Diversity and knowledge of plants used in the treatment of snake bite envenomation in Benin

Ayékotchami Jacques Dossou, Adandé Belarmain Fandohan, Agossou Bruno Djossa and Achille Ephrem Assogbadjo

Research

Abstract

Background: Ophidian envenomation is a public health problem in the tropics and subtropics. Expensive cost of antivenoms forces most of the population to resort to medicinal plants as a first-line treatment. The present study aimed to contribute to a better knowledge of medicinal plants used in the treatment of snakebite envenomation in Benin.

Methods: Ethnobotanical information was collected from 339 people (hunters and traditional healers) across various sociolinguistic groups using a structured interview and the snowball technique. Knowledge was quantitatively assessed using the Relative Citation Frequency. The R software (cran.r-project.org) and Microsoft Excel were used to produce graphs and/or charts.

Results: A total of 109 plants species belonging to 51 botanical families were reported as being used in the treatment of snakebite envenomation. Distribution of these species by family showed that Leguminosae (20.18%), Euphorbiaceae (9.17%), Asteraceae (4.59%), Annonaceae (3.67%) were mentioned the most. The dominant life forms were herbs and shrubs collected mainly from savannas and fallows. Roots and leaves were the most used plant parts in the preparation of remedies.

Conclusion: In-depth pharmacological and toxicological studies must be carried out to validate reported medicinal plants, to contribute to the well-being of local communities in developing countries.

Keywords: Ethnobotanical survey, ophidian envenomation, antivenom, medicinal plants, well-being.

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Ethnobotany Research & Applications
21:48 (2021)

Background

Snakebite envenomation (SBE) is a significant health problem for communities in developing countries (Kasturiratne et al. 2008). It mostly affects people in rural areas in Asia and Africa where its incidence is high and causes huge cases of death

Manuscript received: 07/05/2021 - Revised manuscript received: 22/06/2021 - Published: 24/06/2021

http://dx.doi.org/10.32859/era.21.48.1-20

and amputations each year (Halilu et al. 2019). Its annual incidence is globally estimated at 1.2 to 5.5 million cases worldwide (Kasturiratne et al. 2008). Chippaux (2011) through a meta-analysis estimated over 300,000 cases of bites, 7,300 deaths and nearly 6,000 amputations recorded each year in sub-Saharan Africa. In Benin, it is estimated that on average 4,500 envenomation are recorded in public health facilities each year resulting in more than 650 deaths (Fayomi et al. 1987, Fayomi et al. 1997, Fayomi et al. 2002). Although these data are still underestimated because not all patients systematically resort to modern medicine for treatment. The Beninese population is predominantly agricultural and lives in rural areas, which increases the likelihood of humans encountering snakes and makes them very vulnerable to SBE. Its high incidence and mortality in tropical regions justify its inclusion by World Health Organization recently as "Neglected Tropical Diseases" (Chippaux 2017). Moreover, antivenom treatment is the only one recognized as effective against this disease (Jain et al. 2011). However, this treatment remains quite expensive and very inaccessible to communities in these countries (Gutierrez et al. 2011). The latter, using their empirical knowledge, use a varied range of medicinal plants to treat many ailments, among which are prominent, SBE (Coe and Anderson 2005). In fact, plants have advantage of being available, cheaper and easily accessible in rural areas for the treatment of these snakebites (Minu et al. 2012). In addition, many studies have reported the neutralizing power of snake venom from a fairly large number of plants in various regions of the world, particularly in Asia and America (Butt et al. 2015, Coe and Anderson 2005, Jain et al. 2011). But very few studies have been conducted in West Africa on the herbal remedies use in SBE treatment. In Benin, for example, where 80% of snakebite victims are treated by traditional healers using medicinal plants (Chippaux 1998), studies on plants use in the treatment of snakebite envenomation are practically non-existent, even though Benin has a rich and diverse flora that can be an excellent experimentation field for development and implementation of new herbal remedies in snakebites treatment. The present ethnobotanical study aims to document local knowledge and practices (methods of preparation, administration, and dosage) related to plants used in SBE treatment.

Study area

The present study was conducted in Republic of Benin, a country located in West Africa between 6°10'N and 12°25'N and 0°45'E and 3°55'E and covering an area of 115,762 km², mainland and islands included (Hounkpe 2013). It is bounded to the north by Niger and Burkina Faso, to the south by the Atlantic Ocean, to the west by Republic of Togo, to the east by Nigeria. Benin has an aridity gradient ranging from a humid climate characterized by an annual rainfall of about 1300 mm in the south to a semi-arid climate with a rainfall of about 750 to 900 mm. Average annual temperatures range from 26 to 28 °C and can exceptionally reach 35 to 40 °C in northern localities such as Kandi, Karimama and Malanville (Adomou 2005). Along this water availability gradient, three contrasting biogeographical zones evolved, namely: Guineo-Congolian region, Sudano-Guinean transition zone and Sudanian region (White 1983). The Guineo-Congolian region typically is made of fallows and small forest patches in the wetland, mosaics of sub-humid woodlands while the two dryer areas are covered by savannas and gallery forests (Sinsin et al. 2004). Main soil types include hydromorphic soils, well-drained soils and lithosols in Sudanian region. Soils of Sudano-Guinean transition zone are ferruginous. Soils are either deep ferralitic or rich in clay, humus and minerals in Guineo-Congolian region (Willaine & Volkoff 1967). Adomou et al. (2006), based on water availability patterns and soil types, identified ten finer subdivisions of the three biogeographic regions, named phytogeographic districts. Benin is home to 55 local languages which could be grouped into three major sociolinguistic groups namely Kwa, Gur and Yoruboïd (Judex et al. 2009). The Kwa sociolinguistic group is geographically dispersed in southern and central Benin and represented by Adja, Houeda, Sahoue ethnic groups and their relatives, Mina, Anii, Windji-windji ethnic groups and their allies, Fon, Mahi, Goun, Tofin, Xwla and similars. Yoruboïds are found mainly in central and southeastern Benin, and include Yoruba, Idaasha, Nagot ethnic groups and their relatives. The Sociolinguistic group Gur is located in the north of Benin and includes ethnic groups and relatives Bariba, Ditamari, Berba, Waama, ethnic groups Gurma, Natimba and their parents, Lokpa, Coto-coli, ethnic groups and their parents, Yom, Yoa Taneka ethnic groups and family members (Judex et al. 2009).

Materials and Methods

Sampling and data collection

This study was carried out in the 10 phytodistricts of Benin and in various ethnic groups. Ethnobotanical data were collected within two major socio-cultural groups in two municipalities by phytodistrict (Fig. 1). Data collection was carried out through a structured interview using a survey questionnaire with traditional healers and hunters (major holders of local knowledge) and having proven knowledge in snakebite envenomation treatment. These data collection was carried out using snowball technique (N'Danikou et al. 2015) which makes it possible to collect data from people who have real knowledge on plants used to treat snakebite envenomation.

Traditional knowledge on practices, experiences and methods of plant application was gathered from the respondents. The questionnaire used in the study consisted of three parts: the first deals with demographic data of informants, the second part contains information on local names of the plants, parts used, plants and associated ingredients, methods of preparation and administration and modes of transfer and acquisition of knowledge about plants used in snakebites treatment, and the last part discusses threats and conservation strategies of anti-venoms plants. The "*Flore analytique du Bénin*" (Akouègninou et al. 2006), "*Flore du Bénin*" (de Souza 2008) and resource persons were called upon to identify plant species and samples placed in the Laboratory of Plant Sciences, Horticultural and Forestry of the "*Université Nationale d'Agriculture*" of Benin. The correct plant names have been verified against the International Plant Name Index (IPNI: http://www.ipni.org). Medicinal species have been assigned to the appropriate family according to the Angiosperm Phylogeny website (http://www.mobot.org/MOBOT/research/APweb).

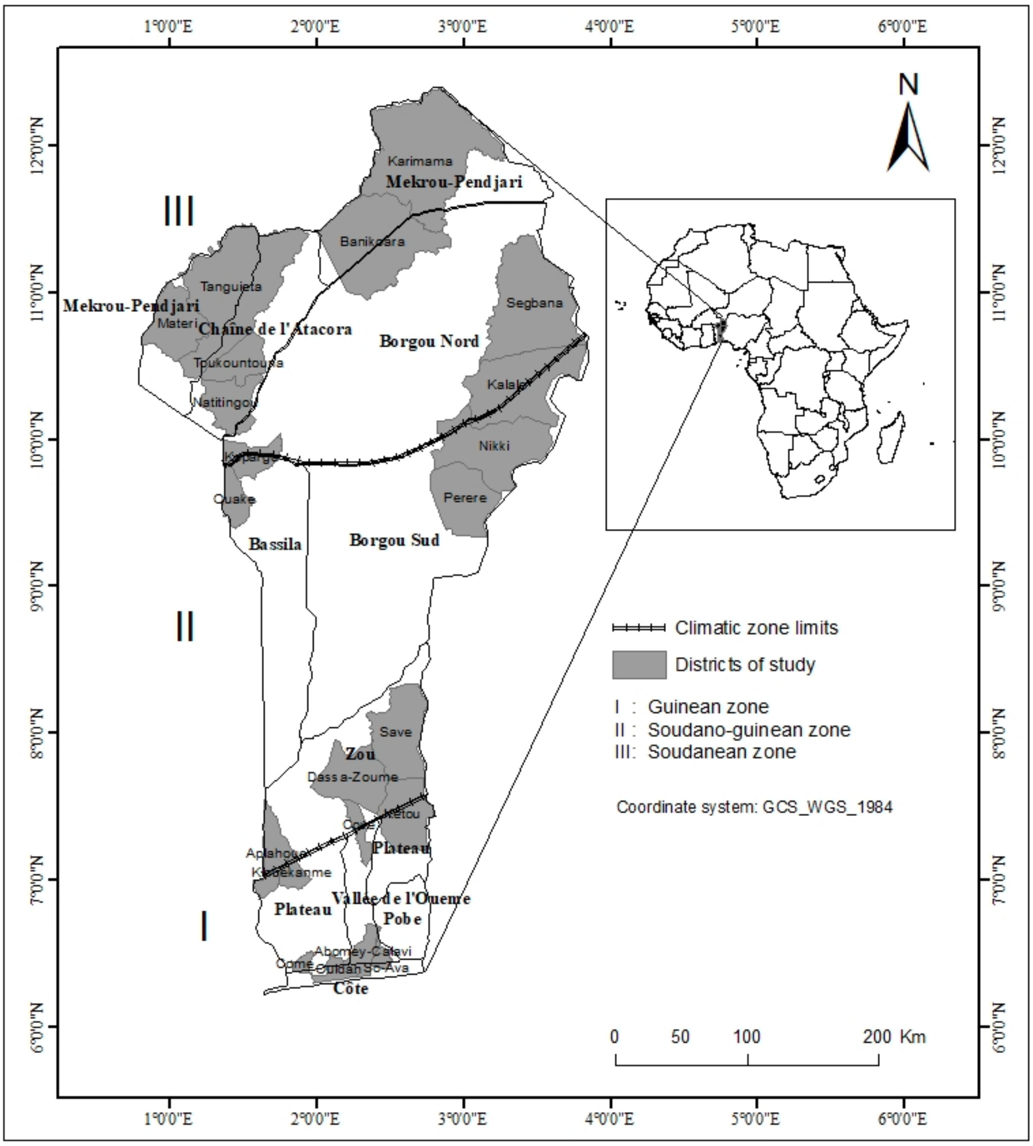

Figure 1. Map of Benin showing the study area.

Data analysis

Diversity of anti-venom plants

Herbal remedies reported as anti-snake venoms have been recorded using Excel in a specially designed format with respect to their local name, botanical name, family, method of preparation and administration and parts used.

Relative citation frequency (RFC)

Indigenous knowledge of plants used in snakebite envenomation treatment was quantitatively assessed using RFC calculated using the following formula (Vitalini et al. 2013).

$$\mathrm{RFC} = \frac{n}{N} \times 100 \ (1)$$

Where RFC is relative citation frequency; n is number of respondents who cited species and N is total number of respondents who participated in the study.

This same index was used for the plant parts, life forms, habitat, potential threats, and plant conservation strategies mentioned.

Construction of phytogeographic spectra
Species recorded were classified into phytogeographic elements using classification of White (1983). Raw and weighted spectra were carried out respectively on basis of the Relative Frequency (RF) and the Relative Dominance Index (RDI) of phytogeographic types considered as below:
Raw spectrum,

$$\mathrm{RF} = \frac{\text{Number of species of a given phytogeographic type}}{\text{The total of listed species}} \times 100 \ (2)$$

Weighted spectrum,

$$\mathrm{RDI} = \frac{\text{Sum of the number of times each species of a given phytogeographic type has been cited}}{\text{The sum of the citation numbers of all species of all phytogeographic types}} \times 100 \ (3)$$

Phytogeographic types used are: Paleotropical Species; Pantropical Species; Sudanian Species; Sudano-Guinean species; Guineo-Congolese and Sudano-Zambezian Species.

Microsoft Excel and R software (cran.r-project.org) were used to produce the various graphs and/or diagrams.

Results

Socio-demographic characteristics of the respondents
The study population consisted of 339 people divided into 17 socio-cultural groups including traditional healers (84.07%) and hunters (15.93%). 97.35% of respondents were male and only 2.65% female (Table 1). The respondents were between 10 and 105 years old. The youngest was a student in northern Benin, from a traditional healer's lineage and having already inherited traditional medicine secrets from his father. The oldest was a great traditional healer from central Benin known for his experiences and the greatness of his knowledge. Most of our respondents were at least fifty years old and those having an age greater than or equal to 60 years were the most represented.

Table 1. Socio-demographic characteristics of the respondents

Variables	Number of Respondents	Proportion (%)
Gender		
Male	330	97.35
Female	9	2.65
Age [10-105] years		
< 20	2	0.59
20-30	13	3.83
30-40	54	15.93
40-50	96	28.32
50-60	73	21.53
≥60	101	29.79
Occupation		
Traditional healers	285	84.07
Hunters	54	15.93
Socio-cultural groups		
Adja	32	9.44
Aïzo	17	5.01
Bariba	41	12.09
Berba	13	3.83
Dendi	26	7.67
Fon	22	6.49
Holli	17	5.01
Idaatcha	17	5.01
Lokpa	13	3.83
Mahi	25	7.37
Nagot	35	10.32
Nateni	11	3.24
Peulh	16	4.72
Toffin	7	2.06
Waama	14	4.13
Yom	9	2.65
Yoruba	24	7.08

Diversity of antivenom plants
This survey recorded one hundred and nine (109) plants species belonging to 51 botanical families being used in snakebites envenomation treatment in Benin (Table 2). The most cited species were among others, *Annona senegalensis* Pers. (RFC = 38.94%), *Securidaca longepedunculata* Fresen. (RFC = 30.68%), *Piliostigma thonningii* (Schum.) Milne-Redh. (RFC = 25.66%), *Parkia biglobosa* (RFC = 9.14%), *Tamarindus indica* L. (RFC = 8.26%). Distribution of these species by family showed that Leguminosae (20.18%), Euphorbiaceae (9.17%), Asteraceae (4.59%), Annonaceae (3.67%), and Anacardiaceae, Combretaceae, Curcubitaceae, Laminaceae, Meliaceae, Sterculiaceae (respectively 2.75%) were the most mentioned (Fig. 2).

Table 2. Anti-snake venom plants used by rural communities in Benin

Family	Scientific name (Voucher number)	Local name	Organs used	Method of preparation	Mode of administration	Frequency of citation	RFC	Life form
Alliaceae	*Allium cepa* L. (ADJ 001)	*Olomanssa, Mansa* (y,n), *Alubosa* (f,m), *Capi* (I), *Albasa* (a)	Bulbs	Mastication, Pounding	O, Ap	17	5.01	Herb
Aloaceae	*Aloe vera* (L.) Burm. f. (ADJ 075)	*Chanman Chanman* (h)	Leaves	Pounding	Ap	2	0.59	Herb
Amaranthaceae	*Alternanthera pungens* Kunth (ADJ 003)	*Dagunro* (y)	Roots, Leaves	Decoction	O	1	0.29	Herb
	Pupalia lappacea (L.) Juss. (ADJ 005)	*Ewon agbo* (y), *Iman iman agbo* (i)	Seeds, Leaves	Pounding, Incineration	S, O, Ap	3	0.88	Herb
Anacardiaceae	*Anacardium occidentale* L. (ADJ 076)	*Acajutin* (f)	Nuts	Maceration	Ap	2	0.59	Tree
	Lannea acida A. Rich. (ADJ 077)	*Aku* (y)	Leaves, Roots, Bark	Decoction	Ap, O	2	0.59	Tree
	Spondias mombin L. (ADJ 006)	*Iwewe, Iyeye* (y,n), *Kuko* (a)	Leaves, Roots, Bark, Fruits	Decoction, Maceration, Incineration, Pounding	Ap, O	10	2.95	Tree
Annonaceae	*Annona senegalensis* Pers. (ADJ 007)	*Otribobo* (i), *Abo* (n), *Ayounglé* (f,m), *Worouhouni* (b), *Winribou* (w), *dukui* (p)	Roots, Leaves	Mastication, Trituration, Pounding, Decoction, Incineration	Ap, O	132	38.94	Shrub
	Cleistopholis patens (Benth.) Engl. & Diels (ADJ 078)	*Hunzonhoun* (t)	Leaves, Roots	Pounding	Ap, O	1	0.29	Tree
	Uvaria chamae P. Beauv. (ADJ 079)	*Amarun fifi* (h), *Erujo*(y), *Gbanna* (a)	Roots, Leaves	Trituration, Decoction, Maceration	Ap, O	8	2.36	Shrub
	Xylopia aethiopica (Dunal) A. Rich. (ADJ 080)	*Ôroun* (i)	Seeds	Pounding, Decoction	S, Ap	2	0.59	Tree
Apocynaceae	*Carissa spinarum* L. (ADJ 081)	*Oshin shin* (i)	Roots, Leaves, Bark	Decoction	Ap, O	1	0.29	Shrub
Arecaceae	*Cocos nucifera* L. (ADJ 011)	*Agokin* (f), *locotior* (t)	Juice, Roots	Maceration, Pounding	Ap, O	2	0.59	Tree
	Elaeis guineensis Jacq. (ADJ 012)	*Edi* (a)	Reproductive organ	Pounding, Incineration	S	1	0.29	Herb
Asclepiadaceae	*Calotropis procera* (Aiton) Dryand. (ADJ 082)	*Ikpan làlà/Ba'mba'mba* (i)	Sap, Leaves, Roots	Trituration, Mastication	S, O	2	0.59	Shrub

Asteraceae	*Acanthospermum hispidum* DC. (ADJ 013)	*Sakpatagbé* (f,m)	Leaves	Mastication	O	4	1.18	Herb
	Chromolaena odorata (L.) R.M. King & H. Rob. (ADJ 083)	*Jekan* (a)	Leaves	Trituration	Ap	1	0.29	Herb
	Emilia coccinea (Sims) G. Don (ADJ 084)	*Désakplèguèdè* (m)	Leaves	Trituration	Ap, O	1	0.29	Herb
	Lactuca taraxacifolia Schumach. & Thonn. (ADJ 085)	*Odôdô yantoto* (i), *yantoto* (f)	Leaves	Trituration, Infusion	O	2	0.59	Herb
	Vernonia amygdalina Delile (ADJ 015)	*Aluba* (h), *Aloma* (f,a)	Leaves	Mastication, Maceration	O	2	0.59	Herb
Bignoniaceae	*Newbouldia laevis* (P. Beauv.) Seem. (AJD 016)	*Déssré* (t)	Bark, Roots, Leaves	Decoction	Ap, O	1	0.29	Shrub
	Stereospermum kunthianum Cham. (ADJ 086)	*Ounsadi* (m)	Leaves, Roots, Bark	Decoction, Trituration, Incineration, Pounding	Ap, O, S	25	7.37	Tree
Bombacaceae	*Bombax costatum* Pellegr. & Vuillet (ADJ 087)	*Moranou* (d), *Houlougou* (l),	Leaves, Roots, Bark	Pounding, Decoction, Incineration	O, Ap	9	2.65	Tree
Boraginaceae	*Ehretia cymosa* Thonn. (AJD 018)	*Zomali* (a)	Leaves, Roots, Bark	Pounding, Decoction, Incineration	O, Ap	2	0.59	Shrub
Burseraceae	*Commiphora africana* (A. Rich.) Endl. (ADJ 088)	*Oriji* (n)	Roots	Mastication	O	1	0.29	Shrub
Capparaceae	*Cleome viscosa* L. (ADJ 089)	*Itè /Feromoni* (h)	Leaves	Pounding	Ap	1	0.29	Herb
Caryophyllaceae	*Carica papaya* L. (AJD 019)	*Aguidi* (i), *Ibèpè* (y), *Dougba* (a), *Degbleti* (az)	Fruits	Pounding	O, Ap	8	2.36	Herb
Celastraceae	*Maytenus senegalensis* (Lam.) Exell (ADJ 090)	*Moukotimou* (ym)	Bark, Roots	Pounding, Decoction	S	1	0.29	Shrub
Combretaceae	*Anogeissus leiocarpa* (DC.) Guill. & Perr. (ADJ 091)	*Agni* (y,n)	Roots	Decoction	O, Ap	1	0.29	Tree
	Combretum glutinosum Perr. ex DC. (AJD 021)	*Gbodomi* (n), *Bouangossa* (ba), *Moufape* (ym)	Roots, Bark, Leaves	Decoction, Pounding, Maceration, Incineration	O, Ap	25	7.37	Tree

	Combretum micranthum G. Don (ADJ 091)	*bouangora* (ba)	Roots, Bark, Leaves	Decoction	O, Ap	6	1.77	Shrub
Convolvulaceae	*Ipomoea involucrata* P. Beauv. (AJD 022)	*Voudranlin* (a)	Leaves	Trituration	O, Ap	3	0.88	Herb
Cucurbitaceae	*Cucumeropsis mannii* Naudin (AJD 023)	*Itoo* (n,y)	Fruits	Maceration	O	1	0.29	Liana
	Cucurbita maxima Duchesne (ADJ 092)	*Elegèdè* (n,y)	Fruits	Juice	O, Ap	1	0.29	Liana
	Momordica charantia L. (AJD 025)	*Shati* (n), *Doukè* (a)	Leaves, Fruits, Roots	Decoction, Pounding	O, Ap	3	0.88	Liana
Cyperaceae	*Cyperus esculentus* L. (ADJ 093)	*orfior* (t)	Seeds, Leaves	Pounding	O, Ap	1	0.29	Herb
Dioscoreaceae	*Dioscorea dumetorum* (Kunth) Pax (ADJ 094)	*Effe* (t)	Leaves	Pounding	Ap, O	1	0.29	Liana
Ebenaceae	*Diospyros mespiliformis* Hochst. ex A. DC. (AJD 026)	*Ouinbou* (ba), *kouari* (w),*Ididoudou*(d), *Tokoï touri, Adjè* (a)	Leaves, Bark, Roots	Maceration, Pounding, Incineration, Decoction	Ap, O	14	4.13	Tree
Euphorbiaceae	*Discoglypremna caloneura* (Pax) Prain (ADJ 095)	*Shokougbolo* (f)	Roots, Fruits	Pounding, Maceration	O	1	0.29	Tree
	Elaeophorbia drupifera (Thonn.) Stapf (ADJ 096)	*Sozo-Allokpodé* (az)	Leaves, Bark	Incineration, Pounding	S, Ap	6	1.77	Tree
	Euphorbia kamerunica Pax (ADJ 097)	*Silo* (m)	Roots, Bark, Leaves	Incineration, Pounding, Trituration	Ap, O	11	3.24	Shrub
	Hymenocardia acida Tul. (ADJ 098)	*Orukpa* (n)	Roots, Bark	Decoction	O, Bath	1	0.29	Shrub
	Jatropha curcas L. (AJD 030)	*Akporo* (n), *Bukatu* (ba), *Gbodowi* (a)	Roots, Leaves	Decoction, Pounding	O, Bath	11	3.24	Shrub
	Jatropha gossypiifolia L. (AJD 031)	*Lapa lapa pupa* (i), *Gbodowi vovo* (a)	Roots, Leaves, Stem	Pounding, Decoction	Ap, O	4	1.18	Shrub
	Mallotus oppositifolius (Geiseler) Müll. Arg. (ADJ 099)	*Eja /Anyja* (h)	Roots	Decoction	O	1	0.29	Tree
	Manihot tristis Müll. Arg (AJD 032)	*Kpaki* (n,y), *Kutu* (a), *Agbedi* (l), *Nougoumia* (ym), *Fenyen* (f,m)	Tuber, Leaves, Stem	Trituration, Pounding	Ap, O	24	7.08	Shrub
	Manihot glaziovii Müll. Arg. (ADJ 100)	*Kutu vovo* (a), *Fenyen* (f,m)	Tuber, Leaves, Stem	Trituration, Pounding	Ap, O	3	0.88	Shrub

	Phyllanthus amarus Schumach. & Thonn. (ADJ 101)	*Hlinwé* (f,m,t), *Eyin olobè* (h)	Leaves	Pounding, trituration	Ap, O	2	0.59	Herb
Hypoxidaceae	*Gladiolus dalenii* Van Geel (ADJ 102)	*Baka* (y)	Leaves	Decoction	Ap	1	0.29	Herb
Lamiaceae	*Hyptis suaveolens* (L.) Poit. (ADJ 103)	*Mapom* (p)	Leaves, Stem	Incineration, Pounding	Ap	6	1.77	Herb
	Ocimum americanum L. (ADJ 104)	*xisi xisi* (i)	Leaves, Stem	Trituration	Ap, O	2	0.59	Herb
	Ocimum gratissimum L. (AJD 033)	*Aribara* (i)	Leaves, Stem	Pounding	Ap, O	2	0.59	Herb
Leguminosae	*Burkea africana* Hook. (AJD 037)	*Ganrebou* (ba)	Bark, Roots	Pounding	Ap, O	5	1.47	Tree
	Guilandina bonduc L (AJD 038)	*adjikuike* (a)	Roots	Pounding	O	1	0.29	Shrub
	Chamaecrista mimosoides (L.) Greene (ADJ 105)	*Attabouman* (f,m)	Leaves, Bark	Pounding, Incineration	S, Ap, O	6	1.77	Herb
	Daniellia oliveri (Rolfe) Hutch. & Dalziel (AJD 039)	*Dinyan* (ba)	Roots, Leaves	Decoction, Incineration	O, Bath	4	1.18	Tree
	Delonix regia (Hook.) Raf. (AJD 040)	*shèkèshèkèman* (az)	Leaves	Pounding	S	1	0.29	Tree
	Detarium microcarpum Guill. & Perr. (AJD 041)	*Bembérékou* (ba)	Leaves, Stem, Bark	Decoction	O	4	1.18	Tree
	Piliostigma reticulatum (DC.) Hochst. (AJD 047)	*Barkehi* (p)	Roots, Leaves, Bark	Pounding	O, Ap	2	0.59	Tree
	Piliostigma thonningii (Schum.) Milne-Redh. (AJD 048)	*Kparounmon* (i,n), *Baroupkapka* (ba), *Kloman* (f,m), *Aklo* (a) *Barkehi* (p)	Roots, Leaves, Bark	Decoction, Pounding, Incineration	O, Ap,S	87	25.66	Shrub
	Senna occidentalis (L.) Link (AJD 051)	*Laloui ashi* (a)	Leaves, Roots	Pounding, Incineration	O, Ap	1	0.29	Herb
	Tamarindus indica L. (AJD 052)	*Poussouka* (w), *Pissiki* (be), *kanyetou* (na), *Natari* (l), *Mososo* (d)	Bark, Roots, Leaves	Decoction, Pounding, Incineration	Ap, O, Bath	28	8.26	Tree
	Acacia ataxacantha DC. (AJD 035)	*Sankikoko,Gairi* (ba, d)	Roots, Bark	Pounding	O	8	2.36	Shrub
	Acacia sieberiana DC. (ADJ 106)	*Mouporipè* (ym)	Leaves, Roots	Decoction	O, Ap	1	0.29	Tree

	Entada africana Guill. & Perr. (AJD 042)	*Foono dooso* (d), *nandjouabou* (na), *Nansoumbou* (be), *Sanwaliliou* (ba)	Leaves, Bark, Roots	Infusion, Pounding, Decoction	O, S	13	3.83	Shrub
	Erythrina senegalensis DC. (ADJ 107)	*Lakalé* (h)	Leaves	Decoction	O	2	0.59	Tree
	Mimosa pudica L. (ADJ 108)	*kpanchala* (a)	Leaves, Roots	Pounding, Decoction	O, Ap	4	1.18	Herb
	Parkia biglobosa (Jacq.) G. Don (AJD 045)	*Igba* (y,n), *Donm* (ba), *doh- ntibou* (w), *Soulaka* (l), *Awatin* (f,m)	Roots, Seeds, Leaves, Bark	Decoction, Pounding	O, Ap	31	9.14	Tree
	Schrankia leptocarpa DC. (AJD 050)	*Tigossabou* (ba,d), *mounora* (p), *weta weta* (a)	Leaves, Roots, Stem	Pounding, Decoction	Ap, O, Bath	19	5.60	Herb
	Abrus precatorius L. (AJD 034)	*Sonman sauanrou* (ba)	Roots	Pounding, Incineration	O	2	0.59	Shrub
	Desmodium ramosissimum G. Don (ADJ 109)	*zenouli* (a)	Leaves	Decoction	Ap	3	0.88	Herb
	Indigofera tinctoria L. (ADJ 110)	*Ahoma* (a)	Leaves	Trituration	O	7	2.06	Herb
	Pericopsis laxiflora (Baker) Meeuwen (AJD 046)	*Ishèdu* (n)	Roots, Bark	Decoction, Maceration	Ap, Ap	2	0.59	Tree
	Pterocarpus erinaceus Poir. (AJD 049)	*Toura* (ba)	Roots, Bark, Leaves	Pounding, Decoction	O, Ap, Bath	11	3.24	Tree
Loganiaceae	*Strychnos spinosa* Lam. (ADJ 111)	*Pemfeya* (p)	Bark, Roots	Incineration, Pounding	S	1	0.29	Shrub
Malvaceae	*Abelmoschus esculentus* (L.) Moench (AJD 055)	*Ila* (y,n), *Mana* (l), *Févi* (f,m)	Fruits	Maceration	Ap	11	3.24	Herb
Melastomataceae	*Heterotis rotundifolia* (Sm.) Jacq.-Fél. (ADJ 112)	*Héhéman* (az)	Leaves	Pounding	Bath	1	0.29	Herb
Meliaceae	*Khaya senegalensis* (Desv.) A. Juss. (ADJ 113)	*Oganwo*(h)	Leaves, Roots	Pounding	Ap	1	0.29	Tree
	Pseudocedrela kotschyi (Schweinf.) Harms (ADJ 114)	*Tchaguigui* (n)	Roots, Bark	Decoction, Maceration	Ap, O	2	0.59	Tree
	Trichilia emetic Vahl (AJD 056)	*Gbékoudiréran* (p), *Waounpirogou* (ym)	Roots, Sap, Leaves	Pounding, Decoction	Ap, O	7	2.06	Tree
Moraceae	*Ficus capreifolia* Delile (AJD 057)	*Ikpin* (y)	Branchs	Pounding	O	1	0.29	Shrub

	Milicia excelsa (Welw.) C.C. Berg (AJD 058)	*Iroko (y,n), lokotin* (f,m)	Roots, Bark	Incineration, Pounding	S	3	0.88	Tree
Moringaceae	*Moringa oleifera* Lam. (ADJ 115)	*Kpatin hisi hisi* (m)	Roots, Leaves	Pounding	O, S	1	0.29	Tree
Musaceae	*Musa paradisiaca* L. (AJD 059)	*Oguèdè Igbo* (h,y)	Fruits, Roots	Incineration, Maceration, Pounding	O, Ap	5	1.47	Herb
Myrtaceae	*Psidium guajava* L. (AJD 060)	*kekluman* (a)	Leaves, Roots	Decoction, Mastication	Ap, O	1	0.29	Tree
Nymphaeaceae	*Nymphaea lotus* L. (ADJ 116)	*Tofla, Tokago* (t)	Leaves	Pounding	Ap	1	0.29	Herb
Onagraceae	*Ludwigia octovalvis* (Jacq.) P.H. Raven (ADJ 117)	*Ewouro odo* (h)	Leaves	Maceration	O, Ap	1	0.29	Herb
Pedaliaceae	*Sesamum indicum* L. (AJD 061)	*Agbonan* (f)	Leaves	Pounding	S,O	1	0.29	Herb
Poaceae	*Imperata cylindrica* (L.) Raeusch. (ADJ 118)	*Ebé* (a)	Leaves		Ap	4	1.18	Herb
	Pennisetum sieberianus (Schltdl.) Verloove (AJD 063)	*Gnocarica* (be), *Haanibii* (d)	Leaves, Regime	Pounding, Decoction, Trituration	O, Ap	6	1.77	Herb
Polygalaceae	*Carpolobia lutea* G. Don (ADJ 119)	*Oshun* (h)	Roots	Maceration	O, Ap	1	0.29	Tree
	Securidaca longepedunculata Fresen. (AJD 064)	*Kpatalè* (i), *Ikpata* (n), *wotiro, Sonnu alé* (ba),*wapohbou* (na), *Poulca* (be)	Roots	Pounding, Maceration, Decoction, Vegetable brush	O, Ap	104	30.68	Shrub
Portulacaceae	*Talinum triangulare* (Jacq.) Willd. (ADJ 120)	*Glazouï* (a)	Leaves	Trituration	O	1	0.29	Herb
Primulaceae	*Portulaca oleracea* L. (ADJ 121)	*Flatokoui* (a)	Leaves, Roots	Maceration, Decoction	O, Ap	3	0.88	Herb
Rutaceae	*Citrus limon* (L.) Osbeck (ADJ 122)	*Ogolotangni werewere* (n), *Gbodohounshi* (a), *Yovozin gbodokle* (f,m)	Fruits, Leaves	Decoction, Trituration	O, Ap	12	3.54	Shrub
Sapindaceae	*Blighia sapida* K.D. Koenig (AJD 068)	*Ishin/Ishin ko* (y,n), *lissè* (f, m), *Peryou* (ym)	Roots, Bark, Fruits	Pounding, Decoction, Incineration	O, Ap	10	2.95	Tree
	Paullinia pinnata L. (AJD 069)	*Attinchè* (m), *Eyikan* (a)	Roots, Bark, Leaves	Pounding, Decoction	Ap, O	6	1.77	Liana

Sapotaceae	*Vitellaria paradoxa* C.F. Gaertn. (AJD 070)	*Emi* (i), *Kolo* (p), *Saflatahou (w), Somougou* (l)*, Tamouya* (ym)	Roots, Resin, Bark, Leaves	Pounding, Incineration, Decoction	Ap, O	23	6.78	Tree
Smilacaceae	*Heteranthera callifolia* Rchb. ex Kunth (ADJ 123)	*Dlo*(t)	Leaves	Decoction	O	2	0.59	Herb
Solanaceae	*Capsicum annuum* L. (AJD 124)	*Dametakin* (f,m)	Fruits	Pounding	S	2	0.59	Herb
	Nicotiana tabacum L. (AJD 071)	*Taba* (n,f)	Leaves, Fruits	Incineration, Pounding	S, O	8	2.36	Herb
Sterculiaceae	*Cola acuminate* (P. Beauv.) Schott & Endl. (AJD 125)	*Obi* (y,n)	Fruits, Leaves, Roots	Decoction, Pounding	Ap, O	2	0.59	Tree
	Cola nitida (Vent.) Schott & Endl. (AJD 126)	*Golo* (az)	Fruits	Pounding, Maceration	Ap, O	2	0.59	Tree
	Waltheria indica L. (AJD 127)	*Louwaci* (a)	Leaves	Pounding	O	1	0.29	Herb
Verbenaceae	*Vitex doniana* Sweet (AJD 128)	*Ori* (i), *Konankou* (d), *Fontin* (f, m)	Bark, Roots, Leaves	Decoction, Maceration	Ap, O	12	3.54	Tree
Vitaceae	*Cissus populnea* Guill. & Perr. (AJD 129)	*Tchokoungbolo* (n)	Roots, Leaves	Decoction	Ap, O	1	0.29	Liana
Zingiberaceae	*Aframomum melegueta* K. Schum. (AJD 073)	*Ataré* (y,n), *Atakoun* (f,m), *takou* (a)	Fruits, Seeds	Pounding, Incineration	S, Ap, O	13	3.83	Herb
	Zingiber officinale Roscoe (AJD 130)	*Atalè* (h)	Rhizome	Pounding	Ap	1	0.29	Herb
Zygophyllaceae	*Balanites aegyptiaca* (L.) Delile (AJD 074)	*Kpanakparou* (ba), *Garbè* (ym)	Bark, Roots, Leaves	Decoction, Maceration	O, Ap	4	1.18	Tree

Method of administration: Ap= Local application, O= Oral Application, S= Scarification
Local language: a =Adja, az =Aïzo, ba =Bariba, be=Berba, d =Dendi, f =Fon, h =Holli, i =Idaatcha, l =Lokpa, m =Mahi, n=Nagot, na =Nateni, p =Peulh, t =Toffin, w =waama, ym =Yom, y=Yorouba

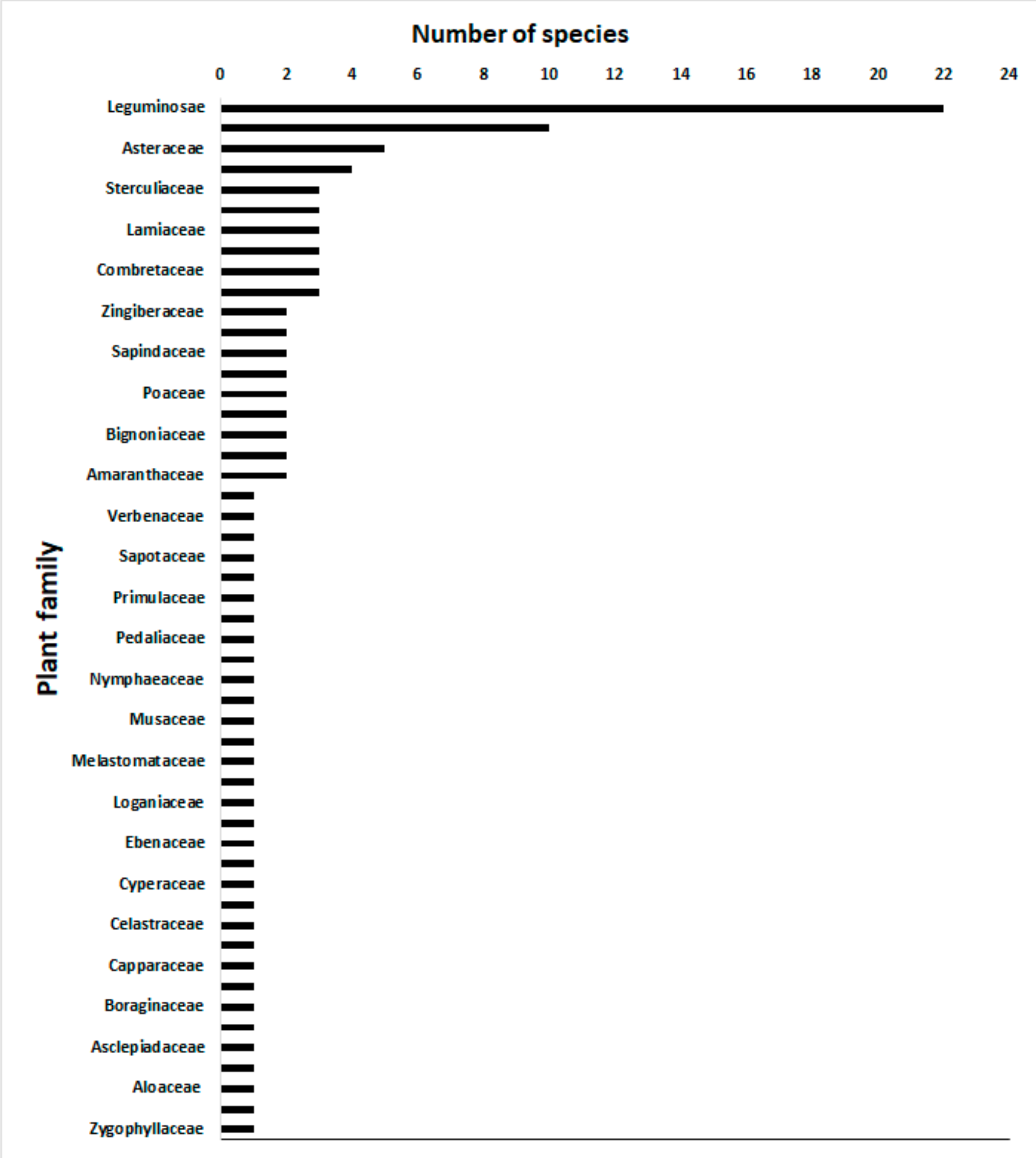

Figure 2. Dominant families of anti-snake venoms plants from Benin.

About 38.53% of species were herbs followed by shrubs (29.36%) (Fig. 3). These plants were harvested by local communities mainly in savannas (34.5%) and fallows (23.39%) while only 13% of these species were harvested in forests (Fig. 4).

Analysis of the raw phytogeographic spectrum shows that Pantropical species were the most represented in the antivenom flora of rural communities in Benin (Fig. 5). Sudanian, Afrotropical and Guineo-Congolian species followed. The weighted spectrum measured against relative dominance index, however, indicates a clear dominance of Guineo-Congolian species, followed by Pantropical, Paleotropical and Sudanian species. Overall, we noted a strong representativeness of native flora. Species with distribution quite influenced by human movements (Cosmopolitan and Pantropical) represented only 23 to 30% depending on whether the spectrum considered is weighted or raw.

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Figure 3. Life forms of anti-snake venoms plants in Benin.

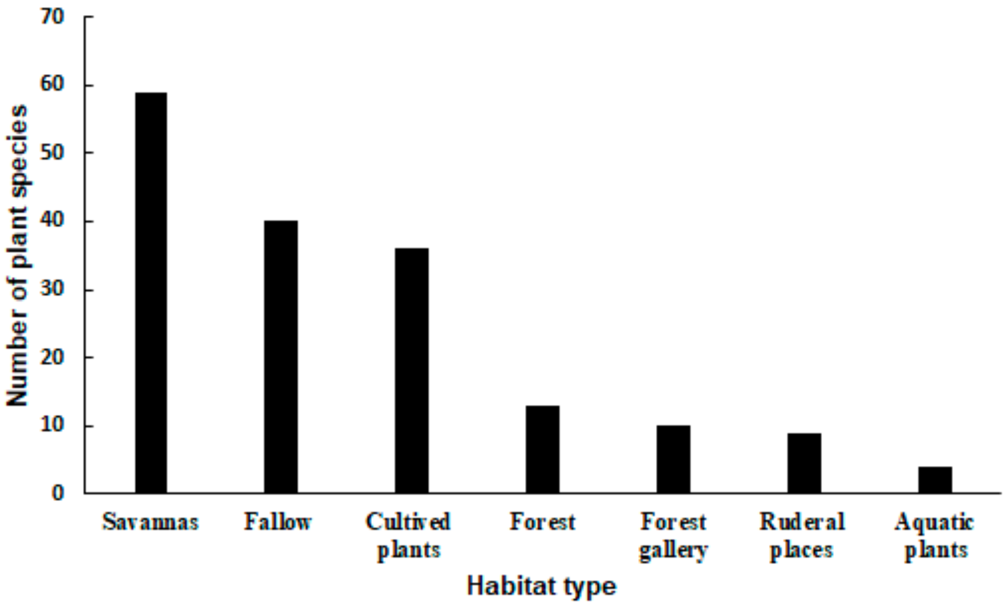

Figure 4. Habitats of anti-snake venoms plants in Benin.

Parts used, method of preparation and administration of anti-venom plants

Roots (37.52%) and leaves (35.63%) were the parts of plants most used by traditional healers and hunters in the preparation of remedies against snakebite envenomation (Fig. 6). On the other hand, sap, fruits, seeds, bulbs, rhizomes, flowers were less frequently used.

Different methods of medicine preparations were used by local communities. Pounding (fresh or dry) and decoction of plant parts were the most frequently used method of preparation of antivenom remedies in Benin (Fig. 7). Oral was the main reported route of administration followed by topical application (Fig. 8). Herbal bath was the least reported route.

The ingredients associated with the preparation of anti-venom remedies

Antivenom remedies were prepared using a single plant part or a mixture of several plant parts or even sometimes a mixture of two or more different plant species. Apart from plant parts, several elements were also used in antivenom remedies preparation in Benin (Table 3). These include, among others, parts of animals, the most frequently cited of which were entire viper (preferably the one that has bitten), viper head, and snake molt. Added to this is the almost systematic use of *Aframomum melegueta* K. Schum in reported herbal remedies. Reported antivenom remedies included some versatile species well known in the handling of others health issues such as *Picralima nitida* (Stapf) T. Durand & H. Durand, *Xylopia aethiopica* (Dunal) A.Rich., *Syzygium guineense* (Willd.) DC., *Monodora mystica* (Gaertn.) Dunal.

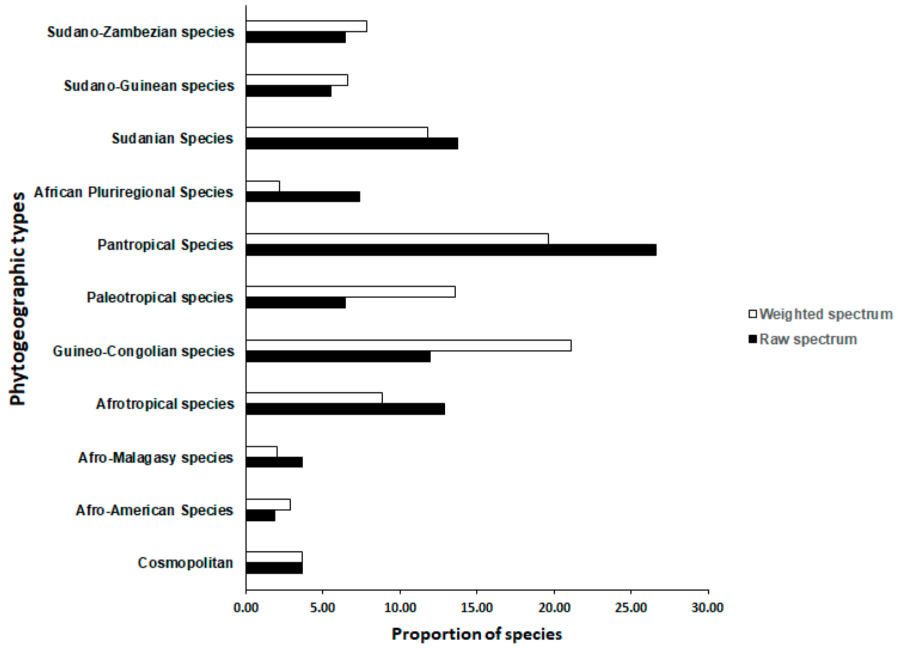

Figure 5. Distribution of anti-snake venoms plants according to phytogeographic types.

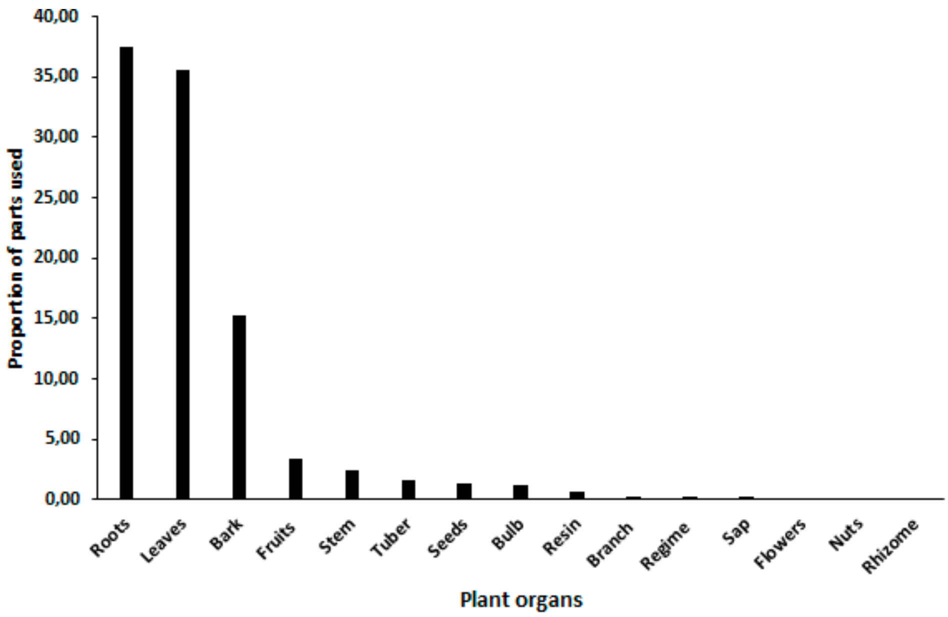

Figure 6. Plants parts used in preparation of anti-snake venom remedies in Benin.

The ingredients associated with the preparation of anti-venom remedies

Acquisition and transfer of knowledge on antivenom remedies

As a rule of thumb in these traditions, orality is the major way of knowledge transmission. Logic dictates that it is not possible to share or transfer endogenous knowledge to someone unless they have a little wisdom. This transmission of knowledge was reported to take place through different modes. In this study, 82% of our respondents reported having acquired their knowledge from their parents and/or grandparents, 15% acquired it by learning from non-relative traditional experts. Yet, 2% reported that they acquired knowledge on snakebites treatments by dream and 1% by geniuses or by intuition (Fig. 9).

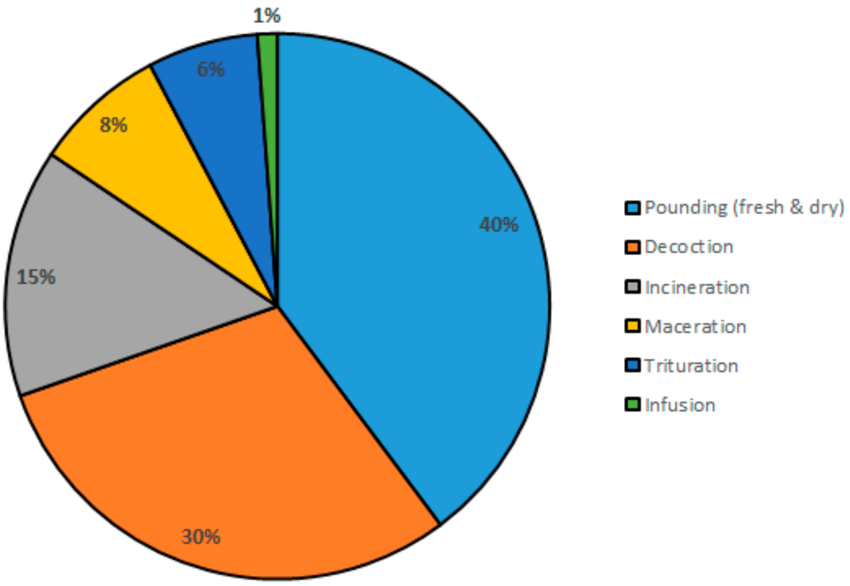

Figure 7. Methods of preparation anti-snake venom remedies in Benin.

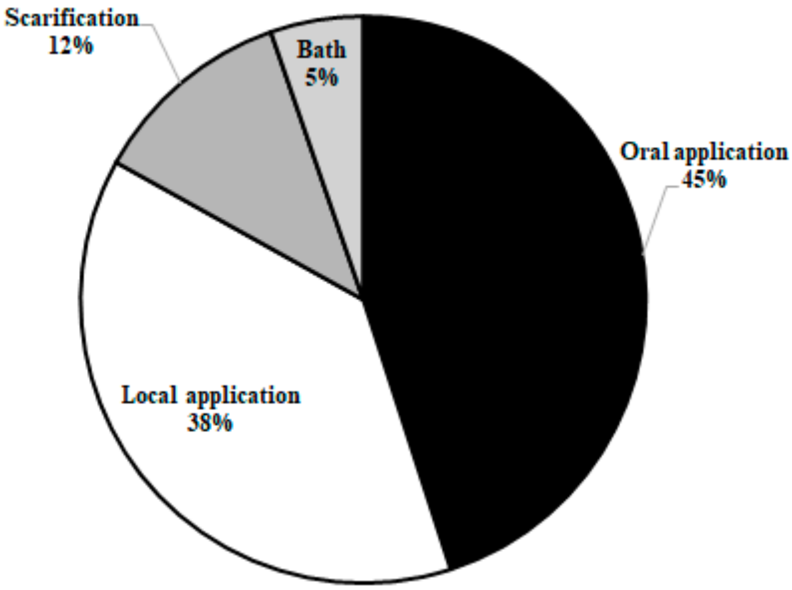

Figure 8. Mode of application of anti-snake venom remedies in Benin.

Table 3. Complementary ingredients of anti-snake venom remedies

Animal parts	Viper, Viper Head, Snake Moult, Bee, Ox Bile, Turtle, Chameleon, Toad, Snail, Rooster, Red Daisies, Doe Horn, Dog Bones, Rat
Food supplements	Palm wine, Lemon juice, Honey, Red oil, shea butter, Sodabi
Mineral and similar elements	Stone, Salt, Alôme, Kanhoun akô (local potash), Sea water
Spices	*Aframomum melegueta* K. Schum, *Picralima nitida* (Stapf) T. Durand & H. Durand, *Xylopia aethiopica* (Dunal) A. Rich., *Syzygium guineense* (Willd.) DC. , *Monodora mystica* (Gaertn.)
Other	Black soap

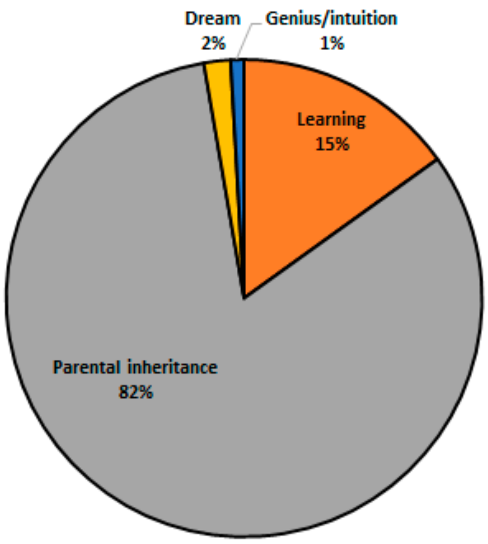

Figure 9. Methods of acquiring and transferring endogenous knowledge on the anti-snake venom treatment in Benin.

Myths around the use of antivenom plants

Preparation of the remedies for snakebites envenomation treatment requires some special measures often taken by traditional healers. Myths and taboos surrounding the use of herbs in the treatment of snakebite envenomation are diverse and were reported to be critically important to the success of the recipes. Most respondents consented to the use of incantatory words and rituals to consolidate and ensure the effectiveness of the remedy. Harvest of some plants parts and preparation of some remedies at late hours of the night (midnight), or very early in morning (4h or 5h in morning) prior to breaking fast (not even a chewing stick) and before talking to anyone, was reported. In addition, the number of scarifications to make varied according to the sex of patient: seven (for women) and nine (for men).

Threats and endogenous conservation strategies

Plant species used in the treatment of snakebite envenomation, like many species, experience tremendous anthropogenic pressures that reduce their chance of survival. Expansion of agricultural land, wildland fires and urbanization were in descending order of factors reported likely to contribute to extirpation or reduction of populations of anti-snake venom plants (Fig. 10). Lack of planting and climate change were perceived to affect plants used in snakebite envenomation treatment to a lesser extent.

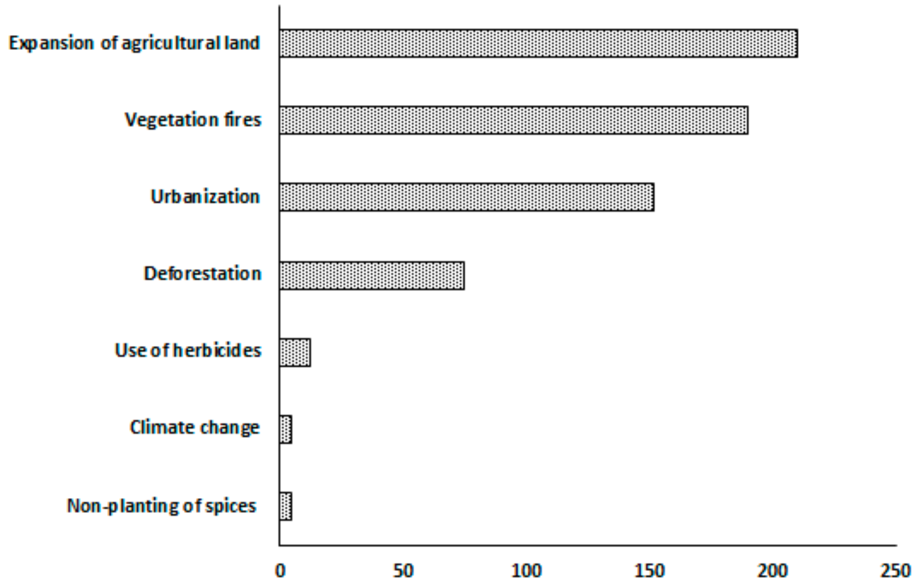

Figure 10. Threats to species used in the treatment of snakebites in Benin.

To deal with these threats, local communities use various conservation strategies. The drying-pounding of plant species is the conservation strategy most used by informants (48%), followed by cultivation of plants in home gardens (36%). Some plants are spared in fields and others are sacred. In addition, most traditional healers have home gardens in which the most important or most difficult to obtain plant species are cultivated (Fig. 11).

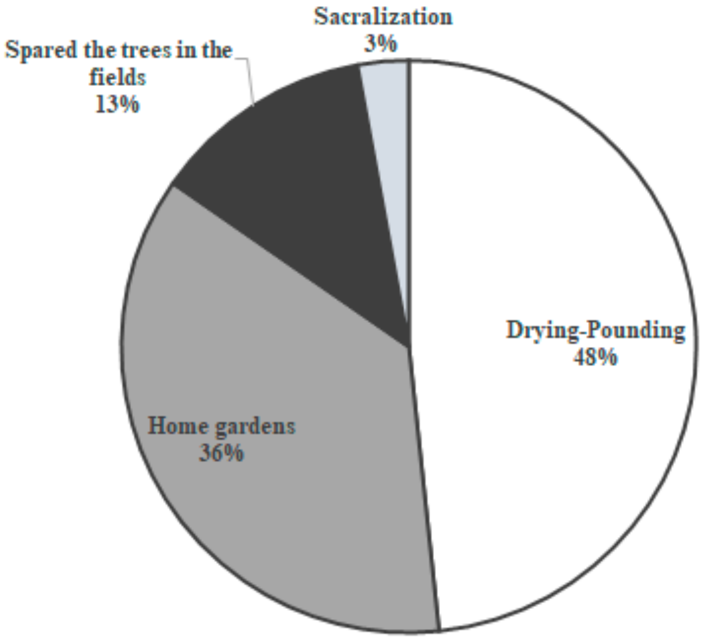

Figure 11. Conservation strategies of anti- snake venom plants in Benin.

Discussion

This study gathered knowledge of rural communities from different socio-cultural groups in Benin on traditional remedies involving the use of medicinal plants in snakebite envenomation treatment. The surveyed groups were male-biased because of scarcity of female respondents in the target professional categories (healers and hunters). In Beninese cultures indeed, women hardly ever go hunting and very few of them engage in traditional medicine as a profession. The few who inherit or develop expertise in healthcare mostly deal with female and childish ailments (infant care, malaria, hypertension, sterility, hemorrhoids, etc.). The latter are also often old, experienced and conservative, which explains why female respondents were more than 50 years old. More than 50% of our respondents were also at least fifty years old. This age bias is associated with the sampling scheme, which prioritized people with proven experience in the treatment of snakebite envenomation, not mentioning that the treatment of this kind of ailments can sometimes require occult fights if they are not natural. Rural communities often do not perceive snakebites as resulting from opportunistic and random coincidence encounter with snakes. Rather, mostly, they perceive this as the result of a malicious act orchestrated by an enemy or an evil power. This is what explains the almost systematic recourse of victims to traditional healers. This study identified 109 species belonging to 51 families, of which *Annona senegalensis*, *Securidaca longepedunculata*, *Piliostigma thonningii*, *Parkia biglobosa*, *Tamarindus indica* are the most cited. The Leguminosae, Euphorbiaceae, Asteraceae, Annonaceae are the most represented botanical families. The Leguminosae family presents an impressive plant diversity and a very wide distribution in the study area. This may justify its availability and its seemingly preferable use by communities (Kadir et al. 2015). In Various studies have previously mentioned most reported species and families in other geographic regions of the world as having anti-ophidic potency. Consistency of use of a given family or species over several regions for similar purpose may indicate richness in secondary metabolites proven to be effective among surveyed communities. The species listed are mainly herbs and shrubs collected from savannas and fallow lands. On the one hand, many previous studies have mentioned herbs as the most used in the treatment of snakebite envenomation, as they occupy a prominent place in many traditional health care systems (Butt et al. 2015, Okot et al. 2020). The widespread use of herbs in treatment of ailments by local communities may be linked to the extensive diversity and inexpensive accessibility of herbaceous plants in their environment (Uniyal et al. 2006). On the other hand, their presence in open plant formations (savannahs and fallow land) which are close to homes, best explains their accessibility and availability to communities. The great representativeness of Guineo-Congolian, Sudanian, and Afrotropical species suggests an excellent knowledge of native flora by socio-cultural groups surveyed, which are among the oldest in the study environment; their arrival in the environment dates back to he tperiod between the 15^{th} and 17^{th} centuries (Pliya 1989, Guingnido 1992). These results are congruent with the availability hypothesis which states that use of plants to solve health problems depends on their accessibility and local abundance (Albuquerque 2006, Voeks 2004). The Remarkable presence of Pantropical and Cosmopolitan species in the local antivenom flora also suggest an ability of indigenous peoples to integrate new knowledge acquired during migratory movements or intermixing with other peoples, as predicted by the diversification hypothesis. This hypothesis suggests that exotic plant species are selected to fill therapeutic gaps in a traditional pharmacopoeia, thus diversifying the set of treatment options (Albuquerque 2006, Alencar et al. 2010, 2014). The quest for new knowledge on newly introduced or discovered taxa can also lead people to test their medicinal powers on different health problems, as stipulated by the hypothesis of the multiplicity of uses of each plant (Alencar et al. 2010, Bennett & Prance 2000).

Part of the plant and extraction solvent are likely to influence active substances extraction, its effectiveness, and its toxicity (Yirgu & Chippaux 2019). The dominant use of roots in antivenom remedies preparation is thought to be due to the capacity of roots to concentrate active principle of the plant (Kunwar et al. 2006, Phumthum et al. 2018). Roots also can maintain bioactive compounds long after harvest (Phumthum et al. 2018). For this purpose, they can be stored and used later in periods of long droughts or difficult environmental conditions when fresh plant material is not available (Nankaya et al. 2020). Local communities may have empirically noticed these scientific observations. However, intense harvesting of roots can lead to severe damage or compromise survival of plants unlike leaves that are not only more accessible and whose harvest is less dangerous, but they also constitute the photosynthesis seat and therefore an important source of bioactives compounds (Butt et al. 2015). In searching for effectiveness of antivenom remedies, a single plant part or several plant parts are used. In addition, there are other ingredients, including animal parts and mainly snake parts. For healers, these additives make the remedy more effective. They explain the preference for viper by the fact that it is one of the most venomous snakes and in that sense, the presence of its bioactive compounds in remedies would neutralize the venom of any snake. Researchers have so far poorly explored scientific evidence for these perceptions. It is however likely that some placebo effects are at play in these recipes. Frequent use of *Aframomum melegueta* in almost all remedies may have to do with the medical and magical power attributed to that species across culture. Most of the respondents inherited their snakebites envenomation treatment related knowledge from their parents and grandparents. Transmission of specific knowledge of traditional medicine in local cultures is often kept within close lineages. As such, some families are known for holding expertise to handle specific ailments.

Finally, it is perceived that expansion of farmlands, wild bush fires and urbanization are major threats to the survival of plants used in snakebite envenomation treatment. Conservation actions focusing popularizing knowledge on these plants, integrating them into formal conservation strategies and restoring home gardens of traditional healers could limits the negative effect of reported threats.

Future prospects

With enthusiasm of rural communities in Benin for traditional medicine and based on their wealth of knowledge on medicinal plants use in snakebites envenomation treatment, health authorities of Benin should work resolutely to integrate traditional treatment in the public health system to address issue of onerous cost of treatment and to help reduce mortality from snakebite envenomation. This ambition requires basic scientific work on composition of bioactive substances and efficacy test of these plants through phytochemical screening of different plant organs, to avoid intense use of their roots and toxicity side effects. It would also be appropriate in the current context of galloping demography and climate change to undertake studies on potential impact of global change on distribution of antiophidic plants most used by local communities.

Conclusion

Medicinal plants are an alternative widely used by people in rural areas of developing countries where snakebite envenomation is common. This study highlighted the major role of herbal medicine in the treatment of snakebites envenomation in Benin. It emerges that local communities use a range of medicinal plants to treat envenomation by snakes. To best contribute to the well-being of these communities through quality medicinal plant-based care, it is imperative to evaluate phytochemical constituents of most widely used plants to ensure their effectiveness in snakebites treatment and control toxicity side effects.

Declarations

Ethical approval and participant consent: All participants gave their prior consent before the interviews after clearly explaining the objectives of the study to them.

Availability of data and materials: Data is available from the corresponding author.

Consent to publication: Not applicable

Conflict of Interest: The authors declare that they do not have a conflict of interest.

Funding: This study was funded by research fund of Doctoral Student Support Program (PAD) of Benin government received by Ayékotchami Jacques Dossou. This fund enabled collection, processing, and analysis of data.

Contributions from the authors: Ayékotchami Jacques Dossou and Adandé Belarmain Fandohan conceptualized and defined the subject of the manuscript, methodology of data collection and analysis. Ayékotchami Jacques Dossou took care of data collection in the field, data processing and analysis. He also wrote the draft manuscript. Adandé Belarmain Fandohan read, corrected, and approved the final version of the manuscript. He oversaw all the work as a whole. Agossou Bruno Djossa and Ephrem Achille Assogbadjo read, corrected, and approved the final version of the manuscript.

Acknowledgments

We thank the Government of Benin's Doctoral Support Program (PAD) for its financial support and Mr. Abel Henrick AKPOVO and Mr. Gabin GANKA for their technical support in carrying out this study.

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