Medicinal plants used in the traditional management of dog bites by herbalists in Eastern, Western, and Central Uganda

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Research

Abstract

Background: Dog bites arise due to man's casual and tactical association with dogs, and it is a global health challenge. Rural and semi-urban communities are the most affected since accessing conventional post-exposure prophylaxis is nearly a myth. As an alternative, readily available and affordable medicinal plants are used. Indigenous knowledge about such plants is limited to specialized herbalists, and with the continuous modernization of African societies, loss of such knowledge is anticipated if not documented. Therefore, the medicinal plants used to manage dog bites in Eastern, Western, and Central Uganda were documented.

Methods: Snowball sampling was used to identify the specialized herbalists. An interview guide was used to collect ethnobotanical data from June 2021 to December 2022. The information collected included; names of plants used, plant parts, methods of preparation, and mode of administration. Descriptive data was analyzed using the relative frequency of citation (RFC) index and informant consensus factor (F_{IC}).

Results: A total of 31 medicinal plants, belonging to 20 families and 30 genera were documented, with the majority from family Solanaceae. The most commonly used plants were: *Baccharoides lasiopus* (O.Hoffm.) H.Rob., *Gymnanthemum thomsonianum* (Oliv. & Hiern ex Oliv.) H.Rob., *Rhoicissus tridentata* (L.f.) Wild & R.B.Drumm, *Phytolacca dodecandra* L'Hér., and *Nicotiana tabacum* L. Leaves were the most used plant parts. The main mode of preparation was infusion. Oral and topical were the major modes of administration. Herbs obtained from the wild were the most used and the conservation strategy was planting around home compounds and in gardens. RFC was ≤ 0.27, and F_{IC} was ≤ 0.19.

Conclusion: Specialized herbalists possess vast indigenous knowledge on the utilization of medicinal plants to manage dog bites in Uganda. However, there is a need for scientific justification of the traditional therapeutic claim, in a bid to find novel bioactive compounds which can act as drug leads for the development of drugs for the treatment of dog bite-related infections.

Keywords: Dog bites, Medicinal plants, Traditional management, Uganda

Background

Dog bites are bruises or breaks/openings on the skin of a particular individual caused by any contact with a dog's tooth. Dog bites constitute a very high percentage of canine bites globally with approximately 1% of emergency hospital visits (Goldstein *et al*. 2018; Morzycki *et al*. 2019; Razali *et al*. 2020). For developing countries in Asia and Africa, dog bites contribute to over 95% of global animal bite cases (Kisaka *et al*. 2021). Despite the high evidence of cases of dog and other animal bites in Africa, several cases of dog bites go unreported. This is because surveillance for dog bites is inadequate, more so in rural and semi-urban communities where healthcare facilities are unable to provide post-exposure treatment. Consequently, the poor and vulnerable African communities acquire unlimited dangers associated with dog bites such as rabies, permanent disfigurement requiring reconstructive surgery, disabilities, zoonotic bacterial infections, and some fatalities (Wangoda *et al*. 2019). As a measure to overcome these dangers, different medicinal plants have been used as an alternative in the management of dog bites in local communities. Ethnobotanical studies on medicinal plants used in the management of dog bites have been reported in different parts of the world (Ramesh *et al*. 2013; Pagadala *et al.* 2015; Meresa *et al*. 2017; Yeweynshet et al. 2022). However, there is a paucity of similar studies in Uganda.

Over 6,601 dog bites occur every year in all regions of Uganda (Masiira *et al*. 2018). The rural and semi-urban communities are highly affected raising a public health concern (Wangoda *et al.* 2019). This is because post-exposure prophylaxis such as antirabies and antibacterial therapies are expensive and inaccessible. Thus, these communities mainly rely on cheaper and available traditional herbal remedies as alternatives to manage dog bites (Kisaka *et al*. 2020). Therefore, this study aimed to carry out an ethnobotanical survey on medicinal plants used in the traditional management of dog bites in Uganda.

Materials and Methods

Study areas and designs

The ethnobotanical survey was conducted to establish the medicinal plants used traditionally to manage dog bites in three regions of (Western, Central, and Eastern) Uganda. The districts of: Sheema: 00°32'S 30°24'E, Bushenyi: 00°33'S 30°12'E, and Hoima: 01°25'S 31°05'E in the Western; Wakiso: 00°24'S 32°29'E in the Central; and Kaliro: 00°54'S 33°30'E, Luuka: 00°42'S 33°18'E and Namutumba: 00°21'S 33°03'E in the Eastern (Figure 1) were purposively selected based on reported incidences of dog bites (Masiira *et al*. 2018; Kisaka *et* al. 2020).

Data collection

Snowball sampling was used to identify specialized herbalists (key informants) who manage dog bites using medicinal plants. Lead person(s) who: (i) could have been bitten by a dog(s) and got treated using medicinal plants or, (ii) individuals who might have heard of dog bite incident and treatment done using medicinal plants, and knew the herbalist of interest, were used to identify the specialized herbalists. Any specialized herbalist identified and belonging to a neighboring district that was initially selected was also included in the study.

Using a semi-structured interview guide, ethnobotanical data were collected from June 2021 to December 2022, following the International Society of Ethnobiology (2006) guidelines. Demographic information was recorded excluding the name of the herbalist for confidentiality and then field walks were conducted as per the procedure described by Martin (1995) and Tahir *et al*. (2023). Information such as; the appearance of the plants, the local name of the plants, plant part used, mode of preparation, period/frequency of administration, and conservation measures were recorded. The voucher specimens were collected and identified by a botanist at Mbarara University of Science and Technology (MUST), where the herbarium specimens were deposited. The plant species, family, and genera names were confirmed using online databases; The World Flora Online (http://www.worldfloraonline.org), Plants of the World (https://powo.science.kew.org/), and International Plant Names Index (www.ipni.org).

Data analysis

The ethnobotanical data collected were analyzed in the form of frequencies, percentages, relative frequency of citations (RFC), and informant consensus factor (F_{IC}). The RFC index expresses the level of traditional knowledge on the use of a particular medicinal plant for a common application. RFC was calculated using the formula: $RFC = \frac{FC}{N}$. Where FC is the number of herbalists who cited the medicinal plant, and N is the total number of herbalists in the study (Ahmed *et al*. 2016; Nazli 2022). RFC value ($0 \leq RFC \leq 1$) was used to identify the herbalists' most common plant species used to manage dog bites. F_{IC} was used to indicate the level of agreement on the use of medicinal plants on dog bites. F_{IC} was calculated using the Trotter and Logan (1986) formula: $F_{IC} = \frac{(N_{ur} - N_t)}{(N_{ur} - 1)}$. Where N_{ur} is the number of use reports from informants for a

particular plant use category and N_t is the number of taxa or plant species used for that category for all informants. The F_{IC} value range is $0 \leq F_{IC} \leq 1$, where a high F_{IC} value (approximately 1) indicates that informants exchange indigenous knowledge on the use of medicinal plants in a well-described criterion in the society (Henrich *et al*. 1998).

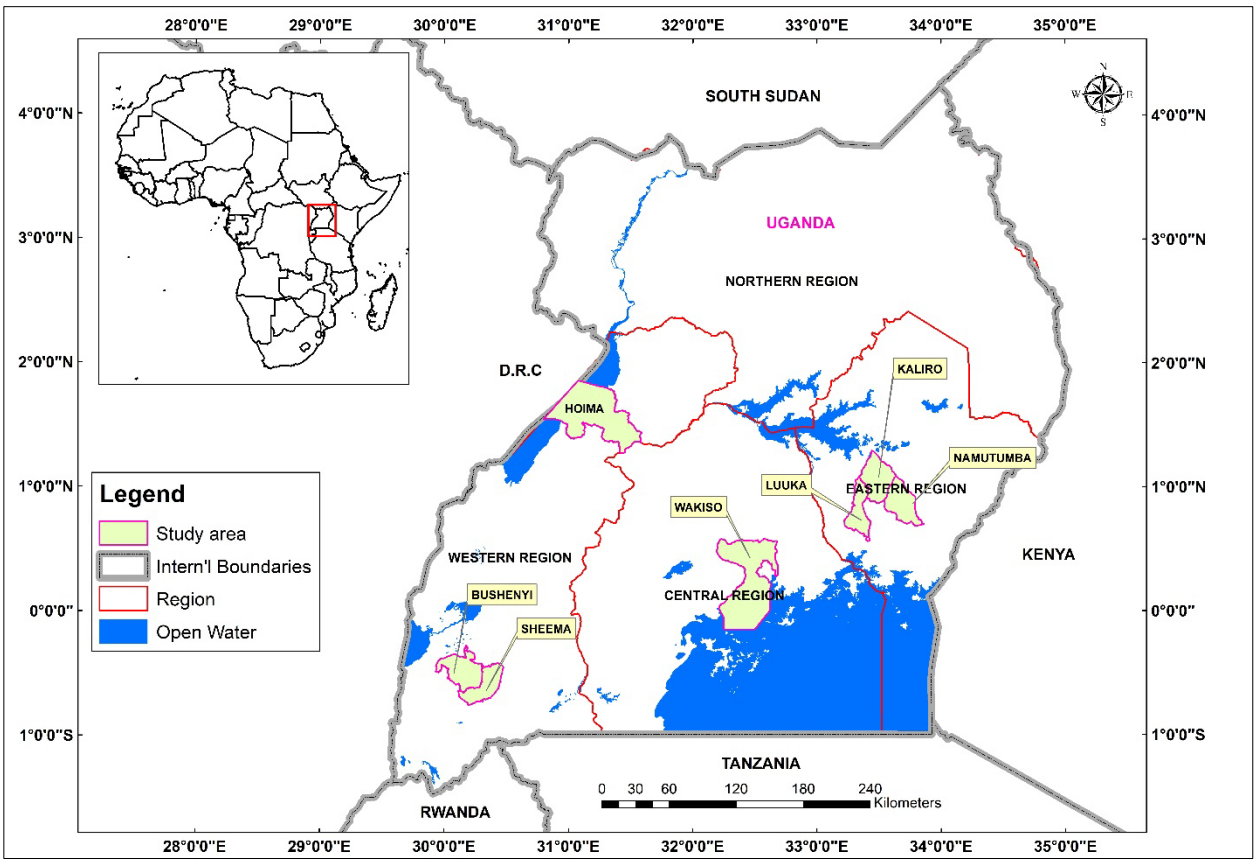

Figure 1. Map of Uganda showing the study areas (created using, ArcGIS version 10.8).

Results and Discussion

Socio-demographic features

Eleven specialized herbalists were identified from seven districts: Sheema, Bushenyi, and Hoima in the Western region; Wakiso in the central region, and Luuka, Kaliro, and Namutumba in the Eastern region of Uganda (Figure 1). The number of herbalists was small because few specialized herbalists in Uganda are known to manage dog bites traditionally using medicinal plants. The majority of the herbalists were men (90.9 %) and only one was female (Table 1). All the herbalists identified confessed that the knowledge background that they inherited about the plants in question is linked to hunting (Table 1), and in African tradition, hunting is associated with men using dogs (Bata *et al*. 2020). This traditional hunting practice justifies the higher number of men taking part in this study as compared to women. Therefore, men possessed more knowledge of plants used to manage dog bites since a bite could arise during hunting and/or during casual as well as tactical interaction with dogs (Owczarczak-Garstecka, *et al*. 2019). The current findings differ from other previous ethnobotanical studies in Uganda which reported more women participants than men (Gumisiriza et al., 2020; Schultz *et al*. 2020). The difference is probably because the current study focused on documenting plants used to manage dog bites, yet the previous studies documented medicinal plants used to treat various ailments. However, the findings concur with Tugume *et al*. (2016), who reported a higher male percentage (70 %) of participation than women during an ethnobotanical survey on medicinal plants used by communities around the Mabira Central Forest Reserve, Uganda. Lutoti *et al*. (2023) also reported more men (72.3 5 %) than women when documenting plants used to manage breast cancer.

The age of all the herbalists who participated in the study was above 40 years and the majority (81.2 %) had taken over 20 years in the practice. The absence of youth with knowledge of plants used as traditional medicine is attached to economic drift to towns, modernization (Schultz *et al*. 2020), brain drain, having limited ownership of productive resources such as land that keep them close to elders for indigenous knowledge transfer and instead, they are forced to move to other places for different opportunities (IOM 2015). These findings coincide with recent ethnobotanical studies in Uganda which reported

a minimal number of youths in possession of knowledge about plants used traditionally to manage several health dares (Gumisiriza *et al*. 2020). However, it should be remembered that the source of the knowledge on plants documented in the current study is associated with hunting, a practice which is seemingly becoming rare in today's society for the youths to participate.

Table 1. Socio-demographic features of herbalists

Feature		Number of participants	Percentage (%)
Sex	Male	10	90.9
	Female	01	9.1
Age	≥ 40	11	100
Marital status	Married	10	90.9
	Widow	01	9.1
Education level	None	02	18.2
	Primary	08	72.7
	Secondary	01	9.1
Occupation	Peasant	11	100
Plant knowledge background	Ancestral spirits	01	9.1
	Hunters	11	100
Experience	≤ 20 years	02	18.2
	≥ 20 years	09	81.2

The majority of the herbalists (72.1 %) who participated in this study had attended up to a lower primary level and could hardly write, and 18.2 % of the herbalists did not attain any formal education. Only 9.1 % of the participants had attained secondary education (Table 1). The results also revealed that all the participants in this study practiced subsistence farming and none of the herbalists had formal employment, hence they were all low-income earners (Tugume & Nyakoojo 2019). Therefore, herbalists rely on treatment using traditional plants as alternative source of income. The current study agrees with some previous ethnobotanical studies in Uganda which reported the majority of participants have attained low or no formal education and relied on indigenous knowledge to manage different health issues, including animal bites (Gumisiriza *et al*. 2019) such as dog bite.

Medicinal plant species used traditionally to manage dog bite

The study revealed a total of 31 medicinal plant species belonging to 20 families and 30 genera (Table 2). The commonly used medicinal plants were; *Baccharoides lasiopus*, *Gymnanthemum thomsonianum*, *Rhoicissus tridentata*, *Phytolacca dodecandra,* and *Nicotiana tabacum* with the frequency of citation of 3, 3, 2, 2, and 2 respectively. *B. lasiopus*, *G. thomsonianum,* and *N. tabacum* were reported used to treat dog bites in both Eastern and Western Uganda, *R. tridentata* in Eastern and Central Uganda, while *P. dodecandra* in Central and Western Uganda (Table 3). None of the mentioned medicinal plants used to manage dog bites was common in all three regions under study.

In the current study, *B. lasiopus* is reported in the management of dog bites in Uganda for the first time. However, Maroyi (2020) reported several other traditional uses of *B. lasiopus* in Uganda which included the management of; inflammation, respiratory infections, splenomegaly, anorexia, fever, and malaria among others. In other East African countries, *B. lasiopus* is traditionally used to treat diseases like colorectal cancer, parasitic worms, back pains, convulsions, epilepsy, typhoid, and diabetes. This means that *B. lasiopus* is widely distributed in tropical Africa and is traditionally useful as was reported by Maroyi (2020), hence it is a valuable plant. The traditional use of *G. thomsonianum* is reported for the first time in Uganda. It is a native of tropical Africa, used traditionally in the treatment of bacterial infections in Rwanda (Mungarulire 1992). *R. tridentata* is also reported in the traditional management of dog bites for the first time in Uganda. However, previous studies have reported the use of *R. tridentata* in the treatment of helminths in livestock (Nalule *et al*. 2011), strange traditional diseases (Gumisiriza *et al*. 2020), and breast cancer (Dube *et al*., 2021) in Uganda. Though *P. dodecandra* has been reported to be traditionally used to treat dog bites/rabies in Ethiopia (Meresa *et al*. 2017) and in DRC (Beressa *et al.* 2020), this is the first time to be cited for the management of dog bites in Uganda. Other traditional uses in Uganda include; the management of skin disorders, inducing abortion, (Nakalembe *et al*. 2019), and cleansing clothes (Beressa *et al.* 2020). In other parts of the world, *P. dodecandra* is used traditionally in treating malaria, sore throat, rabies, tuberculosis, asthma in DRC, epilepsy

in Tanzania (Beressa *et al.* 2020), gonorrhea, and helminthiasis in Ethiopia (Tahir, *et al*. 2023). For *N. tabacum*, other than being reported for the first time to be used to manage dog bites in the current study, the plant is also used traditionally to repel snakes and treat snake bites in Uganda (Omara *et al*. 2020). Other traditional uses reported include; treatment of ulcers, cough, respiratory tract infections, and cancer (Ameya *et al*. 2017).

Table 2. Medicinal plant species traditionally used to manage dog bite

Species, Local name (language), Growth form, Voucher No.	**Family name**	**Part used**	**Mode of preparation and administration**	**FC**
Agapanthus africanus (L.) Hoffmanns., **ekirenga/kitunguru** (lunyr), herb, PM21-14	Amaryllidaceae	Bulbs	Crush, add water, drink a glass 3 times daily for 7 days	1
Mangifera indica L., **muyembe** (lug), tree, PM21-18	Anacardiaceae	Leaves	Crush, squeeze, and apply the juice on the wound 3 times daily for 7 days	1
Asparagus racemosus Willd**., olukira lwengo** (lulmg), herb, PM22-24	Asparagaceae	Leaves	Dry, pound, and apply powder on the wound 2 times daily for 3 days	1
Baccharoides lasiopus (O.Hoffm.) H.Rob. (Synonym: *Vernonia lasiopus* (O.Hoffm.)*,* **kayiririzi/kasalagala/omujuma** (lusg/lumg/luny), herb, PM21-01	Asteraceae	Leaves or roots	Crush, warm, applied on the wound 3 times daily for 5 days	3
Carica papaya L.*,* **mupapali omusaiza** (lumg), shrub, PM22-21	Caricaceae	Roots	Grind, squeeze, and apply the juice on the wound 2 times daily for 5 days	1
Combretum molle R.Br. ex G. Don*,* **endaha** (lumg), tree, PM22-23	Combretaceae	Roots or stem barks	Dry, pound, and apply the powder on the wound 2 times daily for 3 days	1
Gymnanthemum thomsonianum (Oliv. & Hiern ex Oliv.) H.Rob. (Synonym*: Vernonia thomsoniana*), **kabirizi akasadha/twatwa** (lusg/lug), herb, PM21-02	Asteraceae	Leaves or roots	Crush, warm, applied on the wound 3 times daily for 5 days	3
Kalanchoe marnieriana H.Jacobsen, **dimily'ambwa** (lug), herb, PM21-17	Crassulaceae	Leaves	Crush, and tie onto the wound 3 times daily for 7 days	1
Cucurbita moschata Duchesne, **nsujju** (lug), creeper, PM21-15	Cucurbitaceae	Leaves	Crush, and tie onto the wound 3 times daily for 7 days	1
Momordica foetida Schumach.*,* **ibombo eiganda** (lumg), herb, PM22-22	Cucurbitaceae	Roots	Pound, boil in water, mix with crude alcohol, and drink a glass 3 times daily for 5 days.	1
Ricinus communis L., **mukakale** (lusg), shrub, PM21-04	Euphorbiaceae	Leaves or roots	Crush, add water, filter, and drink a glass 3 times daily for 3 days	1
Indigofera arrecta Hochst. ex A.Rich., **omushoroza** (luny), herb, PM21-11	Fabaceae	Leaves	Crush, and tie onto the wound 3 times daily for 7 days	1
Piliostigma thonningii (Schumach.) Milne-Redh*,* **ekirama omukali** (lumg), shrub, PM22-26	Fabaceae	Roots	Pound, boil in water, mix with crude alcohol, and drink a glass 3 times daily for 5 days.	1
Erythrina abyssinica DC., **kiko** (luny), shrub, PM21-12	Fabaceae	Leaves	Burnt to ash, apply on the wound 3 times daily for 5 days	1
Psorospermum febrifugum Spach*,* **kanziro nziro** (lumg), shrub, PM22-25	Hypericaceae	Roots	Dry, pound, and apply powder on the wound 2 times daily for 3 days	1
Hoslundia opposita Vahl, **nfodo** (lumg), herb, PM22-20	Lamiaceae	Leaves	Grind, squeeze, and apply the juice on the wound 2 times daily for 5 days	1
Sida cuneifolia Roxb., **akeyerezo** (luny), herb, PM21-09	Malvaceae	Aerial parts	Crush, tie onto the wound 3 times daily for 7 days	1
Ficus natalensis Hoschst, **mutuba** (lug), tree, PMKGM21-16	Moraceae	Leaves	Grind, squeeze, and apply the juice on the wound, and chew 3 times daily for 7 days	1
Moringa oleifera Lam.*,* **molinga** (lug), shrub, PM21-29	Moringaceae	Root bark	Crush, and tie onto the wound 3 times daily for 5 days	1

Phytolacca dodecandra L'Hér., **omuhoko** (luny), herb, PM21-07	Phytolaccaceae	Leaves	Grind, squeeze, and apply the juice on the wound or drink a glass 3 times daily for 7 days	2
Imperata cylindrica (L.) P.Beauv., **olusenke** (luny), grass, PM21-08	Poaceae	Roots	Crush, squeeze, and apply the juice on the wound 3 times daily for 7 days	1
Pennisetum polystachion (L.) Schult., **Obucece** (luny), grass, PM21-13	Poaceae	Stems	Burnt to ash, apply on the wound 3 times daily for 5 days	1
Cenchrus ciliaris L*.,* **nangeye** (lumg), grass, PM22-30	Poaceae	Leaves	Crush, squeeze, and apply the juice on the wound 2 times daily for 5 days	1
Digitaria abyssinica (Hochst. ex A.Rich.) Stapf, **lumbugu** (lumg), grass, PM22-31	Poaceae	Roots	Pound, boil in water, mix with crude alcohol, and drink a glass 3 times daily for 5 days.	1
Harrisonia abyssinica Oliv*.,* **lusyaike** (lumg), shrub, PM22-27	Rutaceae	Roots	Pound, boil in water, mix with crude alcohol, and drink a glass 3 times daily for 5 days.	1
Datura stramonium L*.,* **kalulu** (lusg), herb, PM21-05	Solanaceae	leaves	Crush, add water, filter, and drink a glass 3 times daily for 7 days	1
Solanum marginatum L.f., **empayira** (luny), herb, PM21-06	Solanaceae	Roots	Crush, squeeze, and apply the juice on the wound; add water take a glass once daily for 5 days	1
Nicotiana tabacum L., **etabe/taaba** (luny/lusg), herb, PM21-10	Solanaceae	Leaves	Crush, squeeze, and apply the juice on the wound once daily for 7 days	2
Solanum villosum Mill (Synonym: *Solanum incanum* Kit. ex Schult.)*,* **ntengotengo** (lug), herb, PM21-19	Solanaceae	Leaves	Crush, boil in water, and drink a glass 3 times daily for 7 days	1
Rhoicissus tridentata (L.f.) Wild & R.B.Drumm*.*, **muvongo/mumara** (lusg/lug), climber, PM21-03	Vitaceae	Roots	Crush, warm, apply on a wound, or add water, Drink a glass 3 times daily for 5 days	2
Cyphostemma adenocaule Desc. ex Wild & R.B.Drumm*.,* **ibombo eisoga**, (lumg), herb, PM22-28	Vitaceae	Roots	Crush, boil in water, mix with crude alcohol, and drink a glass 3 times daily for 5 days.	1

FC, Frequency of citation; lusg, Lusoga; luny, Lunyankore; lunyr, Lunyoro; lug, Luganda; lumg, Lulamogi.

The five commonly cited medicinal plant species belonged to families; Asteraceae, Vitaceae*,* Phytolaccaceae, and Solanaceae (Table 3) and genera; *Baccharoides*, *Gymnanthemum, Rhoicissus, Phytolacca,* and *Nicotiana* respectively. Plants in families of Asteraceae, Vitaceae, Phytolaccaceae, and Solanaceae have been reported in several studies in Ethiopia (Meresa *et al*., 2017; Beasley *et al*. 2022), and India (Arati 2022) to be among those used traditionally in the treatment of dog bites/ rabies. This symbolizes that such plants could be of common use across countries and cultures. Therefore, reporting plants of these families for the management of dog bites in Uganda could be incontestable.

Table 3. Medicinal plant species cited more and their families

Plant species cited more			**Family of the plant**
Plant species name	Fq	RFC	
Baccharoides lasiopus (E^2W^1)	3	0.27	Asteraceae
Gymnanthemum thomsonianum (E^2W^1)	3	0.27	Asteraceae
Rhoicissus tridentata (E^2C^1)	2	0.18	Vitaceae
Phytolacca dodecandra (C^1W^1)	2	0.18	Phytolaccaceae
Nicotiana tabacum (E^1W^1)	2	0.18	Solanaceae

Fq, Frequency; RFC, Relative frequency of citation; ($E^1W^1C^1$), plant species with a frequency of citation (1) in Eastern, Western, and Central Uganda.

Considering all medicinal plant species cited by the specialized herbalists, five common families were identified; Solanaceae (19 %), Poaceae (19 %), Fabaceae (14.5%), Cucurbitaceae (9.5 %), and Vitaceae (9.5 %) (Figure 2).

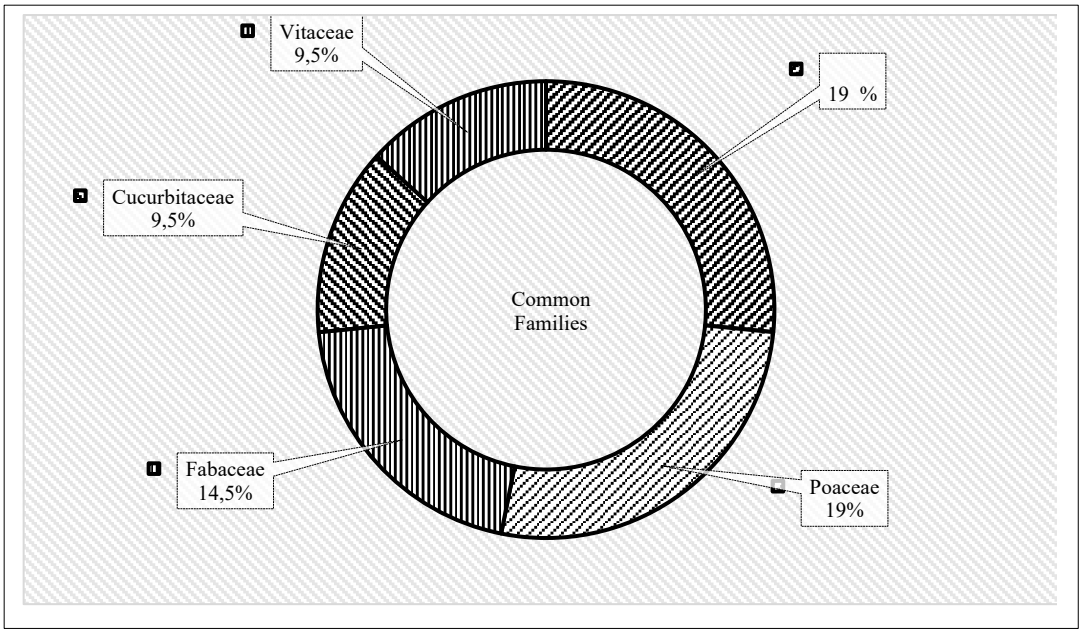

Figure 2. Commonly mentioned medicinal plant families used to manage dog bites

Fortunately, several medicinal plant species in these five families have also been reported among those used traditionally in the management of dog bite/ rabies in Ethiopia (Meresa *et al*. 2017; Beasley *et al*. 2022) and India (Arati 2022). Plant species in the families of Solanaceae, Cucurbitaceae, and Fabaceae are used most in Ethiopia while in India, plant species of the family Fabaceae dominate; this picture has been portrayed in the current study.

Findings in the current study also revealed that only the genus *Solanum* had two plant species while other genera had one plant species cited. Many plants in the genus *Solanum* have been reported for traditional use to manage dog bites (Meresa *et al*. 2017; Chaudhary *et al.* 2018; Beasley *et al*. 2022; Arati 2022); which concur with the present findings. Therefore, the use of the medicinal plant species cited in this study could be a reality, although specific phytochemical studies to justify the claimed traditional use are necessary to be undertaken.

Medicinal plant parts used, mode of preparation, and administration

The use of a particular part of a plant is an indicator of its therapeutic potential (Tahir *et al*. 2021). The commonly used plant part(s) were leaves, followed by roots, stem/stem bark, aerial parts, and bulbs (Figure 3A). The probable reason for the extensive use of leaves is that leaves are abundant, effortlessly obtained and they could contain more effective and active phytochemical components (Tahir *et al*. 2023). Leaves are also easy to prepare (Tahir *et al*. 2021) by crushing since they do not undergo secondary thickening during growth compared to roots and stems. Using leaves has less effect on the plant's future survival and the rate of plant tissue regeneration is higher, while using roots, stems and bulbs may mean the destruction of a particular plant species. These findings are in congruence with preceding ethnobotanical studies in Uganda (Nalumansi *et al*. 2014; Tugume *et al*. 2016;) and other parts of the world (Tahir *et al*. 2023) where leaves were reported as the most plant parts used. However, Kefalew *et al*., (2015) reported that roots are commonly used. It should be noted that specialized herbalists (10 of the 11) stated that for efficiency to be achieved, a mixture of several plants of different plants are always used. This practice acts as an additive form of action or an enhancement to the synergistic effect to destroy the different forms of pathogens (Asiimwe *et al*. 2021) and can be a baseline for overcoming pathogenic drug resistance. The use of different plants in a mixture could also keep the secrecy of the formulae of herbalists (Kuria *et al*. 2001; Jeruto *et al*. 2011).

The most common mode of preparation was infusion, crushing, and decoction and the least was ashing (Figure 3B). Preparation modes like infusion, decoction, and powdering of the plant parts however are preceded by crushing. Crushing is a simple practice carried out at any place, even between one's palm or using any material like stones (Tahir *et al*. 2023). Crushing enables plant materials to be thoroughly drenched in water or any other medium used since it increases the surface area of contact between the bioactive ingredients and the solvent, for instance during infusion. Consequently, crushing leads to effective and fast extraction of the compounds responsible for the targeted health response hence important in supporting the dominant modes of preparation of the plant parts used (Megersa 2013). For example, crushing magnifies the

efficiency of a decoction where boiling enables the active ingredients in the crushed plant materials to dissolve easily. During decoction, the boiling carried out also sterilizes the materials used (Charwi *et al*. 2023) and preserves the herbal remedy prepared than when cold media is used. However, if boiling is done for a long time, it may lead to the degradation of bioactive ingredients in the plant part, more so the aromatic compounds (Tugume & Nyakoojo 2019). These could be the reasons why infusion is the common mode of preparation identified in the current study. During ashing, the plant parts used are burnt into ash and then used during incisions.

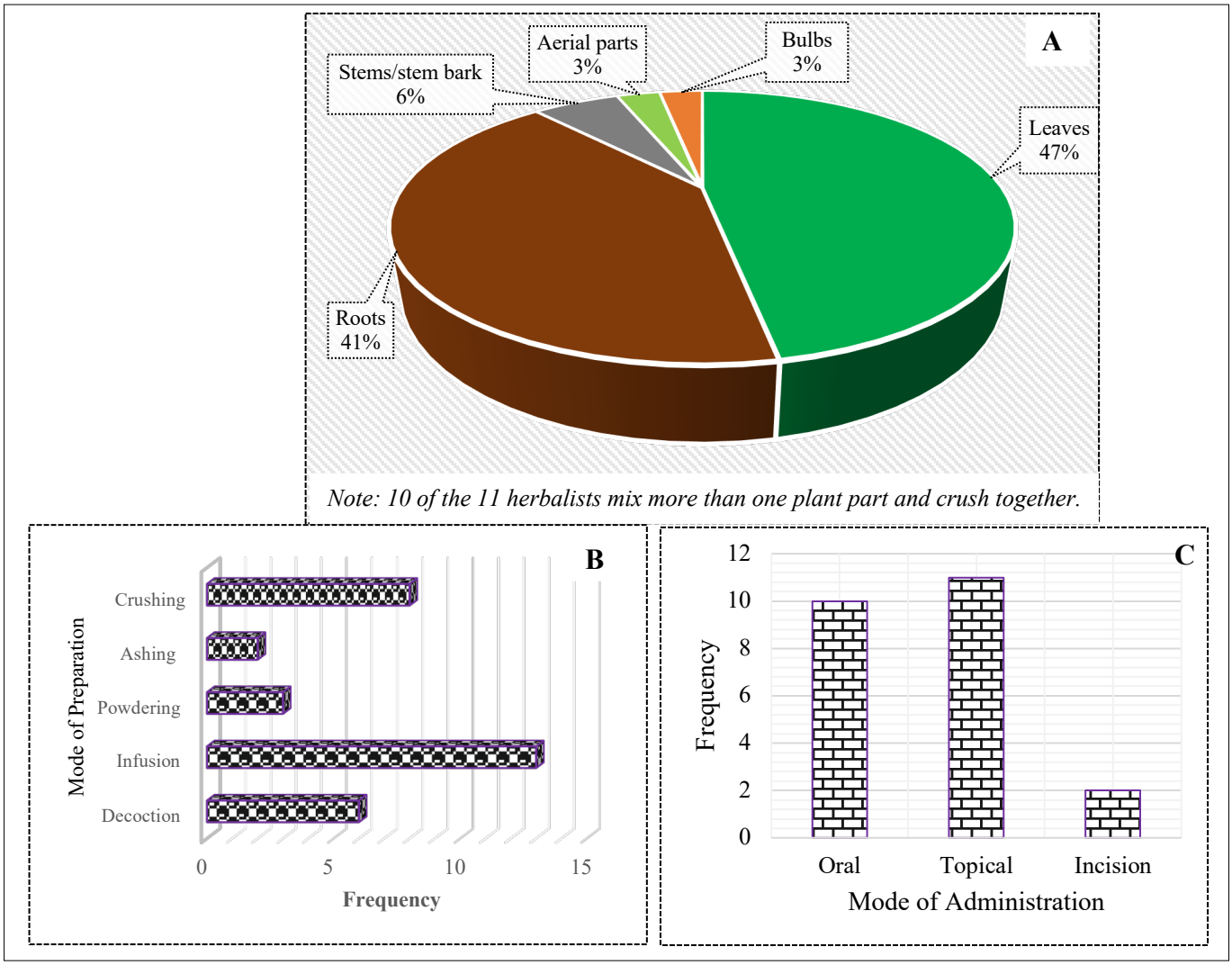

Figure 3. Medicinal plant parts used (**A**), mode of preparation (**B**), and mode of administration (**C**)

Topical was the highest mode of administration, followed by oral, and then incision (Figure 3C). The topical mode mainly involves crushing the plant material, squeezing, and applying the juice onto the wound of the victim. This administration mode was favored because it increases the chances of contact between the pathogens in the wound and the plant ingredients. It also eases penetration of the plant components into the muscles to "counteract the poison". The topical mode of administration can also involve applying powdered materials onto the wound. Using powder was described as relevant since the plant materials stay for a longer time in the wound than when plant juice which could flow out is used. However, powdered materials topically applied were mentioned to be relatively slow in releasing plant ingredients into the wound. Giday *et al*. (2009) study in southwest Ethiopia also reported that most herbal remedies were applied topically. The oral was the second highest mode of administration because the water and/ or food used to prepare the medicinal remedies may act as the vehicle for the transportation of the remedies into the body (Tugume *et al*. 2016). This could be the reason why oral administration is reported as the primary mode of application of plant remedies throughout the world (Tahir *et al*. 2023). Making incision involve the burning of plant materials into ash, and then cuts are made around the wound into which the plant material is applied. It is believed by the herbalist that this mode easily enables the plant ingredients to enter the muscles around the wound and hence into the bloodstream to absorb the "poison" for quicker recovery.

Medicinal plant growth forms, plant habitats, and conservation measures

The medicinal plant species used to treat dog bites mainly grew as herbs (50 %), shrubs (21.9 %), and grasses (12.5 %) (Figure 4P). Abundance, easy accessibility, and short height could be the reasons for herbs to be the common growth form used as compared to relatively tall shrubs and taller trees. Gumisiriza *et al*. (2019) reported similar findings in Uganda. The medicinal plant species were mainly collected from the wild, gardens, and grasslands (Figure 4Q). This means that the wild is the main source of medicinal plants. However, this practice puts several plants at risk of becoming extinct due to seasonal catastrophes, human influence via agriculture, and other anthropogenic activities (Asiimwe *et al*. 2021). As a means of conservation, the majority of the herbalists (90.9 %) planted some medicinal plants around their homestead and in their gardens (63.6 %), especially in banana and coffee plantations (Figure 4R). Some herbalists (18.2 %) had no idea about the conservation of plants, implying that they solely depended on wild sources. None of the herbalists interviewed had immediately planted a particular plant species as a replacement for the harvested one(s) in the wild. These findings are in support of Gumisiriza *et al*. (2019), who reported that domestication and propagation strategies to conserve medicinal plants need to be adopted for sustainability. Nevertheless, conservation strategies such as raising public awareness, planting around public infrastructures like schools, and along the roads, and cultivating in the wild setting are vital to improving future access to the healthcare of all persons and further scientific investigation (Tahir *et al.* 2023).

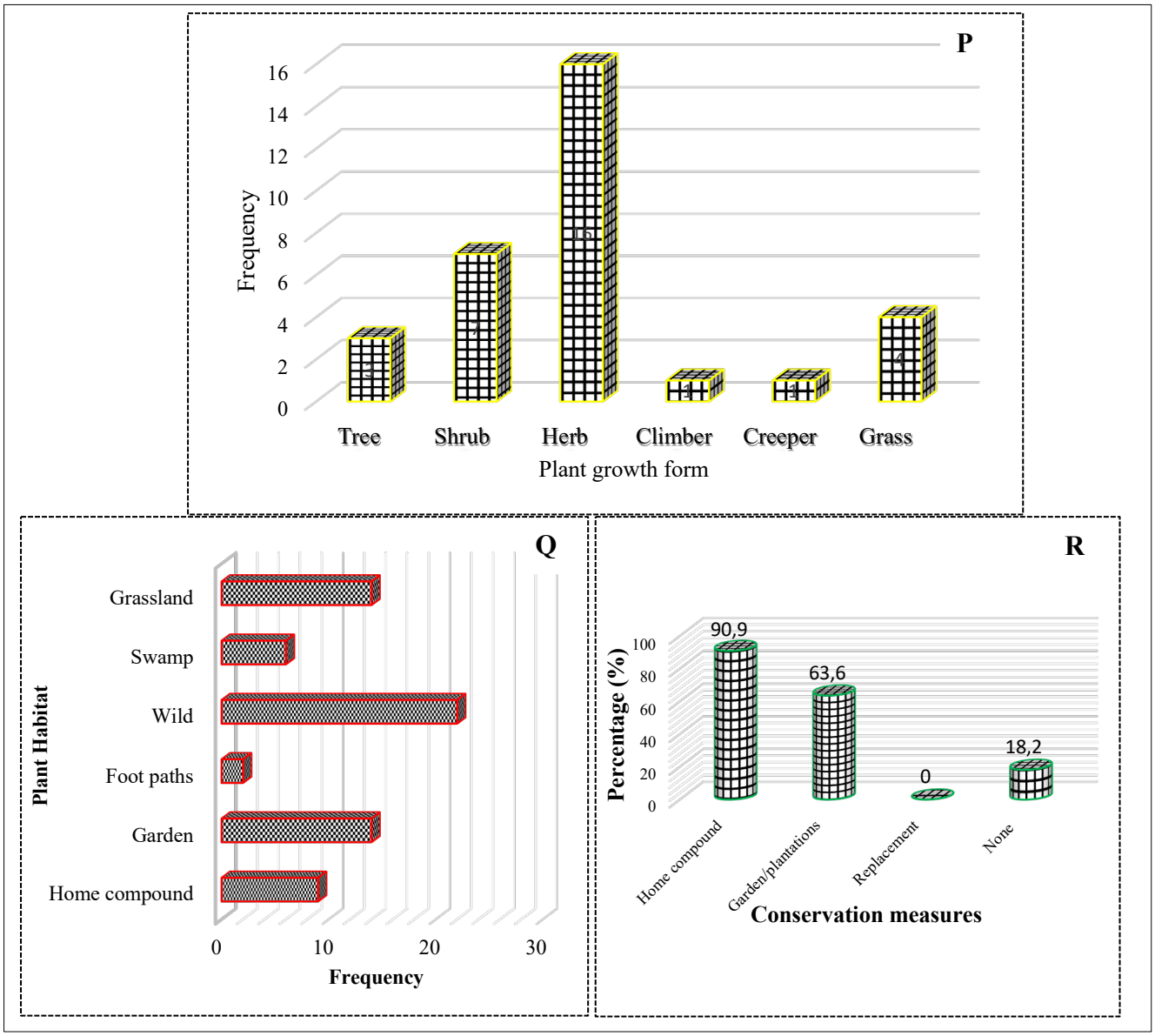

Figure 4. Growth form (**P**), Habitat (**Q**), and Conservation measures (**R**) of the medicinal plants

Informant consensus factor, F_{IC}

There was a low F_{IC} (0.19) between herbalists for medicinal plants used in the management of dog bites (Table 4). For herbalists within regions, the Eastern recorded F_{IC} = 0.11, while the Central and Western had F_{IC} = 0.00. All the F_{IC} values were below 0.5. Kunwar *et al*. (2018) assert that an F_{IC} value less than 0.5 indicates that there is minimal or no agreement between informants about the medicinal plant species used to treat a particular health challenge. In the current study, the F_{IC} values (< 0.2) indicate that there is no exchange of information between herbalists (Heinrich *et* al. 1998). The low F_{IC} values also indicate that there is no cultural convergence (Kunwar *et al*. 2018). This means that indigenous knowledge about the medicinal plant species used to manage dog bites is not shared by herbalists across cultures in Uganda. These observations could also justify the small number of participants and their sparse distribution within the country. However, this reservation threatens the transfer of indigenous knowledge about the plants used, and henceforth their documentation was necessary.

Table 4. Informant consensus factor, F_{IC} values

Region of Uganda	N_{ur}	N_t	F_{IC}
Western	10	10	0.00
Central	08	08	0.00
Eastern	19	17	0.11
Overall	**38**	**31**	**0.19**

N_{ur} = number of use reports, N_t = number of taxa/plant species, F_{IC} = informant consensus factor.

The findings in the current study contrast some ethnobotanical studies in Uganda (Gumisiriza *et al*. 2020; Lutoti *et al*. 2023) which reported agreement about medicinal plants within communities. The contrast is probably because the previous studies focused on several ailments and highly prevalent health challenges respectively.

Pharmacological importance of the commonly used medicinal plants in the management of dog bites

The pharmacological importance was evaluated by cross-referencing with the available literature (Table 5). It was established that *P. dodecandra* was reported to treat rabies/dog bites (Meresa *et al.* 2017), which concurs with the current study. The antirabies potential of *P. dodecandra* has also been evaluated (Zewde *et al*. 2019; Beressa *et al.* 2020). This implies that *P. dodecandra* is a promising plant for the development of a remedy against rabies virus and other pathogenic infections from dog bites. The pharmacological potentials, such as antibacterial and antiviral properties of *B. lasiopus*, *G. thomsonianum*, *R. tridentate,* and *N. tabacum* were reported (Table 5). It is asserted that dog bites lead to polymicrobial infections, which could be due to bacteria like *Streptococcus aureus*, and viruses such as rabies virus (Older *et al*. 2019; Razali *et al*. 2020). The antirabies and antibacterial potential of medicinal plants have been attributed to various compounds such as; flavonoids, tannins, glycosides, alkaloids, phenolics, and terpenoids (Deressa *et al*. 2010; Meresa *et al.* 2017; Sandeepan *et al*. 2017). This gives a baseline for further scientific investigations that could lead to the development of antimicrobial agents to overcome the microbial infections related to dog bites.

Conclusion

The findings in this study and other ethnobotanical studies in Uganda confirm that people use medicinal plants to manage health challenges. Specialized herbalists in Eastern, Western, and Central Uganda possessed vast indigenous knowledge of medicinal plant species used to manage dog bites. It is paramount to have such indigenous knowledge documented for future use before it is lost across generations. A total of 31 medicinal plants belonging to 20 families and 30 genera were documented. Family Asteraceae had the highest number of medicinal plants used. The commonly used medicinal plant species to manage dog bites were: *Baccharoides lasiopus*, *Gymnanthemum thomsonianum*, *Rhoicissus tridentate*, *Phytolacca dodecandra,* and *Nicotiana tabacum.* The leaves were the most used plant parts, and the mode of administration used most was infusion. Most plants identified mainly grew as herbs and were obtained basically in the wild. The specialized herbalists conserve the medicinal plants used mostly around their home compounds and in the gardens or plantations. The medicinal plant species documented in the current study can be subjected to phytochemical investigations to validate the claimed therapeutic use. The validation could lead to the discovery of new bioactive principles that could be of future importance in the management of dog bites and related health challenges.

Table 5. Pharmacological importance of the commonly used medicinal plants used in the management of dog bites

Plant species	Earlier studies			
	Part used	Ethnobotanical use(s)	Pharmacological potential(s)	Compounds reported
Baccharoides lasiopus (O.Hoffm.) H.Rob.	Leaves, roots	Malaria, worms, bacteria, viruses, febrile convulsions, GIT parasites, heartburn, skin diseases, epilepsy, indigestion, stomach-ache, parturition, hepatitis, and kids' constipation (Toyang and Verpoorte 2013; Tarwish *et al*. 2017)	Antiplasmodial, antiviral, and antifungal, inhibition of RBC lysis, larvicidal. (Toyang and Verpoorte 2013; Tarwish *et al*. 2017)	Tannins, saponin, flavonoids, steroids, terpenoids, glycosides (Tarwish *et al*. 2017) Epivernodalol and lasiopulide (Njenga *et al*. 2015). Flavonoids, phenols, alkaloids, saponin, and terpenoids (Guchu *et al*. 2020)
Gymnanthemum thomsonianum (Oliv. & Hiern ex Oliv.) H.Rob.	Leaves	Bacterial infections (Mungarulire 1992)	Antibacterial, antileukemia (Mungarulire 1992; Adesanoye & Ogunkanmi 2010)	Flavonoids, sesquiterpene lactones, saponins (Mungarulire 1992)
Rhoicissus tridentate (L.f.) Wild & R.B.Drumm.	Leaves, roots	Diabetes, infertility, gynecological issues, diarrhea, indigestion, abdominal pains, glandular pains, liver damage, helminth, erectile dysfunction, heartburn, peptic ulcers, renal Disorders, abortion, cuts, wounds, kidney (Mukundi *et al*. 2015; Dube *et al*. 2021)	Antidiabetic, anesthetic, uterotonic, antioxidant, anti-inflammatory, antibacterial, antiproliferative, and hepatoprotective (Mukundi *et al*. 2015; Dube *et al*. 2021)	Phenols, alkaloids, tannins, saponins, catechin, flavonoids, organic acids, triterpenoids, gallocatechin, fisetinidol, mollisacacidin, epicatechin, epigallocatechin, epicatechin-3-O-gallate, procyanidin B3, procyanidin B4, fisetinidol, fisetinidol, catechin, and gallic acid (Mukundi *et al*. 2015; Dube *et al*. 2021)
Phytolaca dodecandra L'Hér.	Leaves, roots, berries, stem bark	Rabies, malaria, rabies, sore scalp, respiratory issues, asthma, tuberculosis, psoriasis, eczema, boils, wounds, ringworms, scabies, leprosy, boils, vitiligo, epilepsy, induces abortion, otitis media (Zewde *et al*. 2019; Nakalembe *et al*. 2019; Beressa *et al.* 2020).	Antirabies, antifungal, anti-inflammatory, antiallergic, molluscicidal, antiepileptic, antimalarial, anthelmintic, antibacterial (Zewde *et al*. 2019; Nakalembe *et al*. 2019; Beressa *et al.* 2020).	Saponin, tannins, steroids, flavonoids, terpenoids, phenolics, glycosides, oleanolic acid, bayogenin and 2-hydroxyoleanolic acid, Esculentoside, esculentoside (Nakalembe *et al*. 2019; Beressa *et al.* 2020).
Nicotiana tabacum L.	Leaves (dry, powder)	Stomachache, common cold, influenza, snake bite, migraine, cancer, ulcer, cough, respiratory tract infections, urinary bladder, vermifuge, skin infection and mastitis, blackleg, toothache, scorpion bite,	Antibacterial, analgesic, anesthetic, anthelminthic, angiogenesis inhibition, antifungal, anticonvulsant, antiestrogenic, antiglaucoma,	Pyridine,3-(1-methyl-2-pyrrolidinyl)-,(S), isododecane, n-pentadecane, tetradecyl aldehyde, 3,4,5,6-Tetrahydro-1,3-dimethyl-2(1h)-pyrimidinone,

	skin diseases, nausea, scabies, bronchitis & pneumonia (Rawat & Mali 2013; Ameya *et al*. 2017; Omara *et al*. 2020)	antioxidant, antistress, antiviral, carcinogenic, antinociceptive, antioxidant, antiaging, anti-hyaluronidase (Rawat & Mali 2013; Ameya *et al*. 2017; Prommaban *et al*. 2022)	nicotine, solanesol, malic and citric acid, phenolics, alkaloids, terpenoids, steroids (Rawat and Mali 2013; Ameya *et al*. 2017; Prommaban *et al*. 2022)

Declarations

Abbreviations: RFC: Relative Frequency of Citation; FIC: Informant Consensus Factor; WHO: World Health Organization; MUST: Mbarara University of Science and Technology

Ethical approval: Ethical approval was obtained from the Mbarara University of Science and Technology Research Ethics Committee (MUST-2021-76) and the Uganda National Council for Science and Technology (UNCST, NS290ES). The Local Council authorities of each study area were consulted before enrolling the informants.

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Authors' contribution: PM developed the concept and proposal; collected and sorted the data. PM and HG analyzed the data and drafted the manuscript. PEO, CA, ORO, and JBL supervised and followed the whole study process, and reviewed the final manuscript. EAO is the Botanist. All the authors read and approved the final manuscript.

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