Heliyon 10 (2024) e22958

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Folk taxonomy and quantitative ethnobotany of Loranthaceae in northern Benin

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A R T I C L E I N F O

Keywords:
African mistletoes
Cultural importance
Agelanthus dodoneifolius
Improved traditional medicines
BENIN

A B S T R A C T

Loranthaceae are parasitic plants whose management remains a challenge. This study aimed to record Loranthaceae species and their local names, assess their use diversity and cultural importance, identify the socio-demographic groups with the highest levels of knowledge about Loranthaceae uses, and analyze the variation of Loranthaceae utilization between and within ethnic groups. Ethnobotanical data were collected in northern Benin from March 2015 to February 2017 through semi-structured interviews and show-and-tell method with 240 informants. We assessed Loranthaceae use diversity and cultural importance using the Relative Frequency of Citations (RFC), Number of Uses (NU), Use Value (UV), Number of Use Categories (NUC), and Cultural Importance Index (CI). Poisson's regression and Jaccard's Similarity Index were used to identify the socio-demographic groups with the highest levels of knowledge about Loranthaceae uses and evaluate the similarity of Loranthaceae uses between ethnic groups. Results showed 15 local names used to designate four Loranthaceae species namely *Agelanthus dodoneifolius*, *Tapinanthus globiferus*, *Phragmanthera kamerunensis*, and *T. ophioides*. Loranthaceae were involved in 113 uses gathered in six categories namely human medicine, magic, veterinary, fodder, food, and cosmetic. Human medicine was the most important category with 0.825 as RFC, 61.10 % of the uses, and 100 % of Loranthaceae species involved. *A. dodoneifolius* was the most important Loranthaceae species regarding its RFC, NU, UV, and NUC of 0.938, 95, 2.296, and 6 respectively. CI showed *A. dodoneifolius* and *T. globiferus* were mainly used in human medicine with 0.729 and 0.458 respectively. *Bariba*, traditional healers and breeders, old people, and animists presented the highest levels of knowledge about Loranthaceae uses. Loranthaceae utilization varied according to ethnic groups and *Bariba* and *Yom* presented a similarity in Loranthaceae uses. Loranthaceae valorization in the production of improved traditional medicines, animal feed, soap, and green fertilizers will contribute to the biological control of these plants.

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https://doi.org/10.1016/j.heliyon.2023.e22958
Received 24 April 2023; Received in revised form 14 November 2023; Accepted 22 November 2023
Available online 30 November 2023
2405-8440/

1. Introduction

The Loranthaceae family comprises c. 76 genera and at least 1000 mistletoe species worldwide [1]. These species are mainly hemiparasitic plants which attached to the branches of trees and shrubs and then affect host viability by withdrawing mineral nutrients and significant amounts of carbohydrates [2]. Loranthaceae parasitism leads to the death of heavily infested hosts, thereby threatening their conservation status with a growth loss of about 14 % [3]. In Africa [4], reported more than 500 Loranthaceae species most of which heavily parasitize several valuable woody species such as *Vitellaria paradoxa* C. F. Gaertn, *Parkia biglobosa* (Jacq.) R. Br. ex

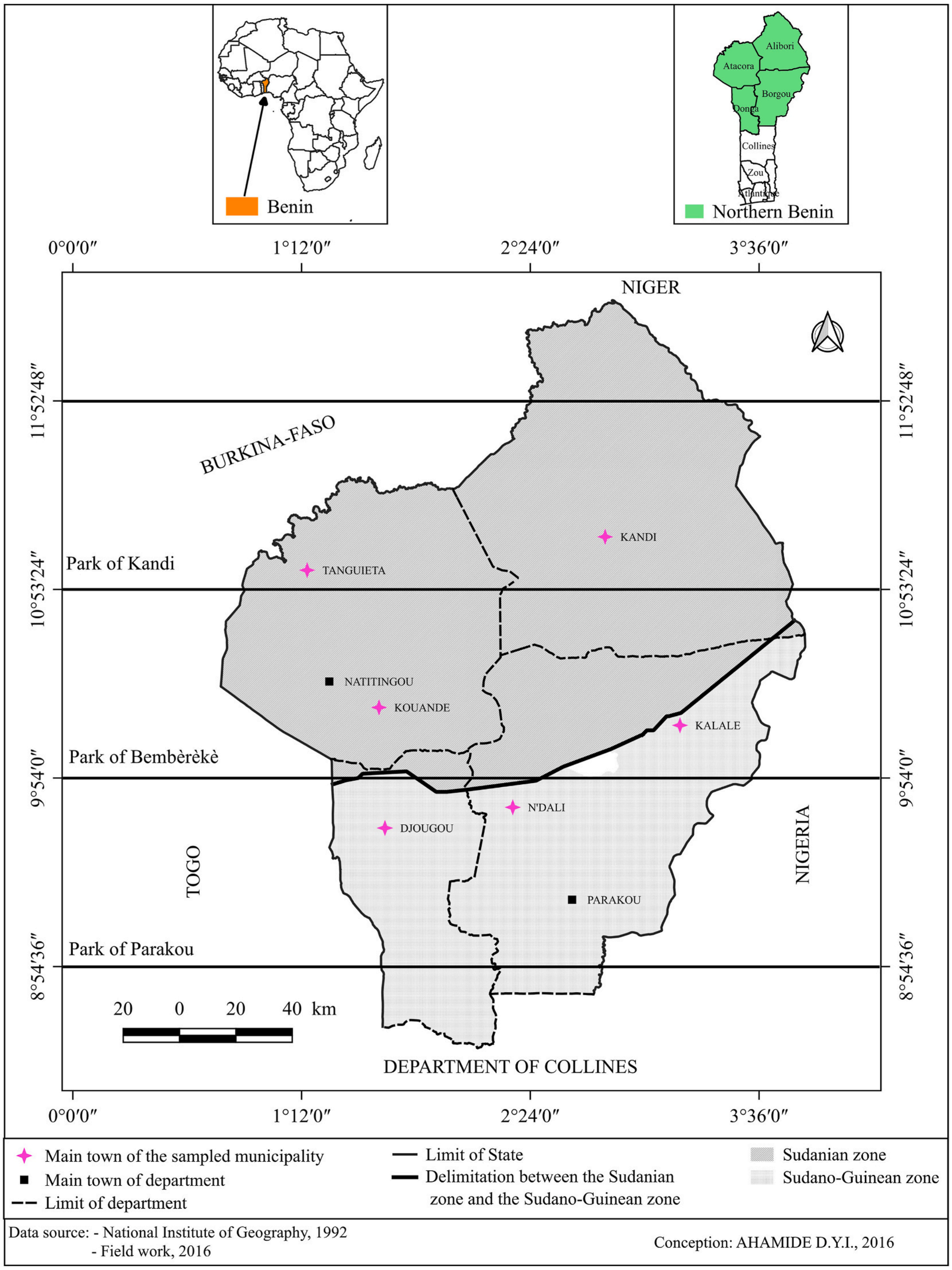

Fig. 1. Map of study area showing the surveyed municipalities.

Benth., *Dacryodes edulis* (G. Don) H. J. Lam., *Citrus sinensis* L., *Theobroma cacao* L., *Hevea brasiliensis* (Willd. ex A. Juss.) Müll. Arg., *Irvingia gabonensis* (Aubry-Lecomte ex O'Rorke) Baill., and *Cola nitida* (Vent.) Schott. & Endl [5–13]. Thus, several mistletoe control methods were implemented through mechanical, chemical, and biological approaches [14–16]. However, mistletoe control is reported to be poorly adopted given its complexity and especially the ecological and socio-economic values of these plants [17–24]. Indeed, Griebel et al. [22] reported mistletoes ecologically promote wildlife habitat, biodiversity, and nutrient cycling. Moreover, previous ethnobotanical studies showed the socio-economic importance of Loranthaceae in human and veterinary medicine, food, fodder, craft, and magic [8,11,25–29]. According to Jiofack Tafokou et al. [30], exhaustive ethnobotanical studies are valuable for mistletoe valorization as a biological method control. In Benin, mistletoes are represented only by Loranthaceae family and are poorly studied. Indeed, apart from the record of 13 Loranthaceae species distributed across the country [25], studies carried out on mistletoes are mainly focused on their diversity and parasitism on *V. paradoxa, C. sinensis*, and *C. nitida* of which 87 %, 60 %, and 53 % respectively were infested [8,11,31,32]. Moreover, research works in northern Benin are scarce despite this area fully harbors several valuable woody species, heavily infested such as *V. paradoxa*, *P. biglobosa*, and *Adansonia digitata* [33–35]. In order to contribute to biological control of Loranthaceae through ethnobotanical data, it is essential to document the diversity of available species, their socio-cultural importance and the socio-demographic groups that depend heavily on these plant resources. Thus, this research aimed to assess the local knowledge of Loranthaceae to promote their valorization as biological method of control. The specific objectives were to: i) record Loranthaceae species and their local names, ii) assess the use diversity and the cultural importance of Loranthaceae, iii) identify the socio-demographic groups with the highest levels of knowledge about Loranthaceae uses, and iv) analyze the variation of Loranthaceae utilization between and within ethnic groups.

2. Methods

2.1. Study area

The study was conducted in northern Benin located between 8°30′N-12°25′N and 0°45′E–3°45′E and across the Sudano-Guinean and Sudanian vegetation zones (Fig. 1). The area covers 83,723 km^2 i.e. 72.97 % of the surface area of Benin. Two climate types are distinguished: the tropical humid climate characterized by two to four seasons with annual rainfall varying from 1200 to 1300 mm, and the dry tropical climate characterized by two seasons with annual rainfall between 900 and 1200 mm [36]. The vegetation consists of Sudanian savannas dotted with gallery forests, dense dry forests, and open forests [36]. Loranthaceae species previously recorded in the study area were *Agelanthus dodoneifolius* (DC.) Polhill & Wiens, *A. heteromorphus* (A. Rich.) Polhill & Wiens, *Phragmanthera kamerunensis* (Engl.) Balle, *P. nigritana* (Hook. F. ex Benth.) Balle, *Tapinanthus bangwensis* (Engl. & K. Krause) Danser, *T. globiferus* (A. Rich.) Tiegh. and *T. ophioides* (Sprague) Danser [25]. The population is estimated at 3,397,104 inhabitants, i.e. 33.94 % of the national population. This area is inhabited by *Bariba* and related (24 %), *Peul* and related (22 %), *Otamari* and related (18 %), *Yoa Lokpa* and

Table 1
Distribution and variation in the number of informants according to their socio-demographic parameters.

Characteristics	Modality	Number of informants	Relative frequency (%)
Gender	Man	216	90.00
	Woman	24	10.00
Age	Young (age <50)	110	46.00
	Adult (50 ≤ age ≤75)	107	44.00
	Old (age >75)	23	10.00
Ethnic group	Bariba	69	28.75
	Gando	40	16.67
	Yom	29	12.08
	Natimba	18	7.50
	Gourmantché	16	6.67
	Peul	14	5.83
	Boo	13	5.42
	Mokolé	10	4.17
	Lokpa	9	3.75
	Wama	8	3.33
	Kabyè	4	1.67
	Berba	3	1.25
	Dendi	3	1.25
	Djerma	3	1.25
	Otamari	1	0.42
Occupation	Traditional healer	120	50.00
	Farmer	90	37.50
	Breeder	30	12.50
Religion	Animist	112	46.67
	Muslim	109	45.42
	Christian	19	7.92
Education level	Illiterate	202	84.17
	Primary	23	9.58
	Secondary	15	6.25

related (16 %), *Dendi* and related (8 %), *Yoruba* and related (5 %), other ethnic groups from Benin (2 %), and foreign ethnic groups (2 %) [37].

2.2. Sampling procedure

A stratified sampling was used to select six municipalities considering the phytogeographic zones, the high density of *V. paradoxa* and *P. biglobosa* (the most sensitive hosts to African mistletoe in the study area), and the high observed extent of mistletoe attack [25, 38]. Such municipalities were Djougou, Kouandé, N'dali, Kalalé, Kandi, and Tanguiéta (Fig. 1).

In each selected municipality, the village chiefs helped us in the selection of 40 informants comprising traditional healers, farmers, and breeders, taking into account their reputation and mistletoe using in their recipes. A total of 240 informants were surveyed through semi-structured interviews and show-and-tell method with translator assistance. Table 1 showed that informants interviewed were mainly men (90 %), traditional healers (50 %), *Bariba* (28.75 %), Animists (46.67 %), and illiterates (84.17 %). Their average age was 52 ± 17 years with more than half being at least 50 years old.

2.3. Data collection

Ethnobotanical data were collected from March 2015 to February 2017 through discussions focusing on: the socio-demographic characteristic of the informants, local names of mistletoes and their meanings, mistletoe species used, and the recipes related to mistletoe uses. Mistletoes mentioned were harvested and identified using the Analytic Flora of Benin [25] and through comparison with the mistletoe specimens available at the National Herbarium of Benin. The taxonomical data were updated using the World Flora Online consortium database (http://www.worldfloraonline.org).

2.4. Data analysis

Data collected were used to list mistletoe species and their local names and meanings. We summarized the total number of specific uses recorded for Loranthaceae in the study area. Concerning Loranthaceae use diversity and cultural importance, a categorization of Loranthaceae uses was performed and the importance of each use category was assessed according to its Relative Frequency of Citations (RFC), diversity in specific uses, and the number of Loranthaceae species involved. We calculated the RFC according to the formula: $RFC = \frac{FC}{N}$. Here, FC is the number of informants who mentioned a mistletoe species, use category, or a mistletoe part and N is the total number of informants interviewed [39]. Then we calculated the Fc of each specific use per Loranthaceae species to identify the most important specific uses in each use category. The cultural importance of each Loranthaceae species was evaluated using the RFC, Number of Uses (NU), Use Value (UV), and Number of Use Categories (NUC). UV was calculated following the formula $UV = \sum \frac{U_i}{N}$ where U_i is the number of different uses mentioned by each informant i and N is the total number of informants interviewed [40]. We used also the Cultural Importance Index (CI) defined by the following formula: $CI = \sum_{u=u1}^{uNC} \sum_{i=i1}^{iN} \frac{URui}{N}$. Here, according to Tardio and Pardo-De-Santanyana [39], first, we sum the UR/N of all the informants (from i_1 to i_N) within each use category for that species (s); i.e., the number of informants who mentioned each use category for the species divided by N. Then, we sum all the UR/N of each use category (from u_1 to u_{NC}).

In order to identify the socio-demographic groups with the highest levels of knowledge about Loranthaceae uses, we assessed the level of knowledge of Loranthaceae uses considering the number of uses reported per informant. The key factors were then selected through Poisson's regression with R software version 4.0.2 [41]. The eight explanatory factors involved in the analysis were: phytogeographical zone, shea park, occupation, ethnicity, religion, level of education, gender, and age of informants. In order to select, from among all these explanatory factors, those that could best explain the dependent variable with the aim of determining the model, the stepwise method was adopted, using, at each stage of the procedure, a selection made on the basis of the information criterion (AIC) [42]. We used the "ANOVA" function to test the significance of the explanatory factors. Given the model was based on count data; the Chi squared test was performed. The probabilities associated with this test were used to verify the significance of the factors. The comparison of the level of knowledge of use of the informants was then made according to key factors by considering the total reported value of use (VUR) within each socio-demographic group [43]. The VUR for a socio-demographic group is the average total number of specific uses reported for Loranthaceae in that group. It is expressed in specific uses per informant according to the formula: $VUR = \Sigma VURi/N$. Here, VURi is the total number of specific uses reported by informant i in the group and N is the total number of informants in the group considered. This index was used to measure and compare the knowledge of informants between different socio-demographic groups showing significant variations in the level of knowledge of Loranthaceae uses. The socio-demographic groups with the highest VURs are those with the greatest overall knowledge of Loranthaceae uses.

To analyze the variation of Loranthaceae utilization between and within ethnic groups, we first checked the link between Loranthaceae species, organs, use categories and informants' ethnic groups through the Chi-square test of independence performed with R software version 4.0.2 [41]. Then we calculated the RFC of Loranthaceae species, plant parts, and use categories in each ethnic group. The similarity in Loranthaceae specific uses reported was assessed per ethnic group pair using Jaccard's Index of Similarity (IS). IS was calculated following the formula:

$IS = 100X \frac{c}{(a+b-c)}$ where, a is the number of Loranthaceae specific uses reported only among the ethnic group A, b is the number of Loranthaceae specific uses reported only among the ethnic group B, and c is the number of common Loranthaceae specific uses between both of the two ethnic groups. If IS > 50 %, the uses are similar and if IS < 50 %, there is dissimilarity between the ethnic groups.

In practice, when IS > 45 %, it is accepted that there is similarity between the ethnic groups concerned [44]. Finally, Community Analysis Package version 2.0 with

Ward's method [45] was used to partition ethnic groups according to the Loranthaceae specific uses reported. This allowed identifying the ethnic group associations based on the similarity of uses reported for Loranthaceae.

3. Results

3.1. Diversity and local names of Loranthaceae

Four Loranthaceae species gathered in three genera were reported to be used in the study area. Such species were *A. dodoneifolius*, *P. kamerunensis, T. globiferus*, and *T. ophioides* (Fig. 2A–D). A total of 21 local names were recorded for these species regarding to Table 2. From this table, it appears that of these names, no was specific to the recorded Loranthaceae species. Their designation was based on six different botanical traits and this was associated with certain particular ethnic groups. Indeed, the parasitic lifestyle of the Loranthaceae was reported in the nomenclature of *Peul*, *Gando*, *Boo*, *Natimba*, *Dendi*, and *Djerma*. Their epiphytic lifestyle was recognized among *Natimba*, *Wama*, *Lokpa*, *Kabyè*, *Mokolé*, and *Dendi*. Through their nomenclature, *Otamari*, *Natimba*, and *Yom* recognized the involvement of birds in Loranthaceae dispersal considering mistletoes as an infestation caused by birds, plants deposited by birds, and tree birds respectively. In contrast, *Boo*, *Gourmantché*, and *Wama* considered mistletoes as the host's own production. The increase of Loranthaceae parasitism according to host senescence was reported by *Bariba* and *Boo* for whom Loranthaceae are known as evidence of tree aging. Finally, *Berba* recognized the negative impact of Loranthaceae on their hosts referring to them as tree burden. From Table 2, it appears also that the number of names associated with particular botanical traits was highest for the parasitic lifestyle (8 names) and the epiphytic lifestyle (6 names).

3.2. Use diversity and cultural importance of Loranthaceae

3.2.1. Diversity of Loranthaceae uses

We recorded 113 Loranthaceae uses distributed in six categories namely human medicine, magic, veterinary, fodder, food, and cosmetic (Figs. 3 and 4A–F). Among these categories, human medicine was the most important with 82.50 % as RFC, 61.10 % of the uses, and 100 % of Loranthaceae species involved. In contrast, cosmetic was the least important use category with 1.7 % as RFC, 0.9 % of uses, and 50 % of Loranthaceae species.

Of the 69 uses of Loranthaceae in traditional medicine, uses against malaria, hyperthermia, and convulsions were the most cited,

Fig. 2. Loranthaceae species reported in northern Benin (A. *Agelanthus dodoneifolius,* B. *Phragmanthera kamerunensis,* C. *Tapinanthus globiferus,* D. *T. ophioides*).

Table 2
Local names of Loranthaceae and their meanings according to ethnic groups.

Ethnic group	Local name	Meaning
Bariba	*Dan gusuru*	Evidence of tree aging
Boo	*Ligbanwo, ligbambo*	Parasitic plant, tree product, evidence of tree aging
Peul and Gando	*Sòtò lèdè, sòtò lèga*	Parasitic plant
Otamari	*Dététchonnii*	Infestation caused by birds
Berba	*Tchitonwangué*	Tree burden
Gourmantché	*(Assan) walba, atitoitoira*	Tree product
Natimba	*Owouori, owouobou, téé tchouanni*	Parasitic plant, epiphytic plant, plant deposited by birds, easy-to-break plant
Wama	*Titongoré, otongoré, titonwaré*	Tree product, epiphytic plant
Yom	*Darhou adjéingan*	Tree bird
Lokpa	*Toroutô tchakalo*	Epiphytic plant
Kabyè	*Agnonmôrô*	Epiphytic plant
Mokolé	*Etché idji*	Epiphytic plant
Dendi	*Touri kassi*	Parasitic plant, epiphytic plant
Djerma	*Kassi tchiré*	Parasitic plant

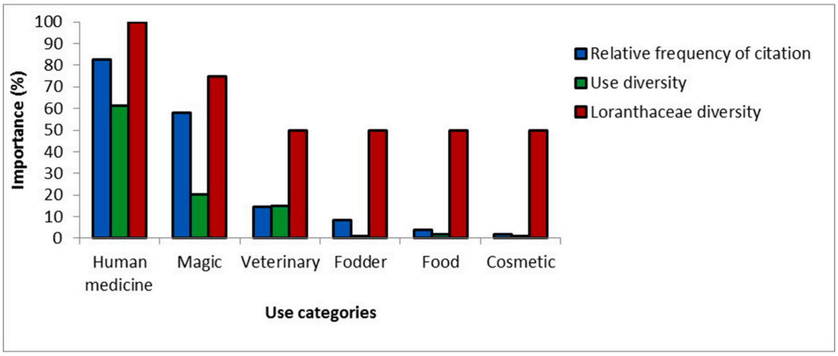

Fig. 3. Importance of Loranthaceae use categories in northern Benin.

Fig. 4. Some uses of Loranthaceae species in northern Benin. (**A.** Bath device from *Agelanthus dodoneifolius* decoctate for the treatment of children with walking delay, **B.** Goats consuming *Agelanthus dodoneifolius* leaves, **C.** Traditional couscous prepared with Loranthaceae leaves, **D.** Potash produced from Loranthaceae, **E.** Soap production from Loranthaceae, **F.** Soap produced from Loranthaceae).

Table 3
Diversity and importance of Loranthaceae uses.

Uses	Frequency of citation per Loranthaceae species				FC
	A. dodoneifolius	*T. globiferus*	*P. kamerunensis*	*T. ophioides*	
Human medicine (69 uses) rowhead					
Malaria	37	9			42
Hyperthermia	23	16			32
Convulsions	24	8	2		29
Headache	24	12			27
Madness	17	10	1		27
Delayed walking	22	3			22
Fractures	9	7			20
Diagnosis of diseases	13	6			16
Oedema	7	8			14
Counter-bewitching	8	4			11
Dystocia	7	5			11
Stomach aches	5	5			11
Asthenia	8	2			10
Immune deficiency	9	3			10
Scabies	3	8			10
Myalitis	5	5			10
Childhood stunting	7	4			10
Ocular disorders	5	3			8
Arthralgia	6	2		1	7
Envenomation	3	4			7
Epilepsy	5	3			7
Boils	6	1			7
Cough	7	3			7
Persistent wounds	2	4			6
Vomiting	3	3			6
Yellow fever	5				5
Memory problems	3	4			5
Hemorrhoids	2	2			4
High blood pressure	4	1			4
Sexual impotence	2	2			4
Rheumatism	2	2			4
Sterility	4				4
Anemia	2	1			3
Mycoses	3				3
Colds	3	2			3
Heart disease	2	2			3
Amenorrhea	2				2
Helminthiasis	2				2
Hemorrhage	1	1			2
Hepatitis	2				2
Hernia		2			2
Infantile emaciation	1				1
Anorexia	1				1
Dysmenorrhea	1				1
Dysuria	1	1			1
Enuresis	1				1
Gonorrhea	1	1			1
Hypoglycemia	1				1
Hypotension	1				1
Insomnia	1				1
Food poisoning	1				1
Ovary cysts	1	1			1
Odontology	1				1
Pleurisy	1				1
Irregular periods	1				1
Tetanus	1				1
Essential tremor	1				1
Gastrointestinal ulcer	1				1
Varicella	1				1
Agalactia		1			1
Spontaneous abortion		1			1
Hemiplegia		1			1
Hiccup		1			1
Tongue hypertrophy		1			1
Icterus		1			1
Laxative		1			1

(*continued on next page*)

Table 3 (*continued*)

Uses	Frequency of citation per Loranthaceae species				FC
	A. dodoneifolius	*T. globiferus*	*P. kamerunensis*	*T. ophioides*	
Leprosy		1			1
Language disorders		1			1
Tumor		1			1
Magic (23 uses) rowhead					
Increase in agricultural yield	39	26	5		60
Luck	24	24			40
Protection against witches	28	15	1		38
Seducing women	20	8			22
Against lack of sales	9	13			19
Success in examinations and competitions	10	9			15
Increase in the size of the livestock	3	5			8
Esteem of all	4	3			6
Against unemployment	4	1			5
Fulfillment of wishes	2	1			3
Promotion	2				2
Delaying the death of twin babies	2				2
Prosperity		2			2
Attracting prey to be captured		2			2
Against traffic accidents	1				1
Against poisoning	1				1
Against infidelity	1				1
Mystical disappearance	1				1
Peace in family	1				1
Protection of the field against the bewitchment	1				1
Protection of the herd against envy	1				1
Victory in elections	1	1			1
Varietal diversification of cereal crops		1			1
Veterinary (17 uses) rowhead					
Bovine Pasteurellosis	9	9			13
Anorexia in cattle and goats	6	5			9
Foot and mouth disease	6				6
Immune deficiency in cattle, goats, and poultry	3	3			5
Bovine placental retention	3	3			5
Sterility of cattle and goats	1	4			5
Cattle and goats emaciation	3	1			4
Helminthiasis in cattle and goats	1	3			3
Bovine madness	2				2
Bellyache in cattle and goats	2	3			2
Envenomation of cattle and goats		2			2
Post-natal convulsions in cattle and goats	1				1
Cattle cramp	1				1
Cattle and goat eye disorders	1				1
Bovine agalactia		1			1
Bovine dystocia		1			1
Post-rainfall bovine fever		1			1
Food (2 uses) rowhead					
Vegetable leaves	5	5			5
Potash	4	2			4
Animal alimentation (1 use) rowhead					
Cattle and goat fodder	20	13			20
Cosmetic (1 use) rowhead					
Soap	4	2			4

with FCs of 42, 32, and 29 respectively (Table 3). Increasing agricultural yield (FC = 60), luck (FC = 40), and protection against witches (FC = 38) are the most important magic uses out of the 23 recorded. In veterinary medicine, a total of 17 uses were recorded, with the treatment of anorexia in cattle and goats, bovine pasteurellosis, and foot-and-mouth disease as the most important, with FCs of 13, 9, and 6 respectively. Soap making was the only cosmetic use recorded, as well as fodder for cattle and goats in terms of animal feed. Finally, two uses were recorded for human food, namely leafy vegetables and potash production with FCs of 5 and 4 respectively. Considering their total FC, the main Loranthaceae specific uses were: increase of agricultural yield (FC = 60), treatment of malaria, (FC = 42), uses for luck (FC = 40), protection against witches (FC = 38), and treatment of hyperthermia (FC = 32).

3.2.2. Cultural importance of Loranthaceae

Considering Loranthaceae species, *A. dodoneifolius* was the most important regarding to its RFC, NU, UV, and NUC which were 0.938, 95, 2.296, and 6 respectively (Table 4). It was followed by *T. globiferus* with 0.688, 78, 1.417, and 6 as RFC, NU, UV, and NUC respectively. Considering the CI of Loranthaceae species, it appears that out of its 6 uses categories, *A. dodoneifolius and T. globiferus*

Table 4
Cultural importance parameters of Loranthaceae species in northern Benin.

Parameters	*A. dodoneifolius*	*T. globiferus*	*P. kamerunensis*	*T. ophioides*
RFC	0.938	0.688	0.029	0.004
NU	95	78	4	1
UV	2.296	1.417	0.038	0.004
NUC	6	6	2	1
RU_{HM}	175	110	3	1
RU_{MAG}	104	79	6	0
RU_{VET}	25	23	0	0
RU_{FOD}	20	13	0	0
RU_{FOO}	9	7	0	0
RU_{COS}	4	2	0	0
CI_{HM}	0.729	0.458	0.013	0.004
CI_{MAG}	0.433	0.329	0.025	0
CI_{VET}	0.104	0.096	0	0
CI_{FOD}	0.083	0.054	0	0
CI_{FOO}	0.038	0.029	0	0
CI_{COS}	0.017	0.008	0	0
CI total	1.404	0.974	0.038	0.004

RFC: Relative Frequency of Citation, NU: Number of Uses, UV: Use Value, UC: Use Categories (COS: cosmetic, FOO: food, FOD: fodder, HM: human medicine, MAG: magic, VET: veterinary).

were mainly used in human medicine with CI of 0.729 and 0.458 respectively. *P. kamerunensis* was mainly reported for magic uses (CI = 0.025) and *T. ophioides* is used in human medicine only (CI = 0.004).

A total of six Loranthaceae parts were reported (Fig. 5A–F). According to their RFC, such plant parts were the leafy stems (1), leaves (0.038), stems (0.013), fruits (0.008), wood rose, and flowers (0.004 each).

3.3. Socio-demographic groups and levels of knowledge about Loranthaceae uses

The number of uses per informant ranged from 1 to 19, with an average of 3.20 ± 2.15 uses. The Chi-square test performed within the results of the Poisson's regression revealed that informant ethnic group, occupation, age and religion were the factors determining the level of knowledge of Loranthaceae uses (Table 5).

The variation in knowledge levels according to determining factors (Table 6) revealed that at ethnic level, *Bariba* presented more knowledge about mistletoe uses. According to the occupation, knowledge level of traditional healers (3.88 ± 2.52 uses) and breeders (3.70 ± 1.51 uses) was higher than that of farmers (2.13 ± 1.13 uses). Considering informant age, old people (aged 50 or over) had the highest level of knowledge of Loranthaceae uses (3.96 ± 1.85 uses). Concerning the religion, the knowledge of Loranthaceae uses decreased from Animists (3.51 ± 2.53 uses per individual) to Muslims (3.04 ± 1.72 uses), and Christians (2.37 ± 1.46 uses). In summary, the socio-demographic groups with the highest levels of knowledge about Loranthaceae uses in northern Benin were: *Bariba*,

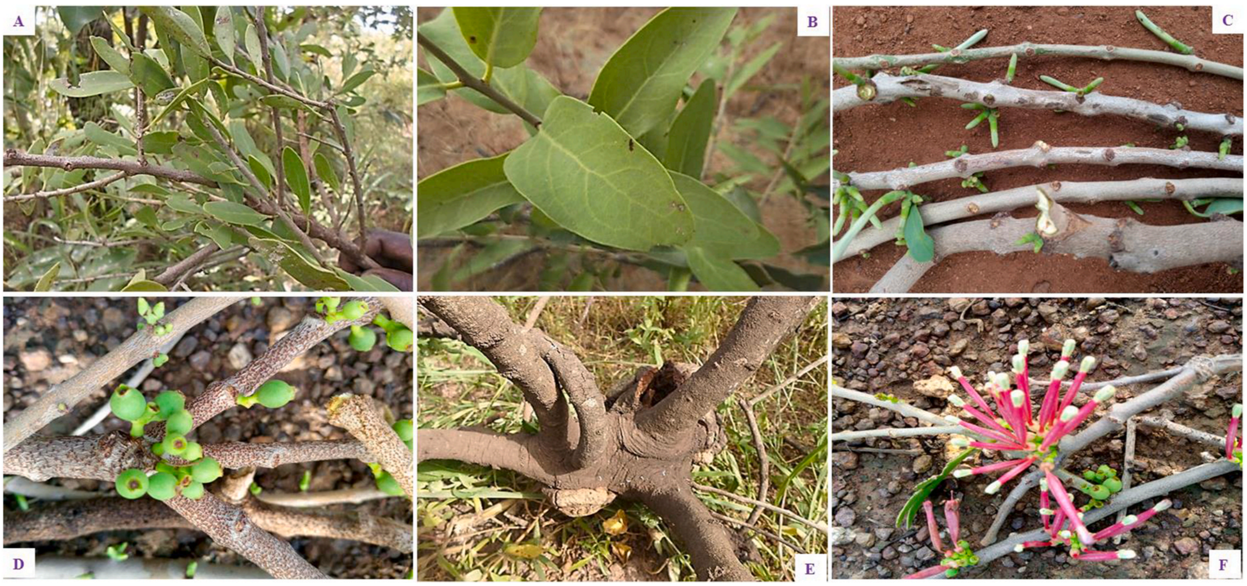

Fig. 5. Loranthaceae parts reported in northern Benin. (**A.** Leafy stems, **B.** Leaves, **C.** Stems, **D.** Fruits, **E.** Wood rose, **F.** Flowers).

Table 5
Outputs of Poisson's regression performed on the number of Loranthaceae uses in northern Benin.

	DF	Deviance	Resid. DF	Resid. Dev	Pr (>Chi)
NULL			239	293.17	
Zon	2	0.75	238	292.41	0.38
Par	2	1.96	237	290.46	0.16
Gen	1	1.88	236	288.57	0.17
Age	84	11.37	235	277.20	0.00
Eth	14	66.09	221	211.11	9.756e-09
Rel	2	8.41	219	202.70	0.01
Edu	2	3.27	217	199.43	0.19
Occ	2	15.03	215	184.40	0.00

Zon: phytogeographical zone, Par: shea and the black locust park, Ethn: ethnic group, Gen: gender, Rel: religion, Edu: level of education, Occ: occupation, Age: age, DF: degree of freedom, Resid. DF: residual degree of freedom, Resid. Dev: residual deviance, Pr (>Chi): probability associated with Chi^2 tests.

Table 6
Variation in knowledge level of Loranthaceae uses according to key factors in northern Benin.

Factors	Average number of uses (VUR±sd)
Ethnic group	
Bariba	3.83 ± 2.74^a
Gando	3.55 ± 1.83^b
Boo	3.46 ± 1.71^b
Peulh	3.36 ± 1.39^c
Mokolé	3.30 ± 0.95^c
Gourmantché	3.13 ± 1.31^c
Wama	2.88 ± 1.46^c
Yom	2.31 ± 1.65^d
Natimba	2.33 ± 1.50^d
Lokpa	1.00 ± 0.00^e
Others ethnic groups	3.36 ± 3.05^c
Occupation	
Traditional healer	3.88 ± 2.52^a
Breeder	3.70 ± 1.51^a
Farmer	2.13 ± 1.13^b
Age range	
Old	3.96 ± 1.85^a
Adult	3.46 ± 2.02^a
Young	2.80 ± 2.26^b
Religion	
Animist	3.51 ± 2.53^a
Muslim	3.04 ± 1.72^b
Christian	2.37 ± 1.46^c
Mean±sd	3.20 ± 2.15

sd: standard deviation; a,b, c: means in a row non-connected by the same letters are significantly different ($p < 0.05$). Other ethnic groups: under-represented ethnic groups including *Berba*, *Dendi*, *Djerma*, *Kabyè*, and *Otamari*.

traditional healers and breeders, old people, and Animists.

3.4. Variation of Loranthaceae utilization between and within ethnic groups

The average number of Loranthaceae species reported was 2.364 ± 0.674 per ethnic group (Table 7). It varied from 1 among the *Lokpa* to 3 among *Bariba*, *Gando, Yom*, and *Gourmantché*. The Chi-square test revealed a significant dependency between ethnic groups and Loranthaceae species used ($X^2 = 2842.3$, df = 99, p-value <0.05). Of the four Loranthaceae species reported, *A. dodoneifolius* was reported by all ethnic groups. Its mean RFC was 0.946 ± 0.059 and its highest value of 1.000 was recorded among *Yom*, *Natimba*, *Mokolé*, *Lokpa,* and *Wama*. *T. globiferus* was cited by all ethnic groups except *Lokpa*. Its mean RFC was 0.603 ± 0.243, with its highest value of 0.813 reported among *Gourmantché*. *P. kamerunensis* has an average RFC of 0.017 ± 0.026 and was only reported among *Bariba*, *Gando*, *Yom*, and other ethnic groups. Finally, *T. ophioides* was only cited among *Gourmantché*, with a RFC of 0.063.

The mean number of Loranthaceae organs reported per ethnic group was 1.818 ± 0.982 and ranged from 1 among *Yom*, *Gourmantché*, *Peul*, *Lokpa*, and *Wama* to 4 among *Bariba*. There was a significant dependency between ethnic groups and Loranthaceae organs used ($X^2 = 3797.4$, df = 90, p-value <0.05). Of the 6 Loranthaceae organs mentioned, leafy twigs were reported by all individuals within all ethnic groups. On the other hand, fruits, wood roses, and flowers were only recorded among *Boo*, *Natimba*, and

Table 7
Variation of Loranthaceae species, organs and use categories according to ethnic groups in northern Benin.

	Bariba	Gando	Yom	Natimba	Gourmantché	Peul	Boo	Mokolé	Lokpa	Wama	Others ethnic groups	Mean ± sd
Number of Loranthaceae species used	3	3	3	2	3	2	2	2	1	2	3	2.364 ± 0.674
Relative Frequency of Citations of each Loranthaceae species												
A. dodoneifolius	0.913	0.925	1.000	1.000	0.938	0.929	0.846	1.000	1.000	1.000	0.857	0.946 ± 0.059
T. globiferus	0.797	0.700	0.414	0.778	0.813	0.643	0.692	0.800	0.000	0.500	0.500	0.603 ± 0.243
P. kamerunensis	0.058	0.025	0.034	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.071	0.017 ± 0.026
T. ophioides	0.000	0.000	0.000	0.000	0.063	0.000	0.000	0.000	0.000	0.000	0.000	0.006 ± 0.019
Number of Loranthaceae part used	4	3	1	2	1	1	2	2	1	1	2	1.818 ± 0.982
Relative Frequency of Citations of each Loranthaceae part												
Leafy stems	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000 ± 0.000
Leaves	0.043	0.050	0.000	0.000	0.000	0.000	0.000	0.100	0.000	0.000	0.214	0.037 ± 0.067
Stems	0.029	0.025	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005 ± 0.011
Fruits	0.000	0.000	0.000	0.000	0.000	0.000	0.154	0.000	0.000	0.000	0.000	0.014 ± 0.046
Wood rose	0.000	0.000	0.000	0.056	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005 ± 0.017
Flowers	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001 ± 0.004
Use category diversity	4	5	2	2	5	4	3	4	1	4	4	3.455 ± 1.293
Relative Frequency of Citations of each use category												
Human medicine	0.913	0.725	0.690	0.833	0.938	0.643	1.000	0.900	1.000	0.750	0.786	0.834 ± 0.124
Magic	0.739	0.625	0.724	0.444	0.313	0.571	0.615	0.400	0.000	0.250	0.500	0.471 ± 0.222
Veterinary	0.043	0.450	0.000	0.000	0.063	0.786	0.077	0.000	0.000	0.000	0.000	0.129 ± 0.255
Fodder	0.058	0.225	0.000	0.000	0.000	0.214	0.000	0.100	0.000	0.000	0.214	0.074 ± 0.098
Food	0.000	0.025	0.000	0.000	0.125	0.000	0.000	0.100	0.000	0.250	0.214	0.065 ± 0.094
Cosmetic	0.000	0.000	0.000	0.000	0.125	0.000	0.000	0.000	0.000	0.250	0.000	0.034 ± 0.081

sd: standard deviation; other ethnic groups: under-represented ethnic groups including *Berba*, *Dendi*, *Djerma*, *Kabyè*, and *Otamari*.

Bariba respectively, with RFCs of 0.154, 0.056, and 0.014.

Finally, the number of Loranthaceae use categories per ethnic group varied from 1 among *Lokpa* to 5 among *Gando*, with an average of 3.455 ± 1.293. A significant dependency was observed between ethnic groups and Loranthaceae use categories ($X^2 = 4298$, df = 110, p-value <0.05). Human medicine was the use category distributed across all ethnic groups. Its mean RFC was 0.834 ± 0.124, with the highest value of 1.00 recorded among *Boo* and *Lokpa* and the lowest value of 0.643 among *Peul*. Magic use category was cited by all ethnic groups except *Lokpa*. Its mean RFC is 0.471 ± 0.222, with the highest value of 0.739 recorded among *Bariba*. The mean RFC of veterinary category was 0.129 ± 0.255. This use category was reported by *Bariba*, *Gando*, *Gourmantché*, *Peul*, and *Boo* with the highest RFC value observed among *Peul* (0.786). The mean RFC of fodder category was 0.065 ± 0.094 with a variation ranging from 0.000 among *Yom*, *Natimba*, *Gourmantché*, *Boo*, *Lokpa,* and *Wama* at 0.225 among *Gando*.

Food category was reported only among *Gando*, *Gourmantché*, *Mokolé*, *Wama*, and others ethnic groups with an RFC whose average was 0.065 ± 0.094 and the highest value of 0.250 was recorded among *Wama*. Finally, cosmetic category was reported only by *Gourmantché* and *Wama* with RFCs of 0.125 and 0.250 respectively.

Table 8 revealed that IS was less than 50 % between all ethnic group couples except between *Bariba* and *Yom* where its value was 75.47 %. *Bariba* and the *Yom* were therefore the only ethnic groups to present a similarity in Loranthaceae uses.

The dendrogram (Fig. 6 and Appendix A, Supplementary data) enabled us to identify three ethnic groupings. Group 1 was solely represented by *Bariba*. This ethnic group was distinguished from the others by its 22 specific uses (Appendix A, Supplementary data).

These were uses against infidelity, poisoning, anorexia, ovary cysts, dental diseases, helminthiasis, hemiplegia, hemorrhage, hepatitis, hiccup, irregular periods, persistent wounds, pleurisy, tetanus, tongue hypertrophy, tumor, yellow fever and those for the protection of the field against the bewitchment, spontaneous abortion, victory in elections, attracting prey to be captured, and peace in family. Group 2 included *Gando* and *Peul* who shared 22 Loranthaceae uses, most of which are veterinary uses. Such veterinary uses were those against bovine pasteurellosis, immune deficiency in cattle, goats, and poultry, bovine placental retention, sterility of cattle and goats, cattle and goats emaciation, helminthiasis in cattle and goats, bovine madness, bellyache in cattle and goats, and envenomation of cattle and goats. Group 3 comprised the eight remaining ethnic groups that had no common Loranthaceae use of their own.

4. Discussion

4.1. Diversity, local names, and management of mistletoes

We documented four Loranthaceae species recognized as used in the study area. This diversity is lower than that of seven mistletoe species recorded in the same area during floristic inventories [34]. Indeed, *Globimelula cupulata, P. nigritana*, and *T. bangwensis* were not mentioned by the respondents despite their presence in the study area. This can be explained by the sampling effort in the ethnobotanical surveys which covered six of the 32 communes in the study area. It is therefore necessary to extend the investigations throughout Benin to obtain more representative data on the use of Loranthaceae. Concerning the local names attributed to Loranthaceae, informants confirm their good knowledge of these plants. Indeed, names such as parasitic plants, infestation caused by birds, and tree burden reveal that the negative influence of Loranthaceae on their hosts is well known by the populations so as to facilitate their adhesion to the fight against these parasites.

4.2. Uses diversity and mistletoe valorization

The study showed that Loranthaceae were involved in 113 endogenous uses grouped into six categories namely human medicine, magic, veterinary medicine, fodder, food, and cosmetics. Previous studies revealed the use of these parasitic plants for human and veterinary medicine, food, and magic in Benin [8,11,25–27,46]. This diversity of 6 use categories is similar to that of five uses reported in Nepal where mistletoes were mainly used in traditional medicine, fodder, food, the making of ritual objects, and as bird-catching equipment [28]. Our study, therefore, expanded the list of mistletoe uses revealing their involvement in new uses such as the production of traditional soap and potash. The using of mistletoes in the production of traditional soap and potash is justified by the high concentration of the leaves of these plants in potassium. Indeed, in Cameroon, Dibong et al. [47] reported levels of up to 143.08 g of Potassium per kilogram of dry leaves of mistletoe. Given the high quantity of biomass it requires, intensifying the production of soap from mistletoe leaves will contribute to biological control these parasitic plants. This will reduce a large part of the mistletoe density on *V. paradoxa* and *P. biglobosa* given these mistletoes were the most abundant in the study area. The preponderance of medicinal uses of mistletoes revealed in this work is well recognized worldwide [20,24,48,49] and explained by the active compounds they contained [50,51]. Thus, we recommend the use of mistletoes in the production of improved traditional medicines to significantly reduce their density and then contribute to the improvement of human health [30]. However, additional physico-chemical and pharmacological tests are required for the exploration of this alternative [52–54]. In addition, we reported in this paper the use of mistletoes for fodder and veterinary medicines. Previous studies also reported the use of mistletoes in the management of convulsions and foot-and-mouth disease in Benin and their effectiveness in the treatment of African trypanosomiasis in Nigeria [27,55]. Therefore mistletoes can be used for the production of food in the form of feed to reduce the costs of feed and animal health which remain a challenge for the profitability of breeding [52,54]. This suggestion is in line with that of Egbewander et al. [56] who recommended the substitution of 10 % of peanut meal by the leaves of mistletoe *T. bangwensis* in poultry feed in Nigeria. Our investigations showed that informants used mistletoes according to their host species. Studies conducted in Benin [8], Nigeria [57], Cameroon [30], and throughout West Africa [48] also showed that mistletoes are very little or rarely differentiated by populations and their uses depend on the host species. Burkill [48] explained this use form of mistletoes by the transfer of active compounds from the host to these parasitic plants. The present

Table 8
Variation in Jaccard's Similarity Index between ethnic groups based on specific uses of Loranthaceae in northern Benin.

Ethnic groups	Bariba	Gando	Yom	Natimba	Gourmantché	Peul	Boo	Mokolé	Lokpa	Wama	Others
Bariba	100.00	34.48	75.47	22.06	20.55	12.20	23.94	26.76	3.03	17.39	31.88
Gando	34.48	100.00	23.81	21.43	25.86	37.50	30.36	27.12	1.92	15.79	33.33
Yom	75.47	23.81	100.00	25.71	25.64	10.42	25.64	24.39	3.57	27.27	33.33
Natimba	22.06	21.43	25.71	100.00	21.88	13.16	25.81	24.24	5.56	18.52	23.53
Gourmantché	20.55	25.86	25.64	21.88	100.00	9.09	29.41	31.43	9.09	32.14	23.68
Peul	12.20	37.50	10.42	13.16	9.09	100.00	20.00	17.95	0.00	5.71	14.63
Boo	23.94	30.36	25.64	25.81	29.41	20.00	100.00	35.29	9.09	19.35	23.68
Mokolé	26.76	27.12	24.39	24.24	31.43	17.95	35.29	100.00	8.33	25.81	25.64
Lokpa	3.03	1.92	3.57	5.56	9.09	0.00	9.09	8.33	100.00	6.25	0.00
Wama	17.39	15.79	27.27	18.52	32.14	5.71	19.35	25.81	6.25	100.00	25.00
Others ethnic groups	31.88	33.33	33.33	23.53	23.68	14.63	23.68	25.64	0.00	25.00	100.00

Other ethnic groups mean under-represented ethnic groups including *Berba*, *Dendi*, *Djerma*, Kabyè, and *Otamari*.

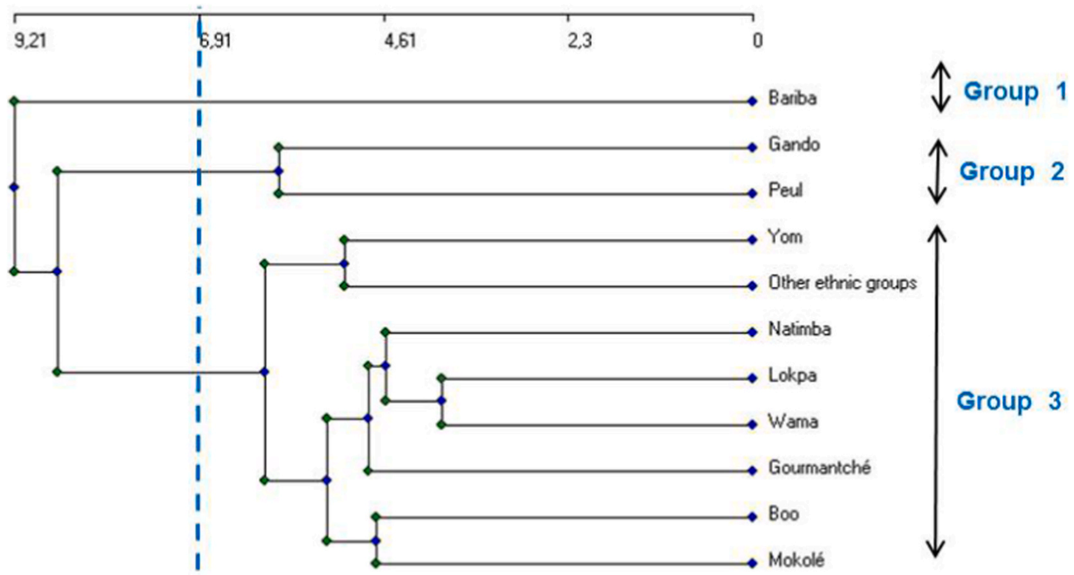

Fig. 6. Hierarchical clustering of ethnic groups based on Loranthaceae uses in northern Benin (Other ethnic groups: under-represented ethnic groups including *Berba*, *Dendi*, *Djerma*, *Kabyè*, and *Otamari*).

results are supported by Wahab et al. [50] who reported in Nigeria that host species significantly influence the chemical composition of mistletoes, and hence their therapeutic properties. In the same country, Efuntoye et al. [58] also demonstrated that the antidiarrhoeal properties of the mistletoe *T. bangwensis* were influenced by its host species. However, given mistletoes recorded in Benin are hemiparasitic plants, they are expected to contain some specific chemical compounds independently of their host species. It is then necessary to evaluate the variations in the chemical compounds of different mistletoe species harvested from the same host species. Physico-chemical and pharmacological analyses are required for mistletoe valorization through the production of improved traditional medicines, animal feed, soap, and green fertilizers. The combination of all these strategies will contribute to reduce the density of these parasites on their hosts. However our study revealed the use of some parts of Loranthaceae such as flowers, fruits, and wood roses, which could be detrimental to the conservation of these plants. Although the frequency of use of these parts is currently low, local populations need to be made aware of the sustainable use of Loranthaceae [30]. We recommend that Loranthaceae be harvested without removing the wood rose. The multiplication of Loranthaceae on specific hosts will also contribute to the sustainable use of these parasites. Further studies could focus on the assessment of the impact of harvesting methods of mistletoes on their conservation.

4.3. Level of knowledge and variation in Loranthaceae uses between and within ethnic groups

The present study revealed that knowledge level about Loranthaceae varied with informant ethnicity, occupation, age, and religion. Although several studies had addressed the factors determining the level of knowledge of plant uses [59–61], the case of Loranthaceae has not yet been specifically addressed to our knowledge. Our results corroborate those of Ahoyo et al. [61] that were obtained in Benin and showed traditional medicinal knowledge varied with informant ethnicity, source of knowledge, membership position, age, instruction level, and professional activity. In more detail, this study showed *Bariba*, traditional healers and breeders, old people, and animists presented the highest levels of knowledge about Loranthaceae uses. This can be explained by the fact that old people accumulated experience in an area where traditional knowledge about Loranthaceae uses is gradually being passed on. The high level of knowledge of traditional healers and breeders, and animists about Loranthaceae uses may be due to their strong direct dependence on plant resources including mistletoes. The high level of knowledge presented by *Bariba* on Loranthaceae uses can be explained by the effect of religion, age and occupation. Indeed, *Bariba* population surveyed was made up of 54 % animists, 61 % traditional healers and 57 % people over 50 years old. These groups should be involved as a matter of priority in the various strategies for promoting Loranthaceae and disseminating knowledge about the use of these parasitic plants. The dendrogram discriminated against *Bariba*, then *Peul* and *Gando* of all the remaining ethnic groups on the basis of the similarity of uses. Bariba discrimination is explained by the fact that this group alone cited 58 % of the 113 uses recorded in this study. The grouping of *Peul* and *Gando* is justified by their cultural backgrounds, which are very similar [62].

5. Conclusion

We recorded, in northern Benin, four mistletoe species which were *A. dodoneifolius*, *T. globiferus*, *P. kamerunensis*, and *T. ophioides*. Mistletoes were used without distinction of their species but rather according to the host species. Mistletoe uses were gathered in 6 categories namely: human medicine, magic, veterinary medicine, food, fodder, and cosmetics. Through these results, we suggest several strategies for mistletoe management in Benin including mistletoe use as a raw material in the production of improved traditional medicines, animal feed, soap, and green fertilizers. However, this study presents some limitations concerning the low sample size of five ethnic groups namely *Berba*, *Dendi*, *Djerma*, *Kabyè*, and *Otamari*, whose informants were gathered into other ethnic groups. Moreover, ethnobotanical data are lacking on *Globimelula cupulata*, *P. nigritana*, and *T. bangwensis*, three Loranthaceae species recorded in the area but not mentioned in this study. The variation in Loranthaceae uses according to host species also remains to be explained. We recommend that future studies be more representative and focused on the impact of Loranthaceae organ harvesting methods on the conservation of these species, the similarity between the uses of Loranthaceae and those of their hosts, the reproductive biology and ecology of Loranthaceae species, and the chemical, biochemical and pharmacological arguments that could explain the local uses of Loranthaceae reported in the present study.

Funding statement

This research was financially supported by the Ministry of Higher Education and Scientific Research of the Republic of Benin who granted the first author a PhD scholarship through the program “Appui aux Doctorants” for the period 2015–2017.

Data availability statement

Data associated with the study has not been deposited into a publicly available repository. Data will be made available on request.

CRediT authorship contribution statement

Dègninou Yélognissè Innocent Ahamidé: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Writing – original draft, Writing – review & editing, Validation, Visualization. **Gbèwonmèdéa Hospice Dassou:** Formal analysis, Investigation, Methodology, Writing – review & editing, Validation. **Sfich Thibaut Bidossèssi Ahouandjinou:** Investigation, Writing – review & editing. **Gbèdomèdji Hurgues Aristide Houénon:** Investigation, Writing – review & editing. **Hounnankpon Yédomonhan:** Methodology, Supervision, Validation, Writing – review & editing, Resources. **Gbèkponhami Monique Tossou:** Methodology, Supervision, Validation, Writing – review & editing, Resources. **Aristide Cossi Adomou:** Conceptualization, Methodology, Supervision, Validation, Writing – review & editing. **Akpovi Akoègninou:** Conceptualization, Methodology, Supervision, Validation, Writing – review & editing, Resources.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors are grateful to the local people for sharing their knowledge and actively contributing to the data collection. They also thank Mr. Rufin N. KPATINNON of the Faculty of Agronomic Sciences of the University of Abomey-Calavi (Benin) for his support in cartography. Special thanks are due to anonymous reviewers for their valuable comments that improved the manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e22958.

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