB, 1; L, 2; R, 7), fallopian tube blockage (R, 1), fibroids (R, 1), impotence (R, 1), infertility in men (FR, 1), kidney failure (R, 1), snake bite (1), worms (R, 1)
Toddalia asiatica	anemia (R, 1), aphrodisiac (L, 1; R, 2), brain disorders (L, 1), diabetes (R, 3), diarrhea (STB, 1; R, 1), HIV/AIDS (STB, 1; R, 1), hypertension (R, 1), menstrual cramps (R, 1), typhoid fever (STB, 1; R, 1), snake bite (STB, 1; R, 1), ulcers (L, 1; R, 2), worms (STB, 1; R, 2)
Warburgia ugandensis	anemia (L, 1), aphrodisiac (STB, 1; L, 2), candidiasis (L, 1), fallopian tube blockage (STB, 1), influenza (L, 1), kidney failure (STB, 1), HIV/AIDS (STB, 4; L, 1; R, 1), hypertension (STB, 2), measles (L, 1), miscarriage (L, 1), nose bleeding (L, 1), nasal congestion (L, 1), syphilis (STB, 1), ulcers (STB, 4)
Zanthoxylum chalybeum	chasing away evil spirits (L, 1), epilepsy (1), fallopian tube blockage (L, 1), psychosis (1), syphilis (L, 1; R, 1)

key: B = bark, L = leaves, R = roots, RB = root bark, S = seeds, ST = stem, STB = stem bark, FR = fruits, F = flowers, WP = whole plant.

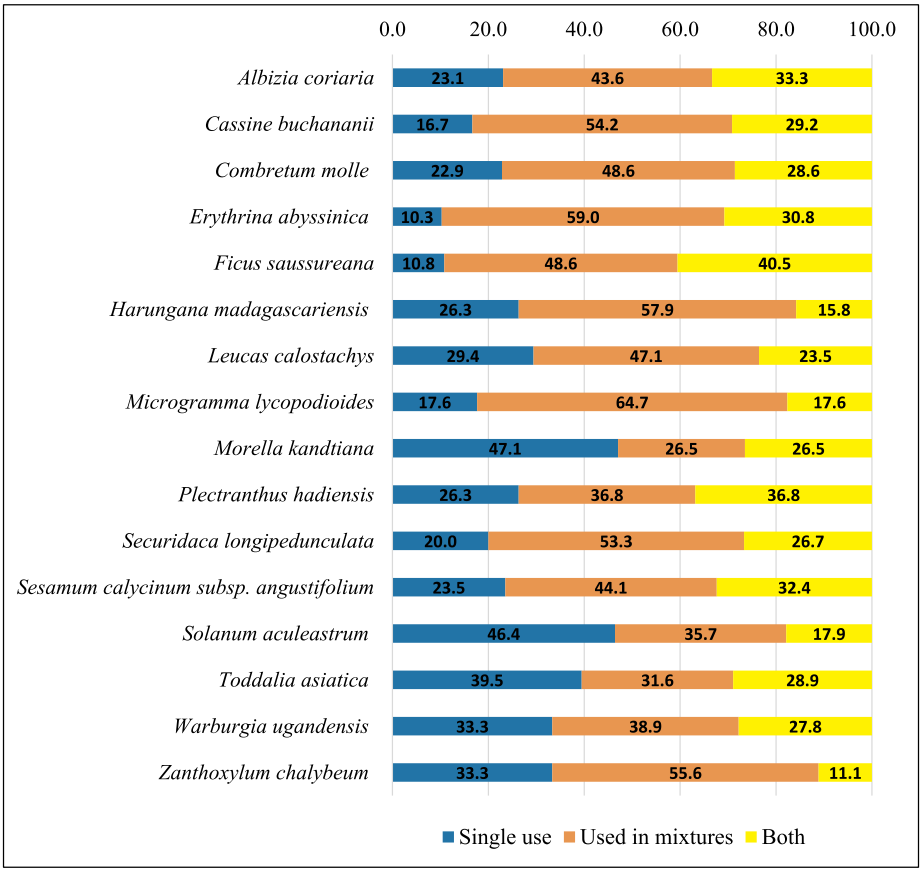

Fig. 4. Percentages of informants using the plant species singly, in mixtures only or both.

of oral transmission of traditional knowledge from 1641 to 1988 is once more remarkable.

3.6. Combinations of medicinal plants

In Western medicine and pharmaceutical industries, purified substances from extracts or (semi-) synthesized active compounds are sold and prescribed for treatment of medical conditions and diseases. Plant extracts prescribed and marketed as "botanicals" on the Western markets are still rather rare and are highly standardized regarding their chemical composition, as well as their individual pharmacological activity and efficacy. This general approach is different in traditional medicine, as here mixtures of many plants are often used, bringing together synergistic effects and supporting a holistic treatment strategy (Chan et al., 2010; Firenzuoli and Gori, 2007; Fu et al., 2014). Fig. 4 shows the response of informants in percentage regarding single plant use only, use in mixtures, or both, for each plant species when prescribing herbal medicines. The majority of the plants are often used both in mixtures with other medicinal plants and singly (> 20%), except for *S. aculeastrum* (17.9%), *M. lycopodioides* (17.6%), *H. madagasciesis* (15.8%) and *Z. chalybeum* (11.1%). Eleven of 16 plant species are predominantly used in herbal mixtures (> 40%). The plant species most often prescribed alone (> 40%) are *M. kandtiana* and *S. aculeastrum*.

3.7. Motivation of traditional healers to participate in study

The researchers adhered to the ethical principles of the International Society of Ethnobiology, and in addition to acquiring appropriate prior informed consent from study participants, efforts were made to engage in access and benefit sharing – specifically with the return of knowledge collected and laboratory results. Bidirectional communication with healers was a priority and the study also aimed to learn more about the healers' motivation for participating in the study and define their future expectations from the authors.

Fig. 5 displays the responses of the traditional healers and their percentage ratios. Multiple responses per participant were welcome. Only 2% of the traditional healers stated that they are interested in future Western drug development and only 5% revealed that they want to benefit financially through the scientific information gained. Some traditional healers prioritized the conservation of their ethnomedicinal knowledge (5%) and the protection of their medicinal plant resources (5%). It is of high interest to 9% of the traditional healers to collaborate for improvement in treatment of patients and 11% want to reinforce their collaboration with the authors, and researchers in health and medicine, in general. The second most common expectation, with 18%, was to receive feedback on the actual findings of the pharmacological studies after the fieldwork and lab experiments are completed. Finally, more than a quarter of the informants stated that getting evidence of whether the plants investigated really do have the claimed medicinal properties is of highest interest to them, as it will boost their confidence in using the plants for individual treatment. Their responses show that there is a high interest in collaboration and also the vital need for feedback.

Unfortunately, very few scientific findings are transferred back to the indigenous peoples and traditional healers that originally set the foundation for advanced ethnopharmacological research endeavors (Maregesi et al., 2007). One of the reasons is that scientific articles are incomprehensible and inaccessible to them (Jaeger, 2005). Screening random plants for bioactivity yields significantly fewer hits than drug development research based on ethnomedicinal uses, making it urgently important to transfer useful findings of lab studies back to information providers in a way that is appropriate to the level of their understanding (Cordell, 1995; Maregesi et al., 2007; Unander et al.,

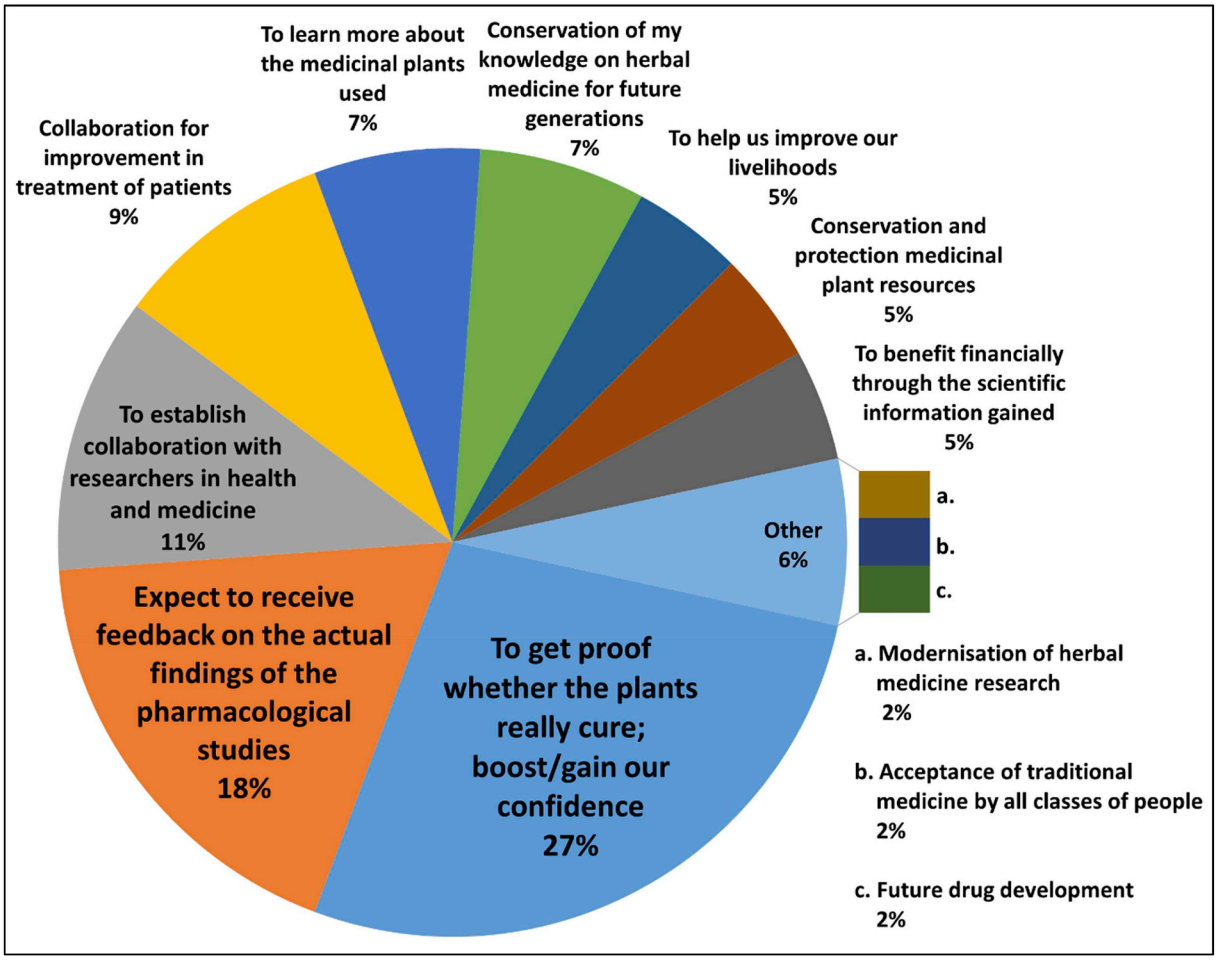

Fig. 5. Future expectations concerning our scientific findings.

1995). Some plants may even pose a threat to local communities, because they might turn out to be toxic and harmful to patients as a direct outcome of treatment. It is the responsibility of ethnopharmacologists to contribute to improving local medicinal plant use, help reduce health hazards derived from herbal drugs, and create a good relationship for future collaborations. Consequently, we commit to transferring all results of our pharmacological evaluation of bioactivity back to our informants in the Greater Mpigi region, e.g. through medicinal plant workshops and continued collaboration.

4. Conclusion

Recording information about traditional medicinal plant use, plant parts used and methods of preparation and administration results in its conservation and facilitates future drug discovery research endeavors, based on ethnobotanical hints. Concerns about the loss of traditional knowledge have been equally expressed by both researchers and policymakers (Bussmann et al., 2018). This study contributes to the conservation of culturally and scientifically valuable medical knowledge of the 16 selected Ugandan plant species.

The species were selected because preliminary studies in the study area suggested a high level of medicinal use in the treatment of malaria, inflammatory disorders, symptoms of general infections, tuberculosis and cancer for all of these species. Results of the ethnobotanical survey fully confirmed these claims. Additionally, various other traditional uses were documented; many for the first time. Moreover, the traditional healers who participated in our survey signified their expectations of the team of researchers: they collectively asked to receive feedback on the findings of any resulting pharmacological study investigating the efficacy of medicinal plants that might lower or boost their confidence in individual herbal remedies.

Author contributions

FS designed the overall strategy of the study and the questionnaires for the ethnobotanical survey. GA and FS conducted fieldwork and collected plant material for future lab analysis. GA collected plant specimens for the Makerere University and Emory University herbaria, prepared the herbarium vouchers and performed plant identifications. FS and BW processed the survey data. FS and CLQ interpreted the data. FS, GA and CLQ wrote the manuscript. LAG directed the study. All authors read, revised and approved the final manuscript.

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Declaration of competing interest

This study was performed according to the international, national and institutional rules considering the Convention on Biodiversity and the Nagoya Protocol. Informed consent was requested and obtained

from all participants of the ethnobotanical survey. All results from future lab work on mentioned plants will be transferred back to traditional healers and survey participants through workshops. The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Appendix A and B Supplementary data. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jep.2020.112742.

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