Perception of malaria and cultural diversity of antimalarial plants in three sympatric ethnic groups: Agni, Akyé and Gwa of Alépé Department (Southeast of Côte d'Ivoire)

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Research

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Abstract

Background

Ethnic groups have developed their own cultures expressed in the form of traditional health care systems. This study aimed to determine how three sympatric communities with different histories, perceive and manage malaria, a disease with a high prevalence rate in the region.

Methods

An ethnobotanical survey was carried out in 10 villages of Agni, Akyé and Gwa communities. Semi-structured interviews were conducted with 290 informants within all three communities. A correspondence analysis associated to hierarchical clusters was used to determine the form of malaria shared within informants. Then, the free listing technique was performed to indicate the plant species which was most important for the respondents. Besides, the Venn diagram coupled to Jaccard similarity index was used to report the homogeneity on antimalarial plants species used within the three studied communities. Moreover, the Kruskal-Wallis test was used to compare the most common antimalarial plant within communities. Finally, the fidelity level index was used to identify the most preferred plant species used to cure various forms of malaria.

Results

The three ethnic groups have overall a similar perception of malaria with various symptoms. However, they did not use the same plants to cure one form of this disease. The study recorded 77 medicinal plants used to cure malaria, in which, a few such as *Annickia polycarpa*, *Gymnanthemum amygdalinum*, *Alstonia boonei*, *Nauclea latifolia*, *Harungana madagascariensis*, *Ocimum gratissimum* and *Senna occidentalis* were the most important. The analysis of intracultural knowledge on antimalarial plants revealed that informants have shared a high knowledge. Meanwhile, there is an intercultural convergence about common plants used within communities. Therefore, 20 antimalarial plant species were shared within communities and actively used, through time. Finally, in terms of antimalarial plants knowledge, Akyé and Gwa communities were closer than Agni communities.

Conclusions

In spite of their different histories, the close contact of communities promote the sharing of the knowledge. People use the same important plants to cure malaria and know five forms of malaria. Knowledge on antimalarial plants does not reach a stable climax, but could be evolved by trial and error, as effective cures malaria.

Introduction

Medicinal plants are one of the most widely known values of traditional knowledge, as they provide primary health care [1]. Certainly, traditional medicine is an important source of health care in rural or tribal areas [2, 3]. In sub-Saharan countries such as Côte d'Ivoire [4, 5], Mali [6] and Guinea [7], people still use traditional medicine to cure many diseases as malaria.

Malaria is among the major vector-borne diseases that kill a lot of people in sub-Saharan Africa [8]. That disease constitutes a real public health issue and motivates the consultation and hospitalization in sanitary centres [9]. However, the raised costs of the sanitary cares lead many people in rural areas, to use traditional medicine as alternative for curing malaria [10]. Even so, in an intercultural region, a given ethnic group could know some species which may not be appreciated by another ethnic group or may even be ignored by them [11]. To that purpose, they do not use and value all plant species equally according to their needs in the same practice [12]. Those reasons could hide a variation in the perception of a particular disease and a different significance of plants for those communities [13], especially while they share the same geographical area with other communities [14].

In Africa, particularly in Côte d'Ivoire, numerous studies dealing with medicinal plant uses are simple lists of plants [15] or ethno-pharmacology uses against malaria [4, 16]. Moreover, they were undertaken solely on intra-cultural background. Other studies in the same way, were undertaken for many diseases [17]. Comparative ethno-botanical studies among communities who share the same area are scarce. Nevertheless, such studies help to find which species are interchanged through communities and for which reasons [1, 18]. Moreover, those studies analyse whether cultural diversity is reflected in the folk phytotherapy knowledge as shown by [11]. These authors argued, as noted by many others [1–18, 19] that the comparative study of medicinal plant knowledge among sympatric ethnic and/or local groups may be divided into two types. The first type focuses on traditional groups with comparatively long residence in the region and the second type concentrates on the comparison of medicinal plants use by ethnic groups with different times of residence in a given region. The present study is within the first statement. Indeed, in the Department of Alépé, in the southeastern region of Côte d'Ivoire, the Agni, Akyé and Gwa ethnic groups have lived in close proximity and contact for many centuries in the Department of Alépé. Agni and Akyé belong to the great Akan ethnic group [20–23], whereas Gwa ethnic groups were adopted by Akan [24, 25]. Although close to the economic capital, Abidjan, this area is extremely difficult of access due to the poor state of the roads. Moreover, these communities are among those whose traditional practices are the least documented. Finally, these communities are in malaria high transmission zone with 200 to 300 confirmed cases per 1,000 inhabitants per year [26]. In the light of these backgrounds, the study aimed to (i) analyse the perception of different forms of malaria and (ii) to assess the importance of antimalarial plants species used among these ethnic groups. Moreover, this study aimed (iii) to determine the intracultural and the intercultural variations on antimalarial plant knowledge within ethnic groups.

Material And Methods

Study area

The Department of Alépé is located in Southeastern Côte d'Ivoire between 5°13'04.49" - 5°55'22.06" N and 3°25'25.25" - 3°57'46.64" W (Figure 1). The climate of this zone is equatorial and humid, characterized by four alternate seasons (two rainy seasons and two dry seasons). The annual rainfall is ranged from 1,200 to 1,600 mm and the annual temperature is 26.4°C with a variation of 3°C. The vegetation type of the study area is a Guinean rainforest characterized by *Eremospatha macrocarpa* (Mann. & Wendl.) Wendel. and *Diospyros mannii* Hiern [27].

The study area harbors three sympatric ethnic groups Agni, Akyé and Gwa. All of them are unequally spread within five sub-prefectures (Aboisso-Comoé, Alépé, Allosso, Danguira and Oghlwapo). These three ethnic groups have been settled in their present territory since the beginning of the 18th century, the Agni and the Akyé from present-day Ghana [22, 23], and the Gwa from Liberia [24, 25]. Upon arrival, these ethnic groups came into conflict for their current installation [28]. All three ethnic groups are essentially farmers.

Ethnobotanical survey

Several field trips were made in 10 villages of the study area from September 2017 to August 2019. A total of 290 informants were selected randomly with semi-structured interview [29]. At first step, free lists were collected through a house-to-house approach in each village. The seek items included forms of malaria, symptoms related to the forms of malaria, plants used for healing malaria.

Respondents were distributed as follows: 97 in Agni ethnic groups (40 men and 57 women), 97 in Akyé ethnic groups (35 men and 62 women) and finally 96 in Gwa ethnic groups (47 men and 49 women). For next step, walks in the surrounding bushes were organised with key informants in each village, to collect herbarium vouchers. At the final step, the lists collected during the first step was completed and herbarium vouchers identified at Nangui Abrogoua University.

Data analysis

A correspondence analysis (CA) combined to a hierarchical cluster analysis was performed in order to show the forms of malaria sharing between ethnic groups. The principle of this analysis is to establish the link between two sets of variables that constitute the rows and columns of a contingency table. This analysis was carried out with the frequency of quotation of the form of malaria by each ethnic group. That frequency of quotation was obtained to assess the extent of form in each ethnic group (Equation 1).

$$F_q = \frac{n_i}{N} \times 100 \quad (1)$$

Where F_q is the frequency of quotation; n_i is the number of times when the form of malaria was mentioned, and N is the total number of informants. When $F_q \geq 50\%$ the form is considered as well known. Below this value, the form can be judged middle known $25 \leq F_q \leq 50\%$ or low known $F_q < 25\%$.

Free listing technique was performed by Anthropac 4.0 following the Smith Index (Equation 2) in order to obtain the salience for each species [30].

$$S = \{\sum[(Li - Rj + 1)/Lj]\}/N \ (2)$$

Where *S* is the importance of quotations, *Li* the length of a quotation list and *Rj* the rank of a quotation in the list and *N* is the number of free lists (number of respondents). A high value of this index (close to 1) indicates the antimalarial plant species which is preferred and important for the respondents.

In addition, the Jaccard similarity Index [31] was used to analyse the homogeneity on antimalarial plants species and reports the similarity within the three studied communities (Equation 3).

$$JI_{ij} = \frac{a}{a + b + c} \ (3)$$

JI is the Jaccard similarity index, *a* is the number of species common to any compared pair ethnic group *i* and *j*; *b* is the number of species mentioned only by group *i*, and *c* is the number of species mentioned solely by group *j*.

Then, the specific abundance shared by each pair of ethnic groups or exclusive to one ethnic group and the common species shared between the three ethnic groups were obtained with Venn diagram. This diagram shows the number of antimalarial plant species shared between ethnic groups. Moreover, a comparison test on the most common antimalarial plant species shared within the ethnic groups, were made with Kruskal-Wallis test. This test determines the intercultural convergence on knowledge exchanges between the ethnic groups.

Finally, the fidelity level (FL) index (Equation 4) was used to identify the preferred plants to heal various forms of malaria and shows the proportion of informants reporting the use of specific plants [32].

$$FL = Np/N \times 100\% \ (4)$$

Where *Np* is the number of respondents citing the use of species for a particular ailment and *N* is the total number of respondents who cited the plants for any form. All statistical analyses were performed with R software (version 4.0.3).

Results

Knowledge and perception of malaria by the three ethnic groups

Six various terms are used to indicate six different forms of malaria according to each ethnic group (Table 1).

Table 1
Local names of malaria and their meanings.

ethnic group	local name	local perception	literal meaning
Agni	*ebunu*	*ebunu fufue, ebunu kokole, ebunu bile, ebunu ewengo, enwulo*	white malaria, yellow malaria, black malaria, red malaria, birds malaria
Akyé	shilo	*shilo fi, shilo nin, shilo bi, shilo poin, n'kaka, kpun shilo*	white malaria, yellow malaria, black malaria, red malaria, birds malaria, mystical malaria
Gwa	djakoadjo	*djakoadjo popon, djakoadjo heni, djakoadjo mlu, djakoadjo nuin, zoku, djakoadjo montinin*	white malaria, yellow malaria, black malaria, red malaria, birds malaria, mystical malaria

Among these six different forms of malaria, five are expressed with symptoms. Meanwhile, the mystical malaria, another form appears without symptoms. Thus, the most common form is yellow malaria mentioned by 72.16% of informants, which means yellowish eyes, yellowish urine and fever. Then, white malaria identified by 58.76% means pale skin and edema. Besides, red malaria is indicated by 42.61% which means fever and reddish eyes. Moreover, black malaria is identified by 24.74%, means fever and dark skin. Otherwise, 5.15% of informants have mentioned bird malaria which means disjointed movements, fever and pale skin. Finally, the mystical malaria is indicated by 1.37% of informants without symptoms. Table 2 summarizes the symptoms mentioned in the study.

Table 2
Symptoms related to the forms of malaria.

Symptom	white malaria (%)	yellow malaria (%)	black malaria (%)	red malaria (%)	bird malaria (%)	mystical malaria
ache/tiredness	4.73	6.91	6.29	9.17		
anemia/dark skin	2.21	0.43	9.09	3.98		
cold sore	7.57	3.24		0.92		
constipation	0.95	1.3	6.29	5.81		
disjointed movements					29.73	
distension	5.36	0.86	0.7		5.41	
dizziness	2.52	0.43	2.1	0.61		
edema	15.46			0.61		
headache	2.84	6.48	2.1	1.22		
hot body/fever	9.15	15.98	11.19	11.32	27.03	
insomnia	2.21	2.16	7.69	1.84		
lack/loss of appetite	2.84	5.83	6.29	6.12		
madness	2.84	1.08	4.9	1.53		
pale skin	24.61	6.26	7.69	9.79	27.03	
reddish eyes		0.65	6.29	10.4		
reddish urine	0.63	0.65	7.69	9.17		
sleepiness	0.32		2.1	2.45		
stomach wound	1.26	2.81	4.9	4.59		
vomiting	2.21	1.73	1.4	5.2		
yellowish eyes	4.1	21.81	6.99	7.34		
yellowish urine	8.20	21.38	6.29	7.95	10.81	

The free lists on the form show that each ethnic group has mentioned two forms of malaria on average, in spite of the various forms of malaria (Fig. 2).

The distribution of the forms of malaria within the ethnic groups is divided into two groups, according to the frequency of quotation (Table 3).

Table 3
Most common forms of malaria according to ethnic groups.

form of malaria	F_{qAgni} (%)	$F_{qAkyé}$ (%)	F_{qGwa} (%)
“white”malaria	62.26	46.59	65.98
“yellow” malaria	88.68	87.5	40.21
“black” malaria	24.53	20.45	28.87
“bird” malaria	02.83	06.82	06.19
“red” malaria	36.79	15.91	07.32
“mystical” malaria		03.41	01.03

The first group (G1) included the forms mentioned by Gwa ethnic groups. Meanwhile, the second group (G2) is formed by the forms mentioned by both Agni and Akyé ethnic groups (Fig. 3).

The distribution on the form of malaria was not significantly different (Chi squared = 0.6874296; p-value = 0.9999699). Agni and Akyé ethnic groups are closer on forms of malaria than Gwa ethnic groups (Fig. 4).

Diversity and intercultural relations of antimalarial plant species

Seventy-seven (77) species, distributed in 71 genera and 38 families were collected (Table 4). The most represented families were Lamiaceae, Asteraceae and Leguminosae with five species. They were mainly composed of 67 trees and shrubs, 10 herbaceous plants and one liana.

Table 4
Cultural importance of antimalarial plant species used in the study area.

			Agni		Akyé		Gwa	
Family	Species	Voucher#	Fq (%)	S	Fq (%)	S	Fq (%)	S
Acanthaceae	*Justicia tenella* (Nees) T.Anderson	DL003					1.04	0.01
	Phaulopsis ciliata (Wild.) Hepper	DL087			2.08	0.02		
Alliaceae	*Allium sativum* L.	DL055	1.03	0.01				
Anacardiaceae	*Mangifera indica* L.	DL021	1.03	0.01	6.25	0.03	3.13	0.02
	Spondias mombin L.	DL011			2.08	0.02	4.17	0.04
	Trichoscypha arborea (A.Chev.) A.Chev.	DL093			6.25	0.05	1.04	0.01
Annonaceae	*Annickia polycarpa* (DC.) Setten & Maas	DL083	44.33	0.23	49.48	0.35	28.13	0.19
	Monodora myristica (Gaertn.) Dunal	DL123					1.04	0.00
	Xylopia aethiopica (Dunal) A.Rich.	DL175			1.04	0.01	1.04	0.00
Apocynaceae	*Alstonia boonei* De Wild.	DL067	38.14	0.27	35.05	0.26	17.71	0.10
	Hunteria umbellata (K. Schum.) Hallier f.	DL070	2.06	0.01				
	Picralima nitida (Stapf) T.Durand & H. Durand	DL089			1.03	0.05	1.04	0.00
	Rauvolfia vomitoria Afzel.	DL075	14.43	0.09	10.42	0.09	7.29	0.05
Arecaceae	*Cocos nucifera* L.						7.29	0.03
Asteraceae	*Ageratum conyzoides* L.	DL002					11.46	0.01

F_q: Frequency of quotation of plant species; S: importance of quotation of plant species

			Agni		Akyé		Gwa	
	Chromolaena odorata (L.) R.M.King & H. Rob.	DL057	5.21	0.05	1.04	0.01		
	Gymnanthemum amygdalinum (Delile) Sch.Bip. ex Walp.	DL013	26.80	0.16	19.79	0.11	35.42	0.25
	Microglossa pyrifolia (Lam.) Kuntze	DL018					1.04	0.01
	Struchium sparganophorum (L.) Kuntze	DL038					4.17	0.02
Bignoniaceae	*Newbouldia laevis* (P.Beauv.) Seem. ex Bureau	DL094					2.08	0.02
Bromeliaceae	*Ananas comosus* (L.) Merr.				1.04	0.00	2.08	0.01
Cannabaceae	*Trema orientalis* (L.) Blume	DL034	2.06	0.01	2.06	0.01		
Cannaceae	*Canna indica* L.	DL054	10.31	0.07				
Caricaceae	*Carica papaya* L.	DL056	18.56	0.09	14.43	0.08	19.79	0.08
Combretaceae	*Terminalia catappa* L.	DL076	3.09	0.01			1.04	0.01
	Terminalia ivorensis A.Chev.	DL078			2.08	0.02		
	Terminalia superba Engl. & Diels	DL077	1.03	0.01				
Crassulaceae	*Kalanchoe crenata* (Andrews) Haw.	DL086			1.04	0.01		
Cucurbitaceae	*Momordica charantia* L.	DL071	7.22	0.05	9.38	0.07	25	0.13
Ebenaceae	*Diospyros sanza-minika* A.Chev.	DL112					1.04	0.01

F_q: Frequency of quotation of plant species; S: importance of quotation of plant species

			Agni		Akyé		Gwa	
Euphorbiaceae	*Alchornea cordifolia* (Schumach & Thonn.) Müll.Arg.	DL007	15.46	0.06	13.54	0.07	11.46	0.07
	Macaranga barteri Müll.Arg.	DL183			1.03	0.01		
	Manihot esculenta Crantz	DL061	6.19	0.05	6.19	0.04		
	Ricinodendron heudelotii (Baill.) Pierre ex Heckel	DL095					1.04	0.00
Hypericaceae	*Harungana madagascariensis* Lam. ex Poir.	DL048	28.87	0.17	14.43	0.10	6.25	0.05
	Vismia guineensis (L.) Choisy	DL079	6.19	0.04				
Irvingiaceae	*Irvingia gabonensis* (AubryLecomte ex O'Rorke) Baill.	DL085			3.09	0.02		
Lamiaceae	*Hoslundia opposita* Vahl.	DL010	11.34	0.06	2.06	0.02	3.13	0.02
	Ocimum gratissimum L.	DL005	22.68	0.15	11.34	0.05	14.58	0.09
	Plectranthus monostachyus (P.Beauv.) B.J.Pollard	DL001	1.03	0.00			1.04	0.01
	Tectona grandis L.f.	DL064	11.34	0.05	1.03	0.01	3.13	0.02
	Vitex grandifolia Gürke	DL148			1.03	0.01		
Leguminosae	*Distemonanthus benthamianus* Baill.	DL069	2.06	0.01	5.15	0.03		
	Parkia bicolor A.Chev.	DL147	4.12	0.02				

F_q: Frequency of quotation of plant species; S: importance of quotation of plant species

			Agni		Akyé		Gwa	
	Piliostigma thonningii (Schumach.) Milne-Redh.	DL090			1.03	0.01		
	Senna alata (L.) Roxb.	DL063					4.17	0.04
	Senna occidentalis (L.) Link	DL023	21.65	0.15	16.49	0.11	20.83	0.13
Loganiaceae	*Anthocleista nobilis* G.Don	DL068	3.09	0.02	7.22	0.06		
Malvaceae	*Cola nitida* (Vent.) Schott & Endl.	DL096					4.17	0.03
	Sida acuta Burm. f.	DL091			3.09	0.01		
	Tarrietia utilis (Sprague) Sprague	DL092			3.09	0.03		
	Theobroma cacao L.	DL065	2.06	0.01				
Meliaceae	*Azadirachta indica* A.Juss.	DL097					8.33	0.07
	Khaya ivorensis A.Chev.	DL098			15.46	0.10	4.17	0.03
Moringaceae	*Moringa oleifera* Lam.	DL099					2.08	0.00
Musaceae	*Musa paradisiaca* L.	DL062	15.46	0.09	14.43	0.07	5.21	0.02
Myrtaceae	*Psidium guajava* L.	DL082			3.09	0.03	1.04	0.01
Ochnaceae	*Lophira alata* Banks ex C.F.Gaertn.	DL032	17.53	0.11	10.31	0.04	2.08	0.01
Pandaceae	*Microdesmis keayana* J.Léonard	DL035	1.03	0.01			4.17	0.01

F_q: Frequency of quotation of plant species; S: importance of quotation of plant species

			Agni		Akyé		Gwa	
Piperaceae	*Piper guineense* Schumach. & Thonn.	DL028	1.03	0.01				
Poaceae	*Bambusa vulgaris* Schrad. ex J.C. Wendl.	DL044	5.15	0.03			14.58	0.11
	Cymbopogon citratus (DC.) Stapf	DL060	2.06	0.02	1.03	0.01	1.04	0.01
	Saccharum officinarum L.	DL100					2.08	0.02
Rhizophoraceae	*Anopyxis klaineana* (Pierre) Engl.	DL081					1.04	0.00
Rubiaceae	*Mitragyna ledermannii* (K.Krause) Ridsdale	DL027	18.56	0.1	16.49	0.10	13.54	0.10
	Nauclea diderrichii (De Wild. & T.Durand) Merr.	DL074	22.68	0.11			1.04	0.01
	Nauclea latifolia Sm.	DL033	21.65	0.16	3.09	0.02	32.29	0.27
Rutaceae	*Citrus aurantiifolia* (Christm.) Swingle	DL058	5.15	0.04	3.09	0.02	18.75	0.09
	Citrus aurantium L.	DL059	8.25	0.07	4.12	0.01	1.04	0.01
	Zanthoxylum gilletii (De Wild.) P.G.Waterman	DL080	1.03	0.01				
Sapindaceae	*Blighia unijugata* Baker	DL084			3.09	0.02		
	Paullinia pinnata L.	DL029	4.12	0.04				
Solanaceae	*Physalis angulata* L.	DL088			1.03	0.01		

F_q: Frequency of quotation of plant species; S: importance of quotation of plant species

			Agni		Akyé		Gwa	
	Solanum nigrum L.	DL039			3.09	0.02		
Urticaceae	*Musanga cecropioides* R.Br.	DL072	3.09	0.02			6.25	0.03
	Myrianthus arboreus P.Beauv.	DL073	4.12	0.03				
Zingiberaceae	*Aframomum melegueta* (Roscoe) K.Schum.	DL066	1.03	0.01				
F_q: Frequency of quotation of plant species; S: importance of quotation of plant species								

Among the 77 collected species, 20 plant species (25.97%) were shared within all ethnic groups. While 12 plant species were exclusive to Agni and Akyé and 15 to Gwa people (Fig. 5). Nevertheless, the Kruskal-Wallis test reveals that there is no significant difference (Chi squared = 3.266; df = 2; p-value = 0.1953), within all ethnic groups on common plants species.

(Table 4 must be here)

All values are below 0.5 i.e 50% which means that there is a low knowledge sharing of antimalarial plants species (Table 5). Thus, Akyé are closer to Gwa ethnic groups whereas, the knowledge of Agni ethnic groups is specifics of them.

Table 5
Similarity (%) on antimalarial plant species used among ethnic groups.

	Agni	Akyé
Akyé	40.3	
Gwa	40.00	41.5

Importance of antimalarial plant species within each ethnic group

Overall from 77 plants used against malaria, only seven (09.09%) are culturally important (with S ≥ 0.15 for threshold). Their values change from one ethnic group to another (Table 4). Thus, the most important species were *Annickia polycarpa* (DC). Setten & Maas [($S_{Akyé}$=0.35; $F_{qAkyé}$=49.48%, Fig. 6a); (S_{Agni}=0.23; F_{qAgni}=44.33%); (S_{Gwa}=0.19; F_{qGwa}=28.13%)], *Gymnanthemum amygdalinum* (Delile) Sch. Bip. ex Walp. [(S_{Gwa}=0.25; F_{qGwa}=35.42%); (S_{Agni}=0.16; F_{qAgni}=26.80%)], *Alstonia boonei* De Wild. [(S_{Agni}=0.27; Fq_{Agni}=38.14%, Fig. 6b); ($S_{Akyé}$=0.26; $F_{qAkyé}$=35.05%)], *Nauclea latifolia* Sm. (S_{Gwa}=0.27; F_{qGwa}=32.29%);

Harungana madagascariensis Lam. ex Poir. (S_{Agni}=0.17; F_{qAgni}=28.87%); *Ocimum gratissimum* L. (S_{Agni}=0.15; F_{qAgni}=22.68%) and *Senna occidentalis* (L.) Link (S_{Agni}=0.15; F_{qAgni}=21.65%). Figure 6 shows two plant species most important in the study area.

The fidelity level (FL) of the recorded plants was less than 40% suggesting that none of them are really specific to a particular form of malaria. Thus, the plants of high cultural values mentioned above are frequently used to cure various forms of malaria (Table 6).

Table 6
Fidelity level of most common antimalarial plants of Agni, Akyé and Gwa people.

	FL (%)				
Species	white malaria	yellow malaria	black malaria	bird malaria	red malaria
Alstonia boonei De Wild.	30.14	30.82	26.42		23.89
Annickia polycarpa (DC.) Setten & Maas	30.82	38.99	22.64		29.2
Carica papaya L.	23.29	16.98	26.42		
Distemonanthus benthamianus Baill.				37.5	
Gymnanthemum amygdalinum (Delile) Sch. Bip. ex Walp.	36.3	21.38	32.08	25	30.97
Momordica charantia L.	19.86	10.69	22.64		12.39
Musa paradisiaca L.				37.5	
Nauclea latifolia Sm.		18.87			22.12
FL: fidelity level of antimalarial plant species					

The intracultural analysis of antimalarial plants lists suggested that knowledge is widely shared in each community (Fig. 7) as the level of saturation of the respondents was quickly reached: after the 15th respondent out of 97 in Agni, the 19th out of 97 in Akyé and the 17th out of 96 informants in Gwa ethnic groups.

However, the Gwa recorded the longest lists (average = 4 plants), followed by the Agni (average = 4 plants), and then the Akyé with an average of three plants (Fig. 8).

Discussion

This study aimed to analyse the perception of various forms of malaria in three sympatric ethnic groups with various sociolinguistic backgrounds. Different terms were used to indicate six forms of malaria across ethnic groups. This diversity on the forms of malaria is not unique to our study area. In fact, in Africa several studies have shown various communities whose have distinguished many forms of

malaria. For example, in Mali the communities of Sélingué subdistricts, have identified malaria through five forms *sumaya*, *nènèdimi*, *djontè*, *djokoadjo* and *farigan* [6]. Besides, in Zimbabwe, in the Chipinge District, traditional healers have recognized two forms of malaria, *muswarara* and *ndangaranga* [10]. However, the knowledge on the symptoms changes from one ethnic group to another. In fact, this variation of the symptoms was allowed to distinguish a simple form and a serious form of malaria. Thus, the symptoms as disjointed movements, fever, pale skin have been frequently reported by the ethnic groups in our study area. In the similar observations, the communities of Chipinge in Zimbabwe have mentioned those symptoms [10]. Moreover, in Mali the Sélingué communities have considered convulsions as an uncomplicated symptom of malaria [6]. Traditional medicine distinguishes a varied range of symptoms. Those symptoms evolve from one country to another. In fact, the variations of symptoms depend on traditional practices and cultural backgrounds [33, 34]. Better, those variations depend on the accessibility of rural communities to conventional medicine [10]. Therefore, local perceptions of malaria can be matched to conventional medicine. In fact, conventional medicine distinguishes two main forms of malaria (simple and complicated form) with many variations [35]. However, traditional medicine as well as conventional medicine cannot cope some disorders as mystical malaria and cerebral malaria. Those difficulties have conducted to the integration of traditional medicine in the region health system [6–10, 33].

However, the high transmission of malaria creates a tendency for people to catch that disease. Indeed, the susceptibility to the malaria changes from one country to another according to cultural backgrounds and was revealed by the ethnic groups behavior. In fact, the immunogenetic factors might be taken in account for distinguishing the susceptibility to malaria [34]. For example, in Mali two sympatric communities have been compared. Their studies have shown that in spite of fever which is a common symptom of malaria, Peulh communities are more susceptible to catch malaria than Dogon communities.

Traditional medicine is a part of people's culture and is closely linked to their beliefs. In fact, people combine religion, sorcery and interpersonal conflict into a single form of belief and practice [36]. As an example, Amazonian people of Upper Rio Negro of Brazil associated malaria to spiritual beings and used to be cured with the blessings of shamans [37].

However, the other issue raised in this study is the importance of antimalarial plants species. As well as mentioned by some authors [37, 38], the use of plants depends on the culture. Indeed, the doctrine of signatures [39], has been used as a means to understand the medicinal plant selection process in traditional cultures. Moreover, for some authors [40] in Mexico and in Côte d'Ivoire [17], the organoleptic properties (bitter taste of bark stems and leaves or yellow color of the bark stems and the shape of plant organs) indicate that a given plant, has a medicinal potential and a therapeutic application. Thus, several studies have confirmed the antiplasmodial activities of the most important antimalarial plant species mentioned in this study. For example, stem bark of *Annickia polycarpa* [41], stem bark of *Nauclea latifolia* [42], stem bark of *Harungana madagascariensis* [43], leaves of *Gymnanthemum amygdalinum* [44], leaves of *Ocimum gratissimum* [45] and leaves of *Senna occidentalis* [46] were confirmed efficiency to manage malaria and related symptoms. However, the stem bark of *Alstonia boonei* was revealed inactive

for inhibition concentration higher than 50 μg/ml against *Plasmodium falciparum* in, in vitro culture [43]. Even so, this plant species was prescribed against shiver and aches [15] in both Côte d'Ivoire and Ghana. For example, in Ghana, the leaves of *Alstonia boonei* have shown that the alkaloid extract of the species have an anti-plasmodial activity at 8.4 μg/ml [47]. Thus, the efficiency of a given plants depends on the parts of plant which were used differently by people to treat malaria [48].

Although the most important antimalarial plants above, have already been mentioned in literature for their antiplasmodial activities, there is no reference in the literature describing some antiplasmodial activities about *Blighia unijugata* Baker, *Diospyros sanzaminika* A.Chev., *Cola nitida* (Vent.) Schott & Endl., *Macaranga barteri* Müll.Arg., *Parkia bicolor* A.Chev., *Plectranthus monostachyus* (P.Beauv.) B.J.Pollard, *Tarrietia utilis* (Sprague) Sprague and *Vitex grandifolia* Gürke. These plant species were less known in our study. Nevertheless, these plant species are known for their analgesic, feverishness and antianaemic properties [15], which represent remedies against certain symptoms of malaria. There is a lack of information exchanges about their uses among informants [3, 9].

On the other hand, the similarity rate between antimalarial plant species was under 50%. The geographical proximity of ethnic groups have influenced the local culture in the uses of medicinal plants [39, 49]. For example, in Pakistan, the communities of Dhirkot, Azad Jammu and Kashmir which share the same vegetation, have the same knowledge on the medicinal plants [3]. In the similar case, the communities of Allada in Benin have shared their knowledge [9].

The different cultural backgrounds have explained, however the uses of plant species to cure malaria. In fact, in our study the greatest amount of plant species was recorded in the family of Lamiaceae, Asteraceae, Leguminosae and Apocynaceae, whereas, in Abidjan plant species belonging to Rubiaceae, Combreataceae, Leguminosae and Meliaceae families were mainly used for their antimalarial properties. Therefore, trees and shrubs were more used than herbaceous plants. Inversely, in Brazil herbaceous plants were observed by [50].

The last issue of this study is to determine the intracultural and intercultural variations of the knowledge within ethnic groups. Thus, the local knowledge on plant uses was influenced by the culture of people which included ethnic group, language, acquired practical experiences [14]. As an example, in the North-East and Central-East of Côte d'Ivoire, four Agni tribes used wild edible plants in two different vegetation. Agni-Barabo and Agni-Bini shared their knowledge [51]. In fact, they shared the same migration histories, the same religion and the same vegetation [14–39, 49]. Meanwhile, the intercultural variation on the common antimalarial plant species, was not significantly different, in this study. Indeed, the common plant species usually shared, are actively used through time and are considered effective. For example, in the South-Central of Ethiopia, four ethnic communities living in two different areas (Gurage, Mareqo, Qebena and Silti), have used the common plants and on the same time are considered effective [13, 48]. In contrary, two ethnic groups Koulango and Lobi, living around the East side of the Comoé National Park of Côte d'Ivoire, were compared about the availability of wild edible plants [52]. These authors have shown in their studies that, in spite of their close contact, Koulango and Lobi ethnic groups like differently

wild edible plants. In fact, their studies have revealed that the uses of a given wild plant species are specific to one ethnic group and its culture [12, 39]. Otherwise, the knowledge sharing depends on the ethnic groups [13], and the preference of the plant species uses [12]. For example, 14 different ethnic groups in the Northern of Benin, were compared through the uses of the parts of *Parkia biglobosa* (Jacq.) G.Don [53]. In their studies, local knowledge varied from one ethnic group to another according to the form of uses and the organs of *Parkia biglobosa*, in the same geographical area. In fact, Lokpa, Waama and Bariba ethnic groups assigned high consensus value for bark, leaves, roots, seeds and pulp. In contrast, Nago, Anii, Dendi, Otamari, Mokolé, Foodo, Yom, Berba, Boko and assigned low value to bark and leaves. For the different form of uses of *Parkia biglobosa*, there is a consensus values for decoction, condiments were high for Bariba, Dendi, Fulani, Waama and Lokpa but low for other ethnic groups.

On the other hand, the extent of the knowledge on the medicinal plants according to the FL, changes from one country to another. As an example, in the rural communities of Dhirkot, Azad Jammu and Kashmir in Pakistan, preferred different plants to cure specifically wound healing, gastrointestinal disorders, body weakness, diabetes and cough [3].

Conclusion

An ethnobotanical study on the perception of malaria and cultural diversity of antimalarial plants used by three sympatric ethnic groups, was conducted in the Department of Alépé, Southeast of Côte d'Ivoire. Six various forms of malaria were observed within the ethnic groups. A total of 77 antimalarial plants distributed in 71 genera and 38 families were collected. Our results show that there is a similar perception on five forms of malaria through all ethnic groups. Exceptionally, Akyé and Gwa ethnic groups perceive a mystical form of malaria. However, seven most important antimalarial plant species, were highlighted *Annickia polycarpa* (DC) Setten & Maas, *Gymnanthemum amygdalinum* (Delile) Sch. Bip. ex Walp, *Alstonia boonei* De Wild. *Nauclea latifolia* Sm., *Harungana madagascariensis* Lam. ex Poir., *Ocimum gratissimum* L. and *Senna occidentalis* (L.) Link. Nevertheless, local people share 20 antimalarial plant species with a similar proximity within Akyé and Gwa ethnic groups. Even so, there is no specific plant species which cure a particular form of malaria.

In conclusion, traditional medicine plays a significant role in local people's daily life. In spite of their different migration histories, the close contact of these ethnic groups promote the sharing of the knowledge. In fact, people use the same important plants to cure malaria and know overall five forms of malaria. Exceptionally, Akyé and Gwa ethnic groups know both the sixth form, mystical malaria, due to their geographical proximity. Knowledge on antimalarial plants in study area does not reach a stable climax, but could be evolved by trial and error, as effective cures malaria.

Declarations

Ethics approval and consent to participate

The present study is purely based on a field survey instead of humans. Before starting investigation, the chief of each investigated village was informed on the research project. Then, an agreement was needed to residents prior to start questions following the recommendations of the International Society of Ethnobiology Code of ethics for the publication of this research and any accompanying images.

Consent for publication

Will be provided

Availability of data and materials

The authors declare that data supporting the findings of this study are available within the article. However, the raw files (Microsoft excel, World) can be provided by the authors on request.

Competing interests

The authors state that they have no competing interest.

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Author contributions

All the authors contributed in a fundamental way to this work. D.F. MALAN and A.L. DIOP designed the subject and the methodological approach. DIOP led the field data collection and performed the data analysis with M.D. KOUGBO and DF MALAN. All the authors have critically read this article and approved it as the final manuscript.

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Figures

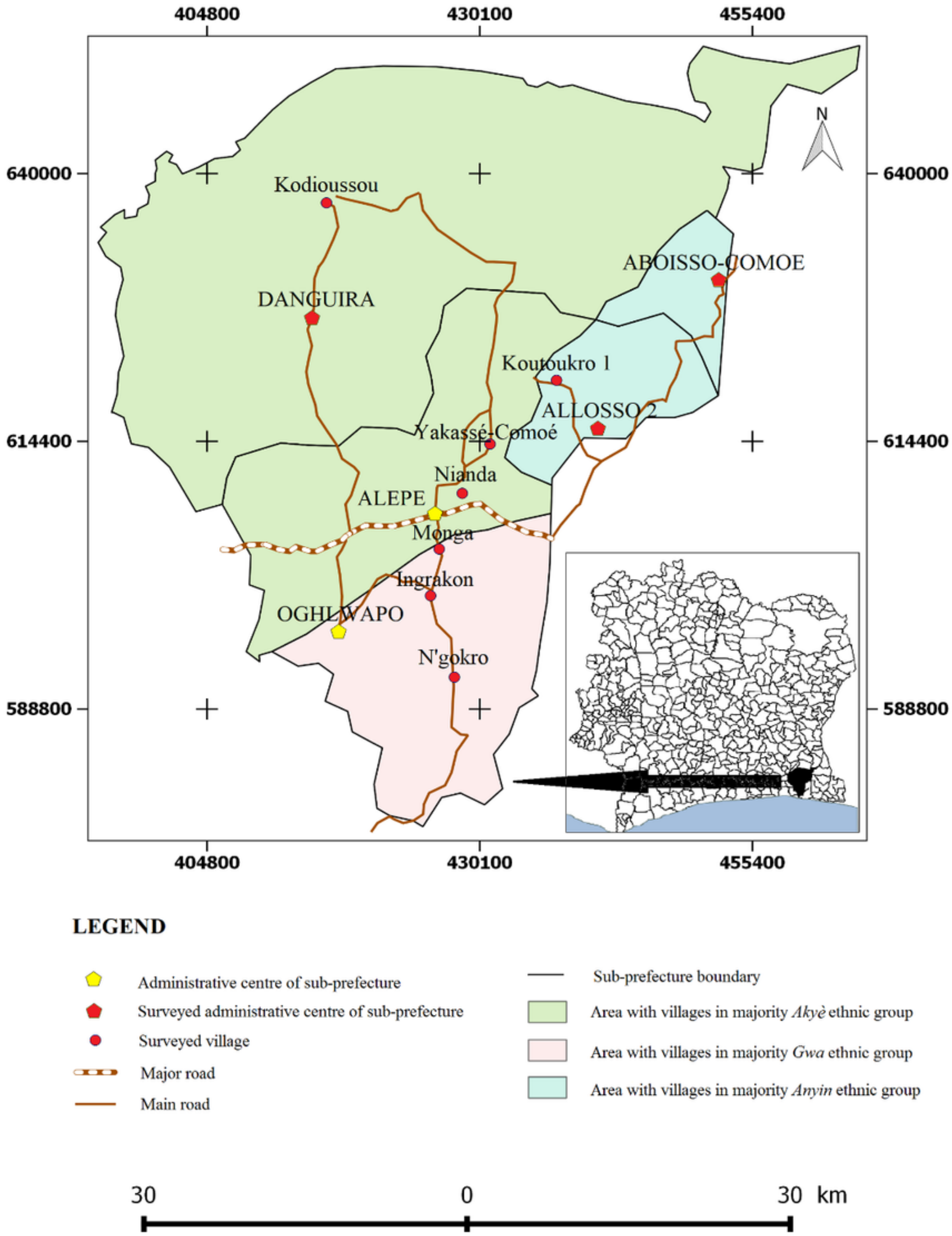

Figure 1

Location of Agni, Akyé and Gwa ethnic groups in Alépé Department.

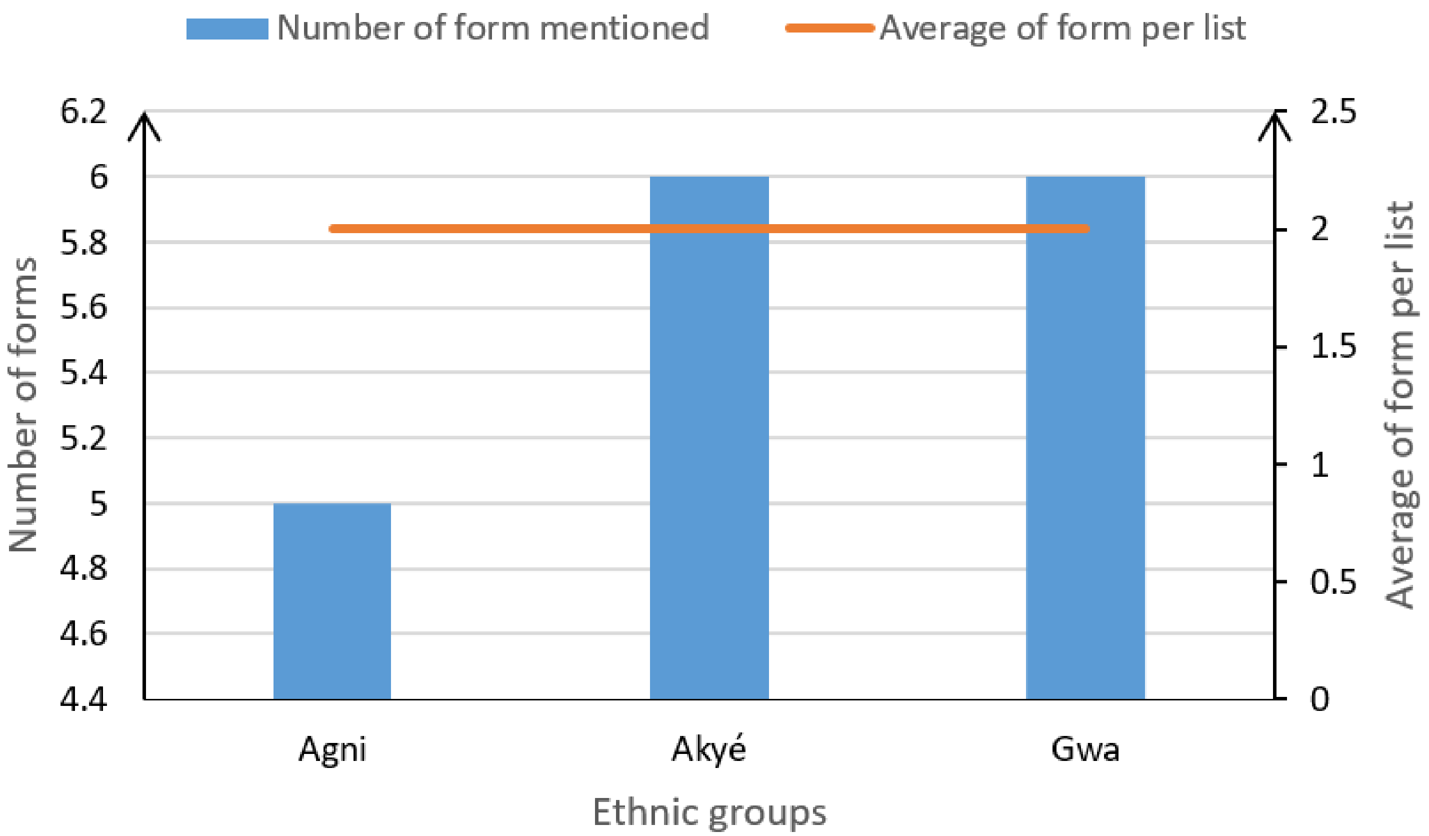

Figure 2

Forms of malaria mentioned by Agni, Akyé and Gwa ethnic groups.

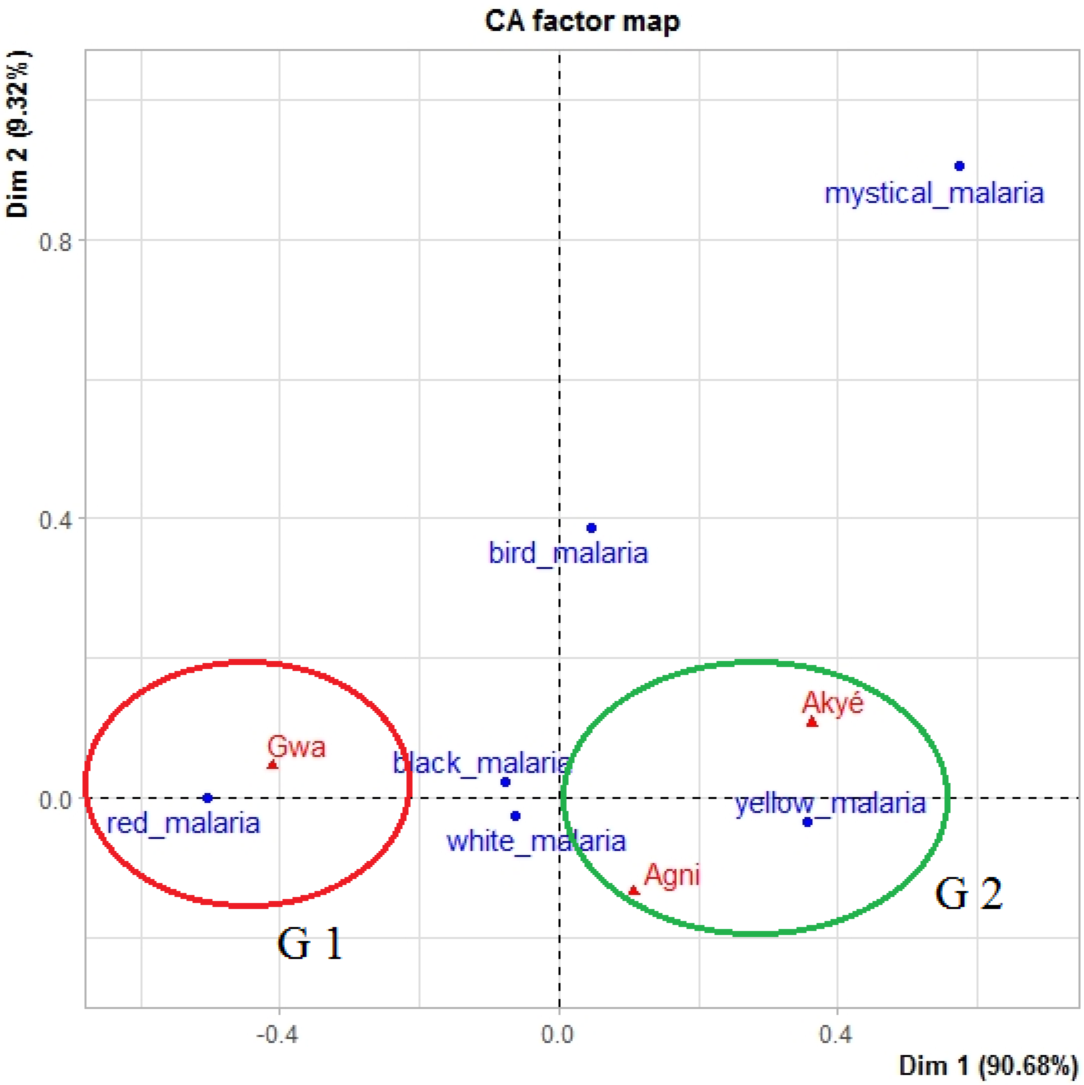

Figure 3

Distribution of the forms of malaria within the ethnic groups

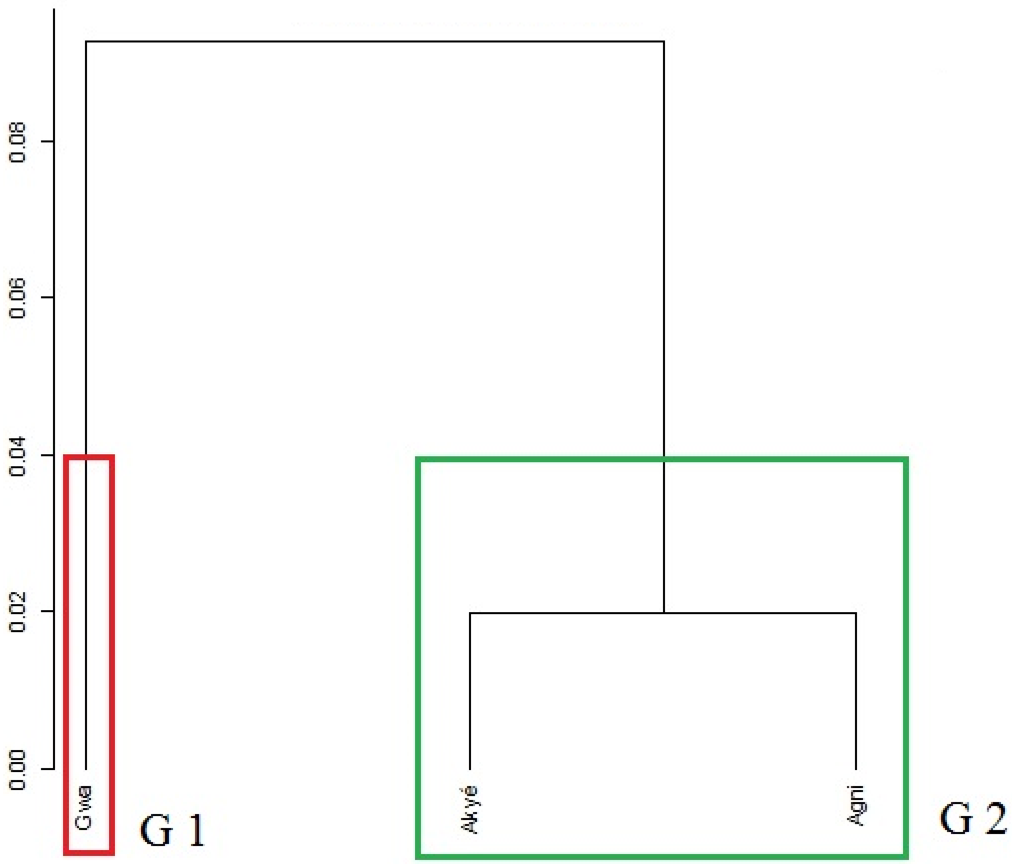

Figure 4

Hierarchical clusters of ethnic groups according to the forms of malaria.

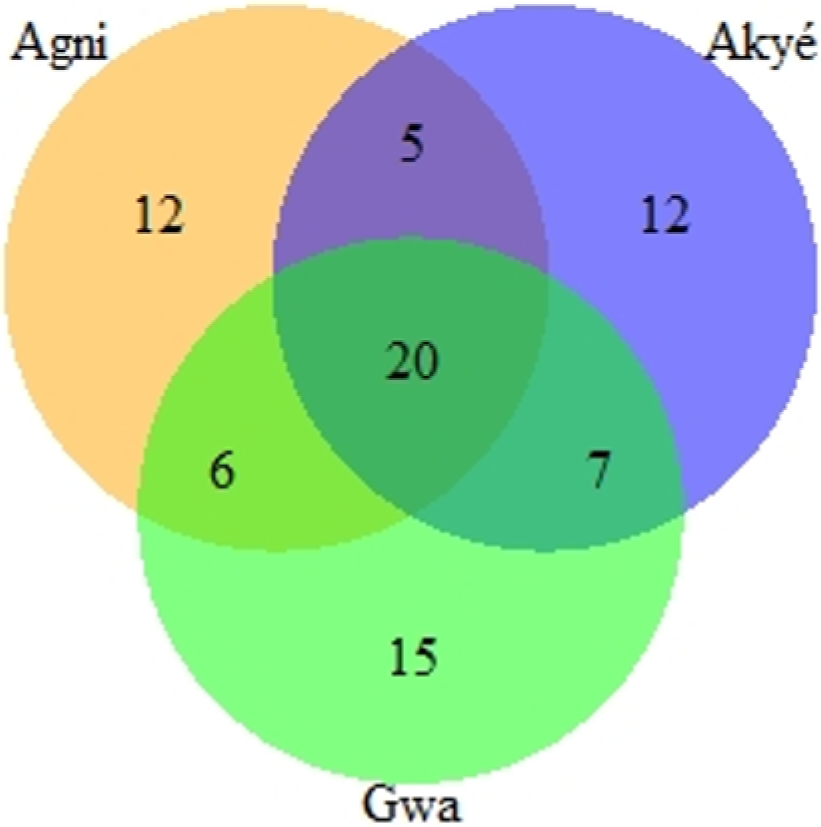

Figure 5

Venn diagram representing abundance of species used against malaria between ethnic groups of the study area.

Figure 6

Two antimalarial plant species most important in the study area: a) bark pieces of Annickia polycarpa (DC.) Setten & Maas collected by a key informant ; b) a tree of Alstonia boonei De Wild.

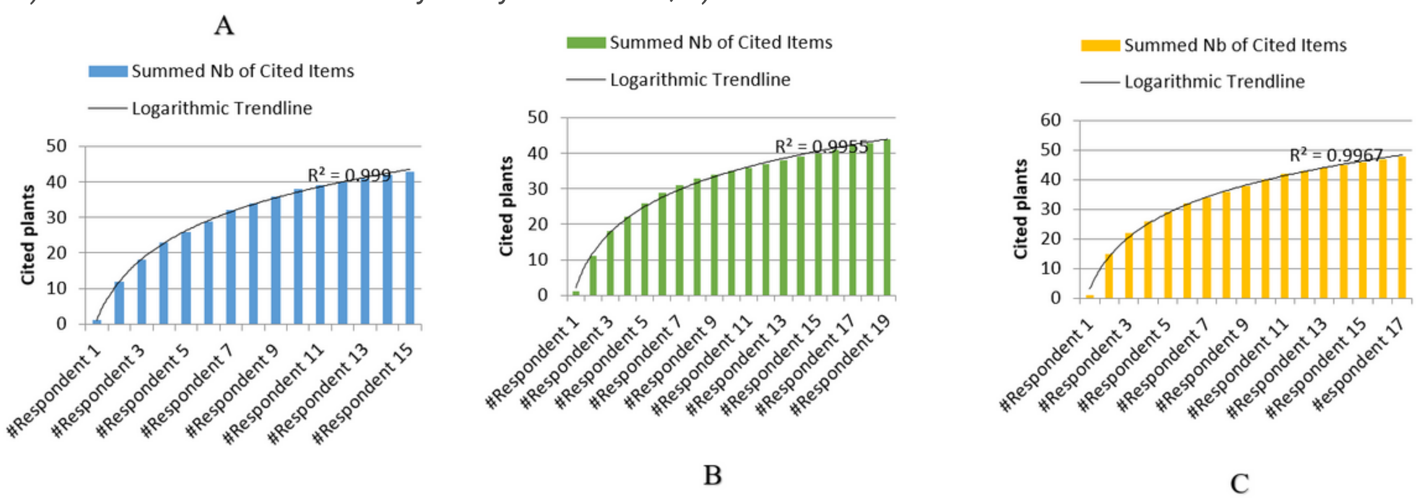

Figure 7

Level of data saturation of antimalarial plants cited by: A) Agni; B) Akyé and C) Gwa people.

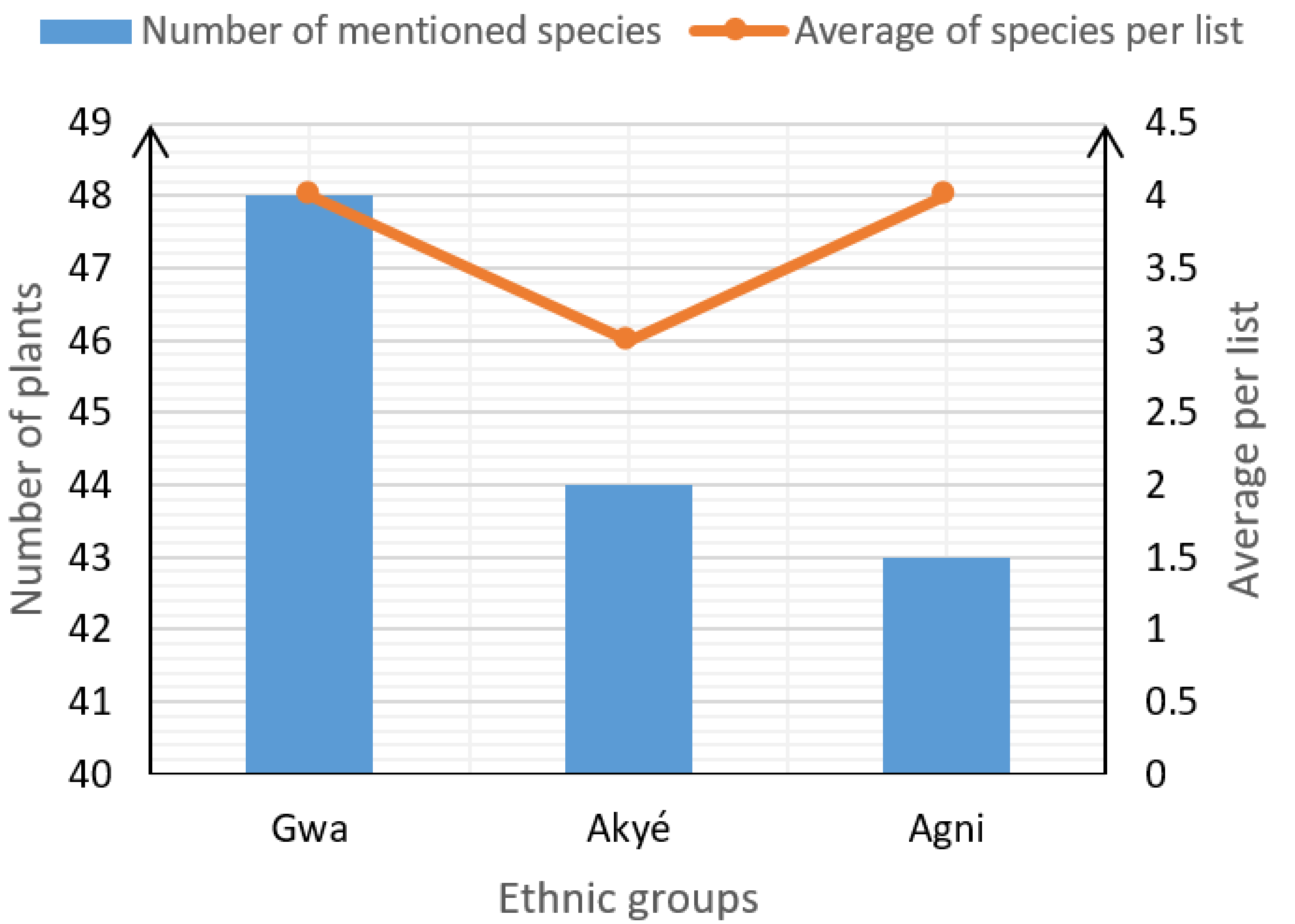

Figure 8

Number of antimalarial plants mentioned and average of plants per list in ethnic groups.