Ethnomedicinal plants used for treatment of snakebites in Tanzania – a systematic review

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ABSTRACT

Context: Snake envenomation is one of the neglected health problems in Tanzania. Since most people, especially in rural areas, suffer from its burden, their cases are not documented due to reliance on medicinal plants. Despite the pivotal role of medicinal plants in treating snakebites, there is a paucity of information.

Objective: This review documents medicinal plants used to treat snakebites in Tanzania.

Materials and methods: A systematic search using electronic databases such as PubMed, Google Scholar, Scopus, Science Direct and grey literature was conducted to retrieve relevant information on medicinal plants used to treat snakebites in Tanzania. The review was conducted as per the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. The obtained information from 19 published articles was organized and analyzed based on citation frequency.

Results: A total of 109 plant species belonging to 49 families are used as snakebite antivenom in Tanzania. Fabaceae had the highest number of medicinal plants (19.3%). The dominant plant growth forms were trees (35%) and shrubs (33%). Roots were the most frequently used plant part (54%), followed by leaves (26%) and bark (11%). Annona senegalensis Pers. (Annonaceae), Dichrostachys cinerea (L.) (Fabaceae), Suregada zanzibariensis Baill. (Euphorbiaceae), Antidesma venosum E.Mey. ex Tul. (Phyllanthaceae), Cissampelas pareira L. (Menispermaceae) and Dalbergia melanoxylon Guill. & Perr. (Fabaceae) were the most cited medicinal plants.

Conclusions: Tanzania has diverse plants used for snakebite treatment; a few have been analysed for their bioactive components. Further study of the phytochemicals may provide scientific information to develop snakebite drugs.

Introduction

Globally, snake envenomation is considered a neglected disease and a significant public health concern (World Health Organization (WHO) 2007). About 5.5 million people are envenomed annually, whereas 9% of the cases are reported in Africa (Chippaux 1998; Giovannini and Howes 2017). Of the reported cases globally, 36% die due to snakebites, and about 7% survive permanent injuries (WHO 2007; Omara 2020). These figures can be lower than the truth because most snakebite incidences occur in rural areas where there are insufficient health facilities, and most cases are not recorded (Zolfagharian and Dounighi 2015; Yirgu and Chippaux 2019; Omara 2020). In sub-Saharan Africa, about one million cases of snake envenomation are reported annually, causing 2% of death cases and 1% get permanent injuries (Chippaux 2015). In East Africa, 108 and 151 cases of snakebite were reported in Uganda (Wangoda et al. 2004) and Kenya (Snow et al. 1994), respectively. In Tanzania, there are no proper records on snakebite cases despite diverse types of snakes (Chippaux 2011; Kipanyula and Kimaro 2015).

Venomous snakes are found in most parts of the world, in all climatic conditions except in frozen environments and at higher altitudes (WHO 2007; Kasturiratne et al. 2008). Africa alone is a home of 400 different snake types, whereby nearly 50% are found in East Africa. Some of them are black mamba (Dendroaspis polylepis Günther (Elapidae)), spitting cobra (Naja nigricollis Hallowell (Elapidae)), Rhus-leafed-beaked snake (Ramphiophis rostratus Peters (Psammophiidae)), puff adder (Bitis arietans Parker (Viperidae)) and green mamba (Dendroaspis jamesoni Traill (Elapidae)) (Kipanyula and Kimaro 2015; Omara 2020). Snakebites are life-threatening due to the scarcity of proven medication. Although antivenom serum has been developed as a lifesaving option, it is associated with the development of immediate or delayed hypersensitivity (anaphylaxis) and does not avert local tissue damage (Maya Devi et al. 2002). For example, an antidote such as immunoglobulin G produced in horses could react to serum and cause sickness, renal failure and anaphylaxis (Cannon et al. 2008; Giovannini and Howes 2017). Still, antivenom administration is considered chiefly a definitive treatment for snakebites. Other treatments include respiratory support therapy, surgical of affected necrosis tissues or even amputation (Cannon et al. 2008; de Moura et al. 2015).

Regardless of the funding issues, there is a paucity of snake venom antiserum in most African countries, predominantly rural areas. Tanzania faces a similar problem that makes the rural...
inhabitants depend on traditional medicines, particularly herbal remedies (Maregesi et al. 2013). Other reasons for reliance on traditional medication are distance to medical facilities, poor infrastructure, storage conditions, scarcity of antidotes in hospitals, restricted application, traditional beliefs, and the high cost of antivenom and modern facilities (Giovannini and Howes 2017; Steinhorst et al. 2021; Kacholi and Amir 2022). Therefore, the use of medicinal plants in addressing snakebite problems has been increasing in the modern era due to their safety, effectiveness, cultural preferences, inexpensiveness, abundance and availability (Maregesi et al. 2013; Omara et al. 2020). Despite the critical role of medicinal plants in combating snakebite problems, there is no specific ethnobotanical study that has compiled data on medicinal plants used to manage snakebites in Tanzania. Thus, this review fills that gap by documenting medicinal plants used in various parts of the country to treat snakebites.

Methods

Description of the country

Tanzania is a country located in East Africa, covering an area of 947,303 km². It is bordered in the North by Uganda, South by Malawi and Mozambique, Northeast by Kenya, East by the Indian Ocean and Comoro Island, Southwest by Zambia, and West by Burundi, Rwanda and the Democratic Republic of Congo. The country is estimated to have about 56.31 million population, making it the second-most-populous country south of the equator after South Africa. The population comprises over 120 ethnic groups with different beliefs and cultural practices. The great African lakes are partly within this country. Lake Victoria, Africa’s largest lake, is located to the north; Lake Tanganyika, Africa’s deepest lake, is to the west, and Lake Nyasa lies to the south. Africa’s highest mountain, Mount Kilimanjaro, is found on the north-eastern side of the country.

Literature search strategy

This systematic review has compiled information on ethnomedicinal plants used to treat snakebites in different parts of Tanzania. The study was conducted following the recommendations stated in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Liberati et al. 2009). The PRISMA flow diagram is presented in Figure 1. A web-based literature search was carried out using various electronic databases, including Google Scholar, Web of Science, African Journals Online (AJOL), Science Direct, Scopus, PubMed, Wiley online library and grey literature to access relevant studies. The following search terms and combinations were used to gather relevant studies; medicinal plants, traditional medicines, ethnomedicine, ethnopharmacology, ethnobotany, alternative medicine, antivenin plants, antivenom, antitoxin, antiophidian, snake antidotes, antisera, snakebite, snake envenomation and Tanzania.

All the searches were conducted independently in all the databases, and only articles published and theses or dissertations having any of the above key terms were considered. The studies written in the English language were only searched and considered. Finally, Tanzanian traditional medicinal plants exclusively utilized to treat snakebites were selected. Records from outside Tanzania, ethnoveterinary studies, pharmacological studies and reviewed articles were excluded from the present study. Also, the studies with no scientific names and the plant parts used were excluded. Studies that possessed required information, such as family name, scientific name, local name, growth habits, method of preparation (if available) and route of administration
The predominance of the family Fabaceae was similarly reported in Uganda (Omara et al. 2020), Ethiopia (Yirgu and Chippaux 2019) and India (Upasani et al. 2017). This family's highest usage is associated with richness in terms of species and comprehensive coverage of ecological habitats (Kadir et al. 2015; Ajao et al. 2019). The family Fabaceae is characterized by active phytochemical compounds such as tannins, phenols and alkaloids (Luís et al. 2011; Żarnowski et al. 2014). Other families reported in this study were also reported to possess antivenin potential for treating or avoiding snakebites in other countries within and outside Africa. For example, Aristolochiaceae and Lamiaceae in Djibouti (Hasan et al. 2016; Yirgu and Chippaux 2019), Acanthaceae, Apocynaceae, Asterolaeae, Euphorbiaceae, Moraceae, Rubiaceae and Rutaceae in India (Upasani et al. 2017), Bangladesh (Hasan et al. 2016) and Central America (Giovannini and Howes 2017), Euphorbiaceae, Asterolaeae, Amaryllidaceae and Solanaceae in Uganda (Omara et al. 2020), and Malvaceae, Annonaceae, Combretaceae and Lamiaceae in Kenya (Omara 2020).

Growth forms of medicinal plants

Among the reported medicinal plants in this review, trees (35%) and shrubs (33%) constituted the greatest proportions, followed by herbs (22%), and the remaining growth forms had a small proportion of less than 10% (Figure 3). The finding is consistent with an ethnobotanical study conducted in Uganda (Omara et al. 2020), which reported that trees and shrubs were the most dominant plant growth forms used for making herbal remedies against snakebites. The predominance of trees and shrubs in treating snakebites could be due to their accessibility throughout the year, local socio-cultural beliefs, and the practice of healers in treating snakebites (Asmeron et al. 2021; Kacholi and Amir 2022). Also, the frequent use of the two growth forms indicates that the locals are conversant with using higher plants in the formulation and preparations of herbal remedies (Kacholi and Amir 2022).

Plant parts used

This review observed that locals in Tanzania use different plant parts to treat snakebites. Roots were the most frequently used plant part (54%), followed by leaves (26%), bark (11%) and whole plant (6%). Other parts, such as fruits, seeds and aerial parts, were rarely used (Figure 4). The common use of roots for treating snakebites was also reported in Kenya (Omara 2020), Ethiopia (Yirgu and Chippaux 2019), Uganda (Omara et al. 2020) and India (Upasani et al. 2017). The regular use of roots and leaves in antivenin preparations is a characteristic feature of traditional antivenin therapy (Owuor and Kisangau 2006; Yirgu and Chippaux 2019); that is why some of these medicinal plants are named ‘snakeroot’ in some rural communities.

The recurrent use of roots is also reported in treating various ailments in other countries apart from snakebites (Maroyi 2013;
| Family          | Species name                                 | Local name   | Growth form | Parts used                                      | MoP and RoA                                                                 | Reference                  |
|-----------------|----------------------------------------------|--------------|-------------|------------------------------------------------|-----------------------------------------------------------------------------|-----------------------------|
| Acanthaceae     | Crassocephalum mannii (Hook. f.)             | Mgangogango  | Shrub       | Leaves                                         | Decoction drunk                                                            | Maregesi et al. (2013)     |
|                 | Justicia heterocarpa L.                      | Mwidi        | Herb        | Roots, leaves                                  | Powdered parts taken orally                                                | Amiri and Kisangau (2012)  |
|                 | Thunbergia alata Bojer ex Sims               | Nyakatoa     | Herb        | Leaves                                         | Powdered leaves mixed with water to give a paste which is then applied in a small incision made on the bite | Maregesi et al. (2013)     |
| Amaranthaceae   | Aerva lanata (L.) Juss. ex Schultz           | Kambunyenye  | Herb        | Roots                                          | Not specified                                                               | Chhabra et al. (1987)     |
| Anacardiaceae   | Lannea schimperi (Hochst. ex A.Rich) Engl.   | Mzulu        | Herb        | Roots                                          | Crushed and applied to the bite                                             | Augustino et al. (2011)    |
|                 | Ozoroa mucronata (Krauss) R. & A. Fern.      | Mgbombokilingu | Tree      | Leaves                                         | Not specified                                                               | Chhabra et al. (1987)     |
| Annonaceae      | Annona senegalensis Pers.                    | Mtopotope    | Tree        | Roots, bark, leaves                            | Decoction drunk                                                            | Augustino et al. (2011), Kapcholi (2014), Maregesi et al. (2013), Ruffo (1991) |
|                 | Friesodelia obovata (Benth.) Verdc.          | Masalasi     | Shrub       | Roots                                          | Crush and then massage the affected area                                   | Augustino et al. (2011), Ruffo (1991) |
| Apocinaceae     | Uvaria acuminata Oliv.                       | Msafu        | Shrub       | Roots                                          | Decoction drunk                                                            | Chhabra et al. (1987)     |
| Araceae         | Xylopia longipetala De Wild & T. Durand      | Mlavilira    | Tree        | Bark                                           | Decoction drunk                                                            | Augustino et al. (2011), Kapcholi (2014) |
| Aristolochiaceae| Aristolochia spp.                            | Kilikamo     | Climber     | Roots                                          | Not specified                                                               | Ruffo (1991)               |
| Asteraceae      | Blephurispermum zanguiecubicum Oliv. & Hiern | Mcokele      | Shrub       | Roots                                          | Decoction drunk                                                            | Chhabra et al. (1989)     |
|                 | Coryza canadensis L. Cronq.                  | Akamwisanga  | Herb        | Whole plant                                    | Decoction drunk                                                            | Maregesi et al. (2013)     |
|                 | Spilanthes mauritana (Rich. ex Pers.) DC     | Mtango       | Herb        | Whole plant                                    | Not specified                                                               | Chhabra et al. (1989)     |
|                 | Vernonia amygdalina Del.                     | Mtugutu      | Shrub       | Leaves                                         | Leaves chewed, and extract swallowed                                       | Chhabra et al. (1989)     |
| Bignoniaceae    | Markhamia obtusifolia (Baker) Sprague        | Ng'ubu       | Tree        | Roots                                          | Chew and swallow the extracts                                               | Chhabra and Mahannah (1994) |
| Burseraceae     | Commiphora africana (A.Rich.) Engl.          | Mutonto      | Tree        | Bark                                           | Crush and massage the affected area                                         | Augustino et al. (2011), Chhabra et al. (1989) |
| Cannoraceae     | Byrsocarpus orientalis (Baill.) Baker         | Mpandaradu   | Herb        | Roots                                          | Dried roots are burnt, mixed with powdered charcoal and tobacco, and the infusion drunk | Chhabra et al. (1989)     |
| Capparaceae     | Capparis tomentosa Lam.                      | Mtungulu'osa  | Tree        | Leaves                                         | Not specified                                                               | Chhabra et al. (1989)     |
|                 | Thyelochium dhianum Lour.                    | Mtomoni      | Tree        | Roots                                          | Not specified                                                               | Chhabra et al. (1989)     |
| Celastraceae    | Maytenus senegalensis (Lam.) Exell           | Mwambangoma  | Tree        | Roots                                          | Not specified                                                               | Ruffo (1991), Chhabra et al. (1989) |
| Combretaceae    | Combretum apiculatum Sond.                   | Muhuluka     | Tree        | Roots                                          | Not specified                                                               | Chhabra et al. (1989)     |
|                 | Combretum collinum Fresen.                   | Mulandala    | Tree        | Roots                                          | Not specified                                                               | Ruffo (1991)               |
|                 | Combretum obovatum F. Hoffm                  | Vugoveko     | Tree        | Roots                                          | Crush roots, then massage the affected part                                 | Augustino et al. (2011)    |
|                 | Combretum zeyheri Sond.                      | Musana       | Tree        | Leaves                                         | Crush roots, then massage the affected part                                 | Augustino et al. (2011)    |
| Convulaceae     | Jacquelmontia paniculata (Burm. f.) Hall. F. | Mwi'limbiti  | Herb        | Leaves                                         | Fresh pounded leaves are applied to the bite                                | Chhabra et al. (1989)     |
| Cucurbitaceae   | Momordica foetida Schumach                   | Ruhunduhundu  | Herb        | Leaves                                         | Not specified                                                               | Chhabra et al. (1989)     |
| Dilleniaceae    | Tetracera boiviana Hall.                     | Mpingga      | Tree        | Roots, leaves                                  | Powdered roots mixed with water and taken orally, while leaves are crushed and juice drunk | Chhabra et al. (1989)     |
| Ebenaceae       | Diospyros fischeri Guerke                   | Mufubata     | Shrub       | Roots                                          | Crushing, then massage the affected part                                    | Augustino et al. (2011)    |
|                 | Diospyros usambarensis F. White              | Mwiloilo     | Shrub       | Roots                                          | Not specified                                                               | Chhabra et al. (1989)     |
|                 | Euclea divinorum Hiern.                      | Mdiaa        | Shrub       | Leaves                                         | Crush leaves and massage the affected part                                  | Augustino et al. (2011)    |
| Euphorbiaceae   | Acalypha fruticosa Forssk.                   | Mluwe        | Shrub       | Aerial parts                                   | Crushed and applied on incisions made on the bitten area                   | Chhabra et al. (1990b), Hedberg et al. (1983a) |
|                 | Cyathogeus buskii Pax                        | Mzidishanguvu| Shrub       | Roots                                          | Not specified                                                               | Chhabra et al. (1990b)     |
|                 | Euphorbia canadensis Tremaux                 | Ganga        | Shrub       | Roots                                          | Not specified                                                               | Hedberg et al. (1983a)     |

(continued)
| Family        | Species name                          | Local name       | Growth form | Parts used                  | MoP and RoA                                                                 | Reference                                                                 |
|--------------|---------------------------------------|------------------|-------------|-----------------------------|----------------------------------------------------------------------------|----------------------------------------------------------------------------|
| Euphorbiaceae| Euphorbia grantii Oliv.               | Mudulansongo     | Tree        | Roots                       | Crushing, then massage the affected part                                   | Augustino et al. (2011)                                                   |
|              | Euphorbia hirta L.                    | Mziwaziwa        | Herb        | Roots                       | Crushing, then massage the affected part. Decoction drunk                  | Augustino et al. (2011), Chhabra et al. (1990b)                            |
|              | Euphorbia tirucalli L.                | Mnyaa            | Shrub       | Roots                       | Crushing, then massage the affected part                                    | Augustino et al. (2011), Ramathal and Ngassapa (2001)                     |
|              | Phylanthus reticulatus Poir.          | Mkwanambamazi    | Shrub       | Roots                       | Infusion drunk                                                              | Chhabra et al. (1990b)                                                    |
|              | Securinega virosa (Roxb. ex Wind.) Pax & K. Hoffm. | Masoke           | Shrub       | Roots, fruits               | Infusion drunk                                                              | Hedberg et al. (1983a)                                                    |
|              | Suregada zanzibariensis Baill.        | Mdimumwitu       | Shrub       | Roots, leaves               | Pounded, then massage the affected part after a small incision is made and decoction drunk | Augustino et al. (2011), Augustino and Gillah (2005), Chhabra et al. (1990b), Hedberg et al. (1983a) |
| Fabaceae     | Abrus precatorius L.                  | Lufambo          | Herb        | Roots                       | Chewed and extracts swallowed                                               | Chhabra et al. (1990a), Hedberg et al. (1983b)                            |
|              | Acacia brevispica Harms               | Mwawo            | Tree        | Roots                       | Decoction drunk                                                             | Chhabra et al. (1990a)                                                    |
|              | Acacia polyacantha Willd. subsp.      | Mgungu           | Tree        | Roots                       | Infusion drunk, and the same is applied to the bite                         | Chhabra et al. (1990a), Hedberg et al. (1983a)                            |
|              | campylacantha (Hochst. ex A. Rich.) Brenan | Mngong           | Tree        | Roots                       | Not specified                                                               | Chhabra et al. (1987)                                                    |
|              | Afzelia quanzensis Welw.              | Mkongo           | Tree        | Roots                       | Not specified                                                               | Augustino et al. (2011)                                                   |
|              | Brachystegia boehmi Benth.            | Muyombo          | Tree        | Leaves                      | Pound and massage the affected part. Decoction is drunk                     | Augustino et al. (2011)                                                   |
|              | Brachystegia specifloris Benth.       | Mugaluka         | Tree        | Bark                        | Pound and massage the affected part. Decoction is drunk                     | Augustino et al. (2011)                                                   |
|              | Pterocarpus angolensis                | Mninga           | Tree        | Roots                       | Chewed and applied on the bite                                              | Augustino et al. (2011)                                                   |
|              | Cassia abbreviata Oliv.               | Muzoka           | Shrub       | Roots                       | Decoction drunk                                                             | Chhabra et al. (1987)                                                    |
|              | Cassia alata L.                       | Mchingu          | Shrub       | Leaves                      | Decoction drunk                                                             | Chhabra et al. (1987)                                                    |
|              | Cassia occidentalis L.                | Mlingajini       | Herb        | Leaves                      | Decoction drunk                                                             | Chhabra et al. (1987)                                                    |
|              | Dalbergia melanarxylon Guill. & Perr. | Mpingo           | Tree        | Bark, leaves                | Fresh leaves are pounded, and juice is drunk                               | Chhabra et al. (1990a), Rufio (1991), Salimbo et al. (2017)               |
|              | Dichrostachys cinerea (L.) Wight et Arn. subsp. africana Brenan et Brummitt | Mkulagenbe       | Shrub       | Roots, bark, leaves         | Leaves are chewed, and the paste is applied to the bite. Roots and bark are chewed or macerated and put on the bite | Chhabra et al. (1990a), Hedberg et al. (1983a), Kacholi (2020), Rufio (1991) |
|              | Erythrina abyssinica DC.              | Mukalawhanhuba   | Tree        | Roots                       | Crushing and then massaging the affected part and sap is used as an antidote | Augustino et al. (2011)                                                   |
|              | Indigofera arrecta Hochst. A. Rich.   | Umusororo        | Herb        | Whole plant                 | The plant is dried and ground into a powder, then applied to the affected part | Ramathal and Ngassapa (2001)                                              |
|              | Isoberlinia angolensis (Welw. ex Benth.) Hoyle & Brenan | Muva             | Shrub       | Bark                        | Chewed and pasted on the bite                                               | Augustino et al. (2011), Rufio (1991)                                      |
|              | Lonchocarpus capassa Rolfe             | Mfumbili         | Tree        | Whole plant                 | Not specified                                                               | Chhabra et al. (1990a)                                                    |
|              | Millettia usaramensis Taub.           | Mhaf             | Tree        | Roots                       | Decoction drunk                                                             | Chhabra et al. (1990a)                                                    |
|              | Oromocarpum trachycarpum (Taub.) Harms | Mukondwanhulu    | Shrub       | Leaves                      | Crushed, then applied to the bite                                          | Augustino et al. (2011)                                                   |
|              | Pterocarpus angolensis (Baker) Meeuwen | Mwungu           | Tree        | Leaves                      | Not specified                                                               | Rufio (1991)                                                              |
|              | Phaseolus radiatus L.                 | Ebhisanda        | Climber     | Seeds                       | Make powder, then mix with honey and rub to the affected area after a small razor incision | Maregesi et al. (2013)                                                    |
|              | Piliostigma thonningii (Schum.) Milne-Redh. | Mutindambogo     | Tree        | Bark                        | Crushing, then massage the affected part                                    | Augustino et al. (2011)                                                   |
| Family               | Species name                  | Local name | Growth form | Parts used          | MoP and RoA                                      | Reference                      |
|----------------------|--------------------------------|------------|-------------|---------------------|-------------------------------------------------|--------------------------------|
| Flacourtia          | *Flacourtia indica* (Burm.f.) Merr. | Mupugusa   | Tree        | Roots               | Crushing, then massage the affected part         | Augustino et al. (2011)        |
| Gramineae           | *Brachiaria reptans* (L.) Gardner et C.E. Hubbard | Lukoka     | Grass       | Whole plant         | The whole dried plant is burned and the ashes applied to the bite | Chhabra et al. (1990b)          |
|                      | *Pennisetum purpureum* Schum.  | Urubingo   | Herb        | Whole plant         | The plant is dried and ground into a powder, then applied to the affected part | Ramathal and Ngassapa (2001)   |
| Icacinaceae         | *Hoslundia opposita* Vahl      | Mulavula   | Shrub       | Leaves              | Crushed and applied to the bite                  | Chhabra et al. (1990b), Chhabra et al. (1990b) |
| Ocimum              | *Ocimum basilicum* Linn.       | Mvumbasi    | Herb        | Roots               | Not specified                                    | Chhabra et al. (1990b), Chhabra et al. (1990b) |
| Lamiaceae           | *Leonotis mollissima* Guerke   | Kitalante   | Herb        | Leaves              | Not specified                                    | Chhabra et al. (1990b), Chhabra et al. (1990b) |
| Lyciaceae           | *Lycium arabicum* L.         | Mlumbia     | Shrub       | Roots               | Pounding, then massage the affected part or chew and swallow | Augustino et al. (2011), Chhabra et al. (1990b), Hedberg et al. (1983a) |
| Malvaceae           | *Hibiscus micranthus* L. f.    | Muambe      | Shrub       | Roots               | Not specified                                    | Chhabra et al. (1990b), Chhabra et al. (1990b) |
|                      | *Sida rhombifolia* L.         | Mase        | Shrub       | Roots               | Decoction drunk                                  | Chhabra et al. (1990b), Chhabra et al. (1990b) |
| Lauraceae           | *Cassia filiformis* Linn.      | Mlangoam    | Herb        | Whole plant         | Not specified                                    | Chhabra et al. (1990b), Chhabra et al. (1990b) |
| Loganiaceae         | *Strychnos spinosa* Lam.       | Mtonga      | Shrub       | Roots               | Pounding, then massage the affected part or chew and swallow | Augustino et al. (2011), Chhabra et al. (1990b), Hedberg et al. (1983a) |
| Menispermaceae      | *Cassypelos mucronata* A. Rich. | Msangwi    | Climber     | Roots               | Root scrapings are taken orally and also rubbed into scars at the place of the bite | Chhabra et al. (1990b)          |
| Moraceae            | *Ficus natalensis* Hochst.     | Mlumbia     | Tree        | Roots               | Not specified                                    | Chhabra et al. (1990b), Chhabra et al. (1990a) |
| Ochnaceae           | *Ochna schweinfurthiana* F. Hoffm. | Kavuhwampako | Shrub       | Roots               | Not specified                                    | Chhabra et al. (1990b), Chhabra et al. (1990b) |
| Olacaceae           | *Ximenia caffra* Sond.         | Mnembwa     | Tree        | Roots               | A decoction is taken orally                       | Augustino et al. (2011), Maregesi et al. (2013) |
| Oleaceae            | *Jasminum flavum* Vell.        | Muafu       | Climber     | Roots, Leaves       | Pounded and compressed in cotton cloth to get the juice which is taken orally | Chhabra et al. (1990a), Maregesi et al. (2013) |
| Orchidaceae         | *Schrebera trichokola* Welw.   | Muputika    | Shrub       | Bark                | Pound and massage the affected part               | Augustino et al. (2011)        |
| Passifloraceae      | *Adenia gummifera* (Harv.) Harms | Inyazya     | Herb        | Bark                | Not specified                                    | Ruffo (1991)                   |
| Phylanthaceae       | *Antidesma venosum* E. Mey. ex Tul. | Mnyembelezu, Musukela | Shrub   | Roots               | Chewed and extracts swallowed                     | Hedberg et al. (1983b)         |
| Poaceae             | *Sporobolus pyramidalis* Beav. | Chinswi     | Grass       | Roots               | Decoction taken orally twice a day                | Maregesi et al. (2013)         |
| Polygalaceae        | *Securidaca longepedunculata* Fresen | Masig       | Shrub       | Roots, bark, leaves | Decoction of roots, leaves and stem bark drunk    | Chhabra et al. (1991), Hedberg et al. (1983b) |
| Ranunculaceae       | *Clematis brachiata* Thumb.    | Tambariko   | Climber     | Leaves              | Not specified                                    | Chhabra et al. (1991)          |
| Rhamnaceae          | *Zaithus mucronata* Wild.      | Kagovole    | Tree        | Roots               | Infusion drunk                                   | Hedberg et al. (1983b), Ruffo (1991) |
| Rubiaceae           | *Agathisanthemum bojeri* Klotzsch | Mtutuma      | Shrub       | Roots               | Infusion drunk                                   | Chhabra et al. (1991)          |

(continued)
| Family          | Species name                      | Local name | Growth form | Parts used       | MoP and RoA                                                                 | Reference                          |
|-----------------|-----------------------------------|------------|-------------|------------------|-----------------------------------------------------------------------------|-----------------------------------|
| Rutaceae        | Citrus limon (L.) Osbeck          | Mlimao     | Tree        | Leaves           | Not specified                                                              | Augustino and Gillah (2005), Ruffo (1991) |
| Sapindaceae     | Paullinia pinnata L.              | Lugoto     | Climber     | Leaves           | Dried and pounded and then applied to the bite. Sap and juice from fruits are applied directly to the bite. | Chhabra et al. (1991)             |
| Solanaceae      | Solanum incanum L.               | Nyanjapori | Herb        | Roots, fruits, leaves | Not specified                                                              | Ramathal and Ngassapa (2001), Chhabra et al. (1993), Hedberg et al. (1983b) |
| Sterculiaceae   | Sterculia africana (Lour.) Flori  | Muhozya    | Tree        | Bark             | Not specified                                                              | Ruffo (1991)                      |
| Sterculia appendiculata K. Schum. | Muhozya    | Tree        | Bark        | Not specified    | Decoction drunk                                                            | Chhabra et al. (1993), Hedberg et al. (1983b) |
| Thymelaeaceae   | Synaptolepis kirkii Oliv.         | Mjanungu   | Climber     | Roots            | Not specified                                                              | Chhabra et al. (1993)             |
| Tiliaceae       | Grewia bicolor Juss               | Mkagari    | Shrub       | Roots            | Crushed roots and wipe on the bite Powdered leaves are tied to the affected site and decoction drunk once a day | Chhabra et al. (1993)             |
|                  | Grewia fallax K. Schum            | Mfungang'ombe | Herb        | Leaves           |                                                                                     | Chhabra et al. (1993), Maregesi et al. (2013) |
| Umbelliferae    | Steganotaenia araliacea Hochst.   | Msumi      | Tree        | Roots            | Pound and then massage the affected part                                     | Augustino et al. (2011), Chhabra et al. (1993), Hedberg et al. (1983b) |
| Verbenaceae     | Premna chrysacolada (Bojer) Gurke | Mtulanwha  | Shrub       | Roots, leaves    | Not specified                                                              | Chhabra et al. (1993), Hedberg et al. (1983b) |
| Vitaceae        | Cissus hildebrandii Gilg.         | Mtuha      | Herb        | Leaves           | Not specified                                                              | Chhabra et al. (1993)             |

MoP: mode of preparations; RoA: route of administration.
Jima and Megersa 2018; Mathibela et al. 2019; Hu et al. 2020; Kacholi and Amir 2022). Plant roots are believed to possess more bioactive compounds than other parts (Chinsembu 2016; Tugume and Nyakoojo 2019). The over-exploitation of roots for herbal preparations may endanger plants’ existence, especially when uprooting (Kacholi and Mvungi 2021). Plants whose roots are preferred for medicinal purposes have been reported to be the most threatened species (Cunningham 2001). Thus, this study suggests that local and traditional healers’ awareness of harvesting and conserving medicinal plants is paramount.

**Preparation and administration of remedies**

The treatment of snakebite in most of the areas in Tanzania involves mono-preparations of plant extracts, while in a few cases, mixtures of various plants and parts are used to prepare the antidotes. The common mode of preparation of herbal remedies may endanger plants’ existence, especially when uprooting (Kacholi and Mvungi 2021). Plants whose roots are preferred for medicinal purposes have been reported to be the most threatened species (Cunningham 2001). Thus, this study suggests that local and traditional healers’ awareness of harvesting and conserving medicinal plants is paramount.

**Pharmacological evidence against snake venoms**

Various pharmacological studies (Núñez et al. 2004; Mali 2010; Sonibare et al. 2016) have proven the wide use of medicinal plants, which revealed that different plant metabolites could antagonize the activity of various crude venoms and purified toxins. For instance, Solanaceae is reported to possess atropine, an alkaloid which inhibits the activity of green and dark mamba (Dendroaspis angusticeps A. Smith (Elapidae) and D. polyxenis) venoms by blocking cholinergic nerve terminals (Omara et al. 2020). Additionally, the family Aristolochiaceae contains aristolochic acid, an alkaloid that acts similarly to atropine (Kini 2005; Kemparaju and Girish 2006).

Moreover, the reported species in the present study have been reported elsewhere to have antivenin activities. For instance, the extract from combined roots, bark and leaves of Securidaca longipedunculata Fresen (Polygalaceae) (Sanusi et al. 2014), stem bark of Commiphora africana (A.Rich.) Engl. (Burseraceae) (Isa et al. 2015), folium extract of Dicistrochys cinerea (L.) Wight et Arn. (Fabaceae) (Agusi and Ogbunachi 2018), roots of Capparis tomentosa Lam. (Capparaceae) and Ziziphus mucronata Wild. (Rhamnaceae) (Molander et al. 2014), and those from the whole plant of Euphorbia hirta L. (Euphorbiaceae) inhibit venom activities of N. nigricollis. Also, extracts from leaves and roots of A. senegalensis inhibit venom activities of Echis ocellatus Steenmler (Viperidae), N. nigricollis and B. arietans (Molander et al. 2014), whereas extracts from aerial parts and roots of Cissampelos parvirea L. var. orbiculata (DC.) Miq. (Menispermacaceae) are reported to neutralize venom activity of Bothrops diporus Cope (Viperidae) (Verrastro et al. 2018). Leaves and roots extracts of Cassia occidentalis L. (Fabaceae) are reported to inhibit venom activities and accelerate wound healing caused by Bothrops moojeni Hoge (Viperidae) (Molander et al. 2014), while the roots and bark extract of Acalypha fruticos Forssk. (Euphorbiaceae) (Molander et al. 2014), and Paullinia pinnata (Ifil 2008; Sanusi et al. 2014) are reported to inhibit venom activities of Echis carinatus Schneider (Viperidae). Therefore, the present study highlights the wealth knowledge locals in Tanzania possess in dealing with snakebites. It also suggests that further pharmacological scrutiny of the recorded medicinal plants is imperative in prepared and administered as 35.7% of the reported species lack the information (Table 1). Thus, it suggests that a significant effort is still needed to gather information on the mode of preparation and administration route.

**Figure 3.** Growth forms of plants used for the treatment of snakebites.

**Figure 4.** Plants parts used for preparations of herbal remedies against snakebites.

**Figure 5.** Modes of preparation (MoP) and Routes of administration (RoA) of snakebite remedies.
understanding bioactive compounds that can be used to prepare antivenin in modern science.

Conclusions
This review presents compiled information on medicinal plant species used to treat snakebites in Tanzania. One hundred and nine medicinal plants representing 48 families were documented. Fabaceae and Euphorbiaceae were the families with the highest number of antivenom plants. Trees and shrubs were the most preferred growth forms to prepare herbal remedies for snakebites, and root was the most used plant part. Despite the diversity of plant species used to treat snakebites problems in Tanzania compiled in this review, few have been analysed for their bioactive components and potential for developing modern drugs. Therefore, effort should be geared towards this area to provide scientific information to develop snakebite drugs and solve the major health challenge. We believe that the data presented in this review will provide baseline information for future research on developing modern drugs for treating snakebite.

Author contributions
Conceptualization and data collection, D.S.K. and N.G.M.; data analysis and manuscript writing, D.S.K., O.J.K., N.G.M. and H.A.M.; manuscript revision, D.S.K. and N.G.M.

Disclosure statement
The authors declare that they have no competing interests.

Funding
The author(s) reported that there is no funding associated with the work featured in this article.

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