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Table of Contents: Volume 12 Number 2 10 January, 2018

ARTICLES

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Review

Woody species from the Mozambican Miombo woodlands: A review on their ethnomedicinal uses and pharmacological potential

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Miombo woodlands cover about two thirds of Mozambique national territory. They provide a wide collection of goods and services to the formal and informal economies. A review on the traditional uses of 15 Miombo tree species in human and animal health, as well as the status of research towards the identification of bioactive compounds is presented. Among the 15 species selected, 12 have been screened for their biological activity and/or pharmacological properties and/or toxicity. The information gathered in this work is a key to further exploit potential new uses and future opportunities for research and valorization of the selected species.

Key words: Ethnobotanical, medicinal plants, Miombo woodlands, non timber forest products.

INTRODUCION

Miombo is the most widespread deciduous woodland formation in Africa, stretching across southern Africa in a belt from Angola and the Democratic Republic of Congo in the west to Mozambique in the east, covering an area of about 2.7 km^2 (Campbell, 1996). It is characterized by the dominance of few woody species in the genera *Brachystegia* (Miombo in local languages), *Julbernardia* and *Isoberlinia* (Fabaceae family). However, plant diversity is significant with 8,500 species, half of which are endemic and 4% are trees (Ribeiro, 2007; Dewees et al., 2011).

Species composition and structure of Miombo woodlands vary along a rainfall gradient across the Miombo ecoregion (Campbell, 1996). Consequently, Miombo woodlands are divided into dry and wet according to the zone rainfall. Besides the interest of their biodiversity, Miombo woodlands also play an important environmental role in energy, water and carbon balances (Campbell, 1996). Over the last decades, the ecological dynamics of Miombo has been progressively disturbed by a combination of changes in the global climatic pattern, herbivory/grazing and human activities (Ribeiro, 2007).

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There is an increased concern that such scenarium may result in a considerable loss of the woodlands, with changes in biodiversity and biomass causing modifications on the pattern of goods and services provided by the ecosystem.

In Mozambique, Miombo woodlands occur north of Limpopo River and occupy approximately two-thirds of the country, dry Miombo being the most common type (White, 1983). Dry Miombo has a structure of an "open forest" with two strata: the upper storey composed of woody vegetation and the lower storey composed of grass and herbaceous elements. The vegetation is floristically poorer than the wet Miombo and is dominated by the presence of *Brachystegia spiciformis*, *B. boehmii* and *Julbernardia globiflora*. Canopy height is generally less than 15 m in height (Ribeiro, 2007).

According to the National Statistics Institute (INE, 2016) about 70% of Mozambican population live in rural areas relying directly upon a variety of products harvested from the woodlands for their daily subsistence as well as for their economic, spiritual and cultural needs (Bruschi et al., 2014). Non-timber forest products (NTFP) have always constituted a large part of the forest economy in developing countries by providing supplementary income to many households. However, the real value of NTFPs, such as wild fruits, honey and medicinal plants is still underestimated and the national Gross Domestic Product does not account for most of them. The raising interest in NTFPs is a result of the search for ways to promote development while at the same time protecting the environment (Kusters and Belcher, 2004).

Medicinal plants are an important part of the culture and traditions of African people (Fennell et al., 2004). Particularly in rural areas people are very dependent on plant medicines as a consequence of the lack of formal health care facilities (Clarke et al., 1996). Roots, leaves and barks of many species from Miombo regions are used to treat common ailments and people are generally very knowledgeable about which plants can be used and how to prepare them (Clarke et al., 1996). In addition to the importance of medicinal plants for local use, they are important sources of income and some are internationally marketed. In the last decades there has been an increased interest in traditional pharmacopoeias with researchers involved in determining the scientific rationale for the plant's usage and also in the discovery of novel compounds of pharmaceutical value (Fennell et al., 2004).

The purpose of this paper is to gather comprehensive information on the uses of 15 tree species from dry Zambezian Miombo, focusing on their applications in human and animal health in Mozambique and also in other countries where these species occurr. It also intends to give an overview of the scientific information concerning the pharmacological potential and safe medicinal use. The information combined in this work will be valuable to further exploit potential new uses and future opportunities for research and valorization of Miombo species as well as to enhance the need for their preservation.

METHODOLOGY

An extensive literature retrieval from scientific journals, books, reports, theses and conference papers was used to obtain the required information. Key words included plant species and recognized author names. Personal contacts were made with Miombo researchers for less accessible literature. Data collected included ethnomedicinal uses and research on biological and pharmacological activities of the selected tree species. Scientific names were validated via The Plant List (www.theplantlist.org).

Selection of tree species

Fifteen tree species from dry Miombo woodlands were selected for this review (Table 1). Across Miombo woodlands these species are used for multiple purposes, such as timber, charcoal and firewood, food, honey collection and raw materials for different activities (Bruschi et al., 2014). The selected species were also identified as the most ecologically important by Ribeiro (2007) in one of the most pristine Miombo areas in Africa, the Niassa National Reserve, located in Northern Mozambique. The area is classified as "dry Zambezian Miombo woodland" with intrusions of East African coastal elements (White, 1983). Additionally, according to Timberlake et al. (2004) the Miombo woodlands in Niassa National Reserve are representative of the woodlands in the ecoregion in terms of vegetation structure and composition.

RESULTS AND DISCUSSION

Overview on ethnobotanical and biocompound research

Ethnomedicine and pharmacology

The 15 selected tree species are used in traditional medicine practices (Table 2) in Mozambique (Ribeiro et al., 2010) and other Southern Africa countries such as Tanzania (Amri and Kisangu, 2012), Namibia (Cheikhyoussef et al., 2011), or Zambia (Chinsembu, 2016). Roots, including root barks, are the plant part mostly referred for medicinal purposes (32% - considering the references cited in this review) followed by leaves and juvenile twigs (30%), stems and stem bark (28%). The use of fruits (2%) and sap (2%) is also referred (Table 2 and Figure 1). Depending on the purpose and the region and/or ethnic group, all plant parts are used, from juvenile twigs to roots.

Most of the selected tree species are used to treat, prevent or alleviate complaints caused by the four main groups of diseases in Africa, which include diarrhea, malaria, sexually transmitted diseases and respiratory ilnesses (including hypertension) (Bandeira et al., 2001). Other applications include the treatment of other frequent illnesses such as mental diseases, rheumatism/arthritis, malnutrition/anemia and parasitic infections (Bandeira et

Table 1. Selected tree species from Mozambican Miombo.

Family	Species
Annonaceae	*Annona senegalensis* Pers.
Apocynaceae	*Diplorhynchus condylocarpon* (Müll.Arg.) Pichon
Combretaceae	*Combretum hereroense* Schinz
Combretaceae	*Combretum zeyheri* Sond.
Combretaceae	*Terminalia stenostachya* Engl. & Diels
Dipterocarpaceae	*Monotes engleri* Gilg
Fabaceae (Leguminosae)	*Brachystegia boehmii* Taub.
Fabaceae (Leguminosae)	*Brachystegia spiciformis* Benth.
Fabaceae (Leguminosae)	*Burkea africana* Hook.
Fabaceae (Leguminosae)	*Dalbergia nitidula* Baker
Fabaceae (Leguminosae)	*Julbernardia globiflora* (Benth.) Troupin
Fabaceae (Leguminosae)	*Pterocarpus angolensis* DC.
Melianthaceae	*Bersama abyssinica* Fresen.
Phyllanthaceae	*Pseudolachnostylis maprouneifolia* Pax
Rubiaceae	*Catunaregam spinosa* (Thunb.) Tirveng.

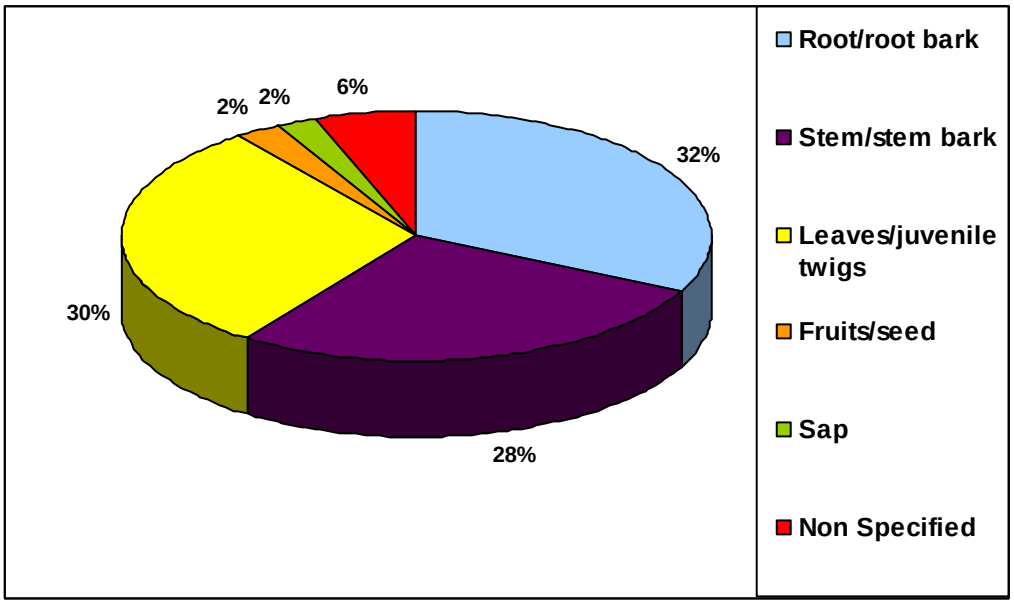

Figure 1. Plant parts used in traditional medicine practices (% of the total references cited in the tables).

al., 2001) as well as wounds and disorders caused by different poisons (Bester, 2006; Ruijter, 2008). Some of the selected plants have been screened for their biological and pharmacological activity (ies) using appropriate *in vitro* and, sometimes, *in vivo* tests (Table 3).

Of the 15 plants selected for this study, 12 (80%) have proven biological and pharmacological activities (Table 3). In some cases, isolation of the active compounds and pharmacological tests provided scientific validation.

Annonaceae

***Annona senegalensis*:** *A. senegalensis* is known by its great medicinal value in Mozambique and other African countries. Different parts of the plant, from leaves to stem bark and roots are used in the management of a wide range of ailments ranging from gastrointestinal disturbances and respiratory system disorders to sexually transmitted diseases (Table 2). Antidiarrheal and antibacterial properties of *A. senegalensis* stem bark,

Table 2. Uses of 15 tree species from Miombo woodlands, in human and animal traditional health systems in Africa.

Family, scientific name	Part(s) used and use(s)	References
Annonaceae		
Annona senegalensis Pers.	Non specified: Diarrhea, respiratory system diseases, sexual complaints	Bandeira et al. (2001)
	Non specified: Sexually transmitted diseases/AIDS	Fumane et al. (2003)
	Juvenile twigs with leaves: Abdominal pain (decoction); head ache (pounded) Leaves: Colds (pounded); dysentery (infusion) Roots: Female sterility (infusion) Roots, flowers: Eye pain	Indjai et al. (2010)
	Stem bark, leaves, roots: Stomach ache, intestinal worms (macerated); cough (infusion or decoction); tuberculosis (macerated or cooked); fever (decoction)	Bruschi et al. (2011)
	Roots, leaves: Eye ache, wounds (crushed or pounded)	Amri and Kisangau (2012)
	Leaves: Stomach upset in babies (porridge) Stem bark: Edema, stomach problems, easy giving birth (decoction) Roots: Stomach problems, infertility, aphrodisiac, pregnancy pains, fever, edema (decoction)	Mahawasane et al. (2013)
Apocynaceae		
Diplorhynchus condylocarpon (Müll.Arg.) Pichon	Leaves: Headache (topic); upset stomach Roots: Blackwater fever (suspension); diarrhea (infusion); snakebite antidote; emetic; cough and tuberculosis (vapor) Fruits: Chronic cough, tuberculosis (vapor) Sap: Remedy for screw-worm	Bester (2006)
	Leaves: Headache, gastric problems Roots: Rectal prolapse, diabetes, testicle inflammation, sore eyes, facilitate giving birth (decoction) Root bark: Indigestion, diarrhea, fever, snakebites, infertility, venereal diseases (decoction); pain in the digestive system (powder in porridge) Sap: Heal cuts	Ruijter (2008)
	Leaves: Diarrhea (infusion)	Chinsembu et al. (2015)
	Stem bark: Malaria (cold infusion)	Ngarivhume et al. (2015)
Combretaceae		
Combretum hereroense Schinz	Young stems, roots: Coughs, diarrhea, tuberculosis, gonorrhea (decoction)	Chinsembu et al. (2015)
	Stem bark, leaves, roots: Coughs, colds, infertility, venereal diseases, diarrhea and dysentery, sores and wounds	Cock and Van Vuuren (2015)
	Leaves: Gonorrhea, chlamydia symptoms in men (suspension in water)	Chinsembu (2016)
Combretum zeyheri Sond.	Roots: Baby delivery, hernia	Luoga et al. (2000)
	Roots, leaves: Diarrhea (decoction or powdered and mixed with porridge); cancer (decoction)	Fyhrquist et al. (2002)
	Non specified: Eye cleaning	Ribeiro et al. (2010)
	Stem bark, leaves, roots: Rectal prolapse, cough, diarrhea, anemia, abdominal ulcers, anal eczema, body pains, stomach ache, wounds, dysentery, infertility, snakebite, hemorrhoids	Augustino et al. (2011)
	Leaves: Skin fungal infections (pounded)	Chinsembu et al. (2015)

Table 2. Contd.

Terminalia stenostachya Engl. & Diels	Leaves, roots: Agitated patients (leaves - bath; roots - maceration)	Agostinho et al. (2009)
	Root: Managing HIV/AIDS patients (decoction)	Mbwambo et al. (2011)
	Rosette leaf: Abdominal disorders, pain, bilharziosis, cancer, coughs and colds, dysentery, diarrhea, fever, venereal diseases, heart disorders, hypertension, jaundice, diabetes, antiseptic	Cock (2015)
Dipterocarpaceae		
Monotes engleri Gilg	Stem bark: Wounds and rash (infusion or decoction) Leaves: Leprosy	Lemmens. (2010)
Fabaceae (Leguminosae)		
Brachystegia boehmii Taub.	Roots: Agitated patients (vapor)	Agostinho et al. (2009)
	Leaves, roots: Snakebite antidote	Augustino et al. (2011)
	Root bark: Sexually transmitted diseases (crushed, mixed with cold water)	Maroyi (2011)
	Leaves: Back pain, dysmenorrhea	Sanogo (2011)
Brachystegia spiciformis Benth.	Stem bark: Agitated patients (maceration) Roots: Agitated patients (bath)	Agostinho et al. (2009)
	Roots: Dysentery, diarrhea (infusion); conjunctivitis (decoction)	Orwa et al. (2009)
	Stem bark, leaves, roots: Snakebite antidote, cough	Augustino et al. (2011)
	Roots: Ear ache, child fever (infusion)	Amri and Kisangau (2012)
Burkea africana Hook.	Stem bark: Headache, migraine, dizziness, pain, inflammation and thrush, antineuralgic, wound-healing, tooth-cleaning agent	Mathisen et al. (2002)
	Leaves, stem bark: Agitated patients Stem bark: Diarrhea Roots: Abdominal complaints, male sexual impotence	Agostinho et al. (2009)
	Roots: Stomach pain; tooth ache (decoction)	Nonyane and Masupa (2010)
	Root bark: Stings and bites antidote, cutaneous and sub-cutaneous parasitic infections, convulsion, pulmonary troubles	Yaro et al. (2010)
	Stem bark: Headache, pain killer	Augustino et al. (2011)
	Roots: Asthma, tuberculosis	Bruschi et al. (2011)
	Leaves: Circumcision Roots: HIV/AIDS	Semenya et al. (2013)
	Stem bark: Diarrhea, tuberculosis (decoction)	Chinsembu et al. (2015)

Table 2. Contd.

Dalbergia nitidula Baker	Leaves: Applied to snakebites (chewed); rubbed on abscesses Stem bark: Wound dressing, ulcers Roots: Toothache (infusion of pounded roots); malaria and cough (decoctions and infusions); epilepsy (pounded and administered in soup); emetic; aphrodisiac. Caution is needed because the roots are highly toxic	Lemmens (2007)
	Leaves: Agitated patients (bath) Roots: Agitated patients (infusion)	Agostinho et al. (2009)
	Leaves: Malaria (concoction)	Moshi et al. (2010)
Julbernardia globiflora (Benth.) Troupin	Stem: Leprosy (ground and smoked) Stem bark: Conjunctivitis (decoction); contraction of the vaginal canal (infusion); constipation, laxative; treatment for diarrhea in cattle Leaves: Snakebite antidote (rubbed) Roots: Depression, stomach problems (decoction)	Jimu (2010)
	Stem bark: Cough (chew); snakebite antidote (massage)	Augustino et al. (2011)
Pterocarpus angolensis DC.	Non specified: Malaria	Lukwa et al. (2001)
	Non specified: Ringworm, stabbing pains, eye problems, malaria, blackwater fever, stomach problems, increase breast milk supply	Aubrey (2003)
	Stem bark: Treatment for general illness, gallsickness, intestinal worms, *blackleg* in livestock	Luseba and Van der Merwe (2006)
	Stem bark, leaves, roots, fruits: Anemia, cough, diarrhea, snakebite antidote	Augustino et al. (2011)
	Non specified: Cough, colds, pain-killer, bleeding	Cheikhyoussef et al. (2011)
	Stem bark: Earache (infusion) Roots: Infertility in women (crushed and mixed with hot water); menorrhagia Sap: Sore eyes	Maroyi (2011)
	Stem bark: Hernia (decoction)	Amri and Kisangau (2012)
Melianthaceae		
Bersama abyssinica Fresen.	Leaves: Convulsion, snakebite antidote (pounded)	Kitula (2007)
	Growing shoots: Burns, ulcers, to clean wounds Leaves: Feverish pains, loss of appetite, debility, jaundice and leprosy (decoctions); convulsions and snakebites, (pounded and mixed with water); eye drop (leaf sap); migraine, headache and colds (powder); diabetes Leaves, stem bark, roots: Abdominal pain, colic, diarrhea, cholera, intestinal worms, amoebiasis, dysentery, rabies, syphilis, gonorrhea, malaria (decoction) Stem bark: Cancer and rheumatism (decoction); diabetes Stem bark (powdered), leaves (chewed): Aphrodisiac Stem bark (poultice); leaves, roots (decoction): Lumbago Roots: Hemorrhoids and epilepsy (decoction).	Bosch (2008)
	Bark: Vermifugue	Focho et al. (2009)

Table 2. Contd.

	Root: Bronchitis (crushed mixed with cold water); febrile illness (concoction)	Mesfin et al. (2009)
	Bark: Tonsillitis	Mirutse et al. (2009)
	Root bark: Aphrodisiac, diabetes (decoction)	Keter and Mutiso (2012)
	Leafy stem tip: Wounds (squeezed)	Abera (2014)
	Stem bark: Snakebite, liver disease	Kidane et al. (2014)
	Leaves and twigs: Diarrhea, constipation	Lulekal et al. (2014)
	Leaves: Ascariasis (roundworm)	Chekole et al. (2015)
	Seeds: Dandruff, wound, skin burn, scabies	Teka et al. (2015)
Phyllanthaceae		
Pseudolachnostylis maprouneifolia Pax	Bark: Diarrhea	Ratshibvumo (2008)
	Leaves : Cough, fever (decoction) Bark: Dizziness, vomiting (infusion) Roots: Stomach-ache and abdominal problems (decoction); pneumonia (smoke). Bark: diarrhea, pneumonia, tuberculosis, anemia (in porridge or drunk); leprosy; abdominal pain, gonorrhea and female sterility (infusion); nosebleed, wounds, headache (powdered) Leaves and roots: Hematuria in cattle (infusion)	Schmelzer (2008)
	Stem bark, leaves and roots: Stabbing sensations, diarrhea, snakebite antidote	Augustino et al. (2011)
Rubiaceae		
Catunaregam spinosa (Thunb.) Tirveng.	Roots: Convulsions, epilepsy (infusion)	Sobiecki (2002)
	Non specified: Sexually transmitted diseases/AIDS; headaches	Fumane et al. (2003)
	Leaves: Agitated patients	Agostinho et al. (2009)
	Roots, bark: Infertility, gonorrhea, hernia, stomach ache, convulsion, abortion	Augustino et al. (2011)
	Stem bark, roots: Aphrodisiac, gynecological ailments, febrile complaints, fever, epilepsy, arthritis	Ndhlala et al. (2013)

namely against *Escherichia coli* and two species of *Salmonella* responsibles for serious gastrointestinal disorders have been reported (Suleiman et al., 2008; Awa et al., 2012) (Table 3). Root bark also revealed high antibacterial activity (Okoye et al., 2012b) and anticonvulsant properties with pronounced hypnotic and muscle relaxant effects in mice (Okoye et al., 2010). Kaureonic acid (a diterpenoid) was identified as the possible phytoconstituent responsible for antibacterial effects and also for anticonvulsant properties (epilepsy and febrile seizures) of the root bark (Konate et al., 2012; Okoye et al., 2012b, 2013), whose extracts proved to be safe at lower doses tested (Okoye et al., 2012a). Cytotoxicity against some human tumor cell lines was detected in essential oils from leaves (Ahmed et al., 2010). These oils also presented cytotoxicity in brine shrimp lethality (Ahmed et al., 2010). Leaf and stem bark extracts showed great potential against trypanosomiasis (Ogbadoyi et

al., 2007; Ugwu et al. 2011). Fractions of leaf methanolic extract neutralized lethal toxicity induced by the viper *Echis ocellatus* venom (Emmanuel et al., 2014). Leaves and stem bark showed some anthelmintic properties that may support the use of this plant by local farmers in traditional animal healthcare (Alawa et al., 2003). Promising ovicidal, larvicidal and pupicidal activity against malarial and filarial mosquito vectors was detected in fractions of leaf extracts by Lame et al. (2015).

Apocynaceae

***Diplorhynchus condylocarpon*:** *D. condylocarpon* is used in traditional medicine to treat ailments such as diarrhea, cough and tuberculosis and headache (Table 2). Scientific studies revealed the presence of alcaloids in both stem and root bark and aqueous root extracts were reported as sympatholytic (Ruijter, 2008).

Combretaceae

Species of the Combretaceae family are amongst the most widely used plants for traditional medicinal purposes in southern Africa (Cock and Van Vuuren, 2015). Many species of *Combretum* and *Terminalia* genera are used for their antibacterial, antifungal, antiprotozoal, antiviral, antidiarrheal, analgesic, antimalarial, antioxidant, anti-inflammatory and anticancer activities (Cock, 2015).

Combretum* spp.*: African traditional healers use leaves, stem bark and roots of *C. hereroense* to treat a number of ailments (Table 2). Indications are often related to treat infections. Leaf extracts of the *C. hereroense* and *C. zeyheri* inhibited the growth of *Staphylococcus aureus*, *Enterococcus faecallis, Pseudomonas aeruginosa* and *E. coli* isolates (Cock and Van Vuuren, 2015). Antibacterial activity against *Mycobacterium fortuitum* and *S. aureus* was also detected in stem-bark extracts of *C. hereroense* (Fyhrquist et al., 2004). Leaves, stem bark and fruits of both species presented antifungal activity against different *Candida* spp. (Cock and Van Vuuren, 2015; Fyhrquist et al., 2004; Mangoyi et al., 2015; Masoko et al., 2007; Mutasa et al., 2015; Runyoro et al., 2013). Anti-inflammatory activities (inhibition of hematopoietic prostaglandin D2 synthase) were detected in leaves of both species (Chimponda and Mukanganyama, 2015; Eloff et al., 2001; McGaw et al., 2001). Leaf extracts of *C. hereroense* were also referred as anthelmintic (McGaw et al., 2001). Potential anticancer activity in *C. hereroense* leaf extracts (McGaw et al., 2001) and cytotoxicity against a human cancer cell line in *C. zeyheri* stem bark extracts (Nibret et al., 2010) were reported. Antiproliferative activity of bloodstream form of *Trypanosoma brucei* was also reported for stem bark extracts of *C. zeyheri* (Madamombe-Manduna et al., 2015). Leaf extracts of this species also revealed strong antioxidant activity (Chirisa and Mukanganyama, 2016). Toxicity tests were negative for *C. hereroense* leaf extracts (Cock and Van Vuuren, 2015). These scientific studies partially validate the usage of Combretaceae in traditional systems and many therapeutic properties of the Combretaceae may be attributable to their antimicrobial activity.

***Terminalia* spp.:** *Terminalia* is a genus comprising 200 to 250 species widely used in traditional medicine systems (Table 2). The last decade has seen a large increase in the number of studies into the use of *Terminalia* species as therapeutic agents. Several species used in Ayurvedic medicine, such as *T. arjuna*, *T. bellerica*, *T. catappa* and *T. chebula*, have received much recent attention (Cock, 2015). *Terminalia* species are used for their antibacterial, antifungal, antiprotozoal, antiviral, antidiarrheal, analgesic, antimalarial, antioxidant, anti-inflammatory and anticancer activities. Wound healing and cardiovascular effects have also been credited to some species (Cock, 2015). *T. stenostachya* was found to exhibit antimicrobial activity against *S. aureus*, *S. epidermidis*, *Baccillus subtilis* and *Enterobacter aerogenes* (Fyhrquist et al., 2002). Root, stem bark and leaf extracts showed considerable activity against a wide range of microorganisms (Mbwambo et al., 2011). The antibacterial activity exhibited by the extracts specifically against some *Mycobacterium* spp., indicate that these extracts could be effective against *M. tuberculosis* (Mbwambo et al., 2011). Leaves and fruit extracts exhibited activity against *M. smegmatis* (Fyhrquist et al., 2014) and stem bark and leaf extracts showed activity against three species of *Candida* (Fyhrquist et al., 2004). According to Mbwambo et al. (2011) the whole antiprotozoal, antifungal and antimicrobial activity shown by the extracts of *T. stenostachya* corroborate well with the traditional uses for treatment of HIV/AIDS-associated secondary infections, like tuberculosis, malaria, stomach ulcers and candidiasis. Stem bark extracts exhibited cytotoxic activity against human cancer cell lines (Fyhrquist et al., 2006). The brine shrimp test results have shown that stem bark, root and leaf extracts had mild and/or no toxicity (Mbwambo et al., 2011).

Dipterocarpaceae

Monotes engleri: Few authors refer the use of *M. engleri* in traditional medicine (Table 2). However, some studies were carried out concerning the potential medicinal properties of this species. Meragelman et al. (2001) isolated flavonoids exhibiting HIV-inhibitory activity from leaf extracts of *M. engleri* and antifungal activity against *Candida albicans* was reported by Kenez et al. (2008).

Table 3. Phytochemical and pharmacological studies on 12 tree species from Miombo woodlands.

Family, scientific name	Part(s) used and reported biological/pharmacological activities(s)	Bioactive compound(s)isolated and/or identified	References
Annonaceae			
Annona senegalensis Pers.	Leaves, stem bark: Anthelmintic		Alawa et al. (2003)
	Leaves: Antitrypanosomal	Leaves: Tannin, phlobatanin and saponin	Ogbadoyi et al. (2007)
	Stem bark: Antidiarrheal		Suleiman et al. (2008)
	Leaves (essential oil): Cytotoxicity against cancer cell lines.	Leaves (essential oil): Seventy three compounds identified	Ahmed et al. (2010)
	Root bark: Anticonvulsant	Root bark: Alkaloids, resins, glycosides, carbohydrate, reducing sugars, flavonoids, terpenoids, saponins and tannins	Okoye et al. (2010)
	Stem bark: Antitrypanosomal	Stem bark: Alkaloids, saponins, tannins and flavonoids	Ugwu et al. (2011)
	Root bark: Antibacterial	Root bark: Kaurenoic acid	Okoye et al. (2012b)
	Stem bark: Antibacterial		Awa et al. (2012)
	Root bark: Anticonvulsant		Konate et al. (2012)
	Root bark: Toxicity evaluation		Okoye et al. (2012a)
		Leaves, root bark: Six alkaloids isolated and identified	Fofana et al. (2013)
	Root bark: Anticonvulsant	Root bark: Kaurenoic acid	Okoye et al. (2013)
	Leaves: Anti-venom		Emmanuel et al. (2014)
	Leaves: Mosquitocidal		Lame et al. (2015)
Apocynaceae			
Diplorhynchus condylocarpon (Müll.Arg.) Pichon	Roots: Sympatholytic	Stem, root bark: Alkaloids	Ruijter (2008)
Combretaceae			
Combretum hereroense Schinz	Leaves: Anti-inflammatory		Eloff et al. (2001)
	Leaves: Anti-inflammatory, anthelmintic; potential anticancer activity		McGaw et al. 2001)
	Stem bark: Antimicrobial	Seventeen phenolic constituents including four phenanthrenes	Fyhrquist et al. (2002)
	Stem bark: Antifungal		Fyhrquist et al. (2004)
	Leaves: Antifungal		Masoko et al. (2007)
	Fruit: Antibacterial		Katerere et al. (2012)
	Leaves: Antibacterial, antifungal		Cock and Van Vuuren (2015)
	Roots: Antioxidant		Madamombe-Manduna et al. (2015)
Combretum zeyheri Sond.	Leaves: Anti-inflammatory		Eloff et al. (2001)
	Leaves: Anti-inflammatory		McGaw et al. (2001)
	Stem bark, roots, fruits: Antimicrobial		Fyhrquist et al. (2002)
	Stem bark: Antifungal		Fyhrquist et al. (2004)

Table 3. Contd.

	Leaves: Antifungal		Masoko et al. (2007)
	Stem bark: Antitrypanosomal, cytotoxicity against cancer cell line		Nibret et al. (2010)
	Leaves: Antifungal	Leaves: Isolation of five triterpenoids	Runyoro et al. (2013)
	Antiallergic and inflammatory		Chimponda and Mukanganyama (2015)
	Leaves: Antifungal	5-hydroxy-7, 4'- dimethoxyflavone.	Mangoyi et al. (2015)
	Leaves: Antifungal		Mutasa et al. (2015)
	Leaves: Antioxidant		Chirisa and Mukanganyama (2016)
Terminalia stenostachya Engl. & Diels	Stem bark: Antibacterial		Fyhrquist et al., 2002
	Leaves, stem bark: Antifungal		Fyhrquist et al. (2004)
	Stem bark: Cytotoxic against cancer cell lines		Fyhrquist et al. (2006)
	Leaves, stembark, roots: Antibacterial, mild and/or no toxicity (brine shrimp test)		Mbwambo et al. (2011)
	Leaves, fruits: Antibacterial		Fyhrquist et al. (2014)
		Triterpenes, flavonoids, tannins	Cock (2015)
Dipterocarpaceae			
Monotes engleri Gilg	Leaves: HIV-inhibitory	Leaves: Six flavonoids isolated	Meragelman et al. (2001)
	Antifungal	Two O-prenylated flavanone derivatives were isolated	Kenez et al. (2008)
Fabaceae (Leguminosae)			
Brachystegia boehmii Taub.	Leaves: Antibacterial		Chitemerere and Mukanganyama (2011)
	Leaves: Anti-inflammatory		Chirisa and Mukanganyama (2016)
Burkea africana Hook.	Stem bark: Antioxidant	Proanthocyanidins	Mathisen et al. (2002)
	Root bark: Anticonvulsant		Yaro et al. (2010)
	Leaves: Analgesic and anti-inflammatory	Alkaloids, cardiac glycosides, flavonoids, tannins, saponins, steroids and terpenoids.	Danjuma (2011)
	Roots: Antibacterial		Mbatchou et al. (2011)
	Stem bark: Antidiarrheal	Stem bark: Flavonoid cardiac glycosides, tannins and triterpenes.	Tanko et al. (2011)
	Stem bark: Antioxidant		Cordier et al. (2013)
	Root bark: Antibacterial		Tor-Anyiin and Anyam (2013)
	Leaves: Antioxidant, anti-inflammatory and anticholinesterase		Dzoyem and Eloff (2015)
	Root bark: Sedative and anxiolytic	Root bark: Saponins, flavonoid, aglycones, tannins, anthraquinones, cardiac glycosides, unsaturated steroids and triterpenes	Yaro et al. (2015)

Table 3. Contd.

Dalbergia nitidula Baker	Leaves: Antibacterial, antioxidant; low cytotoxicity		Dzoyem et al. (2014)
Pterocarpus angolensis DC.	Stem, stem bark, leaves: Anthelmintic		Molgaard et al. (2001)
	Seeds: Antibacterial		Steenkamp et al. (2004)
	Stem bark: Antibacterial and anti-inflammatory; lack of mutagenicity		Luseba et al. (2007)
	Stem bark, leaves: Anthelmintic, antibacterial and cytotoxic		McGaw et al. (2007)
	Antibacterial		Obi et al. (2007)
	Stem bark: Antibacterial	Stem bark: Epichatechin and derivatives	Samie et al. (2009)
	Stem bark: Antibacterial Leaves, stem bark: Antifungal, HIV-1 reverse transcriptase inhibitory		Mulaudzi et al. (2011)
	Leaves, stem bark: Anti-inflammatory		Mulaudzi et al. (2013)
	Stem bark, roots: Antibacterial	Stem bark, roots: Tannins and saponins	Munodawafa et al. (2013)
Melianthaceae			
Bersama abyssinica Fresen.	Root bark: Anti-HIV		Asres et al. (2001)
	Root bark: Antibacterial		Geyid et al. (2005)
	Roots: Antibacterial		Bolou et al. (2011)
	Roots: Antibacterial and antifungal		Lulekal et al. (2014)
	Leaves and twigs: Antioxidant, anticancer		Tauchen et al. (2015)
Rubiaceae			
Catunaregam spinosa (Thunb.) Tirveng.	Stem bark: Anticancer activity	Stem bark: Two novel norneolignans, three known neolignans	Gao et al. (2010)
	Stem bark: Antifeedant	Stem bark: Seven triterpenoid saponins, including four new compounds, catunarosides A–D (**1**–**4**), and three known compounds, swartziatrioside (**5**), aralia-saponin V (**6**), araliasaponin IV (**7**)	Gao et al. (2011)
	Leaves: Antioxidant and anti-inflammatory; protection of DNA plasmid *in vitro*.		Shailasree et al. (2014)

Fabaceae (Leguminosae)

***Brachystegia* spp.:** *Brachystegia boehmii* and *B.spiciformis* are referred in the literature as being used in traditional medicine (Table 2). Extracts from *B. boehmii* leaves exhibited bacteriostatic activity against *S. aureus*, *P. aeruginosa*, *E. coli*, *Bacillus cereus* and *B. subtilis* (Chitemerere and Mukanganyama, 2011) and significant anti-inflammatory activity (Chirisa and Mukanganyama, 2016). However, the potential of these species for medicinal use is poorly exploited.

Burkea africana: *B. africana* is used in traditional African medicine for the management of different health conditions (Table 2). *B. africana* is known to be rich in antioxidant sources and high levels of polyphenols and antioxidants have been reported in stem bark extracts (Cordier at al., 2013). Mathisen et al. (2002) investigated the bark of *B. africana* for antioxidant and radical scavenging activity. Hydroethanol bark extract showed excellent antioxidant, radical scavenging and 15-

lipoxygenase inhibitor activity. The active constituents were identified as proanthocyanidins and the effects, to a large extent, were attributed to the presence of profisetinidin-type proanthocyanidins (Mathisen et al., 2002). However, some cytotoxicity was observed, requiring further isolation and purification of polyphenolic-rich fractions aiming to identify and to eliminate cytotoxic elements (Cordier et al., 2013). Such refinement could increase the potential of the polyphenolic-rich fraction of stem bark to be used as an antioxidant supplement for oxidative stress-related disorders (Cordier et al., 2013). According to Tanko et al. (2011), *B. africana* stem bark extracts possess pharmacological activity against diarrhea. Root bark methanol extracts revealed the presence of saponins, flavonoids, aglycones, tannins, antraquinones, cardiac glycosides, unsaturated steroids and triterpenes (Yaro et al., 2015) and showed anticonvulsant properties (Yaro et al., 2010, 2015). Roots also revealed antibacterial activity against *Salmonella typhi* (Mbatchou et al., 2011) and root bark against *S. aureus* and *E. coli* (Tor-Anyiin and Anyam, 2013). Danjuma et al. (2011) showed that methanol leaf extracts of *B. africana* contained phytochemical constituents with analgesic and anti-inflammatory activities, and had the potential to be used in the management of pain and inflammatory conditions. Dzoyem and Eloff (2015) confirmed the anti-inflammatory, anticholinesterase and antioxidant activity of *B. africana* leaf extracts. According to these authors, the results obtained validated the use of leaf extracts of this plant in South African traditional medicine against inflammation and might be of value in the management of various diseases emerging from oxidative stress and related degenerative disorders.

Dalbergia nitidula: The genus *Dalbergia* has been shown to possess various pharmacological activities including analgesic, antipyretic, antimicrobial, antioxidant, anti-inflammatory, antidiarrheal, antiulcerogenic, antigiardial, antiplasmodial, antifertility, cancer chemopreventive as well as larvicidal and mosquito repellent properties (Mutai et al., 2013). The occurrence of isoflavones, isoflavanones (including the rare flavonoid 3-hydroxiso-flavanone), neoflavones, sterols, anthraquinones, cinnamyl esters and triterpenes in this genus have been reported (Mutai et al., 2013; Vasudeva et al., 2009). So far, few species have been screened for their biological activity (Vasudeva et al., 2009). Leaves and roots of *D. nitidula* were reported to be used in traditional medicine in east and southern Africa (Table 2). Leaf extracts of *D. nitidula* showed a low cytotoxicity and high antimicrobial and antioxidant activity, representing a promising candidate for pharmaceutical industry (Dzoyem et al., 2014).

Julbernardia globiflora: Although roots, barks and leaves of *J. globiflora* have been recorded to be toxic, various plant parts are used in traditional African medicine, mainly externally (Table 2). To our knowledge no pharmacological studies were carried out to validate ethnomedicinal uses of this species.

Pterocarpus angolensis: Traditionally, all parts of the *Pterocarpus angolensis* are used for medicinal purposes (Table 2). The bark with its blood-red, gummy, resinous exudate is used as a powerful astringent, e.g. to treat diarrhea, heavy menstruation, nose bleeding, headache, stomach-ache, parasitic worms, sores and skin problems (Takawira-Nyenya, 2005). Pharmacological studies on *P. angolensis* revealed antibacterial activity of seeds (Steenkamp et al., 2004), stem bark, roots and leaf extracts (Luseba et al., 2007; Mulaudzi et al., 2011; Samie et al., 2009) and antifungal activity of leaf and bark extracts (Mulaudzi et al., 2011). The latter also showed HIV-1 reverse transcriptase inhibitory activity (Mulaudzi et al., 2011) as well as anthelmintic effects (McGaw et al., 2007; Molgaard et al., 2001). Anti-inflammatory activity was also detected in stem bark extracts (Mulaudzi et al., 2013). Samie et al. (2009) demonstrated the presence of epichatechin and derivatives (with strong antibacterial activities but generally weak activities against *Entamoeba histolytica*) in stem barks.

Melianthaceae

Bersama abyssinica: Bark, leaf and root decoctions of *B. abyssinica* are widely taken to treat a range of health disorders including intestinal worms (Table 3). However, all plant parts are poisonous; therefore dosage is critical for internal use (Bosch, 2008). Ethanol extracts of leaves and twigs revealed antiproliferative activity against Hep-G2 carcinoma cell lines (Tauchen et al., 2015). Methanol extract of the root bark exhibited potent inhibition of HIV-1 replication (Asres et al., 2001). Root and root bark extracts showed antibacterial and antifungal activities (Bolou et al., 2011; Geyid et al., 2005; Lulekal et al., 2014).

Phyllanthaceae

Pseudolachnostylis maprouneifolia: Stem bark, roots and leaves of *P. maprouneifolia* are used to treat pulmonary and abdominal disorders (Augustino et al., 2011; Schmelzer, 2008). Other medicinal uses include venereal diseases, dizziness, wounds and snakebites (Augustino et al., 2011; Schmelzer, 2008). Many important medicinal uses against different infectious ailments have been reported for *P. maprouneifolia*. However, to our knowledge, much remains to exploit in order to understand the medical potentialities of this species.

Rubiaceae

Catunaregam spinosa: *C. spinosa* (also known as *Randia dumetorum*) is used in African an Asian traditional

medicinal practices (Table 2). It is considered as a usual drug of choice for Ayurvedic physicians as a result of the different therapeutic properties like emetic, antipyretic, anti-inflammatory, antiallergic, anthelminthic, immunomodulatory, analgesic and wound healing to mention a few (Prakash, 2015). *C. spinosa* extracts mainly contains glycosides, triterpenoid glycoside and saponins (Prakash, 2015). Triterpenoid saponins were isolated from stem bark extracts (Gao et al., 2010, 2011) and two of the compounds isolated (catunaregin and epicatunaregin) exhibited moderate inhibition against the mammary cancer F10 cell line (Gao et al., 2010). Leaf extracts showed antioxidant and anti-inflammatory activities, human cyclooxygenase (COX)-2 inhibitory effects and a prominent protection of DNA (Shailasree et al., 2014). Antifeedant activity against the pest *Plutella xylostella* was detected in components (triterpenoid saponins) of the stem bark (Gao et al., 2011). *C. spinosa* use should be treated with caution, as studies have shown that it can cause damage to genetic material (Fennell et al., 2004).

DISCUSSION

Miombo woodlands are very important to informal and formal economies in Mozambique and other southern Africa countries, providing valuable sources of wood; edible plant products and mushrooms; fiber and related products; insect products (honey and bee wax, edible insects); medicinal plants, among others. The important wood products obtained from Miombo woodland include timber, firewood, charcoal, materials for fencing and making farm tools, household and handicraft items (Clarke et al., 1996). The high collection of woody resources leads to their over-exploitation, negatively impacting plant diversity and conservation of the Miombo ecosystem. Charcoal production is a very important forestry activity in Africa and one of the major factors responsible for high rates of deforestation. The charcoal market is the largest among the forestry products in Mozambique, rural communities depending exclusively on firewood for cooking, while in suburban areas charcoal is the major source of energy for cooking (Salomão and Matose, 2008).

However, Miombo woodland provide a wide range of other products that appear in smaller quantities, including medicines and wild foods, which provide a living for several families (Clarke et al., 1996). There is a growing interest on how non-wood forest products can contribute to livelihood security and to generate income. Miombo ecosystem remains an untapped source of natural bioactive molecules, such as pharmaceuticals, nutraceuticals, cosmetics or agrochemicals. Nowadays there are new and niche emerging markets for forest products as a result of consumer demand for “green” and “fair trade” products (Dewees et al., 2011) and the commercialization of products derived from indigenous plants may provide additional income to rural communities. Research on ethnobotany can bring value to local knowledge and contribute to put natural resources at the service of those communities. Interest in medicinal plants has been expanding globally due to their importance to basic healthcare, local markets and industry. There has been an increasing effort to isolate and characterize new active ingredients from plants, as many conventional drugs fail due to the development of resistance. For major diseases such as cancer, some good examples of efficient remedies obtained from plants are already available.

An impressive number of modern drugs have been isolated from plants, often based on their ethnomedical use. The inclusion of plants with pharmacological potential in the human diet may also contribute to diminish the need for medicines (WHO, 2003). Miombo tree species, namely Caesalpinoideae (Fabaceae) and Combretaceae, are often rich in phenolic compounds. A diet rich in antioxidants is associated with a decreased incidence of chronic diseases. High antioxidant levels have also been shown to act as a preventive measure against the development of degenerative disease such as cancer, cardiovascular diseases, neural degeneration, diabetes and obesity (Cock, 2015). Some of the species already described can be highlighted for their therapeutical interest: *A. senegalensis*, *C. hereroense*, *C. zeyheri*, *B. africana*, *P. angolensis* and *B. abyssinica*. A considerable number of studies concerning chemical composition, pharmacological action and toxicity have been conducted with promising results against important ailments, such as parasitic, bacterial and fungal infections, as anticonvulsants, antioxidants and anti-inflammatories (Table 3). *T. stenostachya* is also a species with potential for the pharmaceutical industry as it has shown a wide range of antibacterial activity, specifically against mycobacteria, indicating that it may be a good source of antimicrobial compounds and is worth further development (Mbwambo et al., 2011). It is also important to highlight less studied species such as *J. globiflora, P. maprouneifolia* and *D. condylocarpon* which are widely used in traditional medicine and need detailed phytochemical and pharmacological studies.

Particular attention should be given to species with strong potential to treat major diseases, e.g. *M. engleri*, *B. abyssinica* and *P. angolensis* (anti-viral) (Asres et al., 2001; Meragelman et al., 2001; Mulaudzi et al., 2013); *A. senegalensis*, *C. zeyheri*, *T. stenostachya* and *C. spinosa* (anti-tumoral) (Ahmed et al, 2010; Fyhrquist et al., 2006; Gao et al., 2010; Nibret et al., 2010); *Burkea africana* (glaucoma) (Dzoyem and Eloff, 2015). Attention should also be given to potentially new eco-friendly pesticides providers such as *Annona senegalensis* (Lame et al., 2015) and *Catunaregam spinosa* (Gao et al., 2011). The safety and efficacy of traditional medicine has been demonstrated by its long historical use. However, much

remains to be studied. Besides the quality of the natural products there must be safety guarantees concerning toxicity and knowledge about e.g. secondary effects, interactions, counter-indications, mutagenicity and also the existence of pharmacological studies and clinical experimentation proving their efficacy (Fennell et al., 2004). Attention must also be given to the collection of medicinal plants and other non-timber forest products, as wide-spread harvesting puts pressure on natural populations. Little research has been done on sustainable harvesting rates for non-wood products (Shackleton and Clarke, 2011). Impacts from fruit removal, provided no damage is done to the trees, seem small (Shackleton and Clarke, 2011). However, according to Bruschi et al. (2014), reproductive ability of the species, including seed production and seed dispersal, can be of critical importance in population dynamics, and should be taken into consideration in the context of sustainable harvesting of useful plants. For example, *Brachystegia*, *Julbernardia*, and other Caesalpinioideae such as *P. angolensis* show an extremely low capacity for seed dispersal and produce short-lived seeds thus reducing the community resilience. *P. angolensis* is included in the IUCN Red List of Threatened Species, in the category lower risk/near threatened (World Conservation Monitoring Centre 1998).

Harvesting of the bark for different uses such as medicines, rope fiber or for making beehives can be highly destructive for the trees. The growing interest in medicinal plants from both international industry and local markets requires management of tree bark harvesting from natural forests in order to prevent inappropriate exploitation of target species (Delvaux et al., 2009). A number of methods for reducing the negative impact of bark harvesting have been proposed and tested, these include: the use of leaves to obtain medicinal products rather than bark; obtaining bark from woody material that has already been cut; improved harvesting methods that prevent ring barking and reduce fungal infection (Shackleton and Clarke, 2011). Bark regrowth response of a selected number of medicinal tree species as a basis for the development of optimal bark harvesting method is also being studied (Delvaux et al., 2009).

Conclusions

The 15 tree species selected for this review are used in traditional medicine practices in Mozambique and other countries from the ecoregion. Twelve species have proven biological and pharmacological activities. In most cases, isolation of the active compounds and/or pharmacological tests provided scientific validation. Most of the species are rich in anti-inflammatories and antioxidants, which are known to prevent several chronical and degenerative diseases. Besides that many are described as promising sources of therapeuticaal agents against important ailments, such as parasitic, bacterial and fungal infections and six revealed potential anti cancer activity. The information gathered in this paper reflects the richness of the natural and cultural heritage from the Miombo woodlands. Local Knowledge Systems (LKS) have an immeasurable value in community health, nutrition, education, cultural heritage and conservation, and when integrated with scientific knowledge constitute one of the pillars of bio-based socio-economic development. However, much is still to be investigated to unravel the potential of these tree species for multipurpose uses. In parallel, the development of adequate conservation strategies and *ex-situ* tree propagation methods will be of utmost importance to ensure the sustainable use of those resources.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests.

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Ethnobotanical study of medicinal plants used to manage HIV/AIDS opportunistic infections in Rungwe, Mbeya Region, Tanzania

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The current ethnobotanical study identified medicinal plant species used to manage HIV/AIDS opportunistic infections by the communities in Rungwe District, Tanzania. Data were collected using questionnaires (n=193), interviews (n=9) and field observations. A total of 31 plant species from 23 families are used in managing HIV/AIDS opportunistic infections. *Compositae* and *Rosaceae* were predominantly used in disease management by 15% each. Of the plant parts, leaves were the most used (44%), followed by roots (28%), bark (7%), fruits, seeds and stem (5%) while the least used plant parts were tubers (4%) and the whole (2%). Tuberculosis utilized 60% of the species, Herpes simplex 55%, chronic diarrhea 40%, oral candidiasis 35% and Herpes zoster 30%. *Dissotis phaeotricha* scored the highest fidelity value (73%), followed by *Berberis holstii* (60%). The knowledge on medicinal plants among respondents was influenced by; informal education ($p<0.01$), village location ($p<0.01$) and ethnic background ($p<0.05$). The study exposed the presence of reasonable knowledge of traditional medicinal plants among communities in Rungwe District. The results contribute to the conservation of experimental experiential knowledge of medicinal plants used in the management of HIV/AIDS opportunistic infections hence, shouldering world's efforts geared towards anti-HIV/AIDS innovations.

Key words: Ethnobotany, conservation, medicinal plants, traditional practitioner.

INTRODUCTION

Medicinal plant products constitute the largest percent of traditional medicine which anchors the lives of majority (Zhou, 2015). The reports by the world health organization (WHO) confirm that 80% of the world's population in developing countries rely on traditional medicine (WHO, 2013). The importance of traditional

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medicinal plants in people's welfare is opened for studies across the world.

According to Kisangau et al. (2007) and Bukuluki et al. (2014), 60% of the Tanzanians rely on traditional medicine for their primary health care. Generally, the use of medicinal plants has been reported to rise (Moshi et al., 2010; Ekor, 2014; Agisho et al., 2014). The reasons attributed to the trend include; constraints associated with the antiretroviral therapies (Chinsembu and Hedimbi, 2010), modern drug resistance in managing some diseases including HIV/AIDS opportunistic infections and conceived side effects of conventional medicine (Mustapha, 2014), the existing shortage of modern health personnel and stigma (Chinsembu, 2016; Denver et al., 2014).

The current reports by WHO and the United Nations AIDS (UNAIDS), cited by the Tanzanian national AIDS control programme (NACP), indicate that 36.7 million people across the world nations were living with HIV at the end of 2015, with 2.1 million new infections, and 1.1 million people died of HIV/AIDS opportunistic infections (NACP, 2016).

In general, morbidity and mortality among the people living with HIV/AIDS are connected to related infections (Yineger et al., 2007). In sub-Saharan Africa, the number of AIDS-related deaths was cut down by 39% in 2013, but, still there are many people (74%) who were reported to die from HIV/AIDS-opportunistic infections such as tuberculosis (TB), candidiasis, herpes simplex and herpes zoster (UNAIDS, 1998; Kisangau et al., 2011).

Runyoro et al. (2006), Kisangau et al. (2011), Magadula et al. (2014) and Omolo et al. (2014), conducted studies on medicinal plants which are used in managing HIV/AIDS opportunistic infections in Tanzania. The studies have revealed sound knowledge of plant species used by HIV/AIDS patients in managing opportunistic infections. However, most of the identified species varied among communities; the difference indicate the importance of considering the background of communities when studying knowledge about medicinal plants. Hence, this study was carried out to assess the knowledge of medicinal plants by communities in Rungwe District.

MATERIALS AND METHODS

Study area

Rungwe District is located between latitudes 08°30' and 09°30' south of the Equator and longitudes 33°00' and 34°00' east of the Greenwich Meridian (Figure 1).

Rungwe District (the highest altitudes of Rungwe and Poroto have attracted valuable forests for medicinal plant species) rises up between 770 and 2865 meters above sea level making it one of the mountainous districts in Tanzania. The district covers approximately 2 211 sq.km of which 75% is arable land. The cool climate due to high altitudes makes the district renown for higher rainfalls which favour evergreen thick vegetation which is a potential source of plant medicine. Moreover, the District is one of the densely populated areas in Tanzania recorded to have 371 451 people in 2015 with 168 per sq.km (Mbeya Region, 2016). One of the reasons for high population is the availability of plenty food. When not well managed, high population can have impacts on the utilization of resources including medicinal plants. The HIV/AIDS status of the District presumes for authentic source of data for the scientific documentation of medicinal plants often used in managing HIV/AIDS opportunistic infections. It is for this reason, Rungwe District was chosen. The District is recorded with HIV prevalence of 11% with 22 251 people living with HIV (UNAIDS, 2014; President's Emergency Plan for AIDS Relief in Tanzania, PEPFAR/T,2015).

Field survey

This study commenced with a desk review of literature followed by field work where a cross sectional design enabled data to be collected from representative population at a single point in time. Cross section designs are popular in collecting information related to practices, attitudes, knowledge and beliefs of a certain population (Mann, 2003; Carlson and Morrison, 2009).

The main respondents for this study involved people living with HIV/AIDS from seven purposively sampled villages located adjacent to Mount Rungwe Nature Reserve and Poroto Forest Reserve. The respondents were obtained through snowball techniques as these are effective in recruiting hidden populations such as the HIV patients (Voicu and Babonea, 2007; Barirega et al., 2012). A total of 193 people living with HIV/AIDS were interviewed after informed consents being obtained from respondents. Semi- structured questionnaires were used to gather quantitative data. The information collected included: commonly known plants used to manage HIV/AIDS OIs, specific infections treated, their local or common names, parts used and other related information. Similar information was collected from key informants.

Specimen identification

Preliminary identification of species was done in the field by using manuals and unidentified specimens were identified using herbarium materials, expert and taxonomic keys found in the volumes of the flora of Tanzania. The collected specimens with voucher numbers, family names, species and vernacular names, dates and collection sites were recorded and deposited at the University of Dar es Salaam herbarium.

Data analysis

The data were organised and analysed by using Microsoft Excel spreadsheet software, through which computations of proportions on plant species used, plant part (s) used and categories of infections managed were achieved.

Fidelity level

Of equal importance is the fidelity level (FL) which reveals quality, reliability or loyalty of the medicinal plant species. Through fidelity level calculations the relative healing ability of the identified medicinal plants is determined (Friedman et al.,1986). Studies that have adopted this approach include; Giday et al. (2010), Ugulu (2012), Abera (2014) and Parthiban et al. (2016). The fidelity level (FL) is defined as the ratio of the number of informants who independently suggested the use of a species for the same major purpose and the total number of informants who mentioned the plant for any other use. In the FL, *Np* is the number of informants

Figure 1. Map showing study villages adjacent to Rungwe Nature Reserve and Poroto Forest Reserve in Rungwe District, Tanzania.

who reported the use of a plant species to treat a particular disease, and *N* is the number of informants who used the plants as a medicine to treat any given disease (Friedman et al., 1986);

$$FL = \frac{Np}{N} \times 100$$

The highest FL (=100) indicates that a species manages the major disease equally with other ailments and vice versa.

Distribution of medicinal plants knowledge among the respondents

The collected ethnobotanical data with regards to distribution of medicinal plants knowledge based on socio-demographic characteristics were summarized using descriptive and inferential statistics. The presence or absence of significant differences among the variables was computed using the binary logit model because the dependent variables were categorical. The rationale for choosing this model relies on its suitability in cross-sectional data analysis as confirmed by Cramer (2003).

In the binary case, some event *Y* either occurs *(Y* =1) or not*(Y* =0). This model was specified as;

$$\ln(odds(highknowl = \ln(\frac{prob(highknowledge)}{prob(lowknowledge)}) \quad (1)$$

This model was modified from (Cox, 1958).

$$z = b_0 + b_1X_1 + bX_2 + \ldots\ldots + bX_k \quad (2)$$

Where z is the dependent variable or slope parameters and Xs are independent variables influencing z whereas bs are slope coefficients.

RESULTS

Identified medicinal plant species used to manage HIV/AIDS opportunistic infections

This study revealed a total of 31 plant species distributed among 23 families to be used for medicinal purposes particularly in managing HIV/AIDS opportunistic

infections in Rungwe District (Table 1). The mostly used families involved: Compositae and Rosaceae by 15% each. These were followed by Amaryllidaceae, Leguminosae, Musaceae and Myrtaceae by 10% each (Figure 2).

Some plant species have the ability to deal with multiple ailments, this study exposed four plants among the total identified medicinal plant species to be useful in managing four or more HIV/AIDS related conditions. The list includes; Conyza bonariensis (Compositae) which was mentioned to be potential in managing all six infections that were set as case studies in this study.
Those mentioned that deal with four ailments include *Berberis holstii* (Berberidaceae)*, Dissotis phaeotricha* (Melastomataceae) and *Myricia salicifolia* (Myricaceae). The fidelity values are given in Table 1.

With regards to plant parts extracted for medicine, the mostly used plant parts (s) were leaves (44%) and roots (28%). While bark (s) was used by 7%, fruits, seeds and stem were equally used at 5%. The least used plant parts found in this study were tubers and whole plant by 4% and 2% respectively (Figure 3). Moreover, the proportions of medicinal plant species which are known for managing specific HIV/AIDS opportunistic infections included: Tuberculosis (60%), Herpes simplex (50%), chronic cough (45%), chronic diarrhea (40%), Oral candidiasis (35%) and Herpes zoster (30%) (Figure 4).

DISCUSSION

HIV/AIDS is still a major health problem in Tanzania. Medical practitioners are struggling to invent a cure for the pandemic, but with little success, as a result, traditional medicine continues to gain popularity. The popularity attached to traditional medicinal plants especially in managing HIV/AIDS-related infections has prompted for this study which enabled documentation of plant species that are known to be useful in the management of the HIV/AIDS associated infections.

Considering plant families, Compositae and Rosaceae, Amaryllidaceae, Leguminosae, Musaceae and Myrtaceae were revealed as the most sources of medicinal plant species in managing HIV/AIDS opportunistic infections. The relative high uses of the surveyed species are attributed to their healing potentialities. Similar to this study, Kisangau et al. (2007) identified Myrtaceae as one of the predominant plant families used in managing HIV/AIDS opportunistic infections. Differently, Chinsembu and Hedimbi (2010) found Combretaceae, Anacardiaceae, Mimosaceae and Ebanaceae as the most used plant families in the management of the HIV/AIDS opportunistic infections. The difference demonstrated in plant families' use across areas signifies the reliance of medicinal plants on indigenous knowledge for identification. Indigenous knowledge is context based hence, extensive documentations of medicinal plant species is crucial.

The popular use of leaves and roots for medicine preparations correspond with the report by Chinsembu and Hedimbi (2010). Further, a more recent study in Zambia, confirms leaves being the most used plant parts in making medicine for managing HIV/AIDS opportunistic infections (Chinsembu, 2016). More studies with similar findings include: Giday et al. (2010), Otang et al. (2012) and Nankaya (2014). The relative high use of leaves could probably be due to the fact that they are easily to be found and collected over a long period of time. Moreover, people know that plucking leaves of the plant selectively ensures conservation of the plant. On the contrary, a conservation implication of the plants which the most used parts or the most extracted part (s) for medicines are their roots the sustainability of the plants remains uncertain.

With regards to tuberculosis consuming most of the plants indicates its prevalence among the HIV/AIDS patients in the study area. A close study by Kisangau et al. (2007) reported the highest percentage of plant species used to manage TB by Haya traditional practitioners. Other studies which revealed TB among the infections consuming largest percent of species include those of: Orwa et al. (2008), Singh et al. (2008), Gutiérrez et al. (2009), Amri and Kisangau (2012), Stackpole et al. (2013), Maana et al. (2014), Amuka et al. (2014), Gebeyehu et al. (2014),Cascaes et al. (2015) and Silva et al. (2015).

Moreover, Herpes simplex was managed by many plant species by communities in Rungwe District. For example *Ricinus communis* species is used in managing herpes simplex and studies elsewhere report its usage in managing body itchy (Agisho et al., 2014). Body itch can be related to herpes simplex. Chronic cough is another reported as common opportunistic infection among people living with HIV/AIDS. Similar to this study, there are evidences of some medicinal products found to manage chronic coughs, they involve; *Psidium guajava* (Chinsembu and Hedimbi, 2010) in Namibia, and *Myricia salicifolia* (Kariuki et al., 2014; Kigen et al., 2014) in Kenya.

Oral candidiasis was among the lowest in the list of opportunistic infections that was managed using few medicinal plants. The reason for few medicinal plant species use for oral candidiasis may imply that it is not common in the area and so the traditional practitioners have not been able to identify many species for the infection. Moreover, limited species that are known to manage herpes zoster as revealed in the study may be due to its complex features in relation to managements. As reported in other studies, *Aloe* species were frequently cited to be used in the purpose of managing the infection (Chinsembu and Hedimbi, 2010).

With regards to *Conyza bonariensis,* the plant contributes much in the health care as it was cited to be useful across all the cited HIV/AIDS opportunistic

Table 1. Traditional medicinal plants used in managing HIV/AIDS opportunistic infections.

Family	Scientific name	Local name	Part used	Infection managed	Fidelity Level	Voucher Number
Amaryllidaceae	*Allium sativum*	Kitungulu saumu	Tuber	Chronic cough, Tuberculosis	7.6	Not collected
	Allium cepa	Kitungulu	Tuber	Chronic cough	0.6	Not collected
Berberidaceae	*Berberis holstii*	Rungwe	Whole	Chronic diarrhea, Chronic cough, Herpes simplex, Tuberculosis	60.1	KMS-S64-2015
Caricaceae	*Carica papaya*	Mpapai	Leaves, Roots	Tuberculosis	0.6	Not collected
Compositae	*Conyza bonariensis*	Nzumba/ mbaluka	Leaves,Roots	Oral candidiasis, Chronic diarrhea, Chronic cough, Herpes zoster, Herpes simplex, Tuberculosis	30.1	KMS-S03-2015
	Vernonia adoensis	Ipasapasa	Leaves	Herpes zoster	3.5	KMS-S22-2015
	Bidens pilosa	Mitatila	Leaves	Herpes simplex	2.0	KMS-S02-2015
Convolvulaceae	*Ipomoea batata*	Mbatata	Leaves	oral candidiasis	0.6	Not collected
Cucurbitaceae	*Momordica foetida*	Nkungufya	Leaves, Roots	Chronic cough, Herpes simplex	2.7	KMS-S19-2015
Euphorbiaceae	*Ricinus communis*	Mijembajemba	Leaves, Seeds	Herpes simplex	0.6	KMS-S27-2015
Lamiaceae	*Geniosporum rotundifolium*	Nkulilo	Leaves	Herpes simplex	2.0	KMS-S33-2015
Lauraceae	*Persea americana*	Ntakapela	Leaves, Leaves, Barks	Tuberculosis	9.7	KMS-S31-2015
Leguminosae	*Vignaungu iculata*	Mbange	Roots	oral candidiasis	0.6	Not collected
	Erythrina abyssinica	Nsebhe	Barks	Herpes simplex	0.6	KMS-S28-2015
Melastomataceae	*Dissotis phaeotricha*	Kyumika	Leaves	Chronic diarrhea, Herpes zoster, Herpes simplex, Oral candidiasis,	73.4	KMS-S35-2015
Meliaceae	*Azadirachta indica*	Mwarobaini	Leaves, Roots, Seeds	Herpes zoster, Herpes simplex, Tuberculosis	5.6	Not collected
Musaceae	*Musa* spp.	Ndyali	Roots	Oral candidiasis	1.3	Not collected
	Ensete ventricosa	Ibhangalala	Pulp	Chronic diarrhea	1.3	Not collected
Myricaceae	*Myricia salicifolia*	Nsibhisibhi	Leaves,Roots	Oral candidiasis, Chronic diarrhea, Chronic cough, Tuberculosis	29.3	KMS-S08-2015
Myrtaceae	*Psidium guajava*	Ngajabi	Leaves	Chronic diarrhea, Chronic cough	40.5	KMS-S68-2015
	Eucalyptus maidenii	Ndongoti	Leaves, Roots, Barks	Chronic cough, Tuberculosis	14.6	KMS-S23-2015
Poaceae	*Bambuseae*	Ilasi	Roots	Oral candidiasis	0.6	Not collected
Polygonaceae	*Rumex usamberensis*	Nsemwasemwa	Leaves	Herpes zoster, Herpes simplex	5.6	KMS-S05-2015
Primulaceae	*Embelia schimperi*	Lisonzoko/ Lusonjogo	Stem	Chronic cough, Tuberculosis	2.0	KMS-S10-2015
Rosaceae	*Eriobotrya japonica*	Songwa	Leaves, Roots	Chronic diarrhea, Herpes zoster, Tuberculosis	46.1	KMS-S30-2015

Table 1. Contd.

	Hagenia abyssinica	Mtululunga/Ntululunga	Leaves, Roots,	Chronic diarrhea	2.0	KMS-S09-2015
	Prunus persica	Mfyulisi	Leaves, Roots	Chronic cough	0.6	KMS-S36-2015
Rutaceae	*Citrus limon*	Malalanji	Fruit	Chronic cough	5.6	Not collected
Verbenaceae	*Lippia javanica*	Lufiso	Leaves	Chronic diarrhea	13.9	KMS-S12-2015
Xanthorrhoeaceae	*Aloe* spp.	Alovera	Leaves	Herpes zoster, Herpessimplex, Tuberculosis	47.5	Not collected
Zingiberaceae	*Zingiber officinale*	Mbwigha	Stem	Oral candidiasis, Chronic cough,	40.5	Not collected

Not collected **=** species not collected in the field.

infections. The plant has a support in literature to indicate that a single plant species can be used to manage more than one infection. This is termed as broad spectrum use of the plant (Chinsembu and Hedimbi, 2010).

Generally, the respondents' recognition of most species in managing HIV/AIDS opportunistic infections for example, *Zingiber officinale* indicates importance of the species in disease management. Close related results were revealed in North-West Cameroon by Noumi and Manga (2011). Also, Sankaranarayanan et al. (2010) associated *Z. officinale* with chronic cough treatments and *P. guajava* reported in the present study has been acknowledged in literature to be historical potential in dealing with diarrhea cases elsewhere for example in Nigeria (Famuyide et al., 2013), diarrhea and tuberculosis (Kisangau et al., 2011), diarrhea (Hazarika et al., 2015). The fact that medicinal plants are being used for the same function by more than one community might be a sign of their pharmacological effectiveness (Giday et al., 2010).

The medicinal plants *Dissotis phaeotricha* (used against Chronic diarrhea), *Berberis holstii* (used against Tuberculosis) and *Aloe* spp. (used against skin related infections) indicated highest fidelity level values. According to Trotter and Logan (1986), plants which are used in some repetitive manner are more likely to be biologically active. *Berberis holstii* has been cited to be useful in managing various diseases (Maliwichi-Nyirenda et al., 2011; Srivastava et al., 2015). *Aloe* spp. have been reported for their miracles in healing various diseases in different areas (Verma et al., 2015).

Analytically, the knowledge on medicinal plants that manage HIV/AIDS opportunistic infections was independent of sex and age categories of a respondent. It was expected that the level of knowledge would vary among the respondents as it has been found in other studies such as Giday et al. (2010), but it was not the case in this study (Table 2). This could probably be because the interviewees fell under homogenous sample (HIV patients) hence they possess almost the same experience.

Likewise the level of knowledge on medicinal plants among the respondents does not depend on primary education because knowledge on medicinal plants is mostly obtained outside classroom. Therefore, ethnobotanical knowledge is normally acquired through experience verbally and traditionally, elders passing the knowledge to younger generation (Absolon, 2010).

Origin of people can have an impact on knowledge. For instance the Kinga for this case have less knowledge on the list of medicinal plants that manage opportunistic infections compared to the Nyakyusa. The difference was attributed by being not Rungwe natives rather immigrants from another part of the District. The same was found by Pouliot (2011) in her study. The likelihood of knowing medicinal plants that manage opportunistic infections for respondents in Ibumba village was high, but this was by chance because Ibumba is not the only village closest to the forest, rather there are other villages like Syukula and Ngumbulu which are found at the foot of the mountain forest. Chance events may have influence on knowledge of respondents as disclosed by Byg et al. (2010).

Conclusion

The community in Rungwe District is knowledgeable on ethnobotanical knowledge especially on those used to manage HIV/AIDS opportunistic infections. The people's knowledge was exhibited among other things, and their ability to identify multiple uses of medicinal plants which confirms broad-spectrum of antimicrobial agents of the species. The information by this study adds up to the existing ethnobotanical body of knowledge. Also, it forms a base for future discovery of novel drugs to fight HIV/AIDS related infections along with a need to prove safety and

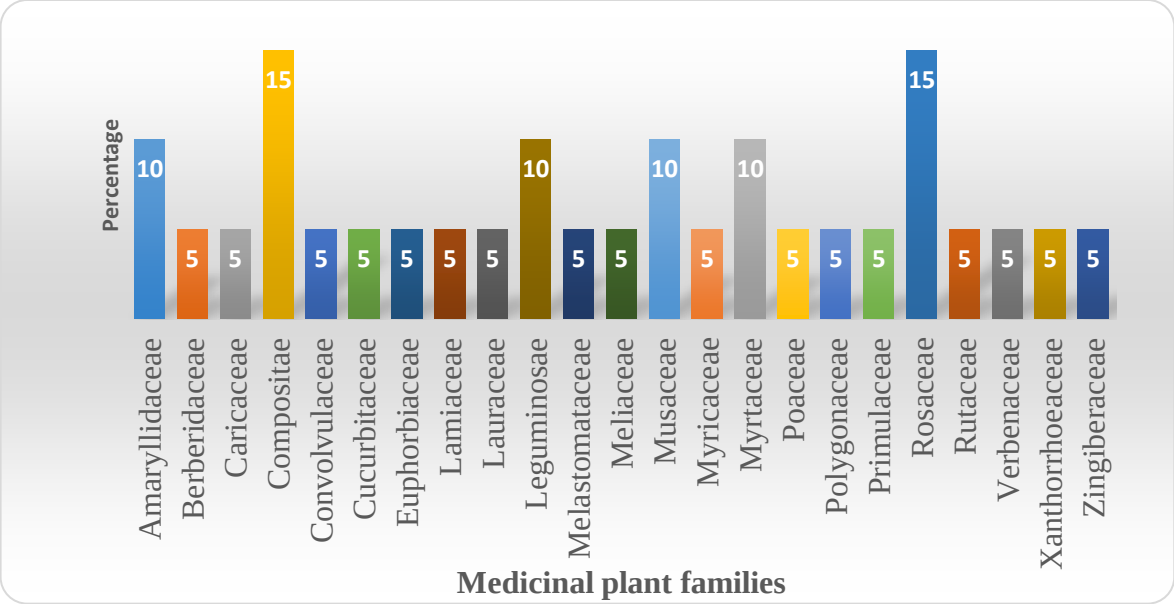

Figure 2. Percentage of plant families used in infections management.

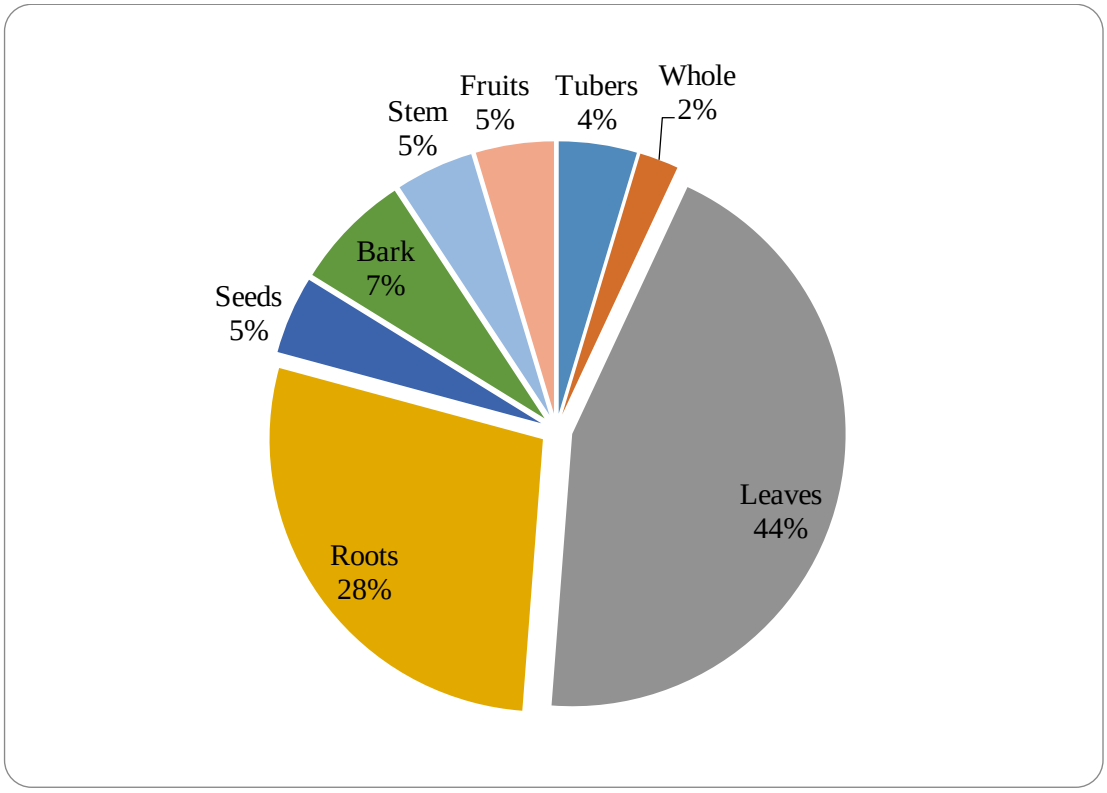

Figure 3. Plant parts used in disease management by percentage.

efficacy of medicinal plants hence, building confidence to medicinal plant users. The study recommends more studies on identification and documentation of species potential for managing HIV/AIDS opportunistic infections.

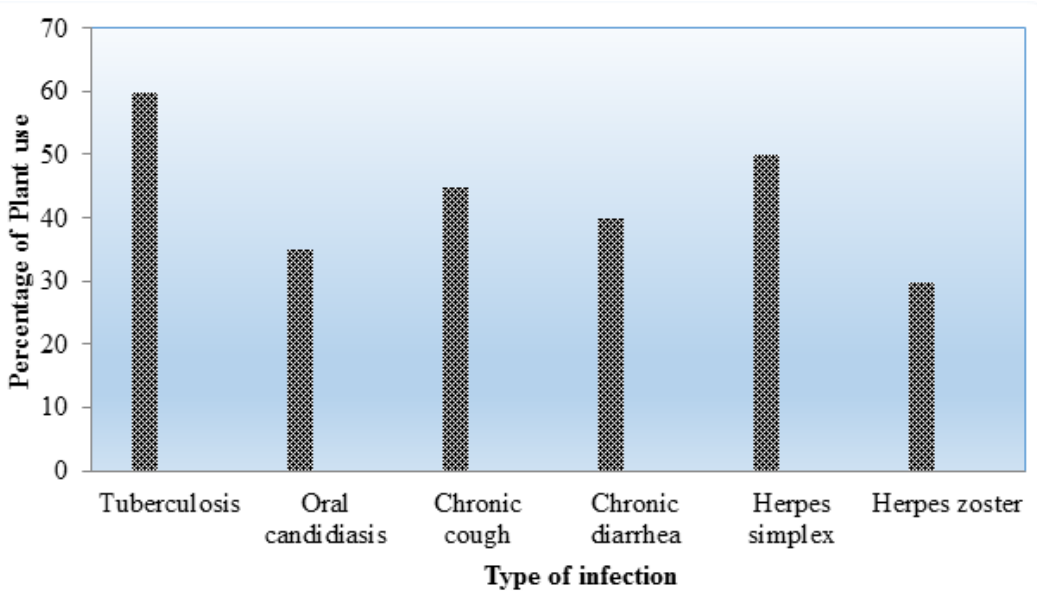

Figure 4. Percentage use of plants per infection.

Table 2. Influence of socio-demographic factors on ethnobotanical knowledge.

Chosen independent variable	Odd ratio	P-value
Sex	**0.76**	**0.34**
Education level		
2(Secondary)	1.07	0.89
3(Tertiary)	0.59	0.89
4(Informal)	3.29**	0.00
Ethnic background		
2(Safwa)	1.15	0.82
3(Nyamwanga)	2.49	0.55
4(Kinga)	0.03**	0.00
5(Malila)	1.18	0.76
Village location		
2 (Ibumba)	4.51**	0.00
3 (Ndaga)	5.04	0.11
4 (Ngumbulu)	2.64	0.52
5 (Mbeye1)	6.39	0.09
6 (Idweli)	4.21	0.17
Constant	0.52	0.09

*, **, *** Significant at 10, 5, 1% level of significance.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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