When local phytotherapies meet biomedicine. Cross-sectional study of knowledge and intercultural practices against malaria in Eastern French Guiana

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Abstract

Ethnopharmacological relevance

In French Guiana, traditional phytotherapies are an important part of self-healthcare, however, a precise understanding of the interactions between local phytotherapies and biomedicine is lacking. Malaria is still endemic in the transition area between French Guiana and Brazil, and practices of self-treatment, although difficult to detect, have possible consequences on the outcome of public health policies.

Aim of the study

The objectives of this research were 1) to document occurences of co-medication (interactions between biomedicine and local phytotherapies) against malaria around Saint-Georges de l'Oyapock (SGO), 2) to quantify and to qualify plant uses against malaria, 3) and to discuss potential effects of such co-medications, in order to improve synergy between community efforts and public health programs in SGO particularly, and in Amazonia more broadly.

Materials and methods

This cross-sectional study was conducted in 2017 in SGO. Inhabitants of any age and nationality were interviewed using a questionnaire (122 questions) about their knowledge and habits regarding malaria, and their use of plants to prevent and treat it. They were invited to show their potential responses on a poster illustrating the most common antimalarial plants used in the area. In order to correlate plant uses and malaria epidemiology, all participants subsequently received a medical examination, and malaria detection was performed by Rapid Diagnostic Test (RDT) and Polymerase Chain Reaction (PCR).

Results

A total of 1,566 inhabitants were included in the study. Forty-six percent of them declared that they had been infected by malaria at least once, and this rate increased with age. Every person who reported that they had had malaria also indicated that they had taken antimalarial drugs (at least for the last episode), and self-medication against malaria with pharmaceuticals was reported in 142 cases. A total of 550 plant users was recorded (35.1% of the interviewed population). Among them 95.5% associated pharmaceuticals to plants. All plants reported to treat malaria were shared by every cultural group around SGO, but three plants were primarily used by the Palikur: *Cymbopogon citratus*, *Citrus aurantifolia* and *Siparuna guianensis*. Two plants stand out among those used by Creoles: *Eryngium foetidum* and *Quassia amara*, although the latter is used by all groups and is by far the most cited plant by every cultural group. Cultivated species accounts for 91.3% of the use reports, while wild taxa account for only 18.4%.

Conclusions

This study showed that residents of SGO in French Guiana are relying on both traditional phytotherapies and pharmaceutical drugs to treat malaria. This medical pluralism is to be understood as a form of pragmatism: people are collecting or cultivating plants for medicinal purposes, which is probably more congruent with their respective cultures and highlights the wish for a certain independence of the care process. A better consideration of these practices is thus necessary to improve public health response to malaria.

1. Introduction

In French Guiana, as elsewhere in Amazonia and more widely in Latin America, traditional phytotherapies are still an important part of self-healthcare (Fleury, 2007, 2017; Grenand et al., 2004; Odonne et al., 2011; Tareau et al., 2017; Vigneron et al., 2005). However, a precise understanding of the articulations between local phytotherapies and biomedicine is lacking in this area. This question has not been much addressed in Latin America in general (Calvet-Mir et al., 2008; Vandebroek et al., 2004), and is beginning to emerge as an important research question even in Europe (Djuv et al., 2013; Welz et al., 2018). Given that local practices appear to be continuing among young, urban people in French Guiana (Tareau et al., 2017), a better understanding of these entanglements and their integration with community behaviors is thus necessary in order to foster global health.

French Guiana is a persistent malaria endemic area. The regional control program promotes the use of insecticide-treated bed nets and provides free and accessible bed nets for pregnant women, malaria testing and treatment at local health centers (Nathalie, 2015). Saint-Georges de l'Oyapock (SGO) is particularly affected by malaria (Mosnier et al., 2017; Musset et al., 2014), and *Plasmodium vivax* is responsible for the large majority of diagnosed cases over the last 10 years (Mosnier et al., 2020a; Saldanha et al., 2020). This small multicultural municipality is located along the Oyapock river, the border between French Guiana and Brazil (Davy et al., 2011; Grenand, 2012). Mostly populated by Amerindians (the majority Palikur, and a few Karipuna and Galibi-Marworno), Creole and Brazilian people, it is the meeting point of the lower Oyapock basin. There, interculturality leads to a discrete, highly prevalent but not yet documented, medical pluralism. This piece of the European Union in South America thus experiences singular patterns of medical hybridization. In SGO it is typical for Amerindian, Brazilian and Creole people to treat with herbal remedies while also using biomedicine, as has been documented among many other groups in French Guiana (Grenand et al., 2004; Tareau et al., 2017; Tareau et al., 2019). However, despite the WHO report on traditional medicine, initiatives aiming to integrate collective and local knowledge of communities living in malaria endemic areas are very scarce to date (WHO, 2013), and particularly in French Guiana.

Hidden use of self-treatment has nevertheless possible consequences on the outcome of public health policies and might hamper the relationships between the different medical cultures. When efficient, such treatments might lower the rate of consultation at health centers, possibly leading to a misunderstanding of the real epidemic situation by epidemiologists. When partially efficient, they might lead to the persistence of asymptomatic infections in the less supervised self-medicated population (Okwundu et al., 2013; Howes et al., 2016). Lastly, when inefficient, they may delay the care of sick patients or increase the transmission of malaria.

This study is part of a broader project, Palustop, aiming at understanding the malaria epidemics in Eastern French Guiana and at preventing the emergence of resistance to antimalarial treatments (Mosnier et al., 2019, 2020a; Saldanha et al., 2020).

Consequently, the objectives of the work were 1) to document the reality of co-medications (interactions between biomedicine and local phytotherapies and concomitant use of these two systems), 2) to quantify and to qualify plant uses against malaria, and 3) to discuss potential effects of such co-medications, in order to improve synergy between community efforts and public health programs in Saint-Georges de l'Oyapock, and in Amazonia more broadly.

2. Materials and methods

2.1. Survey and study area

Saint-Georges de l'Oyapock (Figure 1) is a small French overseas municipality located along the left bank of the Oyapock River, which forms the border between French Guiana and the Brazilian state of Amapá. It is inhabited by almost 4,076 people (INSEE, 2020), living mainly in the city center. The population stems from a great diversity of cultural groups: Amerindians (mostly Palikur, Wayãpi and Teko from the upper-Oyapock, and a minority of Karipuna and Galibi-Marworno from Brazil), French Guianese Creoles, a mixed Franco-Brazilian population, and Brazilian migrants. As discussed in previous works (Tareau et al., 2020), defining ethnicity in these mixed-populations is difficult, as cultural groups may be built upon ethnic specificities as much as upon nationalities. We thus adopted the most common self-denominations (for example Palikur or Creole), and considered the broad "Brazilian" group, understood as "non-Amerindian Portuguese speaking people". Therefore, local habits such as agricultural practices or housing types (Ogeron et al., 2018) can vary widely from one area to another and lifestyles range from swidden cultivators practicing hunting and fishing in nearby forests and living in open wooden stilt houses in the riverine areas, to occidental lifestyles with concrete houses. From the biomedical point of view, people from SGO looking for healthcare can choose between the public (and free) health center, depending on the general hospital of Cayenne, the main city of French Guiana, and a unique general practitioner. Health workers from the health center also visit the Trois-Palétuviers village (a part of SGO municipality further North along the Oyapock River) twice a month.

On the opposite bank of the Oyapock River stands the Brazilian city of Oiapoque, a city of about 27,270 inhabitants (IBGE, 2020), of which a minority is Palikur, Galibi-Marworno and Karipuna Amerindians. For medical care, people there can choose between the malaria health center of Taparabo (a small village facing Trois-Palétuviers on the Brazilian riverbank), health centers in the indigenous areas (*Casa de Saúde do Indio*-CASAI), and the public hospital or the public neighborhood health centers (*Unidade Básica de Saúde*-UBS) in Oiapoque.

For the purpose of the study, the village of Saint-Georges de l'Oyapock was divided into 16 areas according to informal geographic and demographic parameters (Figure 1). Thirteen out of these 16 areas were visited during this study. Three of them were not included in the study (in grey on Figure 1) for the following reasons: the town center because inhabitants are rarely affected by malaria, the airport area which is uninhabited and the military camp where soldiers, mainly from mainland France, stay only for short journeys, take preventative treatment against malaria delivered by the French Armed Forces Health Service in French Guiana, and thus hardly consult the public health center. Three areas were accessible only by boat: Blondin 1, Blondin 2 (10 minutes) and Trois-Palétuviers (one hour). The areas surveyed account for 2,663 people, according to the SGO health center's census.

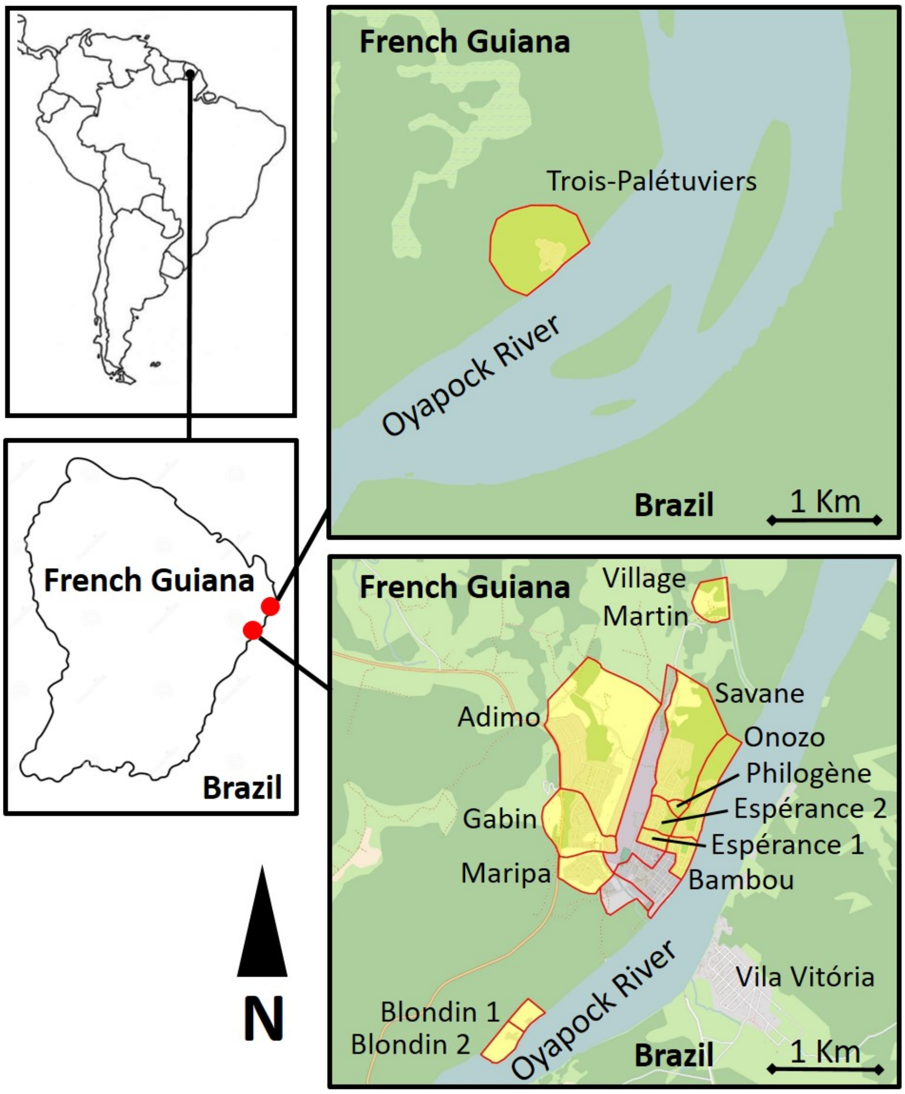

Figure 1: Study area, top right: the village of Trois-Palétuviers, bottom right: the village of Saint-Georges de l'Oyapock showing in yellow the 13 neighborhoods where the study took place.

2.2. Interviews

This cross-sectional study was conducted between October and December 2017. Inhabitants of any age and any nationality from the selected areas were invited to participate, with the aim of approaching a comprehensive census (cf. Mosnier et al., 2019). Community awareness interventions were conducted during the study to secure the commitment and participation of a majority of inhabitants. Community engagement started from meetings with the Amerindian community leaders and the village mayor as well as the healthcare workers and the members of local associations related to health. Stakeholders were informed of the study objectives, interventions and expected role of the community (Mosnier et al., 2020b). Meetings were held in neighborhoods in their local language with trained cultural mediators. Additional mobilization strategies included video clips and WhatsApp messages.

People were interviewed using a questionnaire (122 questions, supplementary data 1) designed to gather multiple information on risk factors for malaria infection, knowledge of the disease, and practices in case of fever or malaria (due to a possible overlap between fever and malaria in vernacular perceptions), with a special focus on remedies (including plants) and therapeutic itineraries.

Questionnaires were administered in either French, Portuguese or Creole by trained cultural mediators from a NGO (*Développement Accompagnement Animation Coopération Guyane*-DAAC), by nurses or by physicians of the study depending on the questions. Due to the length and multiple foci of the questionnaire, the results published here are only a selection of those gathered during this extensive work. Parental agreement was asked for children, and parents were interviewed on behalf of the child. For some questions (such as knowledge of the disease and its signs, or those involving food-producing activities), answers were only taken into account if the interviewee was 15 years of age or older, which corresponds to the perceived age of adulthood. Therefore, the term 'adult' here indicates people over 15 years of age unless otherwise specified.

2.3. Plant selection

Interviewees were asked whether they used plants to prevent or treat fever or malaria. Due to multiple correspondences between vernacular and botanical names, they were invited to point out their potential responses on a poster (supplementary data 2) representing a selection of 17 medicinal plants potentially used in this area, compiled from available literature (Cetout and Weniger, 2016; Grenand et al., 2004; Vigneron et al., 2005) and presenting Portuguese, Palikur, French Guianese Creole and French names when available.

The absence of voucher specimens (although uncommon in ethnobotanical studies) is here justified by the large number of people interviewed (> 1500) and the fact that all the plants selected were widely known in the area and were clearly displayed in the form of detailed pictures with accompanying names. Botanical plant names were updated from references according to *The Plant List* (http://www.theplantlist.org/).

2.4. Medical attention and malaria detection

In order to correlate plant uses and malaria epidemiology, all participants subsequently received a medical examination. Temperatures were taken with an ear thermometer to estimate fever, which was defined as a temperature of ≥38°C according to Oyakhirome et al., 2010. Malaria detection was performed by Rapid Diagnostic Test (RDT) and Polymerase Chain Reaction (PCR). The RDT used was the SD BIOLINE Malaria Ag Pf/Pan test (pfHRP2/pLDH), as used in all French Guianese health centers and Malaria PCR detection was performed as previously described in Mosnier et al. (2019). This allowed the formation of *Plasmodium* positive (*Plasmodium***+**) and *Plasmodium* negative (*Plasmodium***-**) study groups. If RDT or PCR results were positive, voluntary participants were treated for free with a combination of arthemeter and lumefantrine (*P. falciparum* infection) or chloroquine and primaquine, according to the standard therapeutic scheme used in French Guiana (for *P. vivax* infection).

2.5. Data analysis

Data analysis was conducted with STATA 13. Basic social and demographic characteristics were presented as percentage and frequencies. Continuous variables were described with median and interquartile groupings. Chi-square tests were employed to assess any significant difference in knowledge and practices between participants who used local phytotherapies versus those who did not.

Maps were created using QGIS 2.3.

2.6. Ethics statement

The study was approved by the *Comité de Protection des Personnes du Sud-Ouest et Outre-Mer 4* N° AM-36/1/CPP15-024. The database was anonymized and declared to the *Commission Nationale Informatique et Libertés* (n°917186).

Before commencing fieldwork, the study was presented to and approved by the leaders of Amerindian communities and by the municipality of SGO according to the Nagoya protocol.

As the plants presented to the interviewees were selected from bibliographical sources and are widely known and their knowledge shared among many communities, legal authorization from the French Ministry of Environment was not necessary (according to French law N° 2016-1087 of the 8^{th} of August 2016).

3. Results

3.1. Sociodemographic and practices details of participants

A total of 1,566 inhabitants were included in the study (figure 2). Median age was 23.3 years [22.1-24.1], and 36.7 [35.6-37.8] for only those over 15 years old. Sex ratio of males to females was 0.88, or 0.75 for those over 15. More than a half of the participants had French nationality (56.7% 888/1,566), 42.7% (668/1,566) had Brazilian nationality and 0.6% (10/1,566) reported to have another nationality. A third (32.6%; 513/1,566) of participants declared themselves to belong to the Brazilian community. People from Amerindian communities represented 31.7% (498/1,566) of whom a majority was Palikur (74.7%; 372/498) followed by Karipuna (14.5%; 72/498), Teko (7.8%; 39/498) and Wayãpi (3%; 15/498). Lastly, 23.7% (n=371) and 6% (n=98) were French Guianese Creoles and French from mainland France, respectively.

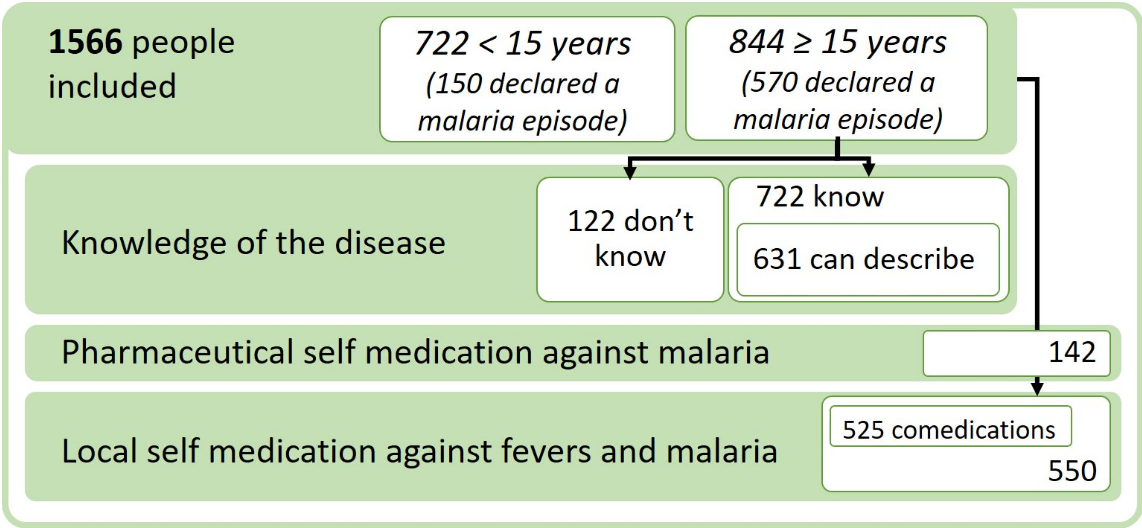

Figure 2: Flowchart of the study

A majority (78.2%; 1,225/1,566) of participants had an effective health insurance (French universal health coverage or Brazilian social coverage or French social security), and 21.8% (n=341) had none or had a precarious coverage (no social coverage or unknown status or French state medical assistance (AME), which is a social coverage for migrants without a residency permit). The large majority of inhabitants (88.7%; 1,385/1,566) live in households counting less than ten people.

Many of the interviewees were under 15 (46.1%; 722/1,566) of which 79.2% (572/722) declared themselves to be pupils. Others were too young to be in school. Among the 844 people over 15 years old (53.9%; 844/1,566), a large proportion reported that they work at home (39.5%; 333/844). People working outdoor (as single occupation workers, excluding informal multiple activities) as farmers, hunters, fishermen or pirogue drivers accounted for 12.8% (108/844), 4.4% (37/844), 3.3% (28/844) and 0.5% (4/844) respectively. Very few participants reported to be employed in the center of SGO or in Oiapoque city (11.0%; 93/844).

3.2. Knowledge of malaria disease

Out of the 844 people over 15 years old at the date of the interview, 722 knew the malaria disease, at least conceptually (85.5%), and 631 were able to describe at least one sign related to the disease (74.8%) from a restricted list of symptoms (figure 2). The symptoms most cited by the interviewees, in decreasing order, are: headache (75.9%; 479/631), fever (62.9%; 397/631), aching muscles (48.0%; 303/631), chills (40.6%; 256/631), tiredness (27.6%; 174/631) and abdominal pain (23.0%; 145/631).

Out of the 722 people who know the disease, most are aware of its transmission by mosquitos (83.4%; 602/722), while 12.7% (92/722) are unaware of the transmission mode of the disease.

Regarding preventive practices, use of mosquito nets is the most frequently cited (57.8%; 417/722), followed by the emptying of water containers for 19.8% of participants (143/722). Use of repellent sprays (19.7%; 142/722) and of indoor insecticides (13.3%; 96/722) follows. Use of long clothes is reported by 8.0% (58/722). Those citing the use of preventive pharmaceutical tablets or medicinal plants are 7.1% (51/722) and 6.8% (49/722) of the sample respectively. Lastly, outdoor spraying seems not to appear as a common practice, with only 2.9% (21/722) of people citing it. People who had no response to this question are nevertheless numerous, 163 respondents (22.6%).

3.3. Cases of malaria among the population

Forty-six percent (720/1,566) of participants declared that they had been infected by malaria at least once, and this rate increased with age: from 20.7% (150/722) among persons under 15 years old to 67.4% (570/844) among participants older than 15. Experience of previous malaria infections is highly variable from one locality to another, ranging from 96% already affected at Martin village to 27.9% at Adimo (supplementary data 3). Other data relative to local epidemiology are available in Mosnier et al. (2019).

3.4. Fever and malaria diagnostic and treatment perspectives

When people experience fever in general or malaria in particular, they reported *often* trying to consult an official health practitioner (58.4%; 915/1,566), while 36.9% (578/1,566) and 4.7% (73/1,566) declared that they *rarely* or *never* go to the health center, respectively.

Among the 651 people that *rarely* or *never* go to the health center, the reasons cited are: the short length of the fever (46.9%; 305/651), followed by the absence of other symptoms (26.3%; 171/651), then by the remoteness of the dispensary (6.5%; 42/651). Lastly, 133 people (20.4%) did not answer or answered with other unspecified reasons. Spatial opportunistic strategies regarding the access to health facilities seems limited. For example, in the Trois-Palétuviers area, only 10% (18/181) of the participants reported a visit in the Brazilian health centers of Taparabo or Oiapoque. In case of health management in Oiapoque, 43.3% (26/60) of participants of the study reported having been at the hospital of the city, 25% (15/60) at an indigenous health center (CASAI), 20% (12/60) at public neighborhood health centers (UBS), 6.7% (4/60) at a malaria health center and only 5% (3/60) in non-institutional health centers or a traditional practitioner's office.

3.5. Malaria and fever treatments

People over 15 years old who are aware of malaria (n=722), when asked what kind of treatment is able to treat malaria specifically, responded both biomedical treatments (86.3%; 623/722) and traditional practices, which encompass medicinal plants (19.3%; 139/722) and spiritual healing (1.2%; 9/722). One hundred people answered both pharmaceuticals and plants/spiritual healing (13.9%; 100/722).

3.5.1. Biomedical treatments against malaria

Every person among the 720 who declared that they had had a confirmed case reported that they took antimalarial drugs (at least for the last episode) mainly provided by the health center or the pharmacy of Saint Georges (57.2%; 412/720 and 15.4%; 111/720, respectively) or from another institution in French Guiana for 8.7% (63/720), while 18.6% of participants reported to have consumed Brazilian drugs from the city of Oiapoque (12.4%; 89/720) or from another place in Brazil (6.2%; 45/720).

Self-medication against malaria with pharmaceuticals was reported in 142 cases. However, the large majority mentioned taking symptomatic medications such as acetaminophen/paracetamol (71.1%; 101/142). The use of an anti-malarial in self-medication was reported by 16.2% of the patients (23/142), and was mostly chloroquine (10.6%; 15/142), then primaquine (2.8%; 4/142), atovaquone-proguanil in 2 cases (1.4%) and Artecom® (dihydroartemisinin-piperaquine-trimethoprim) or doxycycline in 1 case each (0.7%). Eighteen participants (12.4%) reported self-medication with other medications, of which 11 were unknown treatments.

3.5.2. Phytotherapies to prevent and/or treat fever and malaria symptoms

Questions related to plants were widened to malaria and fevers in general, as many plant users cannot confirm that the disease was malaria due to the absence of a diagnostic test. These questions concerned the whole sample (both adults and children), because parents reported which plants they gave to their children. A total of 550 plant users were counted, which represented 35.1% of the interviewed population. Among them, 79.5% and 20.5% (437/550 and 113/550) reported that they *sometimes* or *often* use traditional herbal medicine, respectively. The majority (60.4%; 335/550) declared that they use only one plant, 25.8% (142/550) and 13.8% (73/550) reported the use of up to two and three plants at the same time, respectively.

3.5.3. Complex therapeutic itineraries

Out of all the participants (children and parents included) who reported that they took plants in case of fever or malaria, a large majority utilized pharmaceuticals as well (95.5%; 525/550). More precisely, 40.5% (223/550) took herbal drugs after pharmaceuticals when they thought the pharmaceuticals were not effective enough. Some people, 25.6% (141/550), took plants and pharmaceuticals simultaneously, and 20.4% (112/550) took plants first and switched to pharmaceuticals afterward because the plants were found not to be effective enough. Finally, 8.9% (49/550) used both without describing modalities, and 4.5% (25/550) decided to use plants only.

3.6. Medicinal plant uses

3.6.1. Factors associated with the use of plants

It appeared from the interviews that medicinal plant uses were not homogeneous across the population of SGO (Table 1). People using plants were older than those not using them, 28 vs 20.7 years old (p<0.005), and gender did not affect the use of medicinal plants (p=0.4).

Table 1: Main factors associated with the use of medicinal plants against fever and malaria in Saint-Georges de l'Oyapock

	Not using plants N=1016	**Using plants** N=550	**p-value**	**Not Using plants / ≥15 years old** N=497	**Using plants / ≥15 years old** N=347	**p-value**
Age (Median) [IQR]*	20.7 [19.6-21.8]	28.0 [26.3-29.8]	<0.005	34.5 [33.1-36.0]	39.8 [38.1-41.5]	<0.005
Gender of participants			0.40			0.17
Female	65.8% (547)	34.2% (284)		60.9% (293)	39.1% (188)	
Male	63.8% (469)	36.2% (266)		56.2% (204)	43.8% (159)	
Nationality			0.005			0.41
French	68.2% (606)	31.8% (282)		61.1% (215)	38.9% (137)	
Brazilian	60.3% (403)	39.7% (265)		57.1% (277)	42.9% (208)	
Other	70.0% (7)	30.0% (3)		71.4% (5)	28.6% (2)	
Cultural group			<0.001			<0.001
Amerindians	51.8% (258)	48.2% (240)		45.1% (133)	54.9% (162)	
French Guianese Creoles	61.5% (228)	38.5% (143)		58.8% (100)	41.2% (70)	
French from mainland France	85.7% (84)	14.3% (14)		77.8% (28)	22.2% (8)	
Brazilians	75.8% (389)	24.2% (124)		69.8% (213)	30.2% (92)	
Other	66.3% (57)	33.7% (29)		60.5% (23)	39.5% (15)	
Health insurance			0.003			0.37
No or AME**	58.8% (234)	41.2% (164)		56.6% (146)	43.4% (112)	
Standart social coverage	67.0% (782)	33.0% (386)		59.9% (351)	40.1% (235)	
Level of education						<0.001
≤ primary school				41.9% (109)	58.1% (151)	
> primary school				66.4% (388)	33.6% (196)	
Number of people in household	6.4 [6.2-6.6]	6.6 [6.3-6.9]	0.8			
Neighborhood			<0.001			<0.001
Trois-Palétuviers	44.3% (81)	55.7% (102)		42.2% (35)	57.8% (48)	
Adimo	64.0% (71)	36.0% (40)		51.6% (32)	48.4% (30)	

Bambou	77.8% (35)	22.2% (10)		63.6% (14)	36.4% (8)	
Blondin 1	90.9% (10)	10.1% (1)		100.0% (8)	0% (0)	
Blondin 2	65.9% (29)	34.1% (15)		40.9% (9)	59.1% (13)	
Espérance 1	69.6% (55)	30.4% (24)		64.7% (33)	35.3% (18)	
Espérance 2	68.6% (94)	31.4% (43)		61.3% (46)	38.7% (29)	
Gabin	72.6% (82)	27.4% (31)		73.7% (42)	26.3% (15)	
Maripa	77.8% (42)	22.2% (12)		74.1% (20)	25.9% (7)	
Onozo	70.2% (177)	29.8% (75)		61.8% (89)	38.2% (55)	
Philogène	41.6% (32)	58.4% (45)		38.1% (16)	61.2% (26)	
Savane	68.2% (290)	31.8% (135)		61.7% (142)	38.3% (88)	
Village Martin	51.4% (18)	48.6% (17)		52.4% (11)	47.6% (10)	
Swidden agriculture						<0.001
Yes				47.3% (202)	52.7% (225)	
no				70.7% (295)	29.3% (122)	
Fishing						<0.001
Yes				46.9% (143)	53.1% (162)	
No				65.7% (354)	34.3% (185)	
Hunting						<0.001
Yes				44.0% (92)	56.0% (117)	
No				63.8% (405)	36.2% (230)	
Occupation			<0.001			
Farmer	42.3% (47)	57.7% (64)				
Hunter	55.3% (21)	44.7% (17)				
Work at home	61.0% (203)	39.0% (130)				
Student/Pupil	71.0% (406)	29.0% (166)				
Goldminer	0% (0)	100% (1)				
Fisherman	39.3% (11)	60.7% (17)				
Canoe driver	25.0% (1)	75.0% (3)				
Pensioner	64.9% (24)	35.1% (13)				
Employee in SGO village	71.0% (66)	29.0% (27)				
Others	67.9% (237)	32.1% (112)				
Previous medical history of malaria			<0.001			<0.001
Yes	52.8% (380)	47.2% (340)		52.3% (298)	47.7% (272)	
No	75.2% (636)	24.8% (210)		72.6% (199)	27.4% (75)	
Number of previous malaria infections Median [IQR] *	2.8 [2.5-3.2]	3.6 [2.9-4.3]	0.007	3.1 [2.7-3.6]	4.0 [3.2-4.9]	0.015
Using bed nets			<0.001			<0.001
Yes	60.5% (701)	39.5% (457)		55.4% (347)	44.6% (279)	
No	77.2% (315)	22.8% (93)		68.8% (150)	31.2% (68)	

***Plasmodium* RDT carriage**			0.42			0.68
Yes	53.8% (7)	46.2% (6)		66.7% (4)	33.3% (2)	
No	64.7% (988)	35.3% (539)		58.4% (485)	41.6% (345)	
***Plasmodium* PCR carriage**			0.004			0.03
Yes	51.0% (51)	49.0% (49)		46.5% (33)	53.5% (38)	
No	65.2% (913)	34.8% (488)		59.7% (455)	40.3% (307)	

*IQR: interquartile intervals
**AME: State Medical Assistance - Social coverage for immigrants without a residency permit or a document proving that immigrant have begun the application process for legal residency

Among people over 15 years old, education level seems to have an influence on plant use, as those who have a lower than primary level of schooling are 21.9% among the non-users, while they are 43.5% among the plant users (109/497 vs 151/347; p<0.001).

A trend appears in relation to social insurance, as 41.2% of people with no insurance or AME use plants , while 33.0% of people with standard health insurance do (164/398 vs 386/1168; p=0.003). Nevertheless, when considering only the adults, there is no significance at all (p=0.37).

Interestingly, adults engaged in nature based activities are more prone to be medicinal plant users. As an example, 52.7% of people practicing swidden agriculture are plant users, while they are only 29.3% among those who don't practice local agriculture (225/427 vs 122/417; p<0.001). The same statement applies to fishers, with 53.1% of fishers that use plants (162/305) vs 34.3% of non-fishers (185/539) (p<0.001) or hunters with respectively 56.0% of users among hunters (117/209) vs 36.2% (230/635) (p<0.001). These values might also reflect the large proportion of Amerindians in medicinal plant users. Indeed, the distribution among maternal language (with both adults and children) shows a neat pattern (p<0.001), as 48.2% of Amerindian native speakers (mostly Palikur and Karipuna) are using plants (240/498), while Creoles are only 38.5% (144/371), Brazilian 24.2% (124/513) and French 14.3% (14/98). This observation is further supported by the relative heterogeneity of plant use frequency in the different areas of Saint Georges (supplementary data 4 & 5). For example, inhabitants from Trois-Palétuviers, Philogène and Village Martin, where the Palikur population is largely predominant, are more prone to use medicinal plants.

Lastly, adults who already experienced malaria were more prone to use medicinal plants, (47.7%; 272/570) than those who hadn't (27.4%; 75/274); p<0.001).

3.6.2. Most used plants

A total of 694 use reports (URs) were counted, including 582 citations for the plants of the poster and 112 for other non-identified species. Table 2 presents the result of the most cited plants organized by citation frequency.

Table 2: Citation frequency of plants against fevers and malaria

Species names (**Botanical family**)	**Use reports** N=694	**Citation frequency**	**Agricultural status**
Quassia amara L. (**Simaroubaceae**)	226	32.6%	C*
Cymbopogon citratus (DC.) Stapf (**Poaceae**)	92	32.6%	C
Eryngium foetidum L. (**Apiaceae**)	68	9.8%	C
Citrus aurantiifolia (Christm.) Swingle (**Rutaceae**)	49	7.1%	C
Bryophyllum pinnatum (Lam.) Oken (**Crassulaceae**)	26	3.7%	C
Siparuna guianensis Aubl. (**Siparunaceae**)	22	3.2%	W**
Petiveria alliacea L. (**Phytolaccaceae**)	20	2.9%	C
Solanum leucocarpon Dunal (**Solanaceae**)	13	1.9%	W
Eupatorium triplinerve Vahl (**Asteraceae**)	12	1.7%	C/W
Geissospermum spp. (**Apocynaceae**) *G. argenteum* Woodson, *G. sericeum* Miers, *G. laeve* (Vell.) Miers	12	1.7%	W
Phyllanthus spp. (**Phyllanthaceae**) *P. amarus* Schumach. & Thonn.*; P. niruri* L.	12	1.7%	W
Picrolemma sprucei Hook f. (**Simaroubaceae**)	10	1.4%	W
Aristolochia spp. (**Aristolochiaceae**) *A. stahelii* O.C. Schmidt, *A. mossii* S.Moore, *A. trilobata* L.	9	1.3%	C/W
Zanthoxylum rhoifolium Lam. (**Rutaceae**)	7	1.0%	W
Mikania micrantha Kunth (**Asteraceae**)	4	0.6%	W
Other non-identified species	112	16.1%	-

*C: cultivated; **W: wild

The number of taxa collected wild or cultivated is relatively similar (9 cultivated vs 10 wild), but interestingly, cultivated species accounts for 91.3% of the use reports of identified species (502/550), while wild taxa account for only 18.4% (101/550) (total >100% due to species found both wild or cultivated). This trend is similar for women and men.

Concerning the uses of the plants, there are no significant differences between plants considering gender or ethnicity at the global level, although some trends are interesting to discuss.

All the plant listed are commonly used by every cultural groups around SGO, but three plants are used mostly by the Palikur. They are *Cymbopogon citratus* (44.6% of the total of its use reports; 41/92; p=0.1), *Citrus aurantifolia* (48.9%; 24/49; p=0.03) and *Siparuna guianensis* (40.1%; 9/22; non-significant). Two plants stand out as used mostly by the Creoles: *Eryngium foetidum* (39.7%; 27/68; p=0.03) and *Quassia amara* (35.8%; 81/226; p<0.0001), although the latter is by far the most cited plant by every cultural group.

3.6.3. Modes of preparation and administration of herbal remedies

A total of 662 recipes are described, among which infusions/decoctions stand out (93.5%; 619/662), followed by fresh crushed plants (4.7%; 31/662), alcoholic macerations (1.2%; 8/662) and dry crushed plants (0.6%; 4/662).

Leaves are the most frequently used plant part, with 67.6% of the URs for *E. foetidum* (46/68), 95.6% for *Q. amara* (216/226), 94.6% for *C. citratus* (87/92) and 53.1% for *C. aurantiifolia* 26/49), along with fruit for *C. aurantiifolia* (34.7%, 17/49).

Concerning these plants, the main administration route is unequivocally oral, with 97.1% (66/68), 83.6% (189/226), 77.2% (71/92) and 91.8% (45/49) of the citations, respectively. *C. citratus* is nevertheless also used as a bath (18.5%; 17/92).

3.6.4. Influence of plant uses on parasitaemia

This section aims to establish a correlation between medicinal plant use and biological results. Considering *Plasmodium* spp. carriage detected with a rapid diagnostic test (RDT), it is impossible to conclude (p=0.42) due to a very low proportion of positive results (13).

When considering *Plasmodium* spp. carriage detected by PCR, it appears that infection is correlated to medicinal plant use in general (p=0.004), which is probably the result of several confounding factors hampering a proper interpretation of these results.

4. Discussion

This study offers insight into the complex processes of intercultural therapeutic practices that are too often under-evaluated. The prevalence of medical pluralism demonstrated here is of utmost importance for public health in French Guiana and in Latin America in general.

4.1. Limitations

One of the major limitations of this study is the self-reported nature of the data collected. Despite the participation of professional cultural mediators, who helped interviewees to understand the questions, uncertainty remains about the accuracy of some responses, for example when more people answer they had a test for malaria than those which answered that they knew malaria. This is a common challenge which is difficult to overcome in large scale studies, especially in field sites as complex and multicultural as SGO.

The fact that the project was conducted in association with biomedical professional probably influenced some answers, particularly those dealing with topics often disregarded by the biomedical system.

Due to the length of the questionnaire (122 questions) and the various aspects it dealt with, several themes were not as detailed as they would have been if the work had focused on a single topic. This led to somehow fragmented data. For example, questions related to the reasons of the choice of a treatment would have been insightful and deserve new in depth studies.

No information was collected regarding side effects of antimalarial pharmaceuticals, which could be a factor favoring the consumption of herbal remedies, either to lower them or to replace pharmaceuticals.

The localization of the pictures on the poster (two of the most commonly used plants are at the top) might have influenced respondent's perceptions, as well as the fact that some species had two pictures to show more details, although probably in a minor way.

Finally, the choice to switch from malaria to fever in general, justified by the impossibility to ensure that people were effectively having malaria when they self-treated, might have led to confusion, so the data in response to these questions must be analyzed carefully.

4.2. Sociodemographic and practices details of participants

To our knowledge, this is one of the most extensive epidemiological study addressing the question of co-medication between biomedical and traditional treatments associated with an active *Plasmodium* spp. diagnosis in Latin America (Lipowsky et al., 1992). It is somewhat similar to the one conducted by Vigneron et al. (2005), although they interviewed only 117 people, in the center and eastern part of French Guiana, and did not performed *Plasmodium* spp. detection. Their results are nevertheless used with care on a comparative basis to indicate possibly evolution in practices.
The sampled population represents 38.4% of SGO's population in 2017 (1,566/4,076), but excluding the town center probably shifted the sampling towards a higher Amerindian representation.
The very low average age is representative of the young population of SGO, with 40.6% under 14 years old (INSEE, 2020).

4.3. Knowledge of malaria disease

Malaria description among the interviewees is well correlated to its biomedical definition, although this correlation seems less evident than what was observed 14 years earlier (Vigneron et al., 2005). The difference comes probably from our wider recruitment, as they questioned preferentially more knowledgeable persons. Fever is interestingly not given as the most commonly reported symptom in our study, although it was observed as the most commonly reported symptom by both Vigneron et al., 2005 and by Forero et al. (2014) in three communities in Colombia. By using a closed list of symptoms more or less related to the biomedical definition of malaria, a certain bias was introduced, making it difficult to define more accurately the equivalency between local perception and biomedical definition of malaria.

The question related to transmission included various possibilities such as "*air, contact with an infected person, food*…", and the high rate of response for insect transmission reflects local perception. The same result was observed in Colombia (Forero et al., 2014) and 15 years ago in French Guiana (Vigneron et al., 2005).

Preventive practices cited also show the impact of recurrent prevention messages against vector-borne diseases. Interestingly, medicinal plants, although some are said to be taken preventively, are rarely cited in this section (although they were included in the answer sheet), which indicates a clear difference between biomedical and traditional representations.

4.4. Fever and malaria diagnostic and treatment perspectives

The relatively balanced ratio of people going *often* to the health center vs. those going *rarely* or *never* (58.4% vs 41.6%) is also interesting. Resorting to the health center seemed to be associated with the relative severity of the illness. At the scale of the SGO population, distance seems not to be a major factor deterring people from visiting the health center, probably due to the high mobility of the local population. Nevertheless, the 133 people who did not wish to answer this question probably had other reasons. A degree of mistrust toward biomedicine in general, or toward the health center in particular should not be ignored as a factor influencing choices about treatment (Tareau, 2019), and it might be due to cultural insecurity, the sometimes long queues at the health center, or to previous negative experiences (Valmy et al., 2016). Nevertheless, due to the wide array of options available, access to biomedical antimalarial facilities seems easy, on both the Brazilian and French sides of the border.

Concerning the use of plant medicine in general in French Guiana, access to plants is largely informal, but easy. Plants are often locally collected in gardens or around villages, either by patients themselves or by their relatives (Grenand et al., 2004; Tareau et al., 2017) although important exchange networks have also been documented in the region (Tareau et al., 2019a, 2019b).

4.5. Malaria and fever treatments

4.5.1. Biomedical treatments against malaria

It appears that the distinction between symptomatic and antiplasmodial treatments is not evident, which is a common trend. Pharmaceutical medicines come from official distributors, although 23 people reported self-medication with antimalarials (mainly chloroquine and primaquine). This matches with the local epidemiology of SGO, where a majority of *P. vivax* infection is reported (Mosnier et al., 2019). However, self-medication with artemisinin derivatives is also reported for one patient, which must be considered carefully to prevent the emergence of resistance to artemisinin-based drugs. Even if antimalarial drugs are free in French Guiana and the study was conducted on the French Guianese side of the border, it is interesting to note that Brazilian antimalarials are imported into French Guiana.

4.5.2. Phytotherapies to prevent and/or treat fever and malaria

There is an interesting discrepancy between the 19.3% of interviewees who stated that phytotherapies are able to treat malaria, and the number of people who actually reported using plants in case of fever at large (35.1%; 550/1566).

This important use of medicinal plants against malaria was already highlighted in previous studies, such as Vigneron et al. (2005), or in a rapid assessment of the plants used to treat malaria by patients consulting at the Saint Laurent du Maroni general hospital (at the

Western side of French Guiana, at the border with Suriname) performed in 2016 (Cetout and Weniger, 2016). Regarding other diseases, such as leishmaniasis, a similar trend was observed in the close Upper Oyapock valley (Odonne et al., 2011), and Tareau et al. (2017) encountered a similar pattern of use along the littoral of French Guiana.

Along the Pacific Coast of Colombia, values range from 25.2% (urban areas) to 10.7% (rural areas) for plant use against malaria (Lipowsky et al., 1992), and similar values were observed in Assam (India), where 39.2% of the population refers to *Vaidya* (traditional healers) when experiencing malaria symptoms (Chaturvedi et al., 2009), and approximately one fifth of the people use *Jamu* medicine for this condition in Indonesia (Suswardany et al., 2017).

4.6. Medicinal plant uses

4.6.1. Factors associated with the use of plants

First, medicinal plant users are older than non-users. This trend is common in South America, as exemplified by several studies (Figueiredo et al., 1993; Phillips and Gentry, 1993; Quinlan and Quinlan, 2007; Voeks, 2007; Voeks and Leony, 2004). The observed correlation between use of medicinal plants and past history of malaria in the patient's life has also been reported by Vigneron et al. (2005). It remains unclear to us if this correlation is a consequence of aging, of being more exposed, of a better accessibility to pharmaceuticals in recent times, or other factors. According to Soldati et al. (2015), illness triggers local learning regarding medicinal plant uses.

Factors such as low education level or absence of health insurance, in this case, were not associated with an increased use of medicinal plants. This has already been observed in other situations, for example among Haitian migrants in Cayenne (Tareau et al., 2019a), and seems thus not reproduced here. Even if the renouncement of biomedical health care is a reality in French Guiana among poor populations (Valmy et al., 2016), SGO is another context, and the elevated rate of medicinal plant use seems more related to cultural attachment than to a difficulty of accessing biomedicine.

Moreover, the largest proportion of plant users being among hunters, fishermen and farmers is probably related to their cultural background favoring ethnomedicines more than to their proximity to wild vegetation, since cultivated plants in home gardens are more often used than wild plants (91.3% vs 18.4% of the URs).

Ultimately, distinguishing cultural from socio-economic factors is difficult, but it seems likely that in this case cultural aspects outweigh economical ones. An example comes from the difference between Blondin 1 and Blondin 2, which, despite their geographic proximity (and thus the sharing of common urban patterns), are inhabited by different populations. Thus one is mainly protestant and more averse to medicinal plant uses.

Q. amara is the most cited species. In keeping with Hurrell and Pochettino (2014) and Leonti, (2011), the use of this plant has probably increased due to its prominence in local media. This species of widespread use (Odonne et al., 2020) was in recent years the center of a polemic related to a biopiracy issue (Bourdy et al., 2017) that has certainly added a kind of scientific dressing to its already widespread fame. It is also interesting to note that this species is the most cited in SGO regarding all kind of diseases (Tareau et al., 2019b).

Some seemingly highly cited plants from Eastern French Guiana in 2005, such as *Mikania micrantha*, *Coutoubea* spp., and *Plectranthus* spp., are not or only rarely cited in our study, a testament to the ongoing cultural dynamics in the region, as already discussed by Odonne et al. (2011) and Tareau et al. (2019b). It is likely that some other species would have appeared with an open questionnaire.

As most of the citations refer to widespread plants cultivated in home gardens, it is likely that the utilization of medicinal plants is before all linked to the availability of the resource, and thus is a question of pragmatism and proximity, as much as a question of cultural safety. Moreover, medicinal plants are often perceived to be less toxic than pharmaceuticals, and phytotherapeutic remedies benefit by the way of a positive feeling people associate with them (Tareau, 2019; van Andel et al., 2013).

4.6.2. Complex therapeutic itineraries

As highlighted by Benoist (1996), medical pluralism is a fact in French Guiana. As shown by Vigneron et al. (2005) on the scale of Eastern French Guiana, people normally co-medicate. They observed in 2004 that 58.3% (42/72) of the interviewees who had experienced malaria used both ethnomedical and biomedical therapies to treat malaria, 37.5% (27/72) used only pharmaceuticals and 4.2% (3/72) used only medicinal plants. A slightly different pattern has been observed for leishmaniasis among the Wayãpi and the Teko Amerindians of the Upper Oyapock (Odonne et al., 2011) with respectively 36.8% (25/68) using both therapies, 48.5% (33/68) using pharmaceuticals only and 14.7% (10/68) using traditional therapy only.

Due to the construction of our questionnaire (regarding malaria only or fever and malaria together), it was not possible to determine such ratios. We might nevertheless compare the 525 persons that used both medicinal plants and pharmaceuticals in case of fever to the 720 persons that were treated with biomedicine in case of malaria, and suppose that nearly a quarter would have used only pharmaceuticals.

Cultural differences certainly play a key role in these variations, but it is interesting to note that the most remote Amerindian populations (Wayãpi and Teko) relied more confidently on pharmaceuticals exclusively for leishmaniasis than mixed populations of SGO for malaria. Regardless, such co-medications are undoubtedly an important aspect to be taken into account in further public health projects. Such a high proportion of co-medication also raises questions about the general acceptance of biomedical therapies, a question that would best be investigated by other means (such as qualitative interviews). One study among native Amazonian in Bolivia suggested organizing training workshop between doctors and local practitioners in order to improve collaboration between them, but also to achieve the revalorization of local medicinal knowledge (Vandebroek et al., 2004).

Moreover, these behaviors are thought to possibly delay patients care, possibly resulting in severe cases, the persistence of the parasite in the population, or the creation of reservoirs, notably in *P. vivax* infections. These infections are characterized by an early parasitemia with gametocytes carriage which can contribute to local transmission in case of a delay of efficient antimalarial treatment (Howes et al., 2016).

4.6.3. Influence of plant uses on parasitaemia

Due to several confounding biases, it is impossible to be affirmative regarding a possible causality. As the use of medicinal plants was not related to a specific recent episode of malaria, it might not explain the presence of parasites. Further studies in that field are urgently needed.

4.6.4. Ethnopharmacology of cited species

Uses of plants against malaria are numerous in Latin America (Milliken et al., 2021). Ethnopharmacological works highlighting the therapeutic potential of some of these plants have already been realized *in vitro* and *in vivo*. Among all the species presented on the poster, *Q. amara* has been the most widely and successfully studied, which has led to the isolation of some interesting compounds (Bertani et al., 2007, 2006; Cachet et al., 2009; Houël et al., 2009). *C. citratus* is also a well-studied species and its essential oil has moderate activity against *P. falciparum* (IC_{50}: 48µg/mL) (Kpoviessi et al., 2014; Oladeji et al., 2019). *E. foetidum* seems to have a weak antimalarial potential according to the literature (IC_{50} undetermined but >25 µg/mL) (Paul et al., 2011; Roumy et al., 2007). *C. aurantiifolia*, despite its wide distribution and widespread use as a medicinal species, has not been much studied against malaria. Nevertheless, an interesting clinical study highlighted a higher parasite clearance in children when combining lime juice and ACT vs. ACT alone (Adegoke et al., 2011). *B. pinnatum* is well described from the phytochemical point of view (Fernandes et al., 2019) and a leaf EtOH extract had an IC_{50} *in vitro* ranging between 11–20 µg/mL (Singh et al., 2015). *S. guianensis* EtOH extract was found active *in vitro* against two strains of *P. falciparum* with activities of 6.7 and 14.7 µg/mL (Fischer et al., 2004), but it was considered inactive in another *in vitro* assay (Bertani et al., 2005). Two Peruvian species, *S. aspera* (Ruiz & Pav.) A. DC. and *S. radiata* (Poepp. & Endl.) A. DC. exhibited *in vitro* IC_{50} of respectively 6.4 and 21.7 µg/mL (Valadeau et al., 2009). *P. alliacea* displayed *in vitro* an excellent activity (99% inhibition at 10 µg/mL) but a weak one *in vivo* (41% inhibition at 1 g/kg) (Muñoz et al., 2000a). *S. leucocarpon* seems not to have been tested for antimalarial/antiplasmodial activities. No toxicity has been observed in an *Artemia* assay (Correa et al., 2011), nor on *Aedes aegypti* (Falkowski et al., 2019). An *E. triplinerve* MeOH extract displayed an IC_{50} of 36µg/mL *in vitro* on *P. falciparum* and no toxicity on A-549 cell lines (Jonville et al., 2011), although it was considered inactive (same solvent, IC_{50}>50µg/mL) a few years ago (Jonville et al., 2008). *G. laevis* and *G. argenteum* were considered inactive *in vitro* and exhibited respectively 35% inhibition (23mg/kg) and 44.3% inhibition (324mg/kg) on *P. yoelii* rodent malaria *in vivo.* The later exhibited 83% inhibition on the hepatic stage at the same dose (Bertani et al., 2005). An EtOH extract of *G. laevis* also displayed a good activity *in vitro* (IC_{50} around 3.1µg/mL). It was found active against *P. vinckei* rodent malaria, inactive against *P. berghei* rodent malaria, and highly toxic at 100 mg/kg (Muñoz et al., 2000a). *P. amarus* water and EtOH extracts showed prophylactic and curative effects on *P. yoelii*. For example, water extract inhibited 68% of the parasite growth at 400mg/kg *in vivo* (Ajala et al., 2011), although this species is reported to show a kidney toxicity (Patel et al., 2011). *P. sprucei* (ex. *P. pseudocoffea* Ducke) is the most active species both *in vitro* and *in vivo* against *P. falciparum* studied by Bertani et al. (2005) (IC_{50}=1.4µg/mL; 77.5% inhibition at 95mg/kg), which is probably due to the quassinoid sergeolide that exhibited an IC_{50} of 0.002µg/mL but was also highly toxic (Fandeur et al., 1985; Lemma et al., 2017). No results are available on activities of the *Aristolochia* spp. used against malaria in French Guiana. However, the Bolivian *A. prostrata* Duch. showed a weak *in vivo* activity (10% growth inhibition at 880mg/kg) (Muñoz et al., 2000b). The African *A. elegans* Mast. exhibited no activity (>50µg/mL) *in vitro* (Muganga et al., 2010) while the Indian *A. indica* L. suppressed 52.3% of *P. berghei in vivo* at a dose of 300mg/kg (Gandhi et al., 2019). Nevertheless, kidney toxicity of aristolochic acids encountered in these species raise a concern regarding their use (Debelle et al., 2008). *Z. rhoifolium* was found active *in vivo* (*P. yoelii*), but at a relatively high dose (78% inhibition at 715 mg/kg) (Bertani et al., 2005). This was notably due to benzophenanthridine alkaloids, among which one of the most active, the nitidine, is a well-known cytotoxic molecule (Jullian et al., 2006). It seems that *M. micrantha* had not been tested against *Plasmodium*. *M. congesta* DC. and an undetermined *Mikania* sp. were both found inactive *in vitro* (Muñoz et al., 2000a; Roumy et al., 2007).

5. Conclusion

This study showed *in extenso* that residents of SGO in French Guiana are relying on both traditional plant medicine and biomedicine to treat malaria. This medical pluralism is to be understood as a form of pragmatism, and it is highly probable that local populations do not oppose such therapeutics. Nevertheless, qualitative anthropological research is needed to understand more clearly to what extent these coexisting systems are able to merge.

Plants are indeed a continuing, vibrant tool for local health care along the French Guiana-Brazil frontier. This study shows that, despite the presence of biomedical health facilities, people are collecting, cultivating and utilizing plants for medicinal purposes, which is probably more congruent with their respective cultures and highlights the wish for a certain independence in relation to the care process.

Research should also be conducted, with the support of the communities, to improve our understanding of the functioning of these medicinal plants through an ethnopharmacological approach. As preliminary pharmacological results exist for most of the cited species, further studies should be focused on investigating the synergies between local phytotherapies and pharmaceuticals in order to improve the effectiveness of malaria treatment and avoid negative drug/plant interactions. *Solanum leucocarpon* would also benefit of further pharmacochemical studies due to the overall lack of data concerning this species.

There is a real need for more integrated approaches which target not only generic best practices in malaria prevention and control communication but also adapt these efforts to local practices and knowledge, such as phytotherapies, in order to improve the pragmatic uptake of prevention messages. New collective and participatory approaches between local communities and health workers are needed to co-generate messages of prevention compatible with local cultural safety.

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8. Author Contributions

Designed the study: GO, LM, EM. Performed field study: BP, MG, CM, LE, EM. Performed statistical analysis: CC, GO, EM. Wrote the manuscript: GO, EM. Every author corrected and commented the manuscript.

9. Availability of data and materials

The datasets generated and analyzed during the present study are not publicly available due to the requirement of special authorization to transfer databases provided by the CNIL. Upon prior CNIL authorization, the datasets can be made available from the corresponding author upon reasonable request.

10. Competing interests

The authors declare that they have no competing interests.

11. References

Adegoke, S.A., Oyelami, O.A., Olatunya, O.S., Adeyemi, L.A., 2011. Effects of lime juice on malaria parasite clearance. Phytother. Res. 25, 1547–1550.

Ajala, T.O., Igwilo, C.I., Oreagba, I.A., Odeku, O.A., 2011. The antiplasmodial effect of the extracts and formulated capsules of Phyllanthus amarus on Plasmodium yoelii infection in mice. Asian Pac. J. Trop. Med. 4, 283–287. https://doi.org/10.1016/S1995-7645(11)60087-4

Benoist, J., 1996. Soigner au pluriel: essais sur le pluralisme médical. Karthala Paris.

Bertani, S., Bourdy, G., Landau, I., Robinson, J.C., Esterre, Ph., Deharo, E., 2005. Evaluation of French Guiana traditional antimalarial remedies. J. Ethnopharmacol. 98, 45–54. https://doi.org/10.1016/j.jep.2004.12.020

Bertani, S., Houël, E., Bourdy, G., Stien, D., Jullian, V., Landau, I., Deharo, E., 2007. Quassia amara L. (Simaroubaceae) leaf tea: Effect of the growing stage and desiccation status on the antimalarial activity of a traditional preparation. J. Ethnopharmacol. 111, 40–42. https://doi.org/10.1016/j.jep.2006.10.028

Bertani, S., Houël, E., Stien, D., Chevolot, L., Jullian, V., Garavito, G., Bourdy, G., Deharo, E., 2006. Simalikalactone D is responsible for the antimalarial properties of an amazonian traditional remedy made with Quassia amara L. (Simaroubaceae). J. Ethnopharmacol. 108, 155–157. https://doi.org/10.1016/j.jep.2006.04.017

Bourdy, G., Aubertin, C., Jullian, V., Deharo, E., 2017. Quassia “biopiracy” case and the Nagoya Protocol: A researcher’s perspective. J. Ethnopharmacol. 206, 290–297. https://doi.org/10.1016/j.jep.2017.05.030

Cachet, N., Hoakwie, F., Bertani, S., Bourdy, G., Deharo, E., Stien, D., Houel, E., Gornitzka, H., Fillaux, J., Chevalley, S., 2009. Antimalarial activity of simalikalactone E, a new quassinoid from Quassia amara L.(Simaroubaceae). Antimicrob. Agents Chemother. 53, 4393–4398.

Calvet-Mir, L., Reyes-García, V., Tanner, S., 2008. Is there a divide between local medicinal knowledge and Western medicine? A case study among native Amazonians in Bolivia. J. Ethnobiol. Ethnomedicine 4, 18. https://doi.org/10.1186/1746-4269-4-18

Cetout, H., Weniger, B., 2016. Les remèdes traditionnels dans la lutte antipaludique en Guyane française : une évaluation au centre hospitalier de l’ouest guyanais. Ethnopharmacologia 55, 58–68.

Chaturvedi, H.K., Mahanta, J., Pandey, A., 2009. Treatment-seeking for febrile illness in north-east India: an epidemiological study in the malaria endemic zone. Malar. J. 8, 301.

Correa, Y.M., Mosquera, O.M., Niño, J., 2011. Evaluation of Colombian rainforest plants for their DNA interactions and cytotoxic activities. Int. J. PharmTech Res. 3, 632–638.

Davy, D., Boudoux d’Hautefeuille, M., Nicolle, S., Grenand, F., 2011. Du manioc et un pont : un Observatoire Hommes/Milieux sur la frontière franco-brésilienne, in: Rebelo Porto, J.L., Doff Sota, E. (Eds.), Reformatações Fronteiriças No Platô Das Guianas:(Re) Territorialidades de Cooperações Em Construção. Editora Macapa, pp. 91–118.

Debelle, F.D., Vanherweghem, J.-L., Nortier, J.L., 2008. Aristolochic acid nephropathy: A worldwide problem. Kidney Int. 74, 158–169. https://doi.org/10.1038/ki.2008.129

Djuv, A., Nilsen, O.G., Steinsbekk, A., 2013. The co-use of conventional drugs and herbs among patients in Norwegian general practice: a cross-sectional study. BMC Complement. Altern. Med. 13, 295. https://doi.org/10.1186/1472-6882-13-295

Falkowski, M., Jahn-Oyac, A., Odonne, G., Flora, C., Estevez, Y., Touré, S., Boulogne, I., Robinson, J.-C., Béreau, D., Petit, P., Azam, D., Coke, M., Issaly, J., Gaborit, P., Stien, D., Eparvier, V., Dusfour, I., Houël, E., 2019. Towards the optimization of botanical insecticides research: Aedes aegypti larvicidal natural products in French Guiana. Acta Trop. 105179. https://doi.org/10.1016/j.actatropica.2019.105179

Fandeur, T., Moretti, C., Polonsky, J., 1985. In vitro and in vivo assessment of the antimalarial activity of sergeolide. Planta Med. 51, 20–23.

Fernandes, J.M., Cunha, L.M., Azevedo, E.P., Lourenço, E.M.G., Fernandes-Pedrosa, M.F., Zucolotto, S.M., 2019. Kalanchoe laciniata and Bryophyllum pinnatum: an updated review about ethnopharmacology, phytochemistry, pharmacology and toxicology. Rev. Bras. Farmacogn. 29, 529–558. https://doi.org/10.1016/j.bjp.2019.01.012

Figueiredo, G.M., Leitao-Filho, H.F., Begossi, A., 1993. Ethnobotany of Atlantic Forest coastal communities: diversity of plant uses in Gamboa (Itacuruçá Island, Brazil). Hum. Ecol. 21, 419–430.

Fischer, D.C.H., Gualda, N.C. de A., Bachiega, D., Carvalho, C.S., Lupo, F.N., Bonotto, S.V., Alves, M. de O., Yogi, Á., Santi, S.M.D., Avila, P.E., Kirchgatter, K., Moreno, P.R.H., 2004. In vitro screening for antiplasmodial activity of isoquinoline alkaloids from Brazilian plant species. Acta Trop. 92, 261–266. https://doi.org/10.1016/j.actatropica.2004.08.009

Fleury, M., 2017. Remèdes businenge, businenge deesi. Gadepam, Cayenne (Guyane).

Fleury, M., 2007. Remèdes wayana, wajana epit. Gadepam, Cayenne (Guyane).

Forero, D.A., Chaparro, P.E., Vallejo, A.F., Benavides, Y., Gutiérrez, J.B., Arévalo-Herrera, M., Herrera, S., 2014. Knowledge, attitudes and practices of malaria in Colombia. Malar. J. 13, 165. https://doi.org/10.1186/1475-2875-13-165

Gandhi, P.R., Kamaraj, C., Vimalkumar, E., Roopan, S.M., 2019. In vivo antiplasmodial potential of three herbal methanolic extracts in mice infected with Plasmodium berghei NK65. Chin. Herb. Med. 11, 299–307. https://doi.org/10.1016/j.chmed.2019.06.002

Grenand, F., 2012. Enjeux de territoires sur une frontière méconnue. Entre la France et le Brésil : le fleuve Oyapock. Confins 16, e7961. https://doi.org/10.4000/confins.7961

Grenand, P., Moretti, C., Jacquemin, H., Prévost, M.-F., 2004. Pharmacopées traditionnelles en Guyane : Créoles, Palikur, Wayãpi. IRD Editions, Paris.

Houël, E., Bertani, S., Bourdy, G., Deharo, E., Jullian, V., Valentin, A., Chevalley, S., Stien, D., 2009. Quassinoid constituents of Quassia amara L. leaf herbal tea. Impact on its antimalarial activity and cytotoxicity. J. Ethnopharmacol. 126, 114–118.

Howes, R.E., Battle, K.E., Mendis, K.N., Smith, D.L., Cibulskis, R.E., Baird, J.K., Hay, S.I., 2016. Global epidemiology of Plasmodium vivax. Am. J. Trop. Med. Hyg. 95, 15–34. https://doi.org/10.4269/ajtmh.16-0141

Hurrell, J.A., Pochettino, M.L., 2014. Urban ethnobotany: theoretical and methodological contributions. Methods Tech. Ethnobiol. Ethnoecology 293–309.

IBGE, 2020. Oiapoque (AP) | Cidades e Estados | IBGE [WWW Document]. URL https://www.ibge.gov.br/cidades-e-estados/ap/oiapoque.html (accessed 6.28.20).

INSEE, 2020. Dossier complet − Commune de Saint-Georges (97308) | Insee [WWW Document]. URL https://www.insee.fr/fr/statistiques/2011101?geo=COM-97308#consulter-sommaire (accessed 6.28.20).

Jonville, M.C., Kodja, H., Humeau, L., Fournel, J., De Mol, P., Cao, M., Angenot, L., Frédérich, M., 2008. Screening of medicinal plants from Reunion Island for antimalarial and cytotoxic activity. J. Ethnopharmacol. 120, 382–386. https://doi.org/10.1016/j.jep.2008.09.005

Jonville, M.C., Kodja, H., Strasberg, D., Pichette, A., Ollivier, E., Frédérich, M., Angenot, L., Legault, J., 2011. Antiplasmodial, anti-inflammatory and cytotoxic activities of various plant extracts from the Mascarene Archipelago. J. Ethnopharmacol. 136, 525–531. https://doi.org/10.1016/j.jep.2010.06.013

Jullian, V., Bourdy, G., Georges, S., Maurel, S., Sauvain, M., 2006. Validation of use of a traditional antimalarial remedy from French Guiana, Zanthoxylum rhoifolium Lam. J. Ethnopharmacol. 106, 348–352. https://doi.org/10.1016/j.jep.2006.01.011

Kpoviessi, S., Bero, J., Agbani, P., Gbaguidi, F., Kpadonou-Kpoviessi, B., Sinsin, B., Accrombessi, G., Frédérich, M., Moudachirou, M., Quetin-Leclercq, J., 2014. Chemical composition, cytotoxicity and in vitro antitrypanosomal and antiplasmodial activity of the essential oils of four Cymbopogon species from Benin. J. Ethnopharmacol. 151, 652–659. https://doi.org/10.1016/j.jep.2013.11.027

Lemma, M.T., Ahmed, A.M., Elhady, M.T., Ngo, H.T., Vu, T.L.-H., Sang, T.K., Campos-Alberto, E., Sayed, A., Mizukami, S., Na-Bangchang, K., Huy, N.T., Hirayama, K., Karbwang, J., 2017. Medicinal plants for in vitro antiplasmodial activities: A systematic review of literature. Parasitol. Int. 66, 713–720. https://doi.org/10.1016/j.parint.2017.09.002

Leonti, M., 2011. The future is written: Impact of scripts on the cognition, selection, knowledge and transmission of medicinal plant use and its implications for ethnobotany and ethnopharmacology. J. Ethnopharmacol. 134, 542–555. https://doi.org/10.1016/j.jep.2011.01.017

Lipowsky, R., Kroeger, A., Vazquez, M.L., 1992. Sociomedical aspects of malaria control in Colombia. Soc. Sci. Med. 34, 625–637. https://doi.org/10.1016/0277-9536(92)90190-2

Milliken, W., Walker, B.E., Howes, M.-J.R., Forest, F., Lughadha, E.N., 2021. Plants used traditionally as antimalarials in Latin America: mining the Tree of Life for potential new medicines. J. Ethnopharmacol. 114221. https://doi.org/10.1016/j.jep.2021.114221

Mosnier, E., Douine, M., Epelboin, L., Pelleau, S., Pommier de Santi, V., Dangel, Y., Demar, M., Mutricy, R., Guarmit, B., Nacher, M., Brousse, P., Davy, D., Djossou, F., Musset, L., 2017. Asymptomatic Plasmodium falciparum and vivax infection in the neighborhood of Blondin, Saint-Georges-de-l'Oyapock District, French Guiana. Bull. Soc. Pathol. Exot. 110, 265–269. https://doi.org/10.1007/s13149-017-0572-z

Mosnier, E., Dusfour, I., Lacour, G., Saldanha, R., Guidez, A., Gomes, M.S., Sanna, A., Epelboin, Y., Restrepo, J., Davy, D., 2020a. Resurgence risk for malaria, and the characterization of a recent outbreak in an Amazonian border area between French Guiana and Brazil. BMC Infect. Dis. 20, 1–14.

Mosnier, E., Garancher, L., Galindo, M., Djossou, F.M., Moriceau, O., Hureau-Mutricy, L., Barbosa, R.S., Lambert, Y., Lazrek, Y., Musset, L., 2020b. Paludisme en Guyane: des projets de recherche opérationnelle originaux s' appuyant sur la santé communautaire. Lett. Infect. Online 2020(2).

Mosnier, E., Roux, E., Cropet, C., Lazrek, Y., Moriceau, O., Gaillet, M., Mathieu, L., Nacher, M., Demar, M., Odonne, G., Douine, M., Michaud, C., Pelleau, S., Djossou, F., Musset, L., 2020b. Prevalence of Plasmodium spp. in the Amazonian border context (French Guiana–Brazil): Associated factors and spatial distribution. Am. J. Trop. Med. Hyg. 102 (1), 130–141. https://doi.org/10.4269/ajtmh.19-0378

Muganga, R., Angenot, L., Tits, M., Frédérich, M., 2010. Antiplasmodial and cytotoxic activities of Rwandan medicinal plants used in the treatment of malaria. J. Ethnopharmacol. 128, 52–57. https://doi.org/10.1016/j.jep.2009.12.023

Muñoz, V., Sauvain, M., Bourdy, G., Callapa, J., Rojas, I., Vargas, L., Tae, A., Deharo, E., 2000a. The search for natural bioactive compounds through a multidisciplinary approach in Bolivia. Part II. Antimalarial activity of some plants used by Mosetene indians. J. Ethnopharmacol. 69, 139–155. https://doi.org/10.1016/S0378-8741(99)00096-3

Muñoz, V, Sauvain, M., Bourdy, G., Arrázola, S., Callapa, J., Ruiz, G., Choque, J., Deharo, E., 2000b. A search for natural bioactive compounds in Bolivia through a multidisciplinary approach: Part III. Evaluation of the antimalarial activity of plants used by Alteños Indians. J. Ethnopharmacol. 71, 123–131. https://doi.org/10.1016/S0378-8741(99)00191-9

Musset, L., Pelleau, S., Girod, R., Ardillon, V., Carvalho, L., Dusfour, I., Gomes, M.S., Djossou, F., Legrand, E., 2014. Malaria on the Guiana Shield: a review of the situation in French Guiana. Mem. Inst. Oswaldo Cruz 109 (5), epub aug13. http://dx.doi.org/10.1590/0074-0276140031

Nathalie, M., 2015. Plan de lutte contre le paludisme en Guyane. ARS Guyane.

Odonne, G., Berger, F., Stien, D., Grenand, P., Bourdy, G., 2011. Treatment of leishmaniasis in the Oyapock basin (French Guiana): A K.A.P. survey and analysis of the evolution of phytotherapy knowledge amongst Wayãpi Indians. J. Ethnopharmacol. 137, 1228–1239. https://doi.org/10.1016/j.jep.2011.07.044

Odonne, G., Tareau, M.-A., van Andel, T., 2021. Geopolitics of bitterness: deciphering the history and cultural biogeography of Quassia amara L. J. Ethnopharmacol. 267 (1), e113546. https://doi.org/10.1016/j.jep.2020.113546

Ogeron, C., Odonne, G., Cristinoi, A., Engel, J., Grenand, P., Beauchêne, J., Clair, B., Davy, D., 2018. Palikur traditional roundwood construction in eastern French Guiana: ethnobotanical and cultural perspectives. J. Ethnobiol. Ethnomedicine 14, 28. https://doi.org/10.1186/s13002-018-0226-7

Okwundu, C.I., Nagpal, S., Musekiwa, A., Sinclair, D., 2013. Home- or community-based programmes for treating malaria. Cochrane Database Syst. Rev. CD009527. https://doi.org/10.1002/14651858.CD009527.pub2

Oladeji, O.S., Adelowo, F.E., Ayodele, D.T., Odelade, K.A., 2019. Phytochemistry and pharmacological activities of Cymbopogon citratus: A review. Sci. Afr. 6, e00137. https://doi.org/10.1016/j.sciaf.2019.e00137

Oyakhirome, S., Profanter, K., Kremsner, P.G., 2010. Assessment of Fever in African Children: Implication for Malaria Trials. Am. J. Trop. Med. Hyg. 82, 215–218. https://doi.org/10.4269/ajtmh.2010.09-0419

Patel, J.R., Tripathi, P., Sharma, V., Chauhan, N.S., Dixit, V.K., 2011. Phyllanthus amarus: Ethnomedicinal uses, phytochemistry and pharmacology: A review. J. Ethnopharmacol. 138, 286–313. https://doi.org/10.1016/j.jep.2011.09.040

Paul, J.H.A., Seaforth, C.E., Tikasingh, T., 2011. Eryngium foetidum L.: A review. Fitoterapia 82, 302–308. https://doi.org/10.1016/j.fitote.2010.11.010

Phillips, O., Gentry, A.H., 1993. The useful plants of Tambopata, Peru: II. Additional hypothesis testing in quantitative ethnobotany. Econ. Bot. 47, 33–43. https://doi.org/10.1007/BF02862204

Roumy, V., Garcia-Pizango, G., Gutierrez-Choquevilca, A.-L., Ruiz, L., Jullian, V., Winterton, P., Fabre, N., Moulis, C., Valentin, A., 2007. Amazonian plants from Peru used by Quechua and Mestizo to treat malaria with evaluation of their activity. J. Ethnopharmacol. 112, 482–489. https://doi.org/10.1016/j.jep.2007.04.009

Quinlan, M.B., Quinlan, R.J., 2007. Modernization and medicinal plant knowledge in a Caribbean horticultural village. Med. Anthropol. Q. 21, 169–192.

Saldanha, R., Mosnier, É., Barcellos, C., Carbunar, A., Charron, C., Desconnets, J.-C., Guarmit, B., Gomes, M.D.S.M., Mandon, T., Mendes, A.M., Peiter, P.C., Musset, L., Sanna, A., Gastel, B.V., Roux, E., 2020. Contributing to elimination of cross-border malaria through a standardized solution for case surveillance, data sharing, and data interpretation: development of a cross-border monitoring system. JMIR Public Health Surveill. 6, e15409. https://doi.org/10.2196/15409

Singh, N., Kaushik, N.K., Mohanakrishnan, D., Tiwari, S.K., Sahal, D., 2015. Antiplasmodial activity of medicinal plants from Chhotanagpur plateau, Jharkhand, India. J. Ethnopharmacol. 165, 152–162. https://doi.org/10.1016/j.jep.2015.02.038

Soldati, G.T., Hanazaki, N., Crivos, M., Albuquerque, U.P., 2015. Does environmental instability favor the production and horizontal transmission of knowledge regarding medicinal plants? A study in southeast Brazil. PLoS ONE 10, e0126389. https://doi.org/10.1371/journal.pone.0126389

Suswardany, D.L., Sibbritt, D.W., Supardi, S., Pardosi, J.F., Chang, S., Adams, J., 2017. A cross-sectional analysis of traditional medicine use for malaria alongside free antimalarial drugs treatment amongst adults in high-risk malaria endemic provinces of Indonesia. PloS One 12, e0173522.

Tareau, M.-A., 2019. Les pharmacopées métissées de Guyane : ethnobotanique d’une phytothérapie en mouvement. Université de Guyane.

Tareau, M.-A., Bonnefond, A., Palisse, M., Odonne, G., 2020. Phytotherapies in motion: French Guiana as a case study for cross-cultural ethnobotanical hybridization. J. Ethnobiol. Ethnomedicine 16, 54. https://doi.org/10.1186/s13002-020-00404-1

Tareau, M.-A., Dejouhanet, L., Odonne, G., Palisse, M., Ansoe, C., 2019a. Wild medicinal plant collection in transitional societies: A case Analysis from French Guiana. EchoGéo 47. https://doi.org/10.4000/echogeo.17260

Tareau, M.A., Dejouhanet, L., Palisse, M., Odonne, G., 2019b. Circulations et échanges de plantes et de savoirs phyto-médicinaux sur la frontière franco-brésilienne. Rev. Fr. Santé Territ. - RFST. https://ouest-edel.univ-nantes.fr/rfst/index.php?id=128

Tareau, M.A., Palisse, M., Odonne, G., 2017. As vivid as a weed… Medicinal and cosmetic plant uses amongst the urban youth in French Guiana. J. Ethnopharmacol. 203, 200–213. https://doi.org/10.1016/j.jep.2017.03.031

Valadeau, C., Pabon, A., Deharo, E., Alban-Castillo, J., Estevez, Y., Augusto, L.F., Rosario, R., Dionicia, G., Michel, S., Denis, C., Geneviève, B., 2009. Medicinal plants from the Yanesha (Peru): Evaluation of the leishmanicidal and antimalarial activity of selected extracts. J. Ethnopharmacol. 123, 413–422. https://doi.org/10.1016/j.jep.2009.03.041

Valmy, L., Gontier, B., Parriault, M.C., Van Melle, A., Pavlovsky, T., Basurko, C., Grenier, C., Douine, M., Adenis, A., Nacher, M., 2016. Prevalence and predictive factors for renouncing medical care in poor populations of Cayenne, French Guiana. BMC Health Serv. Res. 16, e34. https://doi.org/10.1186/s12913-016-1284-y

van Andel, T., Carvalheiro, L., G, S., 2013. Why urban citizens in developing countries use traditional medicines: The case of Suriname. Evid. Based Complement. Alternat. Med. 2013, e687197. https://doi.org/10.1155/2013/687197

Vandebroek, I., Calewaert, J.-B., De jonckheere, S., Sanca, S., Semo, L., Van Damme, P., Van Puyvelde, L., De Kimpe, N., 2004. Use of medicinal plants and pharmaceuticals by indigenous communities in the Bolivian Andes and Amazon. Bull. World Health Organ. 82, 243–250.

Vigneron, M., Deparis, X., Deharo, E., Bourdy, G., 2005. Antimalarial remedies in French Guiana: A knowledge attitudes and practices study. J. Ethnopharmacol. 98, 351–360. https://doi.org/10.1016/j.jep.2005.01.049

Voeks, R.A., 2007. Are women reservoirs of traditional plant knowledge? Gender, ethnobotany and globalization in northeast Brazil. Singap. J. Trop. Geogr. 28, 7–20.

Voeks, R.A., Leony, A., 2004. Forgetting the forest: assessing medicinal plant erosion in eastern Brazil. Econ. Bot. 58, S294–S306.

Welz, A.N., Emberger-Klein, A., Menrad, K., 2018. Why people use herbal medicine: insights from a focus-group study in Germany. BMC Complement. Altern. Med. 18, 92. https://doi.org/10.1186/s12906-018-2160-6

World Health Organization, 2013. WHO Traditional Medicine Strategy 2014-2023.

Supplementary data

Supplementary data 1:

Questionnaire

Supplementary data 2: poster presented during the interviews

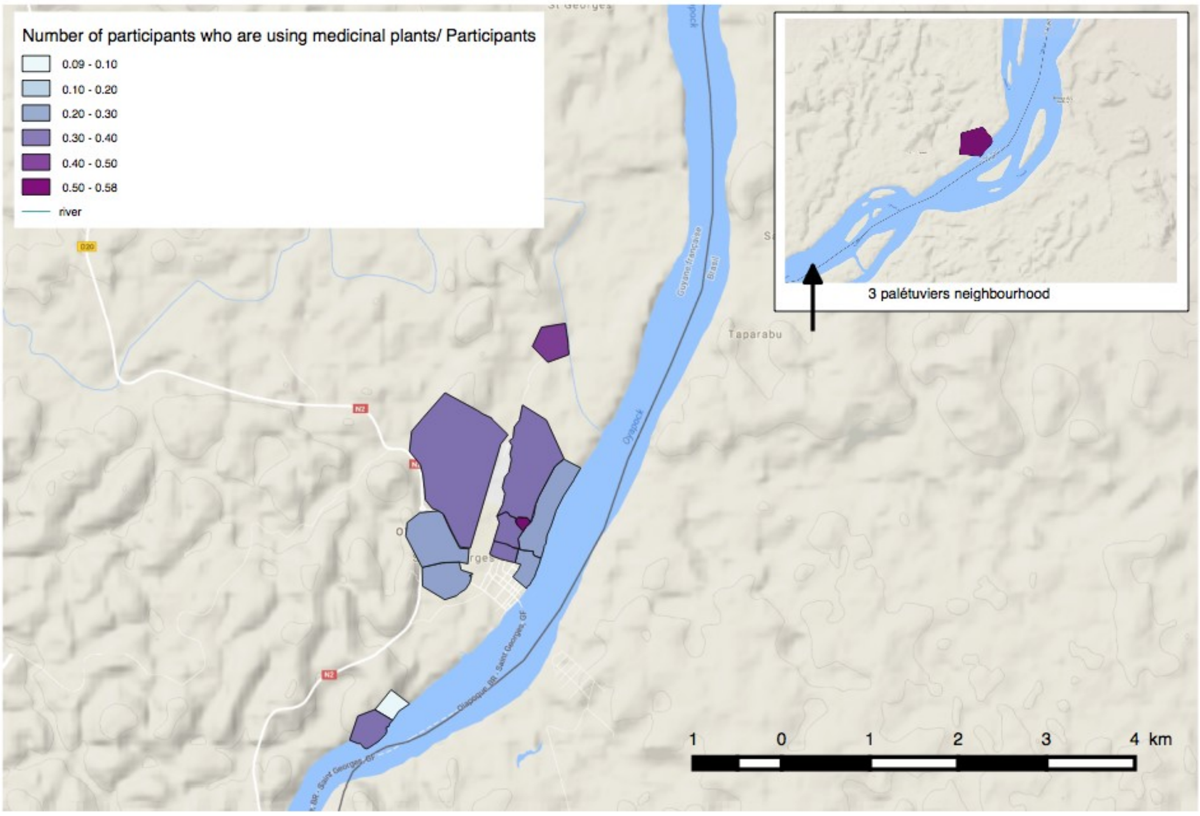
1. *Eryngium foetidum* L. (Apiaceae)

2. *Quassia amara* L. (Simaroubaceae)
3. *Geissospermum argenteum* woodson, *Geissospermum sericeum* Benth. and Hook. f. ex Miers (Apocynaceae)
4. *Phyllanthus amarus* Schumach. & Thonn., *Phyllanthus niruri* L. (Phyllanthaceae)
5. *Aristolochia trilobata* L., *Aristolochia stahelii* O.C. Schmidt, *Aristolochia leprieurii* Duch. (Aristolochiaceae)
6. *Cymbopogon citratus* Stapf. (Poaceae)
7. *Coutoubea spicata* Aublet, *Coutoubea ramosa* Aublet (Gentianaceae)
8. *Citrus aurantiifolia* (Christm.) Swingle (Rutaceae)
9. *Picrolemma sprucei* Hook. f. (Simaroubaceae)
10. *Siparuna guianensis* Aublet (Siparunaceae)
11. *Plectranthus barbatus* Andrews, *Plectranthus neochilus* Schltr. (Lamiaceae)
12. *Solanum leucocarpon* Dunal (Solanaceae)
13. *Petiveria aliacea* L. (Petiveriaceae)
14. *Eupatorium triplinerve* Vahl (Asteraceae)
15. *Mikania micrantha* Kunth. (Asteraceae)
16. *Zanthoxylum rhoifolium* Lam. (Rutaceae)

Supplementary data 3: number of participants who experienced malaria prior to the interview according to their residence

Neighborhood	Participants who experienced malaria prior to the interview (and %)	Participants ≥15 years old who experienced malaria prior to the interview (and %)
Trois-Palétuviers	123/183 (67.2%)	63/83 (75.9%)
Adimo	31/111 (27.9%)	45/62 (72.6%)
Bambou	15/45 (33.3%)	13/22 (59.1%)
Blondin 1	9/11 (81.8%)	8/8 (100%)
Blondin2	28/44 (63.6%)	18/22 (81.8%)
Espérance 1	34/79 (43%)	33/51 (64.7%)
Espérance 2	51/137 (37.2%)	44/75 (58.7%)
Gabin	42/113 (37.2%)	33/57 (57.9%)
Maripa	26/54 (48.1%)	21/27 (77.8%)
Onozo	104/252 (41.3%)	95/144 (66%)
Philogène	33/77 (42.9%)	24/42 (57.1%)
Savane	184/425 (43.3%)	159/230 (69.1%)
Village Martin	24/25 (96%)	20/21 (95.2%)

Supplementary data 4: Spatial distribution of participants who reported the use of medicinal plant against fevers and malaria



Supplementary data 5: percentage of the population using plants according to their residence

Neighborhood name	**% of the population using plants** (p<0.005)	**Use reports**	**Use** ≥15 years old
Philogène	58.4%	45/77	26/42
Trois-Palétuviers	55.7%	81/183	48/83
Village martin	48.6%	17/35	10/21
Adimo	36.0%	40/111	30/62
Blondin 2	34.1%	15/44	13/22
Savane	31.8%	135/425	88/230
Espérance 2	31.4%	43/137	29/75
Espérance 1	30.4%	24/79	18/51
Onozo	29.8%	75/252	55/144
Gabin	27.4%	31/113	15/57
Bambou	22.2%	10/45	8/22
Maripa	22.2%	12/54	7/27
Blondin 1	9.1%	1/11	0/8