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Plant and natural product based homemade remedies for veterinary uses by the Peul community in Benin

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ABSTRACT

Ethnopharmacological relevance: Across Africa, Peul community typically rely on plant-based veterinary knowledge to manage common livestock health problems. Unfortunately, their nomadic life-style being affected by conflicts, land tenure constraints, and drought, they have been shifting to a sedentary life. The process of their settlement led to the erosion of the vast ethnoveterinary skills they had acquired over centuries and forced them to replace the plant and other species they used by commercial products.

Aim of the study: 1) To collect comprehensive data from the Benin Peul community on common plant-based remedies used to treat livestock diseases and document their preparation and administration. 2) To evaluate the differences and consensus among the Peul community across ecological regions in Benin.

Materials and methods: We conducted semi-structured interviews among 88 Peul camps, three (03) bioclimatic zones, and 225 transhumant dialog partners, including agro-pastoralists, healers and pastoralists from mid-July to end of December 2015. Detailed information about homemade herbal remedies (plant species, plant part, manufacturing process) and the corresponding use reports (target animal species, category of use and route of administration) was collected.

Results: A total of 418 homemade remedies were reported, of which 235 involved only one plant species (Homemade Single Species Herbal Remedy Reports; HSHR). Information on a total of 310 use reports (UR) were mentioned for the 235 HSHR, and they included 116 plant species belonging to 39 botanical families. Among them, 229 UR were indicated for cattle, 43 UR for poultry, and 38 UR for sheep and goats. The most cited plant species were *Khaya senegalensis* (19 HSHR; 8.08%), *Parkia biglobosa* (14 HSHR; 5.95%), *Euphorbia unispina* (11 HSHR; 4.68%), and *Anogeissus leiocarpus* (6 HSHR; 2.55%). The URs were indicated for the treatment of viral, parasitic and bacterial diseases but also for multifactorial disorders like diarrhoea, fever, threatened abortion, agalactia etc. The number of plants referred to HSHR decreased from Sudanian to Guineo-congolian zones in concordance with the presence of Peuls.

Conclusion: The Peul community holds a huge ethnoveterinary knowledge, which needs to be documented, valorised, and promoted. It appears vital to assess phytochemical and pharmacological properties of the most reported species, and their availability across the ecological zones in order to ensure their sustainable use and before this indigenous knowledge disappears completely.

1. Introduction

Worldwide, livestock farming contributes to the livelihood of farmers and herders by generating jobs in rural and urban areas and increasing the availability of affordably-priced meat. It involves high numbers of people with livestock farming as their main occupation in various parts of the world. It also provides unprecedented opportunities for sustainable development of the economy of many countries. The relative contribution of livestock farming to the gross domestic production (GDP) is greatest in developing regions, with the highest proportion being in Africa. In their study about the future of livestock farming, Herrero et al. (2014) demonstrated that Africa is the continent

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where “sustainable intensification” of agriculture and livestock systems could yield the most significant benefits for food security, incomes, trade, smallholder competitiveness, and ecosystems services. Unfortunately, this intensification is negatively affected by a high number of factors notably the poor performance of local breeds, the deficiency or poor quality of foods for livestock, the conflicts over pasture land, the recurrent occurrence of diseases, the prevalence of many endemic infectious diseases, the risks of reappearance of some epizootic diseases, the poor prophylaxis, and the deficiency of veterinary care in rural areas (FAO, 2012a). As the Intermediate Technology Development Group and the International Institute of Rural Reconstruction (ITDG and IIRR, 1996) demonstrated at Kenya and Ouachinou et al. (2019) reported from Benin, diseases remain the factor that most negatively affects production. For instance, in the Republic of Benin, domestic animals continue to pay a heavy tribute to various pathologies despite the importation of veterinary drugs at highly competitive prices, so that each year, poultry, small and large ruminants, pork, rabbits and other animal species are under threats according to the Benin Stock Farming Service, the “Direction de l’Elevage (DE)" (DE, 2010). Thus, animal diseases such as the “peste de petits ruminants (PPR)", foot-and-mouth disease, repeated abortions, African swine fever and several viral diseases particularly in poultry pose a real problem to livestock rearing in the Republic of Benin.

Regarding disease management, modern veterinary inputs and services are not often available and they are either too difficult to obtain or too expensive for poor and marginal breeders (ITDG and IIRR, 1996). Under these conditions, for most people living in rural zones in Africa, the use of plant-based remedies in the treatment of animal ailments is the backbone of the primary health care (Wanzala et al., 2005). Breeders, being in permanent contact with animals, accumulate experiences in ethnoveterinary skills, which enable them to control diseases, production, and reproduction of livestock. Thus, each socio-cultural or ethnic group develops and developed a set of traditional medicinal recipes, which is orally handed down through generations. For several authors (Mathias-Mundy and McCorkle, 1989; Bâ, 1994; Tamboura et al., 1998), veterinary ethno-medecine for cattle and small ruminants is considered a speciality of the Peul community. This influence of plant knowledge on ethno-veterinary practice has also been confirmed in Benin (Dassou et al., 2015a). In that study, the Peul ethnic group exhibited a larger veterinary knowledge than other ethnic groups such as Adja, Bariba, Dendi, Fon, Ottamari, Yoa-Lokpa and Yoruba. Among the 4.6 million heads (2,380,323 cattle and 2.5 million small ruminants) tallied by the national census in 2017, the Peul community own 95% (Dehoux and Hounsou-Vè, 1993; Chabi Toko, 2016). The remaining 5% are managed by other ethnics groups including Bariba, Ottamari and Monkolé, who are specialised in breeding of the cattle-zebus and goats (Houessou et al., 2019). The average size of the herd per Peul thereby ranged from 55 to 107 heads of cattle making the Peul the essential recipients of veterinary products (Lesse et al., 2015).

Peul are also called Fulbé (Pullo in the singular) or Fulani and Fufuldés. They are spread over the entire Sahelo-sudanian zone from Tchad, Central African Republic, Sudan and the Democratic Republic of Congo all across West Africa to Senegal (Stenning, 1957) and, their population in Africa has been estimated as 40 million people across sixteen countries (Leclerc, 2019). The Peul community is best represented in Guinea (4.9 million), Nigeria (16 million), Mali (2.7 million), Cameroon (2.9 million), Senegal (3.6 million), Niger (1.6 million), Burkina Faso (1.2 million), Mauritania 400,000), Guinea-Bissau (320,000), Gambia (3124,000), Benin (604,000) Chad (580,000), and Ivory Coast (423,000) (Leclerc, 2019). For Benin, the figure has been reported from the 2016 national housing census and the web edition of the “Ethnologue” (INSAE, 2016; Eberhard et al., 2019).

In Benin, the Peul community is almost always perceived as a group of immigrants, even if they have already lived in the country for a long time. In their encampments, the oldest person is considered as their leader (*pers. obser*). Over the centuries, the Peul have adopted three modes of life-style, namely nomadism, transhumance and settlement (Lobry, 2003); the two last forms being the most practiced nowadays. Transhumance had been adopted in the southern part of the Sahel zone between 1970 and 1980 mostly due to the effects of climate change (water and fodder shortage). This led to an intensification of movements in the entire subregion (FAO, 2012b; Salihou, 2016). During this period when the Peul communities were practicing cross-border transhumance, zebus, sheep and goats numerically dominated (FAO, 2012b; Salihou, 2016; Ima-Ouoba, 2018). Goats thereby were mainly useful for the Peul as odd resources for supplementing their own food with animal proteins.

From 1999 onward, herd movements have intensified, but also more problematic, due to cumulative factors such as: (1) increasing conflicts with native farmers, (2) difficult access to grazing land (Lesse, 2011; Zakari et al., 2015; Chabi Toko, 2016; Salihou, 2016), (3) land cleaning for agriculture (Akpo et al., 2002; Saliou et al., 2014; Diogo et al., 2017), (4) increase of herds, and (5) the emergence of certain pathologies. This led the Peul community to adopt a settled life-style in encampments, initially far from host villages, but nowadays often near native people (*pers. obser.*). In this new lifestyle, animal husbandry is often associated with small-scale farming or even commercial activities (Lesse et al., 2015; Salihou, 2016). The herds are entrusted to young people who look after and feed the cattle. The pastures near the camps are continuously overexploited. Crop residues thereby are an important fodder, even if they do not compensate for the restrictions imposed by the settling process. Children are assigned to drive herds on short to medium distances, while they go along with their fathers in case of herding over long distances (*pers. obser.*). Thus, after having trained for a number of years, the apprentice will be granted the authority to perpetuate this management of herd grazing (Lesse, 2009). During this process, the trainees are also granted the authority to use a given recipe in case an ailment occurs. At the end of the process, these people will be regarded in the community as having mystical healing power as well as having the appropriate training to use medicinal plants. Thus, all Peul acquire a general indigenous knowledge of handling medicinal plants belonging to their native localities. These are used for first aid remedies, to treat different animal diseases.

The aim of this study was to: 1) collect comprehensive data from Benin Peul community about medicinal plant-based remedies commonly used to manage livestock diseases and to document their preparation and administration, and 2) evaluate the differences and consensus among Peul community across ecological regions.

2. Materials and methods

The study was conducted taking into account previously published ethno-veterinary studies (van den Eyden et al., 1993; Schmid et al., 2012; Dassou et al., 2014; Disler et al., 2014).

2.1. Study area description

The republic of Benin is located between 6°15′ and 12°25′N latitudes and 0°40′ and 3°45′ E longitudes in the Gulf of Guinea in West Africa and covers an area of 114,763 Km^2 (Fig. 1). It is bordered by the republics of Togo in the west, Nigeria in the east, Atlantic Ocean in the south with a coastline of 120 km, Burkina Faso and Niger in the north. The straight line distance from the Atlantic coastal line to the Niger River in the north is c. 700 Km. The mean annual rainfall varies from 900 in the southwest and in the far north to 1200 mm in the southeast and centre-west. The mean annual temperatures range from 24 to 29 °C and may exceptionally reach 35–40 °C in the far north. According to Akoègninou (2004), three bioclimatic zones (Fig. 1) can broadly be distinguished: Sudanian zone (SZ) in north, the Sudano-Guinean zone (SG) in the centre and the Guineo-Congolian zone (GC) in the south. Their climatic parameters are described in Table 1.

The Benin flora is estimated to include 2807 plant species

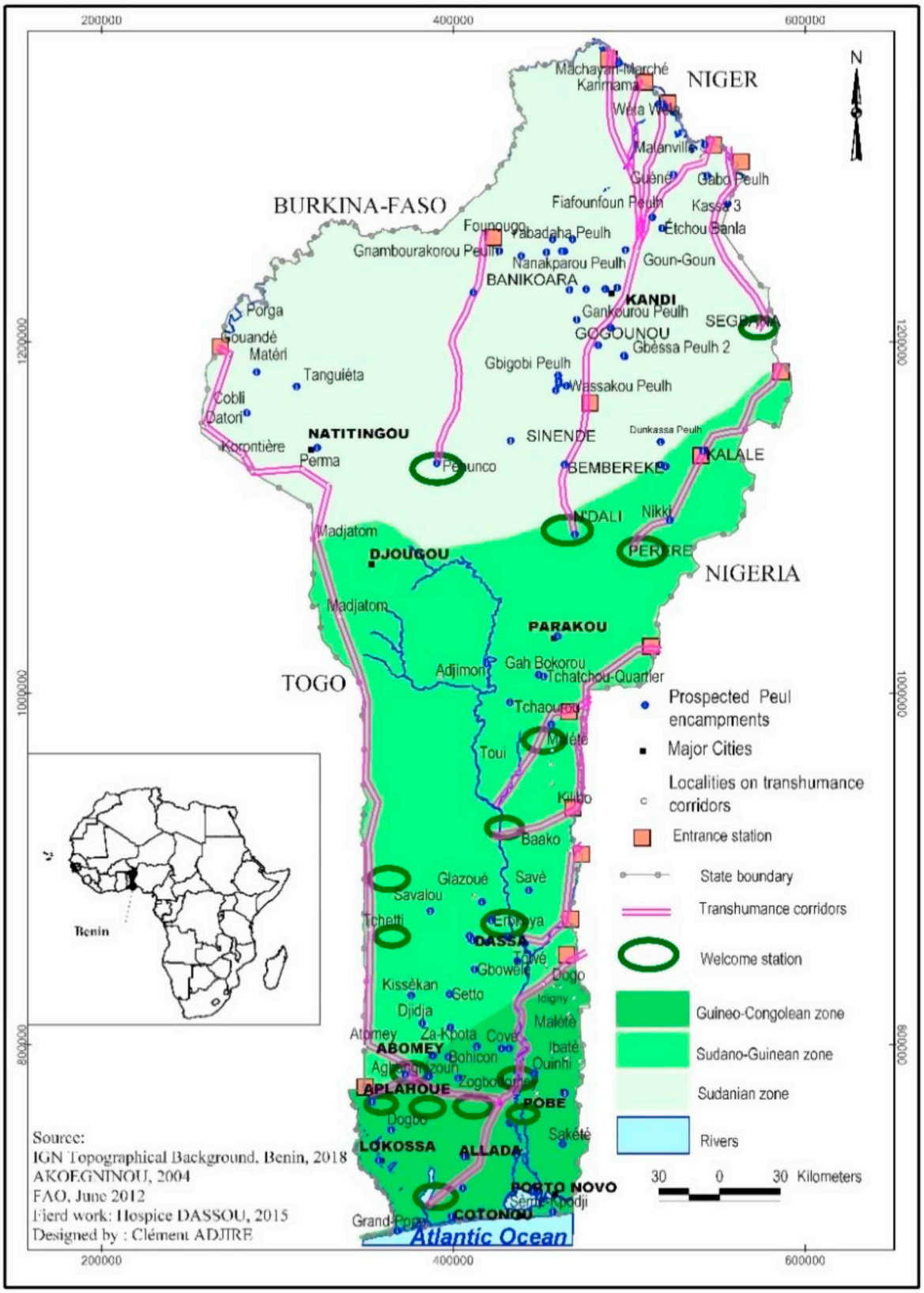

Fig. 1. Map of Benin showing the transhumance corridors and prospected Peul camps.

(Akoègninou et al., 2006). The vegetation is essentially made of secondary grasslands, thickets and patches of semi-deciduous and swamp forests in the south; the north being dominated by a patchwork of woodlands and savannahs with belts of riparian forests along rivers.

Among the three important cross-border transhumance corridors in West Africa, Benin belongs to Eastern zone implying movements across Niger, Burkina Faso, and Nigeria. According to FAO (2012b), border entry points of herds in Benin whatever the season are: 1) Malanville

Table 1
Characteristics of the three climatic zones (Akoègninou, 2004).

Climatic parameters	Sudanian Zone (SZ)	Sudano-Guinean zone (SG)	Guineo- Congolian Zone (GC)
Location	9°45′-12°25′ N	7°30′-9°45′ N	6°25′-7°30′ N
Rainfall regime	Unimodal	Unimodal	Bimodal
Rainfall (mm)	< 1000	900–1110	1200
Temperature (°C)	24–31	25–29	25–29
Relative humidity (%)	18–99	31–98	69–97
Climate type	Dry tropical or truly Sudanian	Humid tropical or subhumid or subsudanian	Guinean or subequatorial

when they come from Niger with Malanville-Bodjécali-Guéné-Goungoun-Angaradébou as transhumance route, 2) Porga for those coming from Burkina-Faso with Porga-Tanguiéta-Natitingou-Djougou-Bassila or Porga-Gouandé-Datori-Korontière-Boukoumbé-Perma-Majatom-Bassila as transhumance routes, 3) Atomey and Lanta: for those coming from Togo from the western side of the Mono River as transhumance route, and 4) Waria, Kaboua, Toui, Ilikimou and Gbanago for those coming from Nigeria with several transhumance routes, including Waria-Bukovo-Malete, Kaboua-Savè-Glazoué-Savalou-Tchetti, Toui-Kilibo-Djègbè, Ilikimou-Idigni-Iladji-Dogo, and Ibatè-Towé-Illolofin-Gbanago (Fig. 1). Once in Benin, the concentration areas of the transhumant cattle herds correspond to the end points of the transhumance routes (FAO, 2012b). Afterwards, cattle are sold in the six livestock market places, namely: Goumori, Founougo, Alibori (Municipality of Banikoara), Mamassi-Peul (Municipality of Karimama), Guéné (Municipality of Malanville) and Kérou (Municipality of Kérou) (Kperou Gado, 2006; FAO, 2012b).

The human population is estimated at 9,983,884 inhabitants (INSAE, 2013), which are distributed into 50 ethnic groups (Fig. 2). According to the INSAE (2013), the main ethnic groups are Fon (39%), Adja (15%), Yoruba (12%), Bariba (9%), Peul (7%), Ottamari (6%), Yoa-Lokpa (4%), Dendi (3%) and others (5%). Agriculture is the first source of income of the population (INSAE, 2013). It is followed by the stock farming dominated by bovine, caprine, ovine and poultry. Peul are the main owners of bovine herds.

2.2. Data collection

2.2.1. Ethics

The research protocol was approved by the Scientific Ethic Committee of the Doctoral School of Life and Earth Sciences of the Faculty of Sciences and Techniques (FAST) of the University of Abomey-Calavi (UAC) under the following referral code: N° 117-15/EDSVT/FAST/UAC. Afterwards, vulgarization workshops involving municipalities, the Agricultural Departments, Peul leaders and traditional healers were organized to direct the attention of the Peul community to the importance of animal pathologies and have their consent in view of a best implementation of the project. In each Peul encampment, consent was obtained before interviews.

2.2.2. Peul encampments and dialog partners (DPs)

At the end of each workshop (as stated above) in each bioclimatic zone, a list of Peul who practise transhumance and wish to become dialog partners (DPs) was established. Afterwards, in each municipality, with the help of a Technician in animal husbandry of the Agricultural Department and Peul leaders, these DP, after having spontaneously agreed to participate in this research, were contacted by phone. They were asked whether they knew other transhumant Peul who used ethno-veterinary knowledge including medicinal plants to treat livestock diseases. Thus, more DPs were recruited via a snowball sampling technique (Disler et al., 2014; Mertenat et al., 2020).

A total of 225 dialog partners participated in the study, of which 93 DP spontaneously wished to become DP while the remaining DPs were identified by snowball sampling. They were distributed over the bioclimatic zones as follows: 90 DPs (40%) in SZ, 70 DPs (31%) in SG and 65 DPs (29%) in GC. The investigations were performed across 88 Peul encampments distributed across 40 municipalities of the three bioclimatic zones. The prospected encampments were selected based on the size of livestock and the criteria defined by van den Eynden et al. (1993), namely: level of recognition in traditional medicinal practices, district-wide reputation or popularity in traditional medicine and exclusive or frequent uses of plant-based remedies in healthcare. All DPs were men among whom 223 were illiterate. Their age ranged from 40 to 83 years with an average age of 45 years. The majority (40%) was 50–59 years old. More than half of the DPs (51%) were agro-pastoralists while 39% and 10% were healers and pastoralists, respectively. Seventy-nine percent (79%) of DPs had more than 30 years of experience in pastoralism. About 80% of the DPs had less than 150 animal heads (cattle and goats). The majority of DPs (99%) adopted mixed treatments combining modern veterinary products with traditional herbal recipes to control diseases and symptoms affecting their livestock. For 214 DPs, ethno-veterinary knowledge originated from their own family.

2.2.3. Questionnaires and plant identification

The 225 semi-structured interviews were conducted by the two first authors (GHD and JMASO) from mid-July to end of December 2015. They were conducted in the mother tongue of the DPs using questionnaires in French in presence of a Peul translator (generally a Peul leader) who speaks French and a Technician in animal husbandry of the Agricultural Department who speaks Fulfuldé. The duration of each interview was 1–2 h, and the interviews were written down with the consent of the DP. Aspects of the questionnaire included: names of the plant species used to treat the disease of cattle and goats, illness and symptoms treated, plant parts used, methods of preparation and administration. Final data were entered into an excel database for each Peul, with his name, sex, age, the locality and climatic zone together with illnesses and symptoms treated, plants and plant parts used, methods of preparation, and the drug administration route.

We systematically made voucher herbarium specimens of every plant indicated by DPs. Most species were directly identified in the field using the Analytical Flora of Benin (Akoègninou et al., 2006). For others, identification was done with the help of botanists of the National Herbarium of Benin (HNB). The botanical nomenclature followed the Angiosperms Phylogeny Group (APG).

2.3. Data analysis

2.3.1. Definition of the applied ethno-veterinary units

The definitions followed those of earlier ethno-veterinary studies (Disler et al., 2014; Bischoff et al., 2016; Mayer et al., 2017; Mertenat et al., 2020).

Homemade remedy report (HR): The HR included [dialog partner] x [plant species or other natural product] x [plant part] x [manufacturing process to the finished product].

Use Report (UR): The UR consisted of [homemade remedy report] x [category of use] x [specification of use] x [animal species] x [administration procedure].

2.3.2. Categorizing illnesses and symptoms treated by Peul

The study was conducted along with a veterinarian doctor who helped identify the illness based on the pathognomy and the checklist of animal diseases provided by Mémento de l'Agronome (1993). For each pathology, we classified the diseases in relation to the causative agent (parasites, bacteria, and viruses). We considered metabolic diseases as any of the disorders that disrupt normal digestion or arise from mineral deficiency. We classified snake bites as nervous diseases. Multifactorial

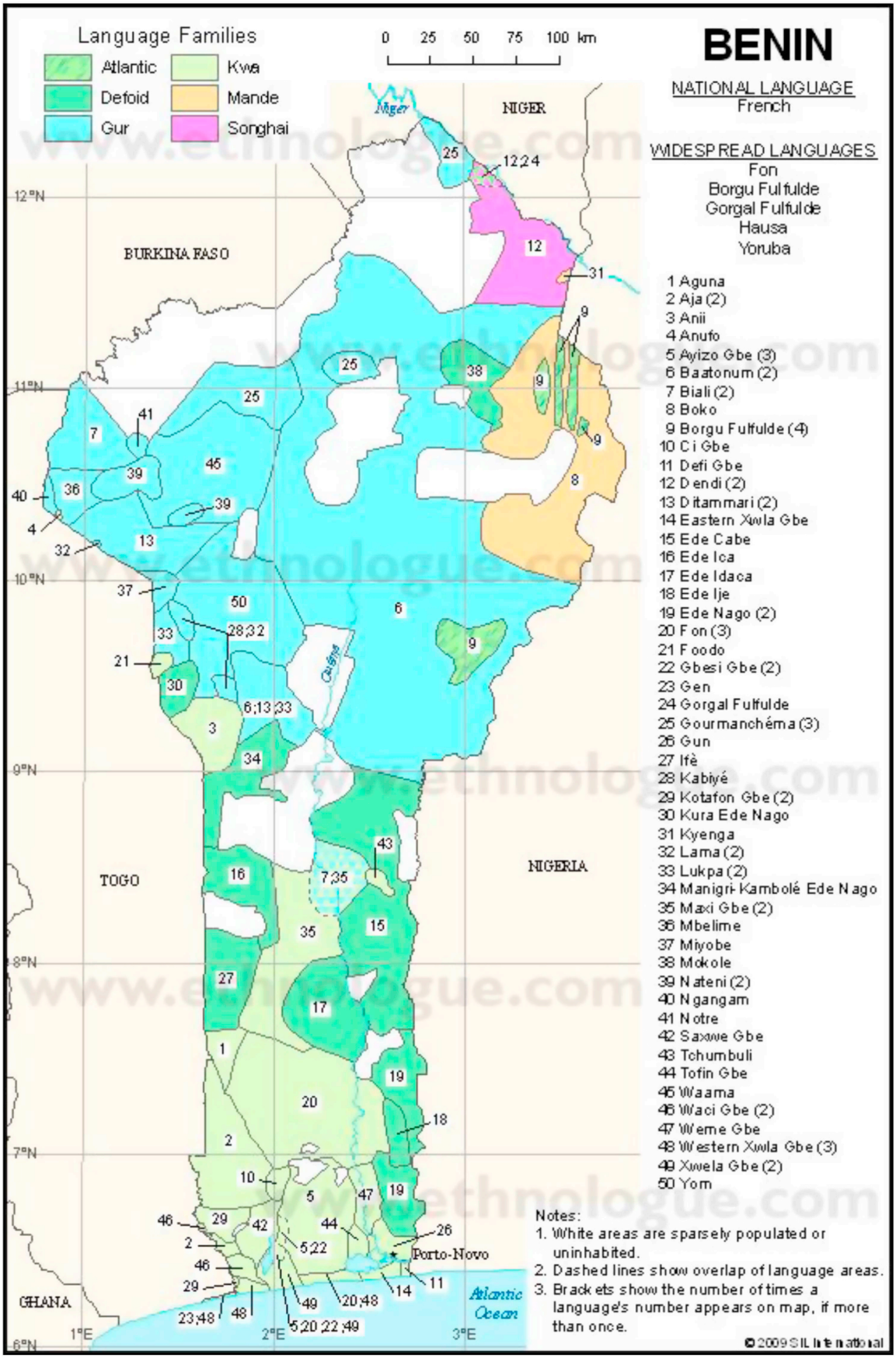

Fig. 2. Map of the ethnic groups of Benin.
(source: Leclerck (2019), http://www.ethnologue.com)

Table 2
Pathology categories and their main characteristics.

Pathological categories	Pathologies	Local names	Main symptoms (Sources)	Causative agents
Parasitic (PA)	Helminthiasis	Djalbi	Rebellious diarrhoea, inappetence, violent colic, slimming (Mémento de l'Agronome, 1993)	Helminths
	Ectoparasitosis	Gougnan	Pruritus, depilation, lesion (Mémento de l'Agronome, 1993)	Arthropods
	Trypanosomiasis	Maasso biguèrè	Intermittent fever, anaemia, lymphadenopathy and weight loss (http://www.cfsph.iastate.edu)	Trypanosome
	Piroplasmosis or bovine babesiosis	Kooti	High fever, anaemia, icterus, hemoglobinuria (http://www.cfsph.iastate.edu)	*Babesia* sp.
Bacterial (BA)	Brucellosis	Konèdjê	Recurring abortions (Mémento de l'Agronome, 1993)	*Brucella* sp.
	Blackleg	Pitè	Gangreneous tumors within the muscle mass (Mémento de l'Agronome, 1993)	*Clostridium chauvoei*
	Dermatophilosis	Bônan/Gougnan	Erythema, matting of the hair, fatal exudative dermatitis (Dalis et al., 2010)	*Dermatophilus congolensis*
	Bovine pasteurellosis	Hêirè	Septicemia (Mémento de l'Agronome, 1993)	*Pasteurella multocida*
	Bovine tuberculosis	Doyirou	Chronic cough (Mémento de l'Agronome, 1993)	*Mycobacterium tuberculosis*
	Contagious bovine peripneumonia (CBPP)	Otél/kouffé	Pleuropneumonia with Exsudation, cough, dyspnoea (Mémento de l'Agronome, 1993)	*Mycoplasma mycoides*
	Pietin (Panartium, foot rot or foul in the foot)	Kokonou	Swelling in the hoof, abscess, lameness (Mémento de l'Agronome, 1993)	*Fusiformis necrophorus*
	Conjunctivitis	Yanhou guitèl	Lacrimation, corneal ulcer formation, corneal opacity, loss of eye (Mémento de l'Agronome, 1993)	*Moraxella bovis*
	Mastitis	Gnanyou layè	Inflammation of the udder (Mémento de l'Agronome, 1993)	*Esherichia coli*
Viral (VI)	Foot and mouth disease	Tchaabou	Fever, vesicle - bullous rash on the palms, soles and aphthous ulcerations in the oral mucosa (Stanimirov and Gateva, 2016)	*Picornaviridae*
	Newcastle disease	Okôli/baaga	Respiratory distress, diarrhoea, nervous signs, and egg production drop (Sharif et al., 2010)	*Paramixoviridae*
	Pseudorinder- pest	Baali/Djaagaou/Gnibolé/Bourê hounnonko	Prodromal period of fever, depression, decreased appetite, decreased milk yield, congestion of mucous membranes, and serous ocular and nasal discharges, sudden death (http://www.cfsph.iastate.edu)	*Morbillivirus* sp.
Metabolic (ME)	Agalactia and Hypogalactia	Wala kosam	Absence or deficiency of milk production (Mémento de l'Agronome, 1993)	Chemical deficiency
	Grass tetany	Ladè	Frenzied behavior, muscle spasms and convulsions (Smith, 2013)	Magnesium Deficiency
Nervous (NE)	Snake bite	Bodi	Inflammation of the area	Venom
Multifactorial (MU)	Diarrhoea	Tcharol/Salti	Liquid or pasty feces	-
	Fever	Fowèrè	Hyperthermia	-
	Otitis	Nonyirou	Hyperthermia, pus, ear ache	-
	Abortion	Redou nantoowol	Pregnancy interruption	-

diseases were regarded as those triggered by a combination of causative agents (parasites, bacteria, and viruses). Thus, six pathological categories were distinguished (Table 2).

3. Results

A total of 418 homemade remedies (HR) were recorded during the 225 interviews. Each dialog partners (DP) cited 1–4 HR (1.88 ± 0.68). The values of UR (Use Report) per DP ranged from 1 to 4 (1.90 ± 0.78). The HR involved 125 plant species belonging to 99 genera and 39 botanical families. Among the 418 homemade remedies, 235 (56.22%) were homemade single species herbal remedy reports (HSHR), i.e. those homemade remedies involving only one plant species as active ingredient. Furthermore, 128 (30.62%) homemade remedies were mixtures of two 2–6 plant species. Fifty five homemade remedies contained added ingredients such as sugar, potassium, bovine urine, and milk.

3.1. Composition and manufacturing process of homemade single species herbal remedy reports (HSHR)

The 235 HSHR involved 116 different plant species belonging to 43 botanical families. Each plant family was represented by 1–26 plant species (Table 3). Species of the family Fabaceae were the most frequently used (60 HSHR, 25.53%), followed by Meliaceae (3 species, 22 HSHR, 9.36%), Combretaceae (12 species, 20 HSHR, 8.51%), Euphorbiaceae (5 species, 19 HSHR, 8.08%), Rubiaceae (5 species, 10 HSHR, 4.25%) and Poaceae (3 species, 10 HSHR, 4.25% (Table 3).

The most reported plant species were *Khaya senegalensis* (Desr.) A.Juss. (19 HSHR; 8.08%), followed by *Parkia biglobosa* (Jacq.) R.Br. ex Benth. (14 HSHR; 5.95%), *Euphorbia unispina* N.E.Br. (11 HSHR; 4.68%), *Anogeissus leiocarpus* (DC.) Guill. & Perr (6 HSHR; 2.55%), *Sorghum bicolor* (L.). Moench, and *Detarium microcarpum* Guill. & Perr. (5 HSHR each; 2.12% each).

The most frequently used plant parts were barks (82 HSHR, 34.89%) and leaves (71 HSHR, 30.21%), followed by roots (31 HSHR, 13.2%), fruits (25 HSHR, 10.63%), whole plant (11 HSHR, 4.7%), stems (7 HSHR, 2.98%), tubers (4 HSHR; 1.7%), bulbs (2 HSHR; 0.85%), leafy stems and seeds (1 HSHR each; 0.42% each).

By far the most of the HSHR (225, 95.74%; Table 3), were prepared using an on-farm extraction process. In 4.26% of the HSRH, the plant parts were directly administered *per os* without prior extraction or processing.

Thirty-one HSHR (13.19% of the total) comprised the natural products (Table 3). For 128 HSHR (54.46%), the drug used was an aqueous extract, either as maceration (47 HSRH; 20%), decoction (56 HSRH; 23.83%), trituration (14 HSRH; 6.95%) or infusion (11 HSHR; 4.68%). The other means of extraction included pounding, powdering, roasting, poultice and fumigation.

3.2. Use reports and categories

For the 235 HSHR, a total of 310 UR were described by the DPs. Most of them were for cattle (229 UR, 73.87%), followed by 43 (13.87%) UR for poultry, and 38 12.25%) UR for sheep and goats (Table 4).

The majority of the UR were cited for the treatment of multifactorial disorders (82; 26.45%), viral infections (71; 22.90%), parasitic diseases (55; 17.74%), and bacterial infections (48; 15.48%).

The most frequently reported plant species for the treatment of multifactorial disorders were *Khaya senegalensis* (Desr.) A.Juss. (9 UR; 10.97%), *Cussonia arborea* Hochst. ex A. Rich. (6 UR; 7.31%), *Spondias mombin* L. (5 UR; 6.09%), *Zea mays* L. (4 UR; 4.87%), *Chromolaena odorata (L.)* R.M.King, *Anogeissus leiocarpus* (DC.) Guill. & Perr. and *Parkia biglobosa* (Jacq.) R.Br. ex Benth. (3 UR each; 3.67% each). Species such as *Euphorbia unispina* N.E.Br. and *K. senegalensis* (9 UR each; 12.67% each), *Sorghum bicolor* (L.) Moench (8 UR; 11.26%), *Cissus quadrangularis* L. (5 UR), and *Parkia biglobosa* (Jacq.) R.Br. ex Benth. (5 UR; 7.04%) were most commonly used to treat viral diseases. For the treatment of parasitic diseases, *Pseudocedrela kotschyi* (Schweinf.) Harms., and *K. senegalensis* (5 UR each; 9.09% each), *Mitragyna inermis* (Willd.) Kuntze and *Asparagus flagellaris* (Kunth) Baker (4 UR each; 7.27% each) were those that were most frequently mentioned. For the treatment of bacterial infections, *K. senegalensis* (9 UR; 18.75%) and *Euphorbia unispina* (7 UR; 14.58%) were the most commonly cited plants.

3.3. Route of administration

Oral administration (274 UR, 88.38%) was most frequently used (Table 4), especially for the treatment of diseases such as helminthiasis, PPR (peste de petits ruminants), foot and mouth affections, and diarrhoeas. The plants were mainly administered as aqueous decoction or maceration. External applications were described for 34 UR (10.96%), especially for the treatment of dermatophilosis, ectoparasitosis, and wounds. Farmers used these HSRH as washes, compresses, or by topical application onto the skin of ointments, oils, tinctures, or fresh plants. Administration by instillation was described for one HSHR and one UR. One UR was also mentioned for the house environment to prevent cattle ectoparasitosis.

3.4. Spatial variation in plant citations and use reports

The number of plant species and UR varied across bioclimatic zones (Table 4; Fig. 3). Informants from the Sudanian zone cited a total of 73 plant species and 180 UR, followed by those of the Guineo-Congolian zone with 43 plant species and 74 UR. In the Sudano-Guinean transition zone, 39 plant species were described for 56 UR. A total of 61 plant species were exclusively reported from the Sudanian zone, 31 species from the Guineo-Congolian zone, and 27 species from the Sudano-Guinean transition zone. These species were associated to 103 UR, 43 UR and 33 UR, respectively. A total of 12 species turned out to be common to all three bioclimatic zones.

4. Discussion

Based on the information (pathognomonic symptoms) obtained from the dialog partners in the study area, with the help of the veterinarian and the Technician in Animal Production, diseases (and causative agents) were documented using the checklist of the diseases given by Mémento de l'Agronome (1993). The methodological approach is different from most of those followed by previous similar studies (Ayyanar and Ignacimuthu, 2005; Faruque et al., 2018). These authors used the body systems treated by a given remedy to define the use categories. Given that final goal of ethno-pharmacological studies is the evaluation of the biological activities of the plants, the methodology developed here appears to be innovative. However, the approach could have its limits, since it did not use the molecular tools to identify the causative agents.

4.1. Comparison with previous approaches

The present study is based on a national inventory covering the three ecological zones of Benin leading to the first large ethno-veterinary data set on the Peul community in Benin with 223 dialog partners (DPs) and 88 Peul encampments, compared to the only previous ethno-veterinary study on 37 encampments (Toïgbé, 1978). The methodology adopted here is based on recent recommendations for ethno-pharmacological studies (Heinrich et al., 2018; Weckerle et al., 2018). Duration and intensity of data collection are higher than in previous ethno-pharmacological studies (Stucki et al., 2019; Mertenat et al., 2020). The richness of plant species used for ethno-veterinary purposes by the Peul

Table 3
Extraction process in the 235 homemade single species herbal remedy reports (HSHR).

Botanical family (number of cited plant species in the family)	Plant species with ≥2 cited HSHR (Number indicate the frequency of mentioned 235 HSHR)	On-site extraction process										
		Additional products	None	MA	DE	IN	TR	PI	CA	PO	FU	RO	PO
Anacardiaceae (4)	All Anacardiaceae (6)												
	***Spondias mombin* L. (3)**												
	Leaves (3)		1		1								1
	***Mangifera indica* L. (1)**												
	Bark (1)	1			1								
	Other Anacardiaceae (2) [a]				1								1
Annonaceae (1)	***Annona senegalensis* Pers. (5)**												
	Roots (3)		1		1								1
	Bark (1)												1
	Leaves (1)			1									
Apocynaceae (4)	All Apocynaceae (5)												
	***Saba comorensis* (Boj.) Pichon (2)**												
	Stem (1)							1					
	Roots (1)							1					
	Other Apocynaceae (3) [b]			1	1			1					
Araliaceae (1)	***Cussonia arborea* Hochst. ex A. Rich. (4)**												
	Leaves (3)	1			1		1	1					
	Roots (1)			1									
Asclepiadaceae (1)	***Calotropis procera* (Aiton) W.T.Aiton (2)**												
	Leaves (2)				1	1							
Asparagaceae (2)	All Asparagaceae (4)												
	***Asparagus flagellaris* (Kunth) Baker (2)**												
	Leaves (1)			1									
	Tuber (1)			1									
	Others Asparagaceae (3)[o]												
	Leaves (3)				1	1		1					
Compositae (1)	***Chromolaena odorata* (L.) R.M.King (2)**												
	Roots (1)						1						
	Bark (1)						1						
Bignoniaceae (2)	All Bignoniaceae (3)												
	***Kigelia africana* (Lam.) Benth. (2)**												
	Bark (1)				1								
	Fruit (1)			1									
	Other Bignoniaceae (1) [c]												
Bombacaceae (3)	All Bombacaceae (6)												
	***Adansonia digitata* L. (3)**												
	Leaves (2)						1		1				
	Bark (1)									1			
	***Bombax costatum* Pellegr. & Vuillet (2)**												
	Leaves (1)		1										
	Bark (1)							1					
	Other Bombacaceae (1) [d]		1										
Combretaceae (12)	All Combretaceae (20)												
	***Anogeissus leiocarpa* (DC.) Guill. & Perr. (6)**												
	Leaves (3)				1		1	1					
	Bark (3)	1		1		1				1			
	***Terminalia mollis* M.A.Lawson (3)**												
	Roots (2)				2								
	Bark (1)				1								
	Other Combretaceae (11) [e]	2	1	2	5			3					
Euphorbiaceae (3)	All Euphorbiaceae (14)												
	***Euphorbia unispina* N.E.Br. (11)**												
	Whole plant (6)			2	2	2							
	Leaves (3)			1	1	1							
	Stem (2)			2	1		1	1					
	Other Euphorbiaceae (3)												
Phyllantaceae (2)	**All Phyllantaceae (4)**												
	***Bridelia ferruginea* Benth. (3)**												
	Bark (2)			1	1			1					
	Leaves (1)		1										
	Other Phyllantaceae (1) [f]	2		2			1			1			

(*continued on next page*)

Table 3 (*continued*)

Botanical family (number of cited plant species in the family)	Plant species with ≥2 cited HSHR (Number indicate the frequency of mentioned 235 HSHR)	On-site extraction process										
		Additional products	None	MA	DE	IN	TR	PI	CA	PO	FU	RO	PO
Fabaceae (26)	All Fabaceae (60)												
	***Parkia biglobosa* (Jacq.) R.Br. ex Benth. (14)**												
	Bark (7)	3		2	2			1		1			1
	Fruits (6)	2		2				2		2			
	Leaves (1)	1						1					
	***Detarium microcarpum* Guill. & Perr. (5)**												
	Bark (3)	1		1	1			1					
	Roots (1)							1					
	Leaves (1)	1						1					
	***Pseudocedrela kotschyi* (Schweinf.) Harms. (4)**												
	Bark (2)				1	1							
	Roots (2)				1	1							
	***Pterocarpus erinaceus* Poir. (5)**												
	Bark (3)	1		1	2								
	Leaves (2)				1					1			
	***Afzelia africana* Sm. (3)**												
	Bark (3)	2		1	1			1					
	***Entada africana* GuilI. & Perr. (4)**												
	Bark (2)			1	1								
	Roots (1)							1					
	Leaves (1)				1								
	***Acacia nilotica* (L.) Willd. (2)**												
	Fruit (1)			1									
	Bark (1)				1								
	***Pericopsis laxiflora* (Benth. ex Baker) Meeuwen (3)**												
	Bark (3)	1			1		1			1			
	***Prosopis africana* (GuilI. & Perr.) Taub. (3)**												
	Bark (3)	1					2	1					
	Other Fabaceae (18) [g]		3	4	5		1	3		2			
Loranthaceae (1)	***Agelanthus dodoneifolius* (DC.) Polhill & Wiens (2)**												
	Leaves (2)	1						1		1			
Moraceae (7)	All Moraceae (8)												
	***Ficus exasperata* Vahl (2)**												
	Leaves (2)		1				1						
	Other Moraceae (6) [h]		1	2	1		2						
Meliaceae (3)	All Meliaceae (22)												
	***Khaya senegalensis* (Desr.) A.Juss. (19)**												
	Bark (14)	8	1	9	2			1		1			
	Leaves (4)			1	1	1							1
	Root (1)			1									
	Other Meliaceae (3) [i]			1	1			1					
Solanaceae (1)	***Nicotiana tabacum* L. (3)**												
	Leaves (3)	1		2				1					
Olacaceae (2)	All Olacaceae (4)												
	***Ximenia americana* L. (3)**												
	Bark (1)				1								
	Root (1)				1								
	Leaves (1)				1								
	Other Olacaceae (1) [j]		1										
Poaceae (3)	All Poaceae (10)												
	***Sorghum bicolor* (L.) Moench (5)**												
	Fruits (5)	2		1	1	2							1
	***Zea mays* L. (4)**												
	Fruits (4)	2		2								2	
	Other Poaceae (1) [k]						1						
Rubiaceae (5)	All Rubiaceae (10)												
	***Mitragyna inermis* (Willd.) Kuntze (4)**												
	Bark (2)			1	1								
	Leaves (2)				1					1			
	***Crossopteryx febrifuga* (G.Don) Benth. (2)**												
	Leaves (1)							1					
	Fruits (1)							1					
	Other Rubiaceae (4) [l]				4								
Sapindaceae (1)	***Paullinia pinnata* L. (2)**												
	Leaves (1)				1								
	Root (1)				1								
Sapotaceae (1)	***Vitellaria paradoxa* C.F.Gaertn. (3)**												
	Fruit (1)	1						1					
	Leaves (1)	1						1					
	Bark (1)									1			

(*continued on next page*)

Table 3 (*continued*)

Botanical family (number of cited plant species in the family)	Plant species with ≥2 cited HSHR (Number indicate the frequency of mentioned 235 HSHR)	On-site extraction process										
		Additional products	None	MA	DE	IN	TR	PI	CA	PO	FU	RO	PO
Vitaceae (4)	All Vitaceae (8)												
	***Cissus quadrangularis* L. (4)**												
	Whole plant (2)			1	1								
	Leaves (1)			1									
	Stem (1)			1									
	Other Vitaceae (4) [m]				1			3					
Zygophyllaceae (1)	***Balanites aegyptiaca* (L.) Delile (2)**												
	Bark (2)				1					1			
Others (18)	18 other plant species (24) [n]	1	6	7	7		8	9		2			
Total (43)	**Total (235)**	36	17	54	63	11	23	39	2	17		2	7

MA-maceration[o]; DE-decoction[o]; IN- infusion[o]; TRI- trituration[o]; PI- pounding[o]; CA-calcination[o]; PO- powder[o]; FU- fumigation[o]; RO- roasting[o]; PO- poultice

[a] *Lannea acida* A.Rich. s.l. (1); *Sclerocarya birrea* (A.Rich.) Hochst. (1).

[b] *Adenium obesum* (Forsk.) Roem. & Schult. (1); *Catharanthus roseus* (L.) G.Don (DGH (1); *Cascabela thevetia* (L.) Lippold (1).

[c] *Stereospermum kunthianum* Cham. (1).

[d] *Rhodognaphalon brevicuspe* (Sprague) Roberty (1); *Cola nitida* (Vent.) Sebott & Endl. (1); *Sterculia setigera* Delile (1); *Corchorus olitorius* L. (1).

[e] *Combretum collinum Fresen*. (1); *Combretum glutinosum* Perr. ex DC. (1); *Combretum molle* R.Br. ex G.Don (1); *Combretum mucronatum* Schumach. & Thonn. (1); *Guiera senegalensis* J.F.Gmel. (1); *Pteleopsis suberosa* Engl. & Diels (1); *Terminalia avicennioides* GuilI. & Perr. (1); *Terminalia glaucescens* Planch. ex Benth. (1); *Terminalia laxiflora* Engl. (2); *Terminalia macroptera* Guill. & Perr. (1).

[f] *Euphorbia poissonii* Pax (2); *Excoecaria grahamii* Stapf. (1); *Hymenocardia acida* Tul. (1).

[g] *Acacia polyacantha* Willd. (1); *Acacia sieberiana* DC. (1); *Aganope stuhlmannii* (Taub.) Adema (1); *Burkea africana* Hook. (1); *Caesalpinia bonduc* (L.) Roxb. (1); *Centrosema pubescens* Benth. (1); *Daniellia oliveri* (Rolfe) Hutch. & Dalziel (1); *Dichrostachys cinerea* (L.) Wight & Arn. (1); *Indigofera nigritana* Hook.f. (1); *Isoberlinia doka* Craib & Stapf (1); *Lonchocarpus sericeus* (Poir.) Kunth (DGH 2); *Piliostigma reticulatum* (DC.) Hoscht. (1); *Piliostigma thonningii* (Schumach.) Milne-Redh. (1); *Pithecellobium dulce* (Roxb.) Benth. (1); *Pterocarpus santalinoides* L'Hér. ex DC. (1); *Tamarindus indica* L. (1); *Vigna unguiculata* (L.) Walp. (1).

[h] *Ficus glumosa* DeliIe (1); *Ficus platyphylla* Delile (1); *Ficus polita* Vahl (1); *Ficus sur* Forssk. (1); *Ficus sycomorus* L. (1); *Ficus trichopoda* Baker (1).

[i] *Azadirachta indica* A.Juss. (2); *Trichilia emetica* Vahl (1).

[j] *Olax subscorpioides* Oliv. (1).

[k] *Cymbopogon giganteus* Chiov. (1).

[l] *Gardenia ternifolia* Schumach. & Thonn. (1); *Macrosphyra longistyla* (De.) Hiern (1); *Sarcocephalus latifolius* (Sm.) E.A. Bruce (2).

[m] *Cissus cornifolia* (Baker) Planch. (1); *Cissus petiolata* Hook.f. (1); *Cissus populnea* Guill. & Perr. (2).

[n] *Gymnosporia senegalensis* (Lam.) Loes. (1) (Celastraceae); *Maranthes polyandra* (Benth.) Prance (1) (Chrysobalanaceae); *Garcinia kola* Heckel (1) (Clusiaceae); *Cochlospermum planchonii* Hook.f. (1) (Bixaceae); *Chasmanthera dependens* Hochst. (1) (Menispermaceae); *Piper guineense* Schumach. & Thonn. (1) (Piperaceae); *Securidaca longipedunculata* Fresen. (1) (Polygalaceae); *Allium cepa* L. (1) (Amaryllidaceae); *Gmelina arborea* Roxb. (1) (Lamiaceae); *Tectona grandis* L.f. (1) (Lamiaceae); *Vitex doniana* Sweet (1) (Lamiaceae); *Quassia undulata* Planch. (1) (Simaroubaceae); *Smilax anceps* (1) (Smilacaceae); *Stylochaeton hypogeum* Lepr. (1) (Arecaceae); *Stylochaeton lancifolius* Kotschy & Peyr. (1) (Arecaceae); *Aristolochia albida* Duch. (1) (Aristolochiaceae); *Paliurus spina-christi* Mill. (1) (Rhamnaceae); *Ipomoea asarifolia* (Desr.) Roem. & Schult. (1) (Convolvulaceae); *Ipomoea batatas* (L.) Lam. (1) (Convolvulaceae); *Ipomoea eriocarpa* R.Br. (1) (Convolvulaceae); *Ipomoea mauritiana* Jacq. (1) (Convolvulaceae).

[o] *Sanseviera liberica* hort. Ex Gerome & Labroy (1) (Asparagaceae); *Asparagus africanus* Lam. (2).

community remains the highest figure (c. 48% of the total Benin's ethno-veterinary flora) (Dassou et al., 2015b). This high number of plants and remedies used by this community can be attributed to several factors such as: i) the important number of plant species in the surrounding environment, the Benin's flora being estimated to 2807 species (Akoègninou et al., 2006), ii) high dependence of human populations on plant-based remedies to manage both human and animal diseases, with ca. 80% of all African populations relying on medicinal plants for primary healthcare (Dike et al., 2012), and iii) cultural exchanges facilitated by their nomadic life-style. Phytogenetic resources are thereby sustainably used. Moreover, when a plant species appears to be unavailable or rare in an area it can be substituted (Ouachinou et al., 2019).

When comparing the data from the present study with findings from previous studies (PBES) in Benin (Fig. 3, Additional file 2), no new species was reported for ethno-veterinary uses. Twelve plant species were common for all zones, but only 27% (for SG and GC each), and 19% (SZ) of the respective UR were connected to them.

Species of the family Fabaceae were most frequently used (60 HSHR, 25.53%). Predominance of Fabaceae in Peul ethno-veterinary medicine can be explained by the ecological apparency hypothesis as originally suggested by Feeny (1976). It stipulates that people tend to collect and use plants that are available and easy to find. Indeed, in Benin Fabaceae constitute the most speciose plant family representing 14.8% of the total flora (Akoègninou et al., 2006).

4.2. Variation in plant uses

The present study revealed that the use of plants for ethno-medicinal purpose in Peul community seems to be determined by the biogeographical position of the informants and the cultural exchanges as affected by their nomadic life. Major vegetation studies recognized three ecologically and floristically different biogeographical zones, namely: the Guineo-Congolian and Sudanian regions separated by the Sudano-Guinean transition zone (Adjanohoun et al., 1989; Adomou, 2005; Akoègninou et al., 2006; Adomou et al., 2006). Due to the uniqueness of the vegetation types of these biogeographical zones, the associated ethnobotanical knowledge would tend to be a particular attribute of the socio-cultural group of the area. Considering the Sudanian/Sahelian geographic origin of Peul, we noticed that there is a decreasing ethnoveterinary knowledge gradient from the Sudanian (dry) to Guineo-Congolian (humid) zone. This implies a loss of knowledge by Peul community while they move towards climatically wetter areas (Table 4).

Most of the 310 UR described by the DPs were indicated for cattle; this can be explained by the fact that bovines are the principal animals bred by Peul community. Since they are in permanent contact with animals, they accumulate a huge amount of ethno-veterinary knowledge and experience on the production and reproduction of animals. Several authors (Mathias-Mundy and McCorkle, 1989; Bâ, 1994; Tamboura et al., 1998) indicated that ethno-veterinary medicine for

Table 4
List of the 310 use reports (UR) for 235 homemade herbal remedies reports involving a single herb (HSHR): plant parts, bioclimatic zone, administration routes, use categories, and target animal species.

Botanical family (number of cited plant species in the family)	Plant species with ≥2 cited HSHR (Number indicates the frequency of use reports)	(Numbers indicate the frequency of use reports)																Total UR
		Bioclimatic zones			Administration routes			EN	Use Categories						Target animal species				
		GC	SG	SZ	ER	OR	IN		BA	VI	PA	ME	MU	NE	GS	CA	PO	
Anacardiaceae (4)	All Anacardiaceae (13)																	
	***Spondias mombin* L. (7)**																	
	Leaves (7)	2	1	4		7					2		5		6	1		7
	***Mangifera indica* L. (3)**																	
	Bark (3)	2	1			3			3							3		3
	Other Anacardiaceae (3) [a]		1	2		3				2			1			2	1	3
Annonaceae (1)	***Annona senegalensis* Pers. (10)**		2	8														
	Roots (6)					6									3	3		6
	Bark (2)				2								2		1	1		2
	Leaves (2)					1		1			1		1		1	1		2
Apocynaceae (4)	All Apocynaceae (5)																	
	***Saba comorensis* (Boj.) Pichon (2)**																	
	Stem (1)			1		1						1				1		1
	Roots (1)			1		1						1				1		1
	Other Apocynaceae (3) [b]			3	1	2						1	1	1		3		3
Araliaceae (1)	***Cussonia arborea* Hochst. ex A. Rich. (6)**														1	4		5
	Leaves (4)	2		2		4							4			1		1
	Roots (2)			2		2							2					
Asclepiadaceae (1)	***Calotropis procera* (Aiton) W.T.Aiton (2)**																	
	Leaves (2)			2	1	1			1			1				2		2
Asparagaceae (3)	All Asparagaceae (16)																	
	***Asparagus flagellaris* (Kunth) Baker (13)**																	
	Leaves (6)	4	2			6				3	2	1			4	2		6
	Tuber (7)	2	3	2		7				3	2	1	1		4	3		7
	Other Asparagaceae (3)[o]	1	2			3						1	1	1		3		3
Compositae (1)	***Chromolaena odorata* (L.) R.M.King (3)**																	
	Roots (2)			2		2							2		2			2
	Bark (1)		1			1							1		1			1
Bignoniaceae (2)	***Kigelia africana* (Lam.) Benth. (3)**																	
	Bark (2)	1		1		2							2			2		2
	Fruit (1)			1		1							1			1		1
	Other Bignoniaceae (1) [c]			1	1						1					1		1
Malvaceae (6)	All Malvaceae (9)																	
	***Adansonia digitata* L. (3)**			3														
	Leaves (2)			2		2							2			2		2
	Bark (1)			1		1			1							1		1
	***Bombax costatum* Pellegr. & Vuillet (2)**			2		2							1	1		2		2
	Other Malvaceae (4) [d]	2	1	1	1	3					1	2	1			4		4
Combretaceae (12)	All Combretaceae (21)																	
	***Anogeissus leiocarpa* (DC.) Guill. & Perr. (7)**																	
	Leaves (4)	1	2	1		4			1		1		2			4		4
	Bark (3)	1		2	1	2			1		2					3		3
	***Terminalia mollis* M.A.Lawson (3)**																	
	Roots (2)			2	1	1				1			1			2		2
	Bark (1)			1		1				1						1		1
	Other Combretaceae (11) [e]	2		9		11			2		4		4	1		10	1	11
Solanaceae (1)	***Nicotiana tabacum* L. (5)**	1		4	1	4												
	Leaves (5)	1		4	1	4				4	1					1	4	5

(*continued on next page*)

Table 4 (*continued*)

Botanical family (number of cited plant species in the family)	Plant species with ≥2 cited HSHR (Number indicates the frequency of use reports)	(Numbers indicate the frequency of use reports)															Total UR
		Bioclimatic zones			Administration routes			EN	Use Categories						Target animal species			
		GC	SG	SZ	ER	OR	IN		BA	VI	PA	ME	MU	NE	GS	CA	PO	
Euphorbiaceae (3)	All Euphorbiaceae (20)																	
	***Euphorbia unispina* N.E.Br. (17)**																	
	Whole plant (12)	1	2	9		12			5	7						1	11	12
	Leaves (3)	1		2		3			1	2						2	1	3
	Stem (2)			3		3				2			1			1	2	2
	Other Euphorbiaceae (3)																	
Phyllantaceae (2)	All Phyllantaceae (7)																	
	***Bridelia ferruginea* Benth. (6)**																	
	Bark (5)			5		5				4	1				2		3	5
	Leaves (1)			1		1							1		1			1
	Other Phyllantaceae (1) [f]		1			1						1				1		1
Leguminosae (26)	All Fabaceae (71)																	
	***Parkia biglobosa* (Jacq.) R.Br. ex Benth. (18)**																	
	Bark (11)					11			3	3	2		1	2		8	3	11
	Fruits (6)				2	4				1	2	3				6		6
	Leaves (1)					1				1						1		1
	***Detarium microcarpum* Guill. & Perr. (7)**																	
	Bark (5)			5		5					2	1	2		1	4		5
	Roots (1)		1			1							1			1		1
	Leaves (1)	1				1				1						1		1
	***Pseudocedrela kotschyi* (Schweinf.) Harms. (7)**																	
	Bark (6)	1	2	3		6			1		4	1				6		6
	Roots (1)	1				1					1					1		1
	***Pterocarpus erinaceus* Poir. (5)**																	
	Bark (3)	1	2		2	1			1	2						3		3
	Leaves (2)	2			1	1							2			2		2
	***Afzelia africana* Sm. (3)**																	
	Bark (3)		1	2		3			2		1					3		3
	***Entada africana* GuilI. & Perr. (4)**																	
	Bark (2)		1	1	1	1				1				1		2		2
	Roots (1)		1			1			1							1		1
	Leaves (1)			1		1				1						1		1
	***Acacia nilotica* (L.) Willd. (3)**																	
	Fruit (2)			2	2					2						2		2
	Bark (1)			1	1				1							1		1
	***Pericopsis laxiflora* (Benth. ex Baker) Meeuwen (3)**																	
	Bark (3)	1		2		3				2			1			2	1	3
	***Prosopis africana* (GuilI. & Perr.) Taub. (3)**																	
	Bark (3)		1	2		3					1		1	1		3		3
	Other Fabaceae (18) [g]	7	5	6	1	17			3		2	5	3	5	2	16		18
Loranthaceae (1)	***Agelanthus dodoneifolius* (DC.) Polhill & Wiens (2)**																	
	Leaves (2)			2	1	1				1				1		2		2
Moraceae (7)	All Moraceae (8)																	
	***Ficus exasperata* Vahl (2)**																	
	Leaves (2)	1		1	2						1	1			1		1	2
	Other Moraceae (6) [h]	1		5		6						2	4			6		6

(*continued on next page*)

Table 4 (*continued*)

Botanical family (number of cited plant species in the family)	Plant species with ≥2 cited HSHR (Number indicates the frequency of use reports)	(Numbers indicate the frequency of use reports)															Total UR
		Bioclimatic zones			Administration routes			EN	Use Categories						Target animal species			
		GC	SG	SZ	ER	OR	IN		BA	VI	PA	ME	MU	NE	GS	CA	PO	
Meliaceae (3)	All Meliaceae (35)																	
	***Khaya senegalensis* (Desr.) A.Juss. (32)**																	
	Bark (27)	7	2	18	2	25			9	8	4		6			21	6	27
	Leaves (4)	1	1	2		4				1	1		2		1	3		4
	Root (1)			1		1							1			1		1
	Other Meliaceae (3) [i]	1		2	1	2					1	1		1		3		3
Olacaceae (2)	All Olacaceae (6)																	
	***Ximenia americana* L. (5)**																	
	Bark (2)			2		2			1		1				1	1		2
	Root (2)	1		1		2							2			2		2
	Leaves (1)			1		1					1					1		1
	Other Olacaceae (1) [j]	1				1					1						1	1
Poaceae (3)	All Poaceae (16)																	
	***Sorghum bicolor* (L.) Moench (9)**																	
	Fruits (9)	1	2	6		9			1	8						8	1	9
	***Zea mays* L. (6)**																	
	Fruits (6)	1	1	4		6			1		1		4		4	2		6
	Other Poaceae (1) [k]		1			1							1			1		1
Rubiaceae (5)	All Rubiaceae (13)																	
	***Mitragyna inermis* (Willd.) Kuntze (6)**																	
	Bark (3)	2		1		3					2		1			3		3
	Leaves (3)	3			1	2					2		1			3		3
	***Crossopteryx febrifuga* (G.Don) Benth. (2)**																	
	Leaves (1)	1				1					1					1		1
	Fruits (1)	1				1					1					1		1
	Other Rubiaceae (5) [l]	1		4		5			2		3					5		5
Sapindaceae (1)	***Paullinia pinnata* L. (2)**																	
	Leaves (1)		1			1							1			1		1
	Root (1)		1			1				1						1		1
Sapotaceae (1)	***Vitellaria paradoxa* C.F.Gaertn. (3)**																	
	Fruit (1)			1	1						1					1		1
	Leaves (1)		1			1			1							1		1
	Bark (1)	1				1			1							1		1
Vitaceae (4)	All Vitaceae (10)																	
	***Cissus quadrangularis* L. (6)**	2	1	3		6			1	5					1	1	4	6
	Whole plant (4)					4			1	3						1	3	4
	Leaves (1)					1				1					1			1
	Stem (1)					1				1							1	1
	Other Vitaceae (4) [m]	2		2		4							4		2	2		4

(*continued on next page*)

Table 4 (*continued*)

Botanical family (number of cited plant species in the family)	Plant species with ≥2 cited HSHR (Number indicates the frequency of use reports)	(Numbers indicate the frequency of use reports)																Total UR
		Bioclimatic zones			Administration routes			EN	Use Categories						Target animal species				
		GC	SG	SZ	ER	OR	IN		BA	VI	PA	ME	MU	NE	GS	CA	PO	
Zygophyllaceae (1)	***Balanites aegyptiaca* (L.) Delile (2)**																	
	Bark (2)	2				2				1		1				2		2
Others (15)	15 other plant species (22) [n]				3	18	1		3	2	4	4	6	3	3	17	2	
Total (43)	**Total (310)**				34	276	1	1	48	71	55	29	82	25	43	229	38	

GC- Guineo-Congolean zone; SG- Sudano-Guinean transition zone; SZ- Sudanian zone; ER-external ; OR- oral ; INS- instillation ; EN- treatment of housing environment ; BA-bacterial ; VI- viral ; PA-parasitic ; ME-metabolic ; MU- multifactorial ; NE-nervous ; GS- goat and sheep ; CA-cattle ; PO- poultry.

[a] *Lannea acida* A.Rich. s.l. (1); *Sclerocarya birrea* (A.Rich.) Hochst. (1).

[b] *Adenium obesum* (Forsk.) Roem. & Schult. (1); *Catharanthus roseus* (L.) G.Don (DGH (1); *Cascabela thevetia* (L.) Lippold (1).

[c] *Stereospermum kunthianum* Cham. (1).

[d] *Rhodognaphalon brevicuspe* (Sprague) Roberty (1); *Cola nitida* (Vent.) Sebott & Endl. (1); *Sterculia setigera* Delile (1); *Corchorus olitorius* L. (1).

[e] *Combretum collinum Fresen.* (1); *Combretum glutinosum* Perr. ex DC. (1); *Combretum molle* R.Br. ex G.Don (1); *Combretum mucronatum* Schumach. & Thonn. (1); *Guiera senegalensis* J.F.Gmel. (1); *Pteleopsis suberosa* Engl. & Diels (1); *Terminalia avicennioides* GuilI. & Perr. (1); *Terminalia glaucescens* Planch. ex Benth. (1); *Terminalia laxiflora* Engl. (2); *Terminalia macroptera* Guill. & Perr. (1).

[f] *Euphorbia poissonii* Pax (2); *Excoecaria grahamii* Stapf. (1); *Hymenocardia acida* Tul. (1).

[g] *Acacia polyacantha* Willd. (1); *Acacia sieberiana* DC. (1); *Aganope stuhlmannii* (Taub.) Adema (1); *Burkea africana* Hook. (1); *Caesalpinia bonduc* (L.) Roxb. (1); *Centrosema pubescens* Benth. (1); *Daniellia oliveri* (Rolfe) Hutch. & Dalziel (1); *Dichrostachys cinerea* (L.) Wight & Arn. (1); *Indigofera nigritana* Hook.f. (1); *Isoberlinia doka* Craib & Stapf (1); *Lonchocarpus sericeus* (Poir.) Kunth (DGH 2); *Piliostigma reticulatum* (DC.) Hoscht. (1); *Piliostigma thonningii* (Schumach.) Milne-Redh. (1); *Pithecellobium dulce* (Roxb.) Benth. (1); *Pterocarpus santalinoides* L'Hér. ex DC. (1); *Tamarindus indica* L. (1); *Vigna unguiculata* (L.) Walp. (1).

[h] *Ficus glumosa* DeliIe (1); *Ficus platyphylla* Delile (1); *Ficus polita* Vahl (1); *Ficus sur* Forssk. (1); *Ficus sycomorus* L. (1); *Ficus trichopoda* Baker (1).

[i] *Azadirachta indica* A.Juss. (2); *Trichilia emetica* Vahl (1).

[j] *Olax subscorpioides* Oliv. (1).

[k] *Cymbopogon giganteus* Chiov. (1).

[l] *Gardenia ternifolia* Schumach. & Thonn. (1); *Macrosphyra longistyla* (De.) Hiern (1); *Sarcocephalus latifolius* (Sm.) E.A. Bruce (2).

[m] *Cissus cornifolia* (Baker) Planch. (1); *Cissus petiolata* Hook.f. (1); *Cissus populnea* Guill. & Perr. (2).

[n] *Gymnosporia senegalensis* (Lam.) Loes. (1) (Celastraceae); *Maranthes polyandra* (Benth.) Prance (1) (Chrysobalanaceae); *Garcinia kola* Heckel (1) (Clusiaceae); *Cochlospermum planchonii* Hook.f. (1) (Bixaceae); *Chasmanthera dependens* Hochst. (1) (Menispermaceae); *Piper guineense* Schumach. & Thonn. (1) (Piperaceae); *Securidaca longipedunculata* Fresen. (1) (Polygalaceae); *Allium cepa* L. (1) (Amaryllidaceae); *Gmelina arborea* Roxb. (1) (Lamiaceae); *Tectona grandis* L.f. (1) (Lamiaceae); *Vitex doniana* Sweet (1) (Lamiaceae); *Quassia undulata* Planch. (1) (Simaroubaceae); *Smilax anceps* (1) (Smilacaceae); *Stylochaeton hypogeum* Lepr. (1) (Arecaceae); *Stylochaeton lancifolius* Kotschy & Peyr. (1) (Arecaceae); *Aristolochia albida* Duch. (1) (Aristolochiaceae); *Paliurus spina-christi* Mill. (1) (Rhamnaceae); *Ipomoea asarifolia* (Desr.) Roem. & Schult. (1) (Convolvulaceae); *Ipomoea batatas* (L.) Lam. (1) (Convolvulaceae); *Ipomoea eriocarpa* R.Br. (1) (Convolvulaceae); *Ipomoea mauritiana* Jacq. (1) (Convolvulaceae).

[o] *Sanseviera liberica* hort. Ex Gerome & Labroy (1) (Asparagaceae); *Asparagus africanus* Lam. (2).

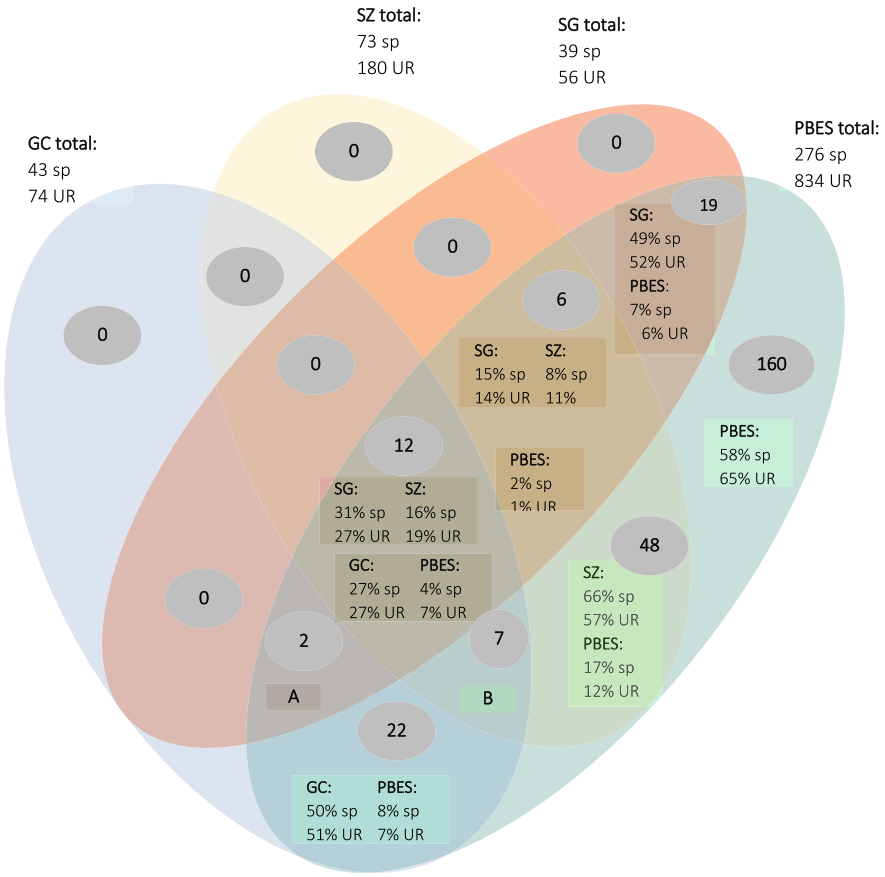

Fig. 3. Comparison of the number of different plant species (sp) and associated use reports (UR). GC = Guineo-Congolian zone, SZ = Sudanian zone, SG = Sudano-Guinean zone, PBES = previous Benin ethnoveterinary studies (Toïgbé, 1978; Dassou et al., 2014, 2015b; Ogni, 2016; Ouachinou et al., 2017, 2019). The whole list of plant species was given in the supplementary file 2.
Legend: **A** (GC: 5% sp, 4% UR; SG: 5% sp, 7% UR; PBES: 1% sp, 2% UR); **B** (GC: 16% sp, 15% UR; SZ: 10% sp, 13% UR; PBES: 3% sp, 2% UR).

cattle and small ruminants is considered an attribute or speciality of Peul community. Yet, with cultural linkages recently established with native people of different ecological zones, Peul acquired additional knowledge, evidenced by specific skills in the treatment of poultry diseases such as Newcastle disease.

The majority of the medicinal use reports (UR) indicated a large spectrum of action (26.45% over a total of 310 UR). In West Africa, antimicrobial plants like plant crude extracts of *Khaya senegalensis* are widely used to treat several bacterial, parasitic and viral ailments of cattle (Koudoro et al., 2014; Dassou et al., 2014; Kpodékon et al., 2015; Dassou, 2016; Ogni, 2016). For example, Atawodi et al. (2002) revealed *K. senegalensis* as the most commonly used traditional plant for the treatment of trypanosomiasis in northern Nigeria while Wurochekke and Nok (2004) and Atawodi (2005) demonstrated the anti-trypanosomal activity of its crude extracts against *Trypanosoma brucei brucei*. According to Ademola et al. (2004), *K. senegalensis* is highly effective against internal parasites.

In the Peul community, *Euphorbia unispina* is one of the most used species to treat viral diseases as already reported by Kpodékon et al. (2015). Since time immemorial, many species of Euphorbiaceae have been popular traditional medicinal plants also for humans. Ethnomedicine of Euphorbiaceae is highly diverse including the treatment of diseases like warts, cancer, gonorrhea, arthritis, asthma, cough, earache, neuralgia, rheumatism, toothache, excrescences, tumors and others (Cataluña and Rates, 1999). This diversity of uses is due to the presence of a wide range of unusual secondary metabolites rendering most of the members poisonous (Seigler, 1994). Some species are also used to treat viral diseases. For example, *Euphorbia thymifolia* is used as an anti-viral agent against simplex virus-2 (Gupta et al., 2007).

Regarding valorization of Peul ethno-veterinary medicine, there are three research and development gaps. i) First, for most of the recorded species, there is a lack of information about phytochemical and pharmacological properties; there is therefore urgent need to investigate their therapeutic effectiveness. As proposed by Dassou et al. (2014) and Ouachinou et al. (2019), plants with high citation frequency can be prioritised for these further studies such as: *Pseudocedrela kotschyi*, *Mitragyna inermis*, and *Asparagus flagellaris* for the treatment of parasitic diseases. Those with known bioactivity could then be implied in the formulation of phytomedicines. For instance, for the elimination of parasites from the gastrointestinal tract of sheep and goats, either by killing adult worms or by reducing their reproduction, some plants have proven effective *in vitro,* as for instance: *Terminalia macroptera* (Conrad et al., 1998), *Khaya senegalensis* (Ademola et al., 2004), *Anogeissus leiocarpa* (Koné et al., 2005), *Pterocarpus erinaceus* and *Parkia biglobosa* (Dedehou et al., 2014). In addition, Tarus et al. (2002) and Nok (2002) showed the anti-trypanosomial effect of *Cassia sieberiana*. ii) Second, veterinary education and national strategies to control and combat the development of microbial resistance should take into account the use of medicinal plants as a means to reducing the use of antibiotics (StAR, 2015). Recommendations must be given to limit the use of antibiotics and other commercial veterinary medicinal products. iii) Third, among the reported species, *Vitellaria paradoxa* and *Khaya senegalensis* are listed as vulnerable on the IUCN redlist (http://www.iucnredlist.org). Their overexploitation in ethno-veterinary medicine could affect their survival in Benin. We propose that certain species with wide distribution be studied to substitute for these threatened species and reduce the pressure on their wild populations. We propose also that farmers adopt non-destructive methods to exploit these target species in order to conserve them in agroforestry systems. On addition, investigations on the reproductive biology and propagation methods should allow their domestication and restoration.

5. Conclusion

The present study provides insights into ethno-medicinal veterinary of Peul community in Benin with some details on the composition and manufacturing process for 235 homemade single species herbal remedies. Viral, parasitic, bacterial diseases and disorders with several origins, notably diarrhoeas, fever, abortion, agalactia and hypogalactia, are the main reasons for the use of the orally administered homemade single plant herbal remedies. It also turns out that the plant-based ethnoveterinary knowledge held by the Peul community of Benin decreased from the Sudanian (dry) to Guineo-congolian (humid) zones.

Authors' contributions

GHD conceptualized the study and ACA, HY, MT reviewed the research proposal. GHD and JMASO conducted the ethnobotanical survey. GHD, ACA and HY identified recorded species. AF, DD, and EG analysed the field data. GHD drafted the manuscript. All the authors participated in writing and giving feedback on the manuscript. All the authors have read and approved the final manuscript. GHD reviewed and edited the last version.

Data availability

The data on specific ailments (of each category of ailment) treated by reported plant species in the present study are available from the authors upon request.

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Declaration of competing interest

The authors have declared that no competing interests exist.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jep.2020.113107.

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