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A Review of the Ethnomedicinal and Ethnoveterinary importance of invasive plant species, their toxicity, pharmacological properties, and therapeutic compounds, in Protected Areas of Uganda

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Abstract

Ethnomedicinal and ethnoveterinary relevance: Invasive plant species, though with negative impacts on the environment, human health, and wildlife health, possess immense roles in ethnomedicine and ethnoveterinary fields. In Uganda, studies on invasive plant species are voluminous. However, studies that focus on ethnomedicinal and ethnoveterinary uses, toxicity, therapeutic compounds, and pharmacological activity of invasive plants in protected areas are extremely rare. **Aim of the study:** This review aimed to compile invasive plant species, their ethnomedicine uses, ethnoveterinary uses, and data on toxicity, pharmacological properties, and therapeutic compounds, in selected protected areas of Uganda. **Materials and methods:** The review examined 17 studies on invasive plants in selected protected areas of Uganda, and this was guided using a PRISMA flowchart. **Results:** 13 invasive plant species from 9 families were recorded, with most species belonging to the Fabaceae plant family. Leaves were highly depended on for both ethnomedicinal and ethnoveterinary purposes, with decoction and infusion being the most common methods of preparing medicine from invasive plants. Oral administration was also common. In humans, diseases that were commonly managed using medicine from invasive plants were syphilis, diarrhea, diabetes, hypertension, and malaria. In animals, ectoparasites were

commonly managed using medicine from invasive plants. Other diseases also managed in animals were measles, diarrhea, lumps, and east coast fever. Invasive plants also possessed toxic effects such as asthma, eczema, skin inflammation and hay fever in humans, and kidney damage, diarrhea, mortality, bloat, and frothy in animals. Anti-bacterial, anti-inflammatory, and anti-oxidant effects were the most common pharmacological activities possessed by invasive plant species followed by anti-cancer activity. **Conclusion and future direction:** There are still many invasive plants affecting Uganda's protected areas with most of them not scientifically documented. The findings from this study can guide the use of invasive plants in drug discovery and product development rather than destroying them. There is a need for studies to investigate the relationship between the pharmacological activity of invasive plants and the toxic effects that they possess.

Keywords: Invasive Plant Species, Ethnoveterinary Medicine, Ethnomedicine, Protected Areas

1. Introduction

There are many plant species that have been introduced to different regions worldwide [1]. Some of these introduced plant species have ended up becoming invasive [2]. Herein, these plants that become invasive are termed invasive plant species (IPS). Invasive plant species (IPS) are plants that threaten or even negatively affect the biodiversity in the ecosystem [3]. IPS show a higher rate of vegetative propagation, which in the long run allows them to be established and thus reproduce efficiently [4]. Many factors like high fecundity, self-fertilization capacity, and the development of large soil seed banks [5] drive the spread of IPS. Anthropogenic activities such as trade [6], establishment of ports [7], and the movement of vehicles and ships [7], [8] also drive the introduction of IPS propagules. In continents such as Europe, several IPS have been introduced to Europe as ornamental plants [9]. Factors causing a rise in atmospheric carbon dioxide levels and an increase in global temperatures also fuel the invasiveness of IPS [3].

Migration [10] and modern intensive agriculture [11] also fuel the spread of IPS. IPS pose many threats not only to plant community structures but also to the environment, wildlife health, human health, agricultural productivity, and also contribute to financial constraints due to expensive methods of combating IPS. To plant community structures, IPS interfere with the establishment of native plant species [12], which contributes to reduction of the biodiversity of native plants [13], [14], which can further enhance the extinction of native plant species [15]. To the environment, IPS cause changes in soil properties [16], and a decline in ecosystem services and environmental

quality [17]. For instance, *Acacia mangium* (Willd.), an IPS in the northern Brazilian Amazon, negatively alters water quality [18]. The invasion of *Eichhornia crassipes* (Mart.) Solms in Lake Victoria is another clear illustration of the effects of IPS invasion on the environment [19]. To wildlife health, alien invaders adversely affect the wildlife [20], and a clear example is *Opuntia stricta* var. *Dillenii* in the African region has contributed to the decline in livestock health [21].

IPS also affect the health of plants [22], [23], and one example is cheat grass, which increases the outbreak of fungal pathogens, which ends up affecting the health of native plants [24]. To human health, aquatic IPS like *Phragmites australis* aid in the establishment and multiplication of vector-borne pathogens, particularly West Nile virus [25]. Other IPS like *Parthenium hysterophorus* L., *Acacia*, and Eucalyptus cause allergic reactions in humans [26]. For agricultural productivity, IPS are often considered as weeds, which compete for nutrients, light, and water [27], and cause great losses in agricultural and livestock production by raising the costs for their effective management [3]. IPS such as *Parthenium hysterophorus* L., cause about 110 million dollars in losses on a yearly basis in Australia [28]. In Africa, IPS such as *Opuntia stricta* var. *Dillenii*, have caused economic losses of about US\$ 500–1000 per household per year [21]. Due to the negative effects associated with IPS, controlling them with effective measures becomes paramount.

Active approaches like the re-establishment of native vegetation communities in areas where IPS were controlled is one of the measures that can reduce the recolonization chances of IPS [29]. Despite the immense negative effects of IPS, some IPS are useful in different communities. For example, some are ecological indicators of environmental pollution [30]. Others have applications in vector-borne control and ethnomedicine [11] and ethno-veterinary. For instance, a mosquito repellent is extracted from *Lantana camara* L. [26]. IPS like *Chromolaena odorata* (L), *Bidens pilosa* L. and *Praxelis clematidea* R.M. King & Robinson have also been recognized as hyper-accumulators for the phytoremediation of harmful heavy metals such as cadmium [31]. Currently, in Uganda, IPS are posing threats in protected areas and mostly national parks and forest reserves. Uganda is among the countries in Africa with the richest biodiversity [32]. In East Africa, it is exceptionally rich in biodiversity with surveys indicating an occurrence of about 18,783 flora and fauna species [33].

As a land-locked country, it is situated in eastern Africa with fresh water and wetlands that cover one-third of its size [34]. Nevertheless, this rich biodiversity in Uganda is at risk due to the presence of IPS. Moreover, key protected areas (national parks and forest reserves) may face a

reduction in both flora and fauna diversity due to IPS. It is worrisome to highlight that the current body of literature on IPS in national parks and forest reserves of Uganda is available but still limited. Furthermore, there is no comprehensive study that has documented IPS, their ethnomedicinal and ethnoveterinary uses, and data on toxicity, therapeutic compounds, and pharmacological activities in the different protected areas (national parks and forest reserves) of Uganda. Most efforts in Uganda are currently aimed at combating IPS in national parks such as Queen Elizabeth National Park and Kibale National Park. The present study thus found it indispensable to compile a single study of IPS, their ethnomedicinal and ethnoveterinary uses, data on toxicity, pharmacological activities, and therapeutic compounds, in Queen Elizabeth National Park (QENP), Kibale National Park (KNP), Semliki National Park (SNP), Mabira Central Forest Reserve (MCFR), Budongo Forest Reserve (BFR), Kidepo National Park (KiNP), and Murchison Falls National Park (MFNP).

2. Materials and Methods

2.1 Literature search strategy

A systematic literature search was conducted from January 1980 to December 2025, and included published scientific literature, theses and dissertations. The following databases, Google Scholar, PubMed, Science direct and Research Gate were searched for research articles on invasive plant species in 7 national parks in Uganda. During the review process, the following search terms were included: invasive plant species, Queen Elizabeth National Park, Kibale National Park, Semliki National Park, Mabira Central Forest Reserve, Budongo Forest Reserve, Kidepo National Park, and Murchison Falls National Park. Study titles and abstracts were critically reviewed for retrieval and were saved to a reference management tool (Mendeley V1.19.8) together with details of where the reference had been found.

2.2 Study selection and data extraction

For any article to be considered in this review, it had to meet certain criteria. First of all, the study had to document invasive plant species either in Queen Elizabeth National Park, Kibale National Park, Semliki National Park, Mabira Central Forest Reserve, Budongo Forest Reserve, and Kidepo National Park, and Murchison Falls National Park. It must have been published or made available from 1980 up to December 2025. Articles that were excluded were review articles (systematic or literature), unpublished articles, and articles published in languages other than English. The

selection of the articles was done in four steps. The first step involved checking the relevance of the studies based on their title.

The second step involved evaluating the abstracts to make sure that they match to the inclusion criteria. If the primary inspection of an abstract of a paper did not give adequate information to make an informed judgment, the full paper was looked for in the third step and reviewed by the authors prior to making a decision concerning inclusion in the review. Lastly, those that appeared to meet the inclusion criteria were retrieved for extra appraisal. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was adopted. All the scientific names of the plants were re-checked and named according to the kew data base <http://powo.science.kew.org> and the plant families were verified using the Angiosperm phylogeny group IV <https://www.gbif.org/dataset/fa8ab13c-52ed-4754-b838-aeff74c79718>.

2.3 Data Analysis

Descriptive statistics were done to evaluate the data collected for the current study. This was made possible with the use of MS Excel Version 2013. Data visualization was done using GraphPad Prism 8.0.2 program (GraphPad Software, Inc., San Diego, CA) to generate figures while visualization of selected protected areas in Uganda was done using Quantum Geographic Information System (Version 3.38.3).

3. Results

3.1 Study characteristics

A total of 30 publication records were identified, and all were assessed and only 17 passed the selection criteria for review and data extraction (Figure 1). All the reviewed studies were from Uganda and containing information on invasive plant species in QENP, KNP, SNP, MCFR, BFR, KiNP, and MFNP.

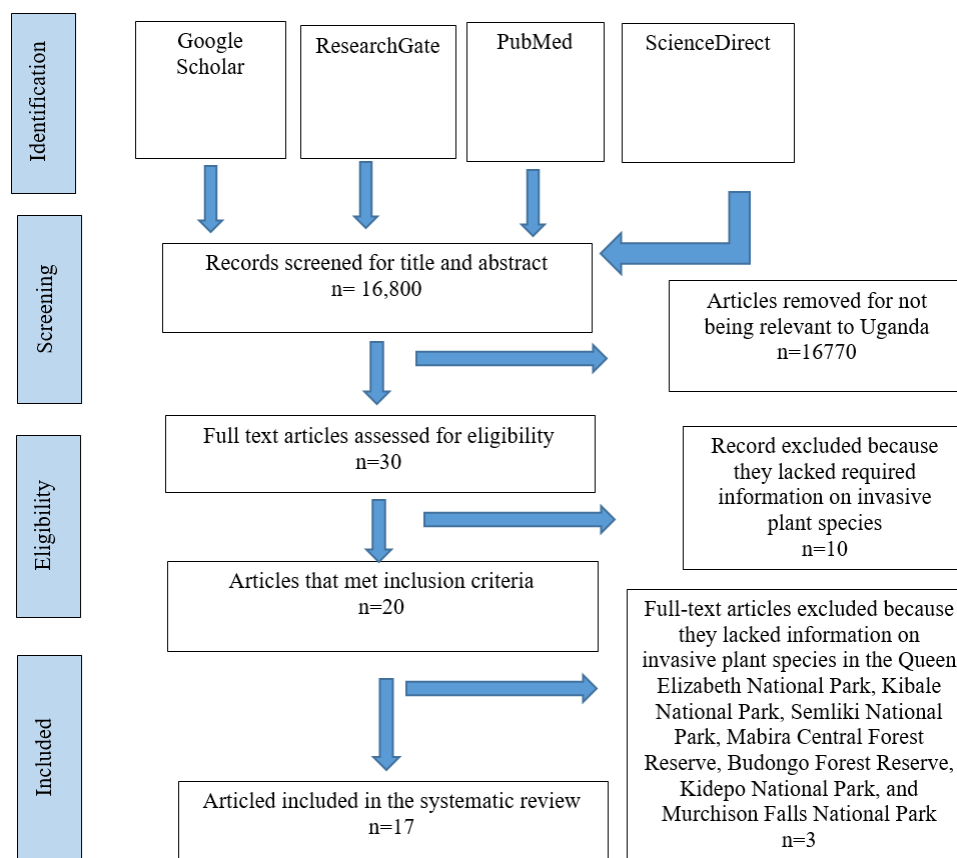


Figure 1. PRISMA flowchart summarizing the workflow adopted in this systematic review

3.2 Ethnomedicinal and Ethnoveterinary uses of invasive plant species found in protected areas of Uganda

13 invasive plant species (IPS) belonging to 9 families were recorded (Table 1). Information in Table 1 on the different IPS was obtained from different published sources. For all the IPS recorded, they both had applications in ethnomedicine and ethnoveterinary medicine (EVM). The family with the most species was Fabaceae (n=4), followed by Moraceae, according to Figure 2.

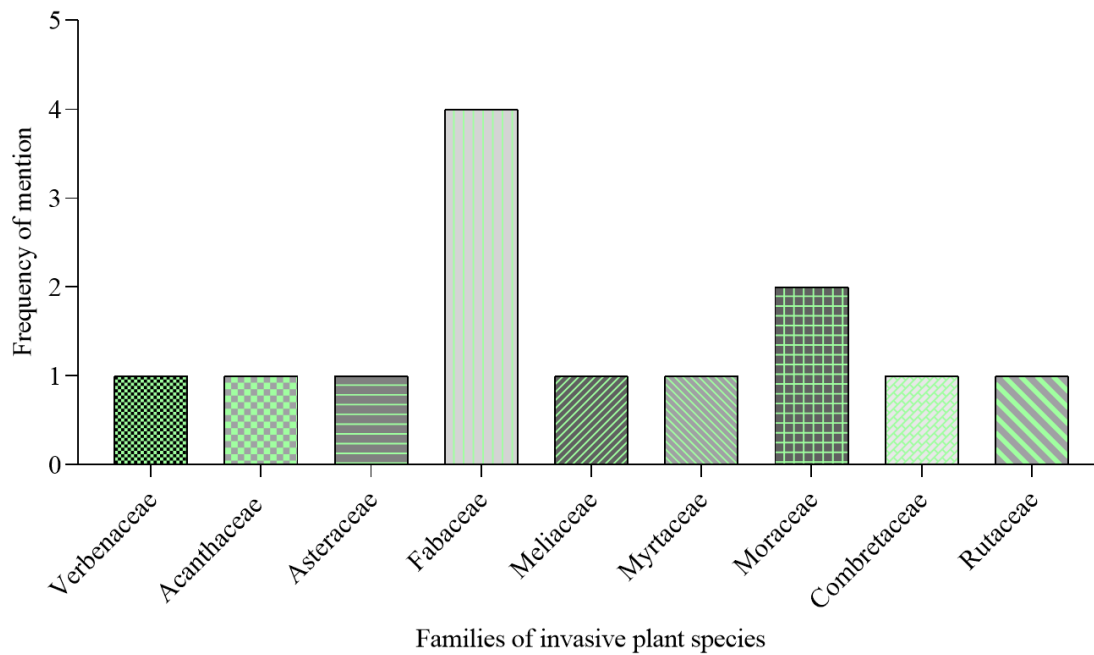


Figure 2. Families of invasive plant species against their frequency of mention

Table 1. Invasive plant species in protected areas of Uganda

			Ethnomedicinal significance (to people)			Ethnoveterinary significance (to animals)			Toxicity and Safety in both humans and animals		Pharmacological activity/ Therapeutic compounds
Scientific Name & family, location	Common name	Life form	Use	Part	Preparation and administration	Use	Part	Preparation and administration			
1. <i>Lantana camara</i> L., Verbenaceae, [KNP] [35], [QENP] [36]	Lantana, wild sage, Surinam tea plant, Spanish flag,	Shrub	Managing inflammation and in treating rheumatic conditions [37]	L	Decoctions derived from the leaves [37]	Measles in cattle [38]	L	Infusion made after adding leaves of <i>C. opulifolium</i> and <i>C. sativa</i> [38].	Poising in cattle mainly affecting the liver and kidneys the most [39].		Anti-viral activity [40] Tannins, steroids, flavonoids, quinones, phenols, coumarins, alkaloids [41], lantadenes [42]; Linaroside, verbascoside, lantanoside, phytol, camarinic acid, oleanolic acid, ursolic acid, and umuhengerin [43]
2. <i>Acanthus pubescens</i> . Thomson ex Oliv. Engl.(Acanthaceae) [KNP] [35]	Prickly acanthus	Shrub	Used to manage Syphilis [44]	Fresh R	Washed, chopped and then decocted, Oral administration. A full cup is taken twice/day until recovery [44]				The dichloromethane extract is the most toxic [45]		Anti-bacterial and anti-fungal activity [45]

3.	<i>Parthenium hysterophorus</i> L. (Asteraceae) [QENP] [46], MFNP [47]	Congress Grass or Feverfew	H	Management of genital and urinary problems in women [48]	L, R	Make tea from the leaves and roots, then drink [48]	It significantly reduces parasitaemia and increases the survival time of <i>Trypanasoma evansi</i> infected animals [49]		Symptoms of skin inflammation, eczema, asthma, allergic rhinitis, hay fever, black spots, burning and blisters around eyes in humans after contact with the plant [50]; <i>Parthenium hysterophorus</i> L. causes diarrhoea, severe papular erythematous eruptions, breathlessness and choking in animals [51]; Exposure to <i>P. hysterophorus</i> also causes systemic toxicity in livestock [52]; Alopecia, loss of skin pigmentation, dermatitis and diarrhoea has been reported in animals feeding on congress grass [50]. Degenerative changes in both the liver and kidneys and inhibition of liver dehydrogenases have been reported in buffalo and sheep [53]	Anti-cancer and cytotoxic properties, anti-inflammatory effects [54] anti-microbial effects [49], wound healing activity [55] [24]. Anti-oxidant activity in rats [56]. Hypoglycemic effect [50]	
4.	<i>Senna siamea</i> L. (Fabaceae) [SNP] [57]	Siamese cassia	Sh	Management of malaria and liver disorders [58] Treating cough, stomach pains [59]	B, L, Whole S	Decoction, then drink, body bath for malaria and liver	It enhances the reduction of lesion scores and oocysts excretion in male chicks [60].	L	One liter of boiled water is used for 100 g of fresh leaves, oral	Aqueous extracts (2000 mg/kg; po / 2 weeks, respectively) leads to hepatic and renal cell destruction in albinos' rats [61]	Anti-oxidant and anti-microbial effect [64], Anti-malarial effects [65], Anti-diabetic and anti-lipemic effects [66], Anti-tumor or anti-cancer effects [62],

					disorders [58]	administration [60].	crude extract of the leaves in continual oral administration for six months decreased the number of humans' hematocrit and neutrophils [62]	Gallic acid [64], chromones and its derivatives (chromone alkaloids, chromones glycosides, dihydronaphthalenone compounds, bischromone), polyphenols (anthraquinones, bianthraquinones, anthrone, flavonoids, isoflavonoids, phenolics, tannins), alkaloids, saponins, steroids, carotenoids [67], [68]
					Decoction of leaves is administered orally (0.5 L, twice daily) for cough and stomach pains [59]		In vitro, cytotoxicity of barakol (5 mM) on hepatocytes of carp fish (<i>Cyprinus carpio</i>) was found after 72 hours of exposure [63]	
5.	<i>Cedrela odorata</i> L. (Meliaceae) [SNP] [57]	Red cedar, "cedro rojo," and Spanish cedar	Tr	Remedy for diarrhea, fever, anti-inflammation, vomiting, and indigestion [69]	B	Infusion made [69]	Slight damage at 200 mg/kg, with the formation of type 0 and 1 comets in rodents [71]	Hepatoprotective activity [71], anti-inflammatory effect [72], anti-oxidant activity [73]
				Management of malaria [70]		Decoction made [70]		Kaempferol-3-O-β-D-glycopyranoside (astragalin), kaempferol-3-O-β-L-rhamnopyranoside, kaempferol-3-O-β-D-rutinoside, kaempferide-3-O-β-D-rutinoside, kaempferide-3-O-β-Drutinosyl-7-O-β-Drhamnopyranoside, and kaempferol-3-O-β-D-rutinosyl-7-O-α-D-arabinopyranoside [71]

6.	<i>Mimosa pigra</i> L. (Fabaceae) [MFNP] [47]	Bashful plant,	Sh	Used to manage head colds, toothaches, and eye problems [74]	R, L, St [74]	Mouth washing for toothache [74]			Roots may be safe at doses below 500 mg/kg may pose toxicological risks at doses greater than 500 mg/kg, with the liver being most affected with prolonged usage [77]	Anti-nociceptive activity and anti-hyperglycemic effect [76], Anti-diabetic activity [78], Anti-convulsant Activity [79], Anti-venom effects [80], anti-tuberculosis activity [81]	
				Used to treat a weak heart or weak pulse [75]	L [75]	Roast and grind leaves [75]					
				Used to lower blood sugar in diabetic patients and for the treatment of pain [76]	L [76]					Triterpene glycosides [82], flavonols: kaempferol, quercetin and myricetin [83]	
7.	<i>Psidium guajava</i> L. (Myrtaceae) [MCFR] [84]	Guava	Tr	Used to treat digestive suffering associated with severe diarrhea [85]	L [85]	Decoction [85]	Used to kill external parasites that cause infections in animals [88].	L	Take 100 g of leaves of each <i>Psidium guajava</i> and <i>Securinega robovates</i> and press out their juice. Mix the juice with jaggery, water or curd and drench once a day for two days [88]	Acute toxicity tests in rats and mice have proven the LD50 of guava leaf extracts to be more than 5 g/kg [85]	Anti-viral, anti-inflammatory, anti-plaque, anti-nociceptive activity and anti-mutagenic activities [91]
				Diabetes mellitus, hypertension [86]	L [86]	Infusion or decoction [86]					α -pinene, limonene, β -pinene, isopropyl alcohol, menthol, terpenyl acetate, caryophyllene, longicyclene and β -bisabolene in the essential oils [91], saponin, oleanolic acid, lyxopyranoside, arabopyranoside, guaijavarin, quercetin and flavonoids [92]
				Used to lower body temperature during a fever [85]	New shoots [85]	Decoction, then drink [85]					
				Vaginal and uterine wash, especially in Leucorrhoea [87]	L [87]	Infusion or decoction [87]					

					Used to treat diarrhea in pigs [89]	Te nd er L	About 50-70 mL of guava leaves extract and 5-7 g of common salt is mixed and administered orally once daily for 5-7 days [89]	
					Used as an anti-parasite drug to treat infections in animals caused by parasitic worms [90]	L	Eaten as fodder [90]	
8.	<i>Senna spectabilis</i> (DC.) H.S. Irwin & Barneby (Fabaceae) [MCFR] [84], [BFR] [93]	Cassia, Golden wonder tree, popcorn tree	Tr	Treatment of L constipation, poisoning and protozoic infections of the gut [94]	Used in the management of ectoparasites [95]		Toxic effects including paralysis in adult worms, inhibition of the secretory activity, tegument lesions and cercaricidal activity [96]	Anti-oxidant activity [97], anti-Klebsiella activity [98], anti-inflammatory, anti-cancer activities [99], immunosuppressive, anti-microbial, laxative, anti-atherosclerotic [100], hepatoprotective properties [101] Tannins, phenols, saponins, phylobatannins, flavonoids, steroids, alkaloids and cardiac glycosides [97], alkaloids,

[illegible]

10. <i>Terminalia a superba</i> Engl. & Diels (Combretaceae) [MCFR] [84]	Afara, Limba	Tree	Used to manage diarrhea [110] Used to manage hypertension [111] Used to treat COVID-19 symptoms [112]	B	Has a potential activity to kill <i>Trypanosoma brucei</i> [113], an extracellular parasite that causes sleeping sickness in mammalian hosts [114]	Stem bark	Extract of <i>T. superba</i> Engl. & Diels is toxic to aquatic life as it causes erratic swimming, loss of equilibrium and respiratory distress in fish [115]	Anti-mycobacterial, anti-bacterial and anti-fungal activities [116], anti-plasmodial activity [117], anti-hypertensive activity [118] Saponins, cardenolides, triterpenes, flavonoids, steroids, phenolics and tannins [110]
11. <i>Broussonetia papyrifera</i> (L.) L'Her. ex Vent. (Moraceae) [MFCR] [119], [120]	Paper mulberry	Tree	Used to treat arthritis [121] Used for wound healing, reducing skin infections, and treating diarrhea [122]. Treatment of dysentery [123] Treating anuria [123]	B, L, R B, L, R L Tw	For increasing milk production in animals [90]	L Leaves are eaten as fodder [90]	The total alkaloid in the fruits exhibit low cytotoxicity (IC50450 mg/mL) on normal human skin epidermal cells [124]	Anti-oxidant, lipid-lowering, heat-clearing, detoxifying, blood-cooling, diuretic, and immunomodulatory activities [125], anti-bacterial, anti-viral, anti-inflammatory [126], and anti-tumor properties [127] Apigenin, cosmosiin, luteolin, vitexin, and scopoletin, D-galactitol, ergosterol peroxide [125]

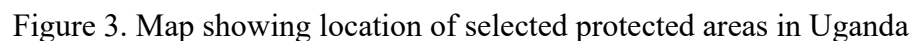
12.	<i>Dichrosta chys cinerea</i> (L.) Wigth & Arn. (DC) (Fabaceae) [QENP] [128]	Sickle bush	Sh	Used in the management of rheumatism, diabetes, coughs, asthma, kidney disorders, gonorrhea, syphilis, malaria, tuberculosis, epilepsy, snake bites, pains, wounds, boils, burns, toothache, headache, and scabies [129]	Root			For treating lumps, and abscesses in cattle [131]	Fr/Se	Dry seeds/fruits crushed and ground to powder, Applied topically as a paste on the affected skin area [131]	Concentrations above 2000ppm have high lethal potential on brine shrimps [129]	Anti-malarial activities, anti-inflammatory, anti-diarrheal, anti-analgesic, hepatoprotective, anti-urolithiatic, anti-lice, anti-dandruff, and neuropharmacological activities [129], anti-bacterial and anti-fungal effect [133], anti-ulcer effect [134], anti-tumour effect [135]
				Used to manage sexually transmitted diseases [130]				For treating wounds in sheep and goat [132]	Fr	Make fried fruit powder, then apply on the skin [132]		Tannins, flavonoids, steroids and saponins [129]
13.	<i>Harrisoni a abyssinica</i> Oliv (Rutaceae) [KiNP] [136]	Ethiopian plum, Abyssinian plum	Sh	Used to manage venereal diseases, malaria, diarrhea, haemorrhoids, diabetes, urinary problems, general body pain, snakebites and intestinal worms [137]	L, R	Make powder from leaves and roots [137]	Managing East coast fever in cattle [38]	R	Infusion, Decoction prepared after adding above ground parts of <i>Oxygonum sinuatum</i> . Give ca. 200 ml,	Methanolic crude extract causes mortality in brine shrimps [138]		Anti-oxidant and anti-bacterial properties [139]
												Alkaloids, terpenoid, flavonoid, tannin and saponins [140]

three times a
day for 5
days.[38].

Key: Sh=Shrub; H=Herb; L=Leaves, F=Flowers, Fr=Fruits, Se=Seeds, Tw=Twig, R=Roots, St=Stem, Tr=Tree; QENP=Queen Elizabeth; SNP=Semliki National park; KNP=Kibale National Park; MCFR=Mabira Central

Forest Reserve; BFR=Budongo Forest Reserve; KiNP=Kidepo National Park; MFNP=Murchison Falls National Park

In the present systematic review, it is indicative that studies (from published sources) on IPS have been conducted in some protected areas (particularly national parks and forest reserves) of Uganda (Figure 3). These include Queen Elizabeth National Park, Kibale National Park, Semliki National Park, Mabira Central Forest Reserve, Budongo Forest Reserve, Kidepo National Park, and Murchison Falls National Park.



3.4 Parts used on medicinal invasive plant species

Diverse parts on IPS were being used for both ethnomedicinal and ethnoveterinary purposes. For ethnomedicinal uses in human, leaves were highly depended on followed by roots and bark, while for ethnoveterinary uses, leaves were highly depended on followed by seeds and fruits (Figure 4). Additionally, other plant parts that were infrequently used for ethnomedicinal uses included; new shoots.

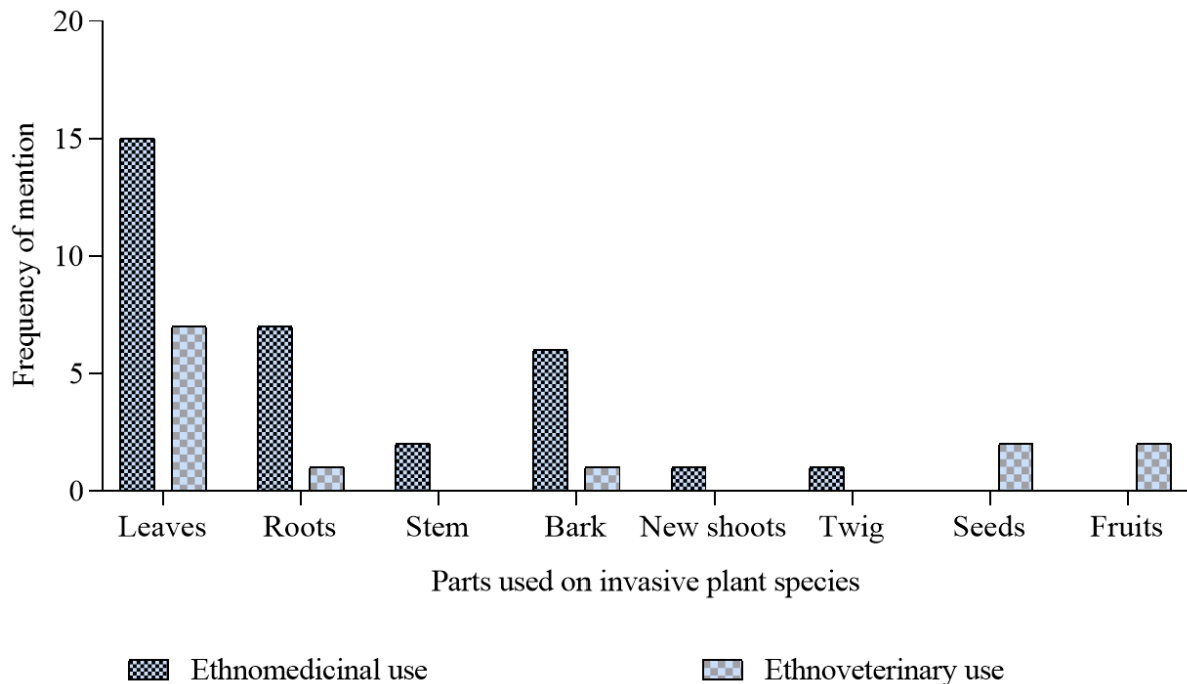


Figure 4. Parts used on invasive plant species against their frequency of mention

3.5 Mode of preparation and administration of medicine from invasive plant species.

Mode of preparation: for both ethnomedicinal and ethnoveterinary uses, decoction method was highly utilized to prepare medicine from IPS followed by infusion method (Figure 5). Besides decoction and infusion methods, other methods such as making juice from IPS were also used.

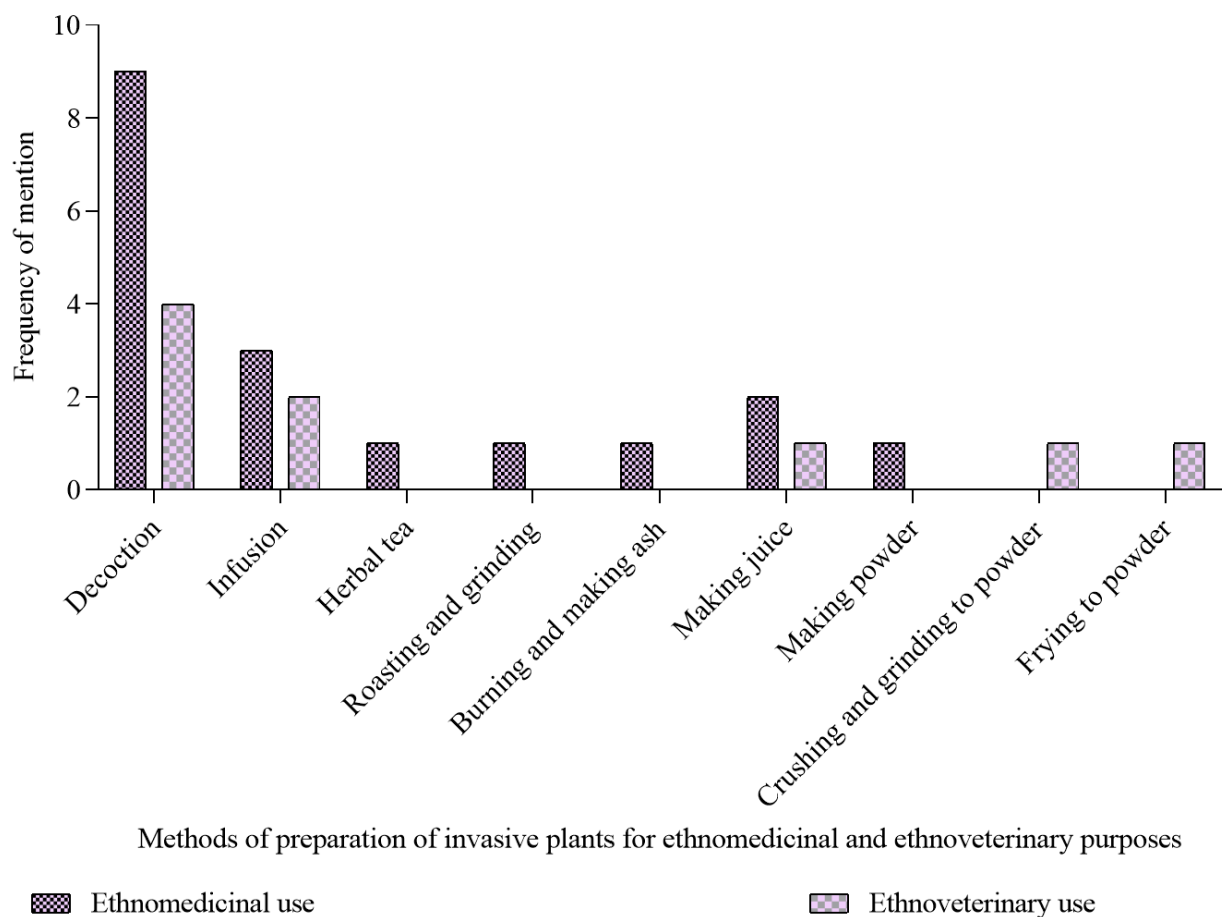


Figure 5. Methods of preparation of medicine from invasive plant species against their frequency of mention

Mode of administration: for both ethnomedicinal and ethnoveterinary uses, oral administration was the most rampant method used to give medicine from IPS to both humans and animals (Figure 6). Besides oral administration in animals, topical method and giving out invasive plants to animals to eat as fodder were utilized and these two methods had the same frequency of mention (n=2)

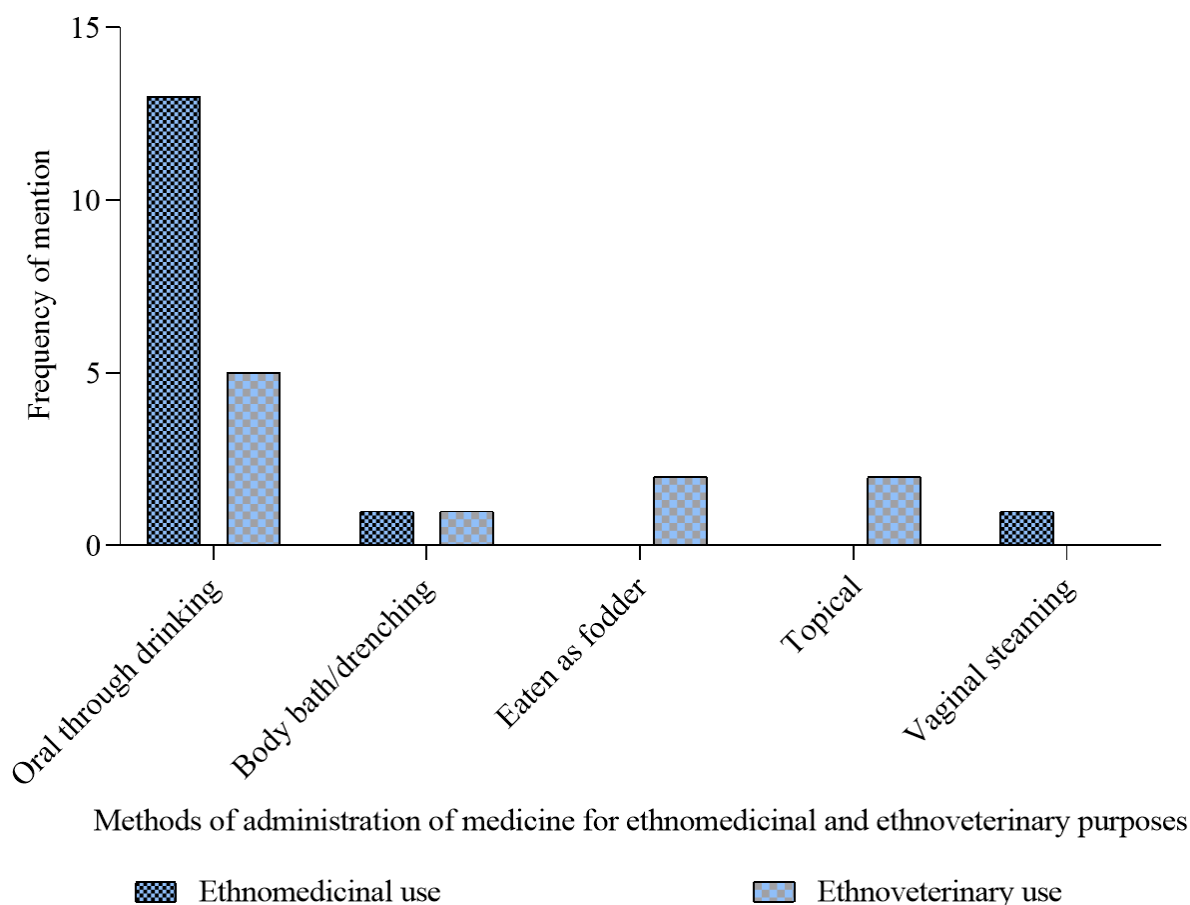
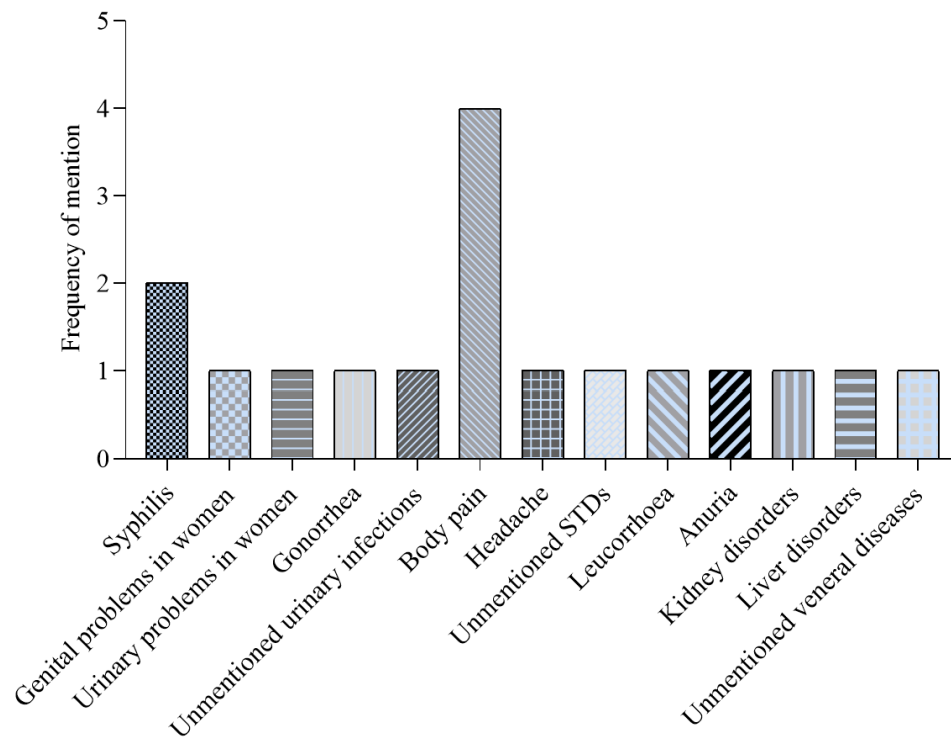


Figure 6. Methods of administration of medicine from invasive plant species against their frequency of mention

3.6 Diseases in humans managed using medicine from invasive plant species

Over 47 diseases (including disease symptoms) (Table 1) were reported to be managed using IPS. These diseases and disease symptoms were grouped into different categories such as sexually transmitted infections (STIs)/ sexually transmitted diseases (STDs), urinary problems, lifestyle diseases, neurological disorders (NDs), and digestive system related diseases and disorders, vector-borne diseases, respiratory related diseases, and skin infections. Animal bites and symptoms to some diseases were also reported.

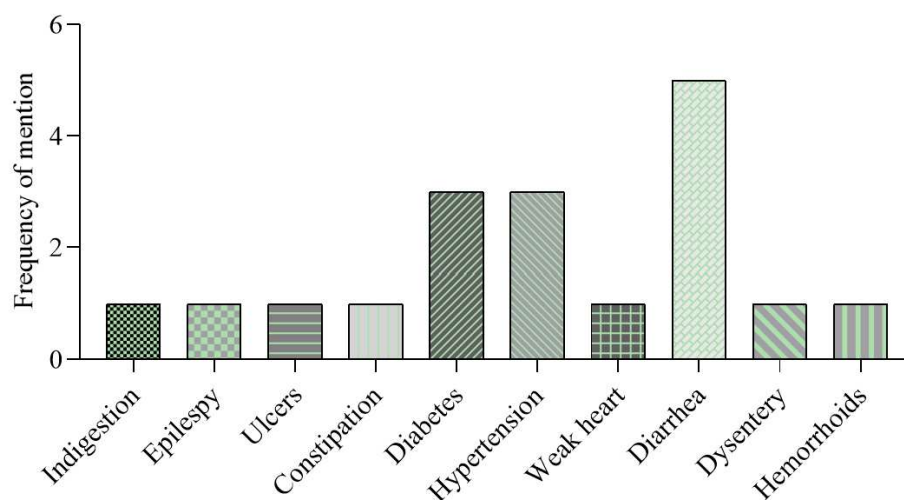
Among the STIs, syphilis had the highest frequency of mention followed by gonorrhea (Figure 7), implying that syphilis and gonorrhea are some of the STIs that are still prevalent in Uganda and this forces people to rely on medicine from IPS to manage them.



STIs, pains, reproductive-health, and excretory system- related problems in humans managed using invasive plant species

Figure 7. STIs, pains, reproductive-health and excretory-related problems in humans managed using IPS against their frequency of mention

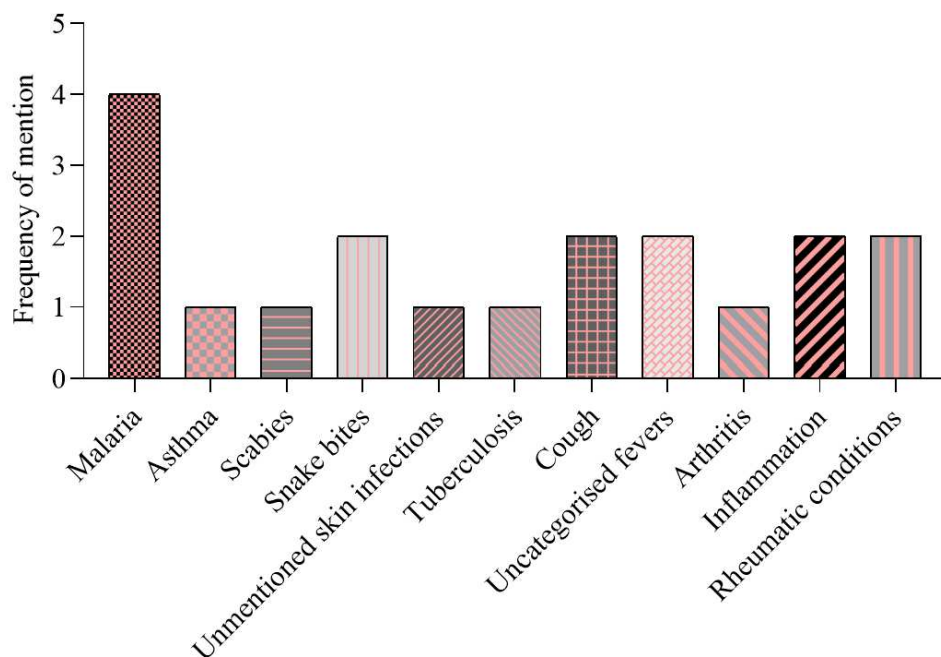
Diseases that arise due to lifestyle were also reported and among these, diabetes and hypertension had the highest frequency of mention (n=3) followed by possession of a weak heart (Figure 8). Among the digestive system diseases and disorders reported, diarrhea had the highest frequency of mention (n=5) (Figure 6). Neurological disorders such as epilepsy were also reported.



Lifestyle, neurological, digestive system related diseases and disorders managed using invasive plant species

Figure 8. Lifestyle, neurological, digestive system-related diseases and disorders in humans managed using IPS against their frequency of mention

Vector-borne diseases were also reported to be managed using herbal medicine prepared from IPS, with malaria being the most frequently mentioned disease (n=4) (Figure 9). Respiratory-related diseases with some caused by viruses and bacteria, were also being managed using herbal medicine, with cough having the highest frequency of mention (n=2), followed by tuberculosis and asthma (Figure 9). Snake bites and skin infections such as scabies, were also being managed using herbal medicine from IPS. Inflammation related conditions such as rheumatic conditions and arthritis were also among the diseases managed using medicine from IPS.



Vector-borne, respiratory-related, animal bites, skin infections, chronic-related, and inflammation-related conditions managed using invasive plant species

Figure 9. Vector-borne, respiratory-related diseases, animal bites, skin infections, chronic-related, and inflammation-related conditions in humans managed using IPS against their frequency of mention

Some diseases managed using herbal medicine prepared from IPS were uncategorized as shown in Figure 10. Among these, wounds and toothache were very common, followed by vomiting, head colds, boils, burns, poisoning, and eye problems. Most importantly, symptoms of COVID-19 were also among those managed using medicine made from IPS.

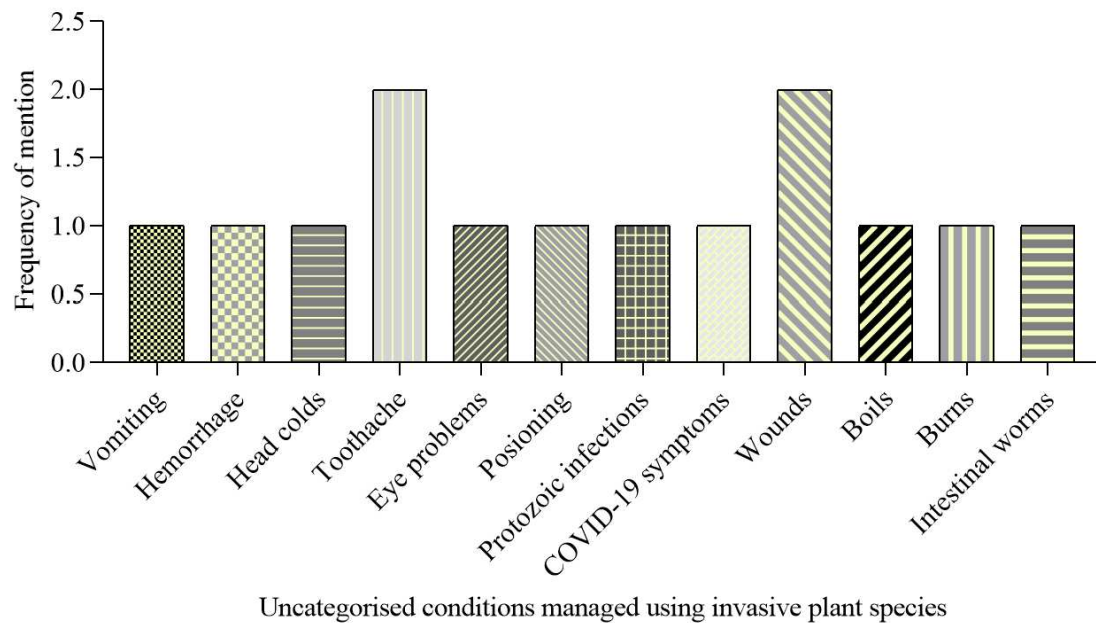


Figure 10. Uncategorized diseases, conditions, and disease symptoms in humans managed using IPS against their frequency of mention

3.7 Diseases in animals managed using medicine from invasive plant species

Regarding EVM, diseases, disease conditions, and symptoms were being managed using medicine from IPS. Though not a disease, ectoparasites are among the parasites that affect livestock, and were reported to be managed using medicine from IPS (Figure 11). Low milk and breast milk production in animals was also managed using medicine from IPS. For diseases, measles, diarrhea and east coast fever were among those managed using medicine from IPS.

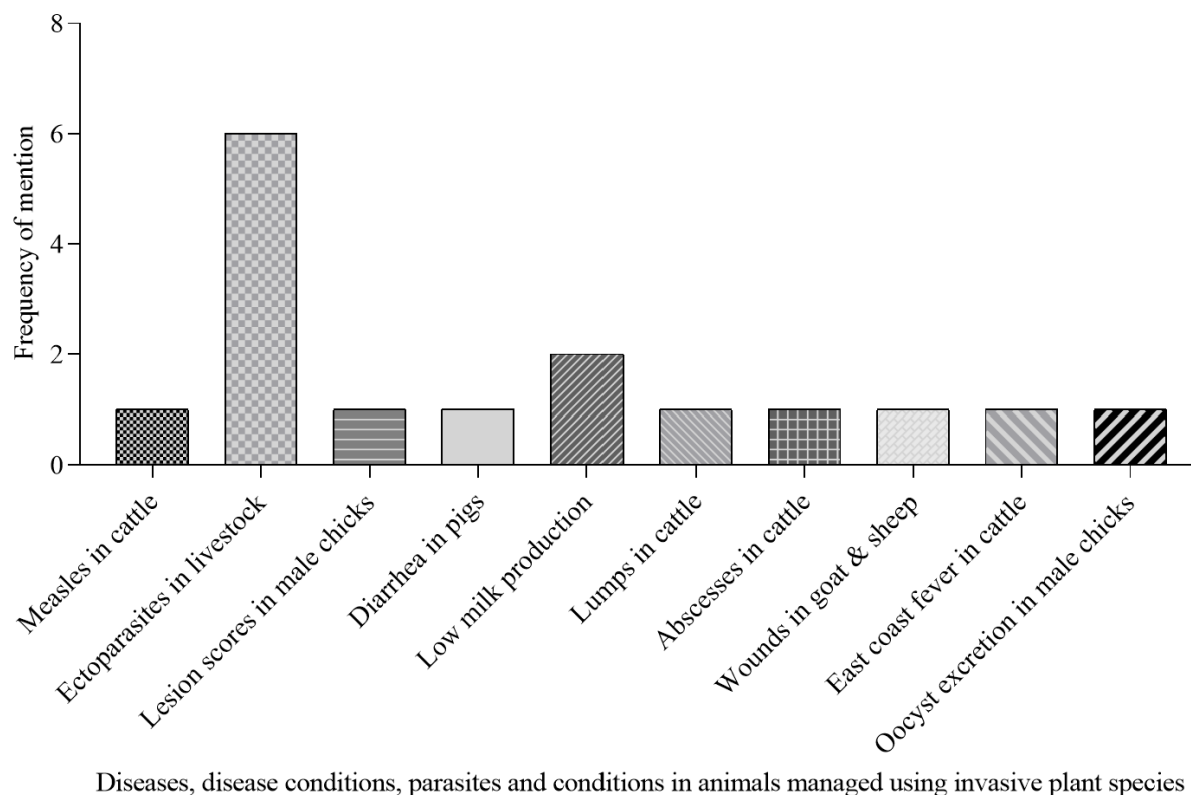


Figure 11. Diseases, disease symptoms, parasites, and conditions in animals managed using IPS against their frequency of mention

3.8 Toxicity of invasive plant species found in protected areas of Uganda

Despite the ethnomedicinal and ethnoveterinary applications of IPS in human and animals, it was also revealed that IPS are associated with toxic effects both in human and animals. In human, some of the toxic effects associated with IPS especially after coming in contact with IPS included; asthma, hay fever, black spots, eczema, skin inflammation, allergic rhinitis, blisters and burning around the eyes (Figure 12). All these effects had the same frequency of mention.

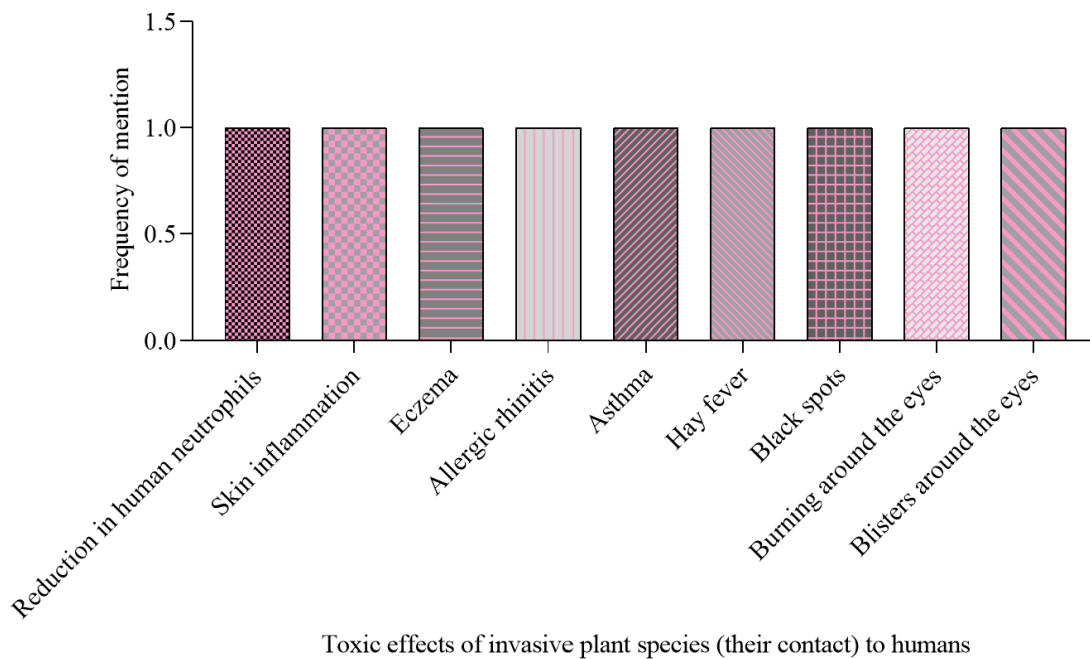
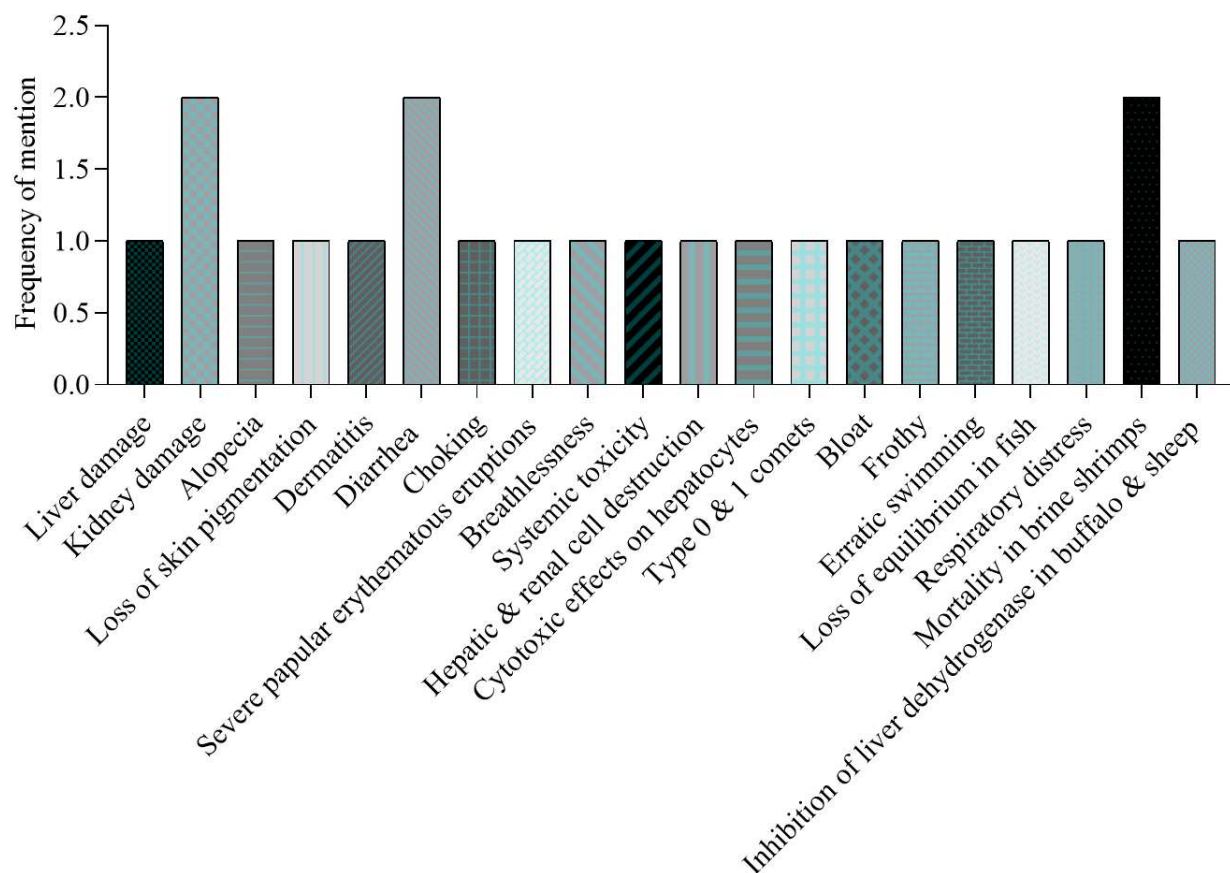


Figure 12. Toxic effects of IPS on humans against their frequency of mention

The toxic effects of IPS on animals were more numerous than in humans as they were about 20 toxic effects in animals and only 9 in humans. The toxic effects that had the highest frequency of mention were kidney damage in cattle, diarrhea in pigs, and death in brine shrimps ($n=2$) (Figure 13). Other toxic effects registered included liver damage, erratic swimming in fish, dermatitis and alopecia (Figure 13).



Toxic effects of invasive plant species (their contact) to animals

Figure 13. Toxic effects of IPS on animals against their frequency of mention

3.9 Pharmacological activities of invasive plant species found in protected areas of Uganda

Various pharmacological properties possessed by IPS were recorded (Table 1) and among these, there were many anti-microbial activities such as anti-viral, anti-bacterial, anti-fungal, and anti-mycobacterial (Figure 14). Most importantly, anti-bacterial activities were dominant compared to other anti-microbial activities.

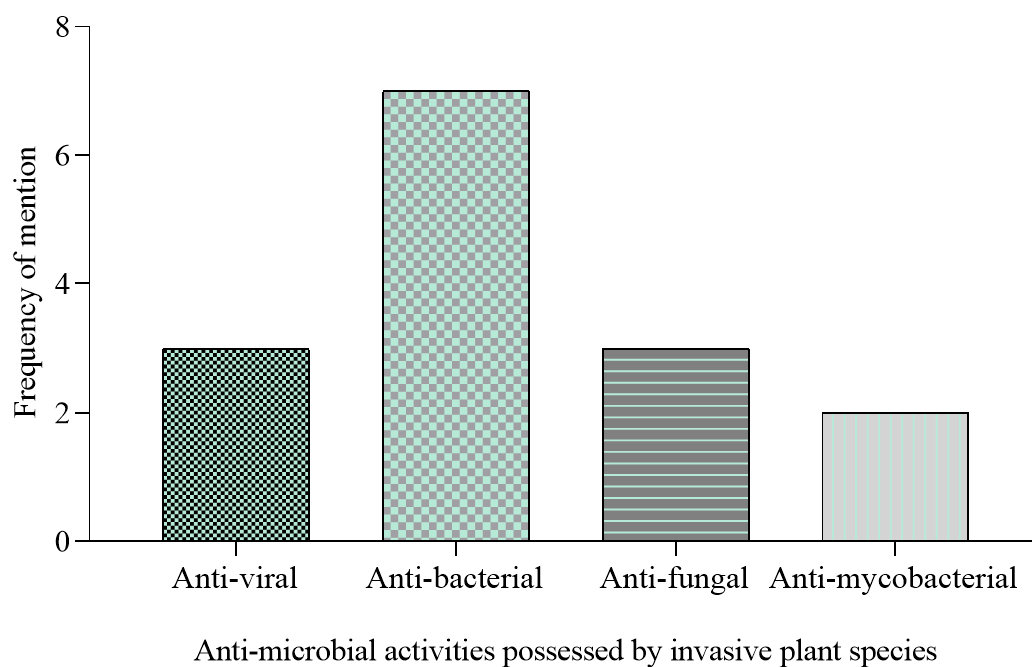


Figure 14. Anti-microbial activities possessed by IPS against their frequency of mention

Other than anti-microbial activities, other pharmacological effects were also registered (Figure 15). Among these, anti-inflammatory and anti-oxidant effects had the highest frequency of mention (n=7), followed by anti-cancer, anti-diabetic, and hepatoprotective effects (Figure 15). Other pharmacological effects recorded but with low frequencies of mention (n=1) were laxative, anti-malarial, anti-aging, ant-cancer, etc.

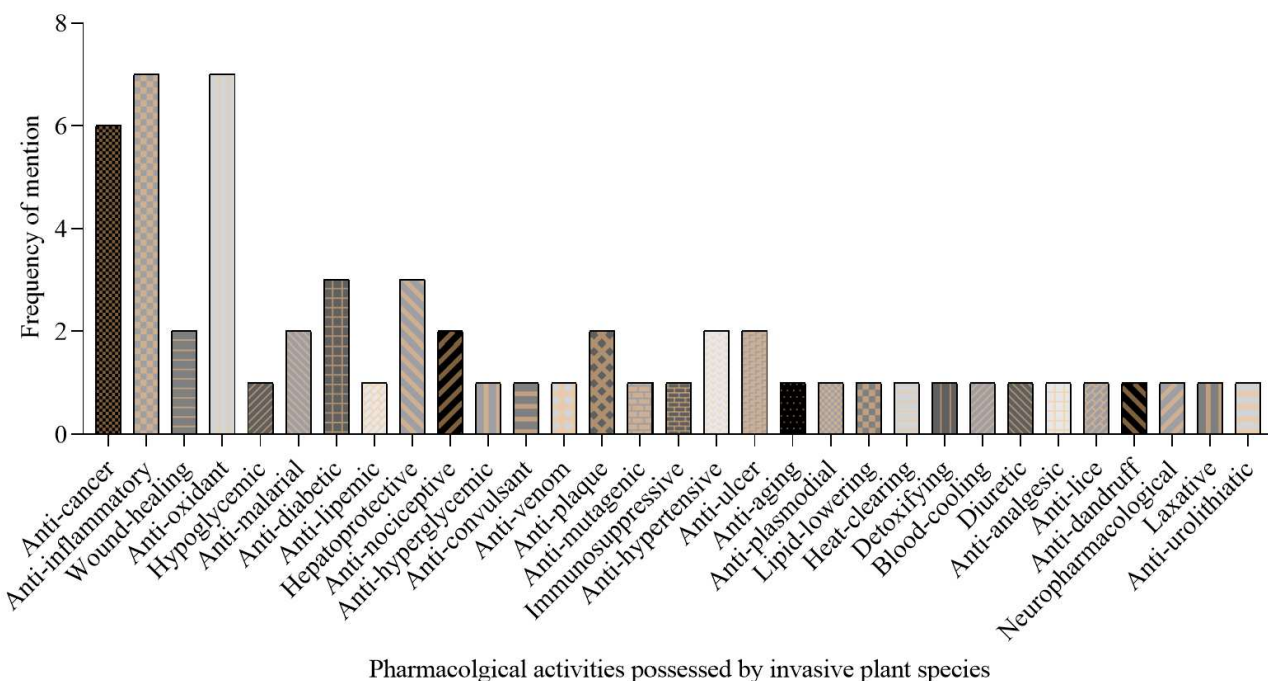


Figure 15. Pharmacological activities possessed by IPS against their frequency of mention

4. Discussion

4.1 Most common invasive plant families in Queen Elizabeth National Park

The family with the most IPS was Fabaceae, followed by Moraceae. This finding is in agreement with another study, which reported this plant family (Fabaceae) as being widely used to make herbal medicine [141]. The study of [142] and [143] also reported the same finding. Fabaceae, having the highest frequency of mention in the present study, may be attributed to the effectiveness of its plant species in treating several infectious disorders [144].

4.2 Plant parts used on invasive plant species

Various plant parts were being relied on for both ethnomedicinal and ethnoveterinary purposes. Leaves were highly depended on for ethnomedicinal and ethnoveterinary purposes. This finding is similar to that of other studies, which highlighted leaves as being frequently used compared to other plant parts [142], [143], [145]. The high reliance on leaves for ethnomedicinal and ethnoveterinary purposes compared to other plant parts may be due to their abundance and their high content of phytochemicals [146] such as alkaloids, saponins, terpenoids, and phenolic compounds.

The ease to harvest leaves compared to other plant parts (such as roots, stem, twig, bark, shoots) and also the push for sustainable and safe harvesting of plant parts in protected areas such as forest reserves and national parks may also be attributed to their high reliance. Additionally, leaves have a high rate of regeneration and in most cases, their removal does not result in drying of the plant [147]. In Uganda, it is also a common practice for people to rely on leaves [148], [149], [150]. Interestingly, the same practice has been reported in other African countries such as Tanzania [151], Ethiopia [152], and in European countries such as Italy [153].

4.3 Mode of preparation and administration of medicine made from invasive plant species

For both ethnomedicinal and ethnoveterinary uses, the decoction method was highly utilized to prepare medicine from IPS, a finding which agrees with studies of [154] and [155], where decoction was the most common method used to prepare medicine from medicinal plants. It is important to emphasize that decoctions are an effective method of herbal medicine preparation in the presence of plant parts such as leaves that are easily accessible [145]. According to [156], decoctions being the most common method of preparation of plant-based medicine may be due to the ease in preparation and administration for individuals or even animals using oral medications when matched with alternative routes of application and preparation options of medicine.

4.4 Management of diseases in humans using medicine made from invasive plant species

Several diseases ranging from lifestyle diseases, STIs, vector-borne diseases, respiratory system-related diseases, digestive system-related diseases, mental health-related diseases, urinary problems, to skin infections were being managed using medicine from IPS. For the two STIs registered, syphilis has the highest frequency of mention, than gonorrhea. The high dominance of syphilis presents a call for intense measures to combat STIs. In developing countries such as Sub-Saharan Africa, much efforts have focused on combatting HIV/ AIDs and this might be the reason behind the increasing prevalence of syphilis. According to [157], syphilis is a significant public health burden in developing countries such as Uganda. Specific STIs such as HIV/ AIDs are however likely to be on the rise in Uganda but also in other African countries that have been battling with HIV/AIDS, and this is due to the cutting of financial resources by USAID [143].

Neurological disorders (NDs) such as epilepsy were also recorded. The presence of such NDs even though at a minimum rate may be attributed to the fact that they are neglected in modern healthcare facilities [158]. As a ND, epilepsy is characterized by seizures and its diagnosis is difficult [159]. Moreover, the disease ranks among the notorious brain disorders worldwide [160] and contributes

to a global health burden of about 70 million people living with the disease [161]. It is imperative that IPS with potent activity such as *Dichrostachys cinerea* (L.) Wight et Arn against epilepsy are further bioprospected.

Lifestyle diseases such as diabetes and hypertension were among those managed using medicine from IPS. For diabetes, it has been recognized as a pertinent public health burden as it affects both human health and health expenditure [162]. Moreover, the disease affects the quality of life of individuals and their functional capacities, which often leads to serious morbidity and premature mortality [163]. Lifestyle conditions such as the high consumption of unhealthy foods, are responsible for diseases such as diabetes [164]. Similar to diabetes, hypertension also presents a health burden as it contributes to a massive disease burden, which influences over one billion people worldwide [165]. The potential of IPS to manage lifestyle diseases underscores the paramount importance of conserving IPS rather than destroying them. For instance, certain IPS such as *Senna spectabilis* (DC.) H.S. Irwin & Barneby were reported to possess anti-atherosclerotic effects. According to [166], atherosclerosis is a well-known factor that can fuel hypertension.

Other diseases that are of economic importance and were reported in the current study to be managed using medicine from IPS are malaria and diarrhea. For malaria, it carries a significant global health burden as over 2000 children die every day from malaria, and with about 90% of the death cases originating from Sub-Saharan Africa (SSA) [167]. Moreover, this is a negative linkage between malaria control expenditures and national economic growth [168]. There is thus a dire need for more effective measures in Uganda and other countries in SSA to limit the distribution of malaria. The dependence on IPS to manage malaria should be highly encouraged in different communities as this will reduce on the rate of overharvesting of medicinal plants that are non-invasive. Some conditions such as fevers and headache might have been due to malaria [169].

Diarrhea on the other hand had a high frequency of mention and yet it a cause of death among children [170]. For instance, statistics of 2021 show that the disease was responsible for 8.7% of all deaths in children below 5 years globally and 5.4% in children and adolescents aged 5–19 years [171]. Furthermore, of the more than 440,000 estimated deaths from diarrhea in children below 5 years in 2021, statistics reveal that 99% were in low-income and middle-income countries [172]. Due to these rampant deaths, management of diarrhea using medicine from IPS such as *Terminalia superba* Engl. & Diels, *Broussonetia papyrifera* (L.) L'Her. ex Vent., and *Harrisonia abyssinica*

Oliv should be highly encouraged through sustainable measures that will again not drive the spread of IPS in regions they have not been to.

Respiratory-related diseases such as asthma and tuberculosis reported in the present study call for urgent attention. For instance, statistics show that in 2019, asthma affected about 300 million people globally and caused 461,000 asthma-related deaths [173]. It is of immense importance to highlight that asthma is not only a disease burden in developing countries in Uganda but also in developed countries such as China. This is because in China, the prevalence of asthma among individuals over 20 years old exceeds 4.2%, which corresponds to 45.7 million cases, with a rising trend every year [174]. Tuberculosis (TB), another respiratory system-related disease, was reported to be managed using medicine made from IPS. Tuberculosis remains the leading cause of death from a single infectious agent [175]. Furthermore, an estimate of about 10.6 million incident cases of TB were reported in 2021 based on the Global TB report of 2022 [175].

Inflammation-related conditions, such as rheumatic conditions, were also being managed using medicine made from IPS. Rheumatic conditions have been known to pose danger to human health since they may involve tendons, bones, and muscles [176] but may also affect other body organs such as the brain, lungs, eyes, heart, and skin [177]. Despite the negative effects associated with rheumatic conditions, their incidence in the general population is about 1%, with the highest proportion in middle age [176]. Due to the global health burden posed by malaria, syphilis, diarrhea, asthma, epilepsy, and TB, especially in people living with these diseases, the use of available and easy-to-access medication sources should be encouraged. This in turn, has implications especially for communities living near areas invaded by IPS. Identifying IPS in national parks and forest reserves and then encouraging the people to harvest them for medicinal uses will serve as a better and cost-friendly alternative compared to the costs that governments put aside to combat IPS in protected areas such as QENP, SNP, KNP, MFNP, and MFCR.

4.5 Management of diseases in animals using medicine made from invasive plant species

About 10 conditions in animals were being managed using medicine from IPS. These conditions include diseases, disease conditions, and symptoms of other diseases. The findings of this study on disease conditions/ symptoms such as lumps in cattle are in line with other studies that reported lumps as being a disease managed in livestock using herbal medicine [142]. Mortality and culling in cattle that result from lumps are usually low, at less than 3% [178]. However, other diseases like East Coast Fever (ECF), which were reported to be managed using medicine from IPS, pose highly

significant risks to cattle health. For instance, ECF has been reported to have a key economic impact on cattle health and production in SSA [179]. The disease is also associated with diarrhea and death of about one million cattle annually [180] and causes a total economic impact of around 300 million USD [181]. Other diseases like measles and diarrhea were also recounted. It is pertinent to highlight that EVM also has applications in boosting milk production in animals, and such knowledge can be relied on to increase milk production in livestock, rather than using inorganic food additives or even synthetic drugs to enhance milk production in animals. Particular IPS such as *Artocarpus heterophyllus* Lam and *Broussonetia papyrifera* (L.) L'Her. ex Vent. that were reported to help in enhancing milk and breast milk production in animals can thus be further investigated and turned into highly organic feed additives for livestock, rather than destroying them due to their invasive nature.

4.6 Toxicity of invasive plant species found in protected areas of Uganda

All the IPS investigated in this study had potential toxic effects both to humans and animals, even though some had unmentioned effects. The possession of toxic elements or effects in IPS, like *Parthenium hysterophorus* L. has also been reported by [26]. In humans, some IPS were reported to have extremely adverse effects like skin inflammation, asthma, hay fever, and allergic rhinitis. IPS causing like skin inflammation, asthma, hay fever, and allergic rhinitis in humans, didn't however have information on their potential to manage skin inflammation, asthma, hay fever, and allergic rhinitis. However, only one IPS (*Parthenium hysterophorus* L.) had anti-inflammatory activity as a pharmacological activity but was also recorded to cause symptoms of skin inflammation in humans. There is thus a need for more scientific investigations to understand the relationship between the pharmacological activity of IPS and the toxic effects that they possess. In animals, over 20 toxic effects were recorded, with mortality in brine shrimps, kidney damage, and diarrhea in animals having the highest frequency of mention. Other toxic effects recorded in this study like cytotoxicity effects in animals like fish and systemic toxicity in livestock were similar to toxic effects reported in other studies [182].

The potential of IPS to cause toxic effects may be attributed to their ability to produce toxic secondary compounds such as tropane alkaloids and pyrrolizidine alkaloids [183]. The secondary metabolites produced by IPS as seen in the present study also have the potential to enhance reproductive problems in livestock production [184]. Other IPS such as *Opuntia stricta* var. *dillenii*, though were not recorded in the present study also possess glochids, which cause

irritations [21]. Likewise, *Senecio inaequidens* DC. also causes adverse health impacts as it contains retrorsine [185]. Additionally, the findings of the present study also revealed over 100 therapeutic compounds in the different IPS (Table 1), some of which are toxic to humans.

4.7 Pharmacological activities of invasive plant species found in protected areas of Uganda

Over 35 pharmacological activities possessed by IPS were registered and among these, anti-bacterial, anti-inflammatory, and anti-oxidant activity were common compared to other pharmacological activities. Other pharmacological activities that followed were anti-cancer, anti-diabetic, hepatoprotective effects, laxative, anti-malarial, anti-aging, and anti-cancer. The different secondary metabolites in IPS may be blamed for the various pharmacological activities [186].

5. Limitations of the study

Many biases arise while collecting ethnobotanical data and these biases influence the reliability of research findings. For example, the reliance on limited studies which are also localized may result into collection of a narrow segment of traditional medicine knowledge [187]. Another common bias is recall bias, where informants may talk about medicinal plants based on memory rather than thorough observation [188]. The review did not investigate any possible relationship between pharmacological activity of IPS and the toxic effects that they possess. The review did not also consider IPS in other protected areas such as wildlife reserves, game reserves, and game sanctuaries yet they may also be under the threat from IPS.

6. Conclusion and future direction

The present study is the first of its kind to document invasive plant species recorded in some national parks and forest reserves, their ethnomedicine uses in human and ethnoveterinary purposes, toxicity information, pharmacological activity, and the different therapeutic compounds that they contain. However, there are still many IPS affecting Uganda's protected areas with most of them not scientifically documented. For instance, IPS such as *Heteropogon contortus* and *Euphorbia candelabrum* var. *bilocularis* are widely known in Uganda due to their severe effects on national parks such as QENP. However, they have not been scientifically documented. Some IPS documented in the present study are occasionally collected from national parks like QENP and then burnt. However, the findings from this study may guide the use of these IPS such as in drug discovery and product development rather than destroying them. There is need for studies to

investigate the relationship between the pharmacological activity of IPS and the toxic effects that they possess.

List of abbreviations

BFR: Budongo Forest Reserve

ECF: East Coast Fever

EVM: Ethnoveterinary Medicine

IPS: Invasive Plant Species

KNP: Kibale National Park

KiNP: Kidepo National Park

MCFR: Mabira Central Forest Reserve

MFNP: Murchison Falls National Park

NDs: Neurological Disorders

PRISMA: Preferred Reporting Items for Systematic reviews and Meta-Analyses

SNP: Semliki National Park

SSA: Sub-Saharan Africa

STIs: Sexually Transmitted Infections

TB: Tuberculosis

QENP: Queen Elizabeth National Park

Statements and Declarations

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Review concept and design: James Thomas Wanyama

Literature search: James Thomas Wanyama

Methodology: James Thomas Wanyama

Data analysis, visualization, and interpretation: James Thomas Wanyama

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Manuscript editing: Janet Kabugho, Julius Musiige, Duke Henry Tamale, Gabriel Alele, and Joseph Kitalikyawe

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