



Research article

The use of antimalarial plants as traditional treatment in Papua Island, Indonesia



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ABSTRACTS

The residents of the Eastern part of Indonesia, specifically, Papua and West Papua provinces, are dependent on traditional medicines with the use of plants, which includes treating malaria. However, there are limited information on the diversity of medicinal plants in Papua Island. Hence, the Indonesian Ministry of Health put together a database of all the natural plant-based raw materials in Indonesia, to address part of the issues encountered as a result of the limited information on the diversity of plants. Based on this background, the aim of the research was to analyze the information on medicinal plants used by the traditional healers in Papua Island based on the results of research on medicinal plants and Jamu (RISTOJA), especially in treating malaria. Data were obtained through ethnomedicine research conducted in 2012 and 2017 involving 54 ethnicities in Papua. Based on the results, 72 species of medicinal plants from 67 genera and 40 families were used traditionally in treating malaria on Papua Island. The most common medicinal plants used as traditional antimalarial concoction are *Alstonia scholaris* (L.) R. Br., *Carica papaya* L., *Andrographis paniculata* (Burm. f.) Nees, and *Physalis minima* L. Similar to other ethnobotany research, the leaves were the most used plant parts in preparing the various traditional concoctions.

1. Introduction

Indonesia is among the developing countries in ASEAN with the high cases of malaria. Until 2007, about 80% of villages and cities in the country were declared malaria-free. However, the incidence of malaria reduced from 2.9% in 2007 to 1.9% in 2013. Five provinces with the highest incidence of malaria include Papua, West Papua, East Nusa Tenggara, Central Sulawesi, and Maluku. Also, Papua and West Papua are the two major provinces in Papua Island, Indonesia, with annual parasite incidence (API) indicator of about 67%. Five districts with the highest API indicator in Papua province include Keerom, Jayapura, Timika, Sarmi, and Boven Digoel Regency. Meanwhile, Manokwari, South Manokwari, and Wondama Bay Regency are the three districts in West Papua with the highest API indicator [1, 2, 3, 4, 5].

High cases of malaria in Papua and West Papua are due to several factors such as the resistance of the malaria-causing parasites, low level of government programs, especially in the underdeveloped areas, as well as limited health facilities in remote areas [1, 2, 6]. The government's efforts in eradicating malaria have been ongoing for a decade. The Minister of Health launched a four-phase of malaria elimination

program, namely eradication, pre-elimination, elimination, and maintaining the elimination status. The program was planned for islands and provinces, which began in 2010 and expected to be fully accomplished by 2030. This was specifically targeted at Papua, West Papua, and several provinces in eastern Indonesia to be malaria-free in 2030 [2,7].

Kumar and Preetha (2012) suggested the need for each community to maximize the current technology development in the health sector in order to reduce the morbidity of the disease. Also, the government should be able to collaborate with the community in terms of organizing programs to eliminate it in various communities. Papua society is made up of various ethnic with diverse cultures and numerous knowledge in overcoming health problems. The knowledge of the society as regards health is based on the use of local approach, including traditional healers, also known as *dukun* or *hattra*. Also, a majority of these traditional healers make use of plants as medicine [8, 9].

Various plants have been known to possess medicinal properties from ancient times. The use of plants as medicine became popular considering the fact that they are more efficient, safe, and economical. Also, the use of plants for treating malaria has been carried out for thousands of years. The forerunner of the antimalarial plant-derived compounds include

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quinine, lapachol, and artemisinin [6, 10, 11]. The discovery and development of plants for drug innovation became one of the priorities in the Malaria Eradication Research Agenda and ethnopharmacology is a promising approach in handling malaria management in the future [10, 12]. According to Supiandi et al. (2019), there is need for the inventory of local wisdom related to the use of medicinal plants for the prevention, as well as in treating diseases, and also highlighted the need to preserve and develop it. Traditional local wisdom is the basis for developing innovative and technological advancement currently experienced, as well as in the future [13].

Based on recent studies, plants diversity in Papua Island ranged from 20,000 to 25,000 species. Several researchers have reviewed the status of exploration and documentation of plants in the island, however, the data collected were unable to accurately describe the plant diversity Research on plant diversity is expected to take a long time to be fully resolved, while some studies put it at 2150 [14,15].

The Health Ministry, through the National Institute of Health Research and Development (NIHRD) in collaboration with some leading universities, have conducted research on medicinal plants and Jamu (hereafter RISTOJA). RISTOJA is an ethnomedical research which explores the utilization of medicinal plants based on ethnics in Indonesia. About 54 ethnics were observed in Papua and West Papua provinces, and the traditional ingredients successfully recorded from the two provinces was around 3,303 traditional concoctions from 2,930 plant species. Also, the traditional concoctions for malaria in Papua Island were the most prominent three used from 74 types of diseases in RISTOJA [16, 17, 18]. In addition, Widiyastuti and Widayat (2013) reported the importance of properly documenting the variety of medicinal plants in Papua Island since the data related to these plants were improperly collected [19]. Based on the background, the aim of this study was to analyze the information on medicinal plants used by the traditional healers in Papua Island based on the results of RISTOJA, especially in malaria treatment. This information is expected to be further explored and developed to bring better innovation in malaria drugs, which would be beneficial in overcoming the problems with disease resistance.

2. Material and methods

2.1. Location and time of study

This study used the metadata of RISTOJA collected in 2012 and 2017, through an electronic questionnaire created using Microsoft Access software. The results of the electronic questionnaire were sent through e-mail to the Laboratory Data Management of NIHRD, which were then added to the data of each province. The data of each province was subsequently processed through cleaning and coding, then compiled into a database. However, access to the RISTOJA database is not open through the website, the usage of data is only possible by submitting proposal to the Head of NIHRD, Ministry of Health of the Republic of Indonesia.

The research was conducted between October and November 2012, involving 6 and 18 ethnics in Papua and West Papua provinces, respectively. Also, in May 2017, 10 and 20 ethnics were observed in Papua and West Papua provinces, respectively, as shown in Figure 1. The ethnics used in this research were selected through purposive sampling method based on the criteria of the ethnic having a minimum population 1000 people according to Statistics Indonesia Database [16, 17]. This criteria was based on that ethnicity with a minimum population of 1000 people has long existed and has a wealth of local wisdom information which could be further developed, especially the traditional knowledge of medicinal plant for treating malaria.

Papua Island is located in the eastern part of Indonesia between 0°19'-10°45' south latitude and 130°45'-141°48' east longitude. The northern part of the island is surrounded by the Pacific Sea, the Maluku islands, and the Banda ocean in the west, the Indian sea, the Gulf of Carpentaria, the Arafuru ocean, and the Australian continent in the south, while the east borders directly with Papua New Guinea. In terms of topographical conditions, Papua Island is mostly tropical rain forests, with valleys, shorelines, streams, lowlands, highlands or mountains difficult to access. Its climatic conditions include relatively high rainfall from 1800 to 3000 mm high humidity of over 80% and a temperature within a range of 19–28 °C depending on the nature of the area, with higher locations

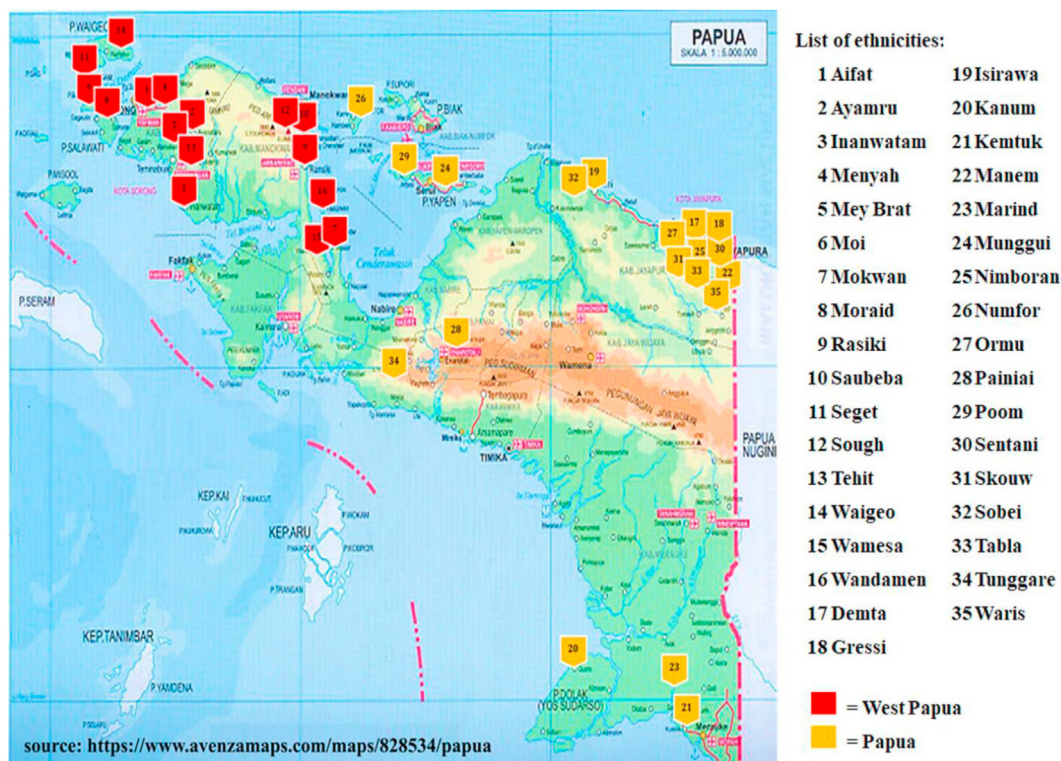


Figure 1. Distribution of research location in Papua island.

having lower air temperature. In addition, the highest location on the island is known as Puncak Jaya Regency in the Jayawijaya mountains, and is frequently covered with snow [20, 21].

2.2. Data collection

Data collection was conducted through direct interviews with traditional healers/*hatra* engaged in providing the services in each local ethnicity and the used medicinal plant specimens were collected. The traditional healers used as informants, were selected through purposive sampling method from the data obtained from the Regional Health Offices, the local community, or the ethnic leaders. The RISTOJA was also used as inclusion criteria in selecting the traditional healers, including those having the knowledge and ability to treat malaria using medicinal plants, as well as truly practicing traditional treatment, and widely known in the community. Traditional healers who did not meet these criteria were excluded. The total traditional healers which has been interviewed in Papua Island are 270 informants, respectively 5 individuals for each ethnicity. All of these traditional healers were unregistered to the regulatory of Ministry of Health but their traditional treatment experiences have been trusted by the local people.

Interviews were conducted using structured guidelines to collect data related to the use of plant species as medicine. The medicinal plant species were recorded based on local names, habitus, parts of plants used, and the use of the plants. Several plants were collected as specimens, identified by plant taxonomist, documented and stored in Herbarium Tawangmanguensis, MPTMRDC.

2.3. Data analysis

The data collected were analyzed qualitatively and quantitatively. Qualitative data analysis was carried out descriptively and supported with literatures review on the plants. Then, the quantitative analysis was conducted by measuring the value of Family Importance Value (FIV), Relative Frequency of Citation (RFC), and Plant Part Value (PPV). The FIV was calculated to identify the significance of plant families and it is an essential index in ethnobotany in estimating the amount of plant taxon. This value was calculated using a formula cited by Sulaiman et al. (2020) [22]:

$$FIV = \frac{FC (family)}{N} \times 100 \quad (1)$$

FC (family) = the number of informants mentioning the family
N = total of informant interviewed

The RFC was calculated to determine which species of plant used as traditional malaria medicine. Also, this value was calculated using the formula cited by Tardío and Pardo-De-Santayana (2008) [23]:

$$RFC = \frac{FC}{N} \quad (2)$$

FC = the number of informants who mentioned a certain species
N = total of informant interviewed

The percentage of plant parts that are used as medicinal ingredients for malaria was calculated using the formula cited by Gomez-Beloz (2002) [24]:

$$PPV = \frac{\sum RU(plant\ part)}{\sum RU} \times 100\% \quad (3)$$

$\sum RU(plant\ part)$ = total number of use cited for each plant part
 $\sum RU$ = total all plant part

3. Results and discussion

3.1. The distribution of malaria herbal concoction in Papua Island

The clinical symptoms of malaria used as operational definitions in RISTOJA include high fever, chills, muscular aching, abdominal pain, nausea, and loss of appetite [17]. Based on the RISTOJA data, 35 out of 54 ethnics in the provinces of Papua and West Papua widely used traditional antimalarial treatments, with a total of 89 concoctions. West Papua was with more antimalarial concoctions compared with Papua province, with 65 concoctions. Also, Waigeo, Wamesa, and Sough were the ethnics in West Papua with the highest number of concoctions. Additionally, there were diverse antimalarial concoctions among ethnics in the province, with 47 single and 18 compound concoctions, while 16 single and 8 compound concoctions recorded in Papua province.

The ethnics with antimalarial concoction are broadly distributed in the province, both in locations accessible and remote areas. This supports the fact that malaria is still a common problem in Papua Island. The Basic Health Research 2018 (RISKESDAS) also showed the prevalence of malaria in the provinces of Papua and West Papua, both ranking the first two among 34 provinces in Indonesia [25]. Ethnics in Papua province with antimalarial concoctions are more dominant in Jayapura Regency, while in West Papua province, antimalarial concoctions are more dominant in Sorong and Manokwari regencies. This is in line with the reports of Health Service (Dinas Kesehatan (DINKES)) showing that the two provinces with the highest API value in Papua Island were Jayapura and Manokwari districts [4].

More people in West Papua are dependent on traditional medicine due to the fact that most locations are difficult to reach by modern medicine. The high diversity of herbs among ethnicities in the province of West Papua shows that local wisdom regarding traditional medicine is still more embraced compared with the province of Papua. Locations in Papua province are more easily accessible, with ease of communication and entry of information from outside, including modern medicine. However, these conditions could lead to changes in ecosystems, environment, cultural values, and local wisdom, one of which is related to traditional medicine [26].

Despite these conditions, people in Papua Island still depend on traditional medicine. According to Triratnawati (2017), traditional medical practices are hereditary and dominant since many areas have not been reached with the modern health system. Also, one of the local wisdom is the use of plant-based materials in treating various diseases. RISKESDAS 2018 also showed the preference of people in both provinces in preparing their traditional medicine for treating various diseases. This is shown by the high proportion in the use of traditional homemade concoctions, which was approximately 81.7% in Papua and 70.8% in West Papua [17, 25, 27].

3.2. Diversity of plant species used for treating malaria

Table 1 shows the plant species usually used by traditional healers in treating malaria in Papua Island. It shows the family, scientific names, local names of the ethnic groups using the plants, the parts of plants used, habitat, and the qualitative values of RFC and FIV.

Based on the results, 72 plant species from 40 families were identified being used as traditional antimalarial medicine in 35 ethnics in the provinces of Papua and West Papua. These plant species belong to 67 genera and 40 families: *Menispermaceae* (5 species), *Acanthaceae* (4 species), *Araceae* (4 species), *Euphorbiaceae* (4 species), *Fabaceae* (4 species), *Phyllanthaceae* (4 species), *Rubiaceae* (4 species), *Areaceae* (3 species), *Meliaceae* (3 species), *Zingiberaceae* (3 species), *Lamiaceae* (2 species), *Moraceae* (2 species), *Sapindaceae* (2 species), *Urticaceae* (2 species) and other families were represented by one species, as shown in Figure 2.

Considering the number of identified species, *Menispermaceae* were the most represented plant family, with a total of 5 species used as antimalarial medicine in Papua Island, as shown in Figure 2. This

Table 1. List of inventory antimalarial plants used in traditional treatment in Papua Island, Indonesia.

No	Family	Scientific name of plant	Ethnic local name of plant	Part Used	Habit	FIV	FC	RFC
1	Acanthaceae	<i>Andrographis paniculata</i> (Burm. f.) Nees	Sambiloto (Moraid, Wamesa, Gresi, Nimboran, Skouw, Tabla); Sambiroto (Demta, Marind), Bedesna/samiroto (Rasiki)	leaves, stem, herb	herb	15.73	3	0.12
2	Acanthaceae	<i>Dicliptera chinensis</i> (L.) Juss.	Mogrovog (Hattam)	leaves	herb	15.73	0	0.01
3	Acanthaceae	<i>Graptophyllum pictum</i> (L.) Griff.	Mosmoga (Meyah)	leaves	herb	15.73	0	0.01
4	Acanthaceae	<i>Justicia gendarussa</i> Burm. f.	Gandarusa (Waigeo)	leaves	herb	15.73	0	0.01
5	Acoraceae	<i>Acorus calamus</i> L.	Hayau (Aifat)	rhizome	herb	1.12	0	0.01
6	Amaranthaceae	<i>Iresine herbstii</i> Hook.	Aregahani (Sough)	leaves	herb	1.12	0	0.01
7	Amoryllidaceae	<i>Proiphys amboinensis</i> (L.) Herb.	Biji malaria (Waigeo)	leaves	herb	1.12	0	0.01
8	Anacardiaceae	<i>Mangifera indica</i> L.	Mangga (Wamesa)	bark	tree	1.12	0	0.01
9	Apocynaceae	<i>Alstonia scholaris</i> (L.) R. Br.	Arasue (Aifat); Pohon susu (Ayamru); Kayu susu (Mey Brat, Wamesa, Wandamen, Manem, Skouw); Igeii (Moi); Epalom (Seget); Yede (Tehit); Aikahahe (Munggui); Ibuong (Nimboran); Yepaa (Tabla)	leaves, stem, bark	tree	21.35	5	0.21
10	Araceae	<i>Colocasia antiquorum</i> Schott	Sunggagahani (Mokwam)	stem	herb	4.49	0	0.01
11	Araceae	<i>Pothos scandens</i> L.	Ngges ngrup (Saubeba)	leaves	herb	4.49	0	0.01
12	Araceae	<i>Schismatoglottis wallichii</i> Hook. f.	Serbou (Saubeba)	leaves	herb	4.49	0	0.01
13	Araceae	<i>Xanthosoma sagittifolium</i> (L.) Schott	Keladi (Sough)	tuber	herb	4.49	0	0.01
14	Araliaceae	<i>Osmoxylon novoguineense</i> (Scheff.) Becc.	Lebe (Moi); Koskogoi (Mokwam)	bark	tree	2.25	0	0.02
15	Arecaceae	<i>Areca catechu</i> L.	Aku (Nimboran); Pinang (Tunggare)	root, fruit	tree	7.87	0	0.02
16	Arecaceae	<i>Cocos nucifera</i> L.	Kim srang (Kemtuk)	root	tree	7.87	0	0.01
17	Arecaceae	<i>Metroxylon sagu</i> Rottb.	Sagu (Wamesa); Mo (Nimboran)	stem, root, whole part	tree	7.87	1	0.04
18	Asparagaceae	<i>Dracaena angustifolia</i> (Medik.) Roxb.	Susmoro (Mokwam)	bark	herb	1.12	0	0.01
19	Balsaminaceae	<i>Impatiens balsamina</i> L.	Ugera tiga (Sough)	herb	herb	1.12	0	0.01
20	Brassicaceae	<i>Cardamine flexuosa</i> With.	Merbetamog (Sough)	leaves	herb	1.12	0	0.01
21	Caricaceae	<i>Carica papaya</i> L.	Peceran (Aifat); Eteradado (Inanwatam); Monofo (Meyah); Pepaya(Sough, Waigeo, Wandamen, Nimboran, Tabla); Labseren (Tehit); Ogoseran (Tehit); Cacaveka (Isirawa); Mbikin (Kanum); Senene ranau (Tunggare); Pepaya bllah (Waris)	leaves, root, flower	tree	21.35	5	0.21
22	Combretaceae	<i>Terminalia catappa</i> L.	Ketapang (Wamesa, Wandamen)	bark	tree	3.37	1	0.03
23	Crassulaceae	<i>Bryophyllum daigremontianum</i> (Raym.-Hamet & H. Perrier) A. Berger	Brimomog (Sough)	herb	herb	1.12	0	0.01
24	Cycadaceae	<i>Cycas rumphii</i> Miq.	Inyom (Mokwam)	bark	shrubs	1.12	0	0.01
25	Dioscoreaceae	<i>Dioscorea bulbifera</i> L.	Audub (Mokwam)	tuber	liana	1.12	0	0.01
26	Euphorbiaceae	<i>Endospermum moluccanum</i> (Teijsm. & Binn.) Kurz	Inyabi (Mokwam)	bark	tree	8.99	0	0.02
27	Euphorbiaceae	<i>Euphorbia heterophylla</i> L.	Arectmot (Mokwam); Kastrol (Waigeo); Kastol (Gresi)	leaves, root	herb	8.99	1	0.03
28	Euphorbiaceae	<i>Homalanthus populifolius</i> Graham	Hinougomog (Mokwam)	leaves	shrubs	8.99	0	0.01
29	Euphorbiaceae	<i>Ricinus communis</i> L.	Dom (Rasiki); Domimog (Sough)	leaves	tree	8.99	0	0.02
30	Fabaceae	<i>Caesalpinia bonduc</i> (L.) Roxb.	Neibi (Sough)	leaves	shrubs	4.49	0	0.01
31	Fabaceae	<i>Falcataria moluccana</i> (Miq.) Barneby & J.W.Grimes	Mosofos (Mokwam)	bark	tree	4.49	0	0.01
32	Fabaceae	<i>Inocarpus papuanus</i> Kosterm.	Gayang (Wandamen)	bark	tree	4.49	0	0.01
33	Fabaceae	<i>Sesbania grandiflora</i> (L.) Pers.	Harimah (Skouw)	leaves	tree	4.49	0	0.01
34	Gesneriaceae	<i>Aeschynanthus radicans</i> Jack	Pomeric (Sough)	leaves	herb	1.12	0	0.01
35	Goodeniaceae	<i>Scaevola taccada</i> (Gaertn.) Roxb.	Anas (Numfor)	leaves	shrubs	1.12	0	0.01
36	Hanguanaceae	<i>Hanguana malayana</i> (Jack) Merr.	Illis hutan (Sough)	leaves	herb	1.12	0	0.01
37	Lamiaceae	<i>Orthosiphon aristatus</i> (Blume) Miq.	Kumis kucing (Moraid, Waigeo, Wamesa, Marind, Tunggare)	leaves, herb	herb	6.74	1	0.06
38	Lamiaceae	<i>Plectranthus scutellarioides</i> (L.) R.Br.	Mayana (Mey Brat)	leaves	herb	6.74	0	0.01

(continued on next page)

Table 1 (continued)

No	Family	Scientific name of plant	Ethnic local name of plant	Part Used	Habit	FIV	FC	RFC
39	Lauraceae	<i>Cassytha filiformis</i> L.	Tali kuning (Tabla)	leaves	liana parasite	1.12	0	0.01
40	Loranthaceae	<i>Dendrophthoe pentandra</i> (L.) Miq.	Iramoub (Mokwam)	leaves	shrubs parasite	1.12	0	0.01
41	Malvaceae	<i>Melochia umbellata</i> (Houtt.) Stapf	Mendewa (Ormu)	leaves	tree	1.12	0	0.01
42	Meliaceae	<i>Azadirachta indica</i> A.Juss.	Pohon india (Marind)	leaves	shrubs	7.87	0	0.01
43	Meliaceae	<i>Lansium parasiticum</i> (Osbeck) K.C.Sahni & Bennet	Langsat (Mey Brat); Rukun (Mey Brat); Lokum ayno (Waigeo); Sandipori (Wamesa)	leaves, stem, bark, seed	tree	7.87	1	0.06
44	Meliaceae	<i>Swietenia mahagoni</i> (L.) Jacq.	Mahoni (Marind)	seed	tree	7.87	0	0.01
45	Menispermaceae	<i>Anamirta cocculus</i> (L.) Wight & Arn.	Emmbait (Tehit)	stem	liana	11.24	0	0.01
46	Menispermaceae	<i>Arcangelisia flava</i> (L.) Merr.	Kilufun (Moi); Aidaga geiho (Mokwam); Kuigwep (Seget); Batang kwigwep (Seget); Tenggara yanggu (Nimboran)	stem, bark	liana	11.24	1	0.06
47	Menispermaceae	<i>Fibraurea tinctoria</i> Lour.	Bai (Rasiki); Giwi saknge (Manem)	stem	liana	11.24	0	0.02
48	Menispermaceae	<i>Tinospora crispera</i> (L.) Hook. f. & Thomson	Tali pahit (Moraid)	stem	liana	11.24	0	0.01
49	Menispermaceae	<i>Tinospora sinensis</i> (Lour.) Merr.	Tali malaria (Inanwatam)	leaves	liana	11.24	0	0.01
50	Moraceae	<i>Artocarpus altilis</i> (Parkinson) Fosberg	Igbi (Rasiki)	exudate	tree	2.25	0	0.01
51	Moraceae	<i>Ficus variegata</i> Blume	Adurakop (Mokwam)	exudate	tree	2.25	0	0.01
52	Musaceae	<i>Musa x paradisiaca</i> L.	Pisang (Inanwatam)	leaves	herb	1.12	0	0.01
53	Myrtaceae	<i>Psidium guajava</i> L.	Giawas (Paniai)	leaves	tree	1.12	0	0.01
54	Orchidaceae	<i>Coelogyne asperata</i> Lindl.	Boumohotmog (Mokwam)	fruit	epiphyte	1.12	0	0.01
55	Phyllanthaceae	<i>Glochidion ferdinandi</i> (Müll.Arg.) F.M. Bailey	Sautrame (Mokwam)	bark	shrubs	10.11	0	0.01
56	Phyllanthaceae	<i>Glochidion lutescens</i> Blume	Sampari (Numfor)	leaves	tree	10.11	0	0.01
57	Phyllanthaceae	<i>Phyllanthus niruri</i> L.	Belakang babiji (Wandamen, Skouw); Kakarvaya (Isirawa); Mesumgag hijau (Nimboran); Momokho akha (Sentani)	leaves, herb, whole part	herb	10.11	1	0.07
58	Phyllanthaceae	<i>Phyllanthus urinaria</i> L.	Aibaba kakopi (Poom)	herb	herb	10.11	0	0.01
59	Piperaceae	<i>Piper betle</i> L.	Sirih hutan (Waigeo)	leaves	shrubs	1.12	0	0.01
60	Poaceae	<i>Imperata cylindrica</i> (L.) Raeusch.	Udong (Kemtuk); Alang-alang (Tabla)	root, whole part	herb	2.25	0	0.02
61	Rubiaceae	<i>Morinda citrifolia</i> L.	Fayu (Mey Brat); Sanyin (Waigeo); Mengkudu (Skouw)	leaves, root, fruit, seed	tree	10.11	1	0.07
62	Rubiaceae	<i>Nauclea orientalis</i> (L.) L.	Nggal (Marind)	bark	tree	10.11	0	0.01
63	Rubiaceae	<i>Neolamarckia macrophylla</i> (Roxb.) Bosser	Kayu kuning (Wandamen)	bark	tree	10.11	0	0.01
64	Rubiaceae	<i>Uncaria gambir</i> (W. Hunter) Roxb.	Ausie (Aifat)	stem	tree	10.11	0	0.01
65	Sapindaceae	<i>Allophylus cobbe</i> (L.) Forsyth f.	Sah (Aifat)	stem	tree	4.49	0	0.01
66	Sapindaceae	<i>Dodonaea viscosa</i> Jacq.	Arwob (Saubeba); Waimu (Sough)	leaves, stem	shrubs	4.49	1	0.03
67	Solanaceae	<i>Physalis minima</i> L.	Pak pak (Tehit, Waigeo); Toki (Wamesa); Daun nipon (Wamesa); Cemplok (Marind); Seberi-nembai (Sobei)	leaves, stem, root, bark, whole part	herb	10.11	2	0.10
68	Urticaceae	<i>Dendrocnide moroides</i> (Wedd.) Chew	Kafa (Tehit)	leaves	shrubs	7.87	0	0.01
69	Urticaceae	<i>Dendrocnide stimulans</i> (L.f.) Chew	Khu/kuh (Manem); Skuah (Nimboran); Daun gatal (Tunggare)	leaves	shrubs	7.87	1	0.07
70	Zingiberaceae	<i>Homostedia conica</i> Ridl.	Mewega esisu (Meyah)	leaves	herb	3.37	0	0.01
71	Zingiberaceae	<i>Homostedia scottiana</i> (F.Muell.) K.Schum.	Irisme (Mokwam)	rhizome	herb	3.37	0	0.01
72	Zingiberaceae	<i>Kaempferia galanga</i> L.	Sihor (Aifat)	rhizome	herb	3.37	0	0.01

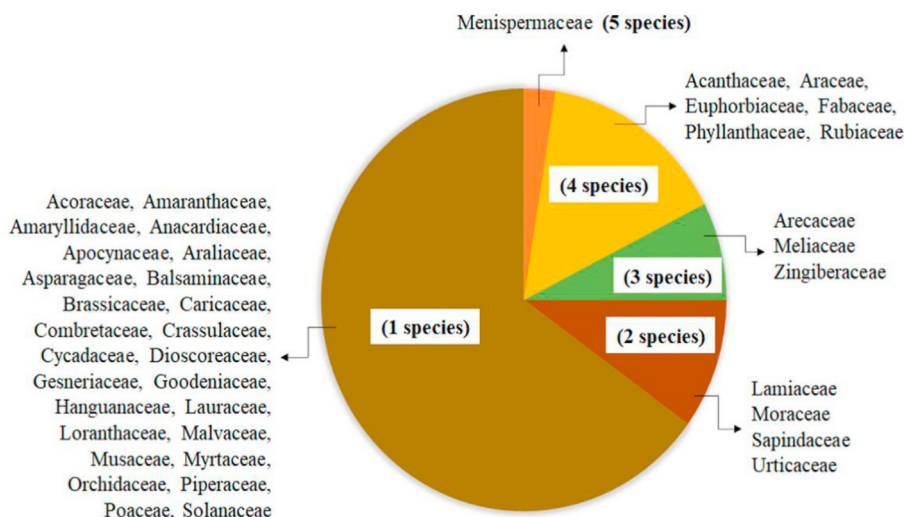


Figure 2. Medicinal plant family and number of family species.

Menispermaceae family is made up of 70 genera with 420 species. In addition, some survey literature in Africa showed that about 21 genera have used as medicine, while other continents used 29 different genera. Some of the genera used as medicine include; *Arcangelisia*, *Cissampelos*, *Cocculus*, *Cyclea*, *Diploclisia*, *Dioscoreophyllum*, *Fibraurea*, *Jateorhiza*, *Menispermum*, *Sinomenium*, *Sphenocentrum*, *Stephania*, *Tiliacora*, *Tinospora*, and *Triclisia*. The most active compound in *Menispermaceae* widely used in treating various diseases is bisbenzylisoquinoline alkaloids. Most species of *Menispermaceae* have detoxification, antidiarrhoeal, anti-gastroenteritis, antioxidant, antimicrobial, antimelanogenesis, hepatoprotective, analgesic, anti-inflammatory, antidiabetic, anticancer, and

antimalarial properties. Some genera of *Menispermaceae* are the main ingredients contained in most traditional herbs used as medicine in various countries, such as *Cocculus* and *Tinospora* in Bangladesh [28], *Arcangelisia* and *Fibraurea* in South Vietnam [29], *Stephania* in Asia and Cambodia, *Triclisia* in Tanzania [30], and *Albertisia* and *Cissampelos* in South Africa [31]. The data of RISTOJA in Papua Island support the potential use of *Menispermaceae* family in the development of antimalarial.

Figure 3 shows that based on FIV index, *Apocynaceae* and *Caricaceae* are families of medicinal plants commonly used in the treatment of malaria in Papua and West Papua, with index values of 21.35,

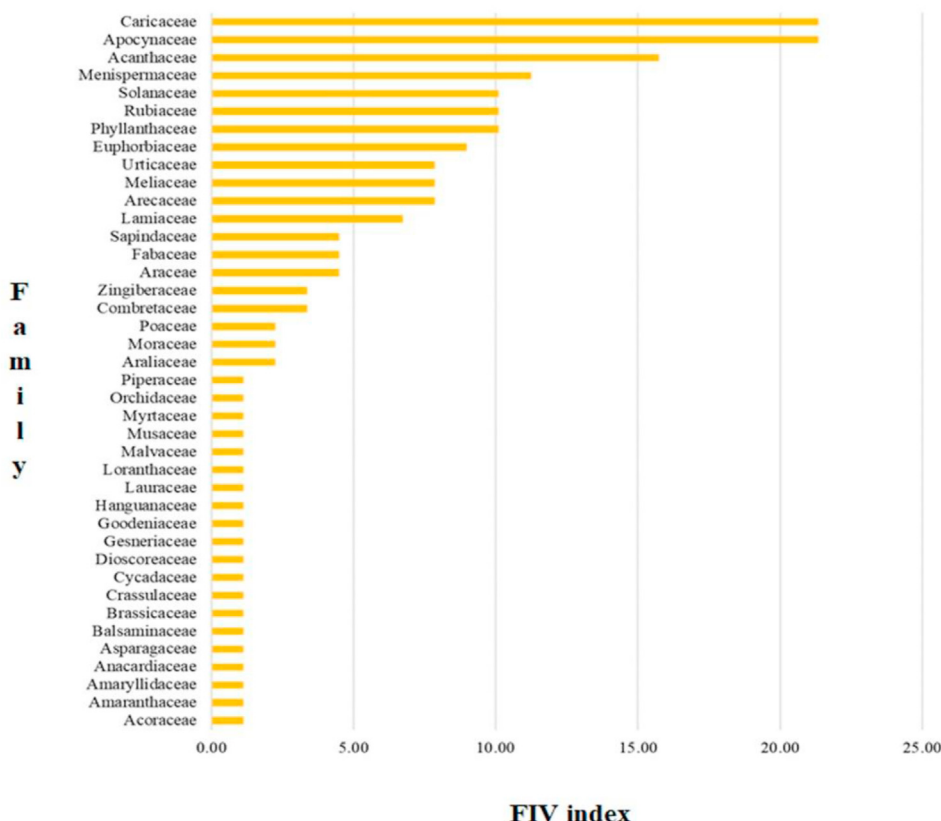


Figure 3. Family importance value (FIV) of medicinal plants used for malaria traditional treatment in Papua Island.

respectively. This is followed by other families, such as *Acanthaceae* (15.73 with four species), *Menispermaceae* (11.24 with five species), *Phyllanthaceae* and *Rubiaceae* (10.11 each with four species), and *Solanaceae* (10.11 with one species) in addition to other families with FIV index above 10. The families with FIV index below 10 include, *Euphorbiaceae* (8.99 with four species), *Arecaceae* and *Meliaceae* (7.87 each with four species), *Urticaceae* (7.87 with two species), *Lamiaceae* (6.74 with two species), *Araceae* and *Fabaceae* (4.49 each with four species), *Sapindaceae* (4.49 with two species), *Combretaceae* (3.37 with one species), *Zingiberaceae* (3.37 with three species), *Araliaceae* and *Poaceae* (2.25 each with one species), and *Moraceae* (2.25 with two species). Also, twenty other families have a minimal FIV index, at 1.21 with one species.

Apocynaceae and *Caricaceae* were the most cited plant families with the FIV index of 21.35, respectively, as shown in Figure 2. *Apocynaceae* is made up of 250 genera and 2000 species of tropical trees, shrubs, and vines. Based on literature, *Apocynaceae* species are generally used as traditional medicine in treating fever, malaria, pain, diabetes, digestive disorders, skin diseases, or ailments caused by parasites. *Alstonia*, *Calotropis*, *Dyera*, *Kopsia*, and *Vallisneria* are among the genera known to have antimalarial activity. Active compounds isolated from the *Apocynaceae* family include alkaloids, cardenolides, triterpenoids, iridoids, pregnanes, flavonoids, and phenolic acids. The triterpenoid compounds are present in majority of the *Apocynaceae* family, which has the antimalarial potential [32, 33].

One species of the *Caricaceae* family known to have antimalarial potential is *Carica papaya*. This family is made up of around 35 species in 6 genera and widely distributed in Africa and Neotropics [34]. Research on *Caricaceae* family is predominantly specific to the *C. papaya* species. Some ethnobotany research documented the common use of the plant in the treatment of dengue, malaria, digestive disorders, cancer, inflammation, rheumatoid arthritis, skin diseases as well as acting as antibacterial substances. The contents of flavonoid, tannins, alkaloids, triterpenes, and carbohydrates also play important role in determining the bioactive nature of the *Caricaceae* family [35].

3.3. Most used plant species for traditional treatment of malaria

The relative use of the medicinal plant species by traditional healers is shown through the Relative Frequency of Citation (RFC) value. The assessment results showed RFC values within a range of 0.01–0.21. The highest RFC value was obtained from *Alstonia scholaris* and *Carica papaya*, each with a value of 0.21, followed by *Andrographis paniculata* at 0.12 and *Physalis minima* at 0.10. The four medicinal plant species occupying the first four positions are the most widely used among the 72 plant species. Other medicinal plant species have RFC values below 0.10, ranging from 0.07 to 0.01. Generally, medicinal plant species with the highest RFC values are the ones abundantly used traditionally in the treatment of malaria in Papua. The abundant use of these medicinal plant species is an indication that the knowledge on the use of the plants is widely distributed.

Table 1 shows that *A. scholaris* and *C. papaya* were with the second-highest RFC values among the 72 medicinal plant species traditionally used treating malaria in Papua Island, Indonesia. Based on this, these two species are the commonly used in the traditional treatment of malaria on the island. The tree of *A. scholaris* is as high as 40 m with bark-like tessellated cork and grayish-brown color. It is a native plant from Australia, with wide distribution in Southeast Asia, China, India, Nepal, Solomon Islands, Papua New Guinea, and America [36, 37]. The bark, flowers, leaves, and roots contain alkaloids as the most dominant compound, with approximately 180 types. Other typical compounds successfully isolated from the bark of *A. scholaris* include several types of ditamine and echitamine alkaloids, chitamine, and echinacoutchin. The leaves contain anilinoacrylate alkaloids, scholaricine, dihydrocondylocarpine alkaloids, vallesamine, lagunamine, angustilobine B acid, losbanine, alstonamine, rhazimanine, akuammiginone, and other indole alkaloid compounds. These alkaloids contents and their

derivatives determine the biological activity of these plants [37, 38, 39]. Traditionally, *A. scholaris* are commonly used to treat diseases such as fever, malaria, fever, diarrhea, dysentery, dyspepsia, abdominal disorders, skin diseases, pruritus, tumors, asthma, bronchitis, helminthiasis, as well as antidepressants, anticancer, antituberculosis, immunostimulating, hepatoprotective etc. Also, the plant is used in commercial herbs mixture Ayush, Ayurvedic, Siddha/Tamil, and Unani [37, 38]. Its antimalarial potential has been proven scientifically by testing it against *Plasmodium falciparum* K1 strain, with a very high activity category. The bisalole alkaloids, namely villalstonine and macrocarpamine, are the bioactive components of these plants responsible for these activities [40]. A research by Rezeki et. al (2012) showed the use of *A. scholaris* in effectively reducing the levels of malaria parasites in some patients at the Local Hospital of Manokwari, West Papua. This treatment was also proven to reduce the clinical symptoms of malaria such as fever, headache, muscle aches, and diarrhea [41].

C. papaya has a wide distribution area owing to the fact that it is very easy to grow, especially in tropical regions. It is a native plant of America introduced to India in the 16th century. The tree of *C. papaya* is recognized through its morphology, with a delicate and weak trunk, generally unbranched, produce sap, and with the capacity of growing as high as 20 m [35, 42, 43]. Traditionally, this plant is commonly used in the treatment of a wide range of ailments. Each part of the plant could be used for different illnesses, as the leaves are generally used for treating malaria, dengue, jaundice, as antiviral and immunomodulatory. Its flowers are commonly utilized to treat digestive disorder, diuretics, and as tonics, while the roots are used as antifungal, for treating piles, and bruises. Also, different chemical contents are found in different parts of this plant, including flavonoids, alkaloids, phenolic compounds, β -carotene, lycopene, anthraquinone glycosides, etc [35, 43]. Teng et al. (2019) carried out a scientific research on the potential use of this plant as an antimalarial agent testing it against *P. falciparum* 3D7 parasites and Dd2 strains. The results showed an antimalarial activity in the medium category. The compound responsible for this activity is carpaine, which belongs to the alkaloids group. Several studies have also proven the plant to have some anti-inflammatory, antitumor, and antihypertensive properties as well as being used in treating hypoglycemic, fertility, and in wound healing [35].

Two other species worthy of consideration are *A. paniculata* and *P. minima*, with RFC values of 0.12 and 0.1 respectively. *A. paniculata* is one of the herbs within the family of *Acanthaceae*, widely cultivated in South and Southeast Asia. Traditionally, this plant is widely used in the treatment of a broad spectrum of ailments or as herbs mixture in preventing various health issues. This plant has also been commercialized in Ayurvedic, Unani, and Siddha formulas [44, 45]. The andrographolide and its derivatives are the bioactive chemical contents of *A. paniculata*. Andrographolide is a diterpenic lactone compound known with its antiviral, anti-inflammatory, and anticancer properties [46, 47]. According to Mishra et al. (2011), andrographolide compounds have antimalarial activity, both in vitro (*P. falciparum*) and in vivo (*P. berghei*).

Then, *P. minima* is an annual herbaceous, upright, semi-shrub, perennial species with 0.5–1.5 m height, belonging to the *Solanaceae* family. This plant is widely distributed in Asia, Africa, Australia, North and South America. Also, the plant was reported as one of the important medicinal plants in the Indian Traditional System of Medicines [48, 49]. According to Angamuthu et al. (2014), *P. minima* is traditionally used as analgesic, and in treating diuretic issues, anthelmintic, as tonic, and purgative. Also, steroidal lactones contained in this plant, have been reported to possess anti-inflammatory, antibacterial, analgesic, antipyretic, antimalarial, hypoglycemic, and antioxidant properties [50].

Literatures have shown that several medicinal plants traditionally used in the treatment of malaria in Papua, have modern scientific back up. According to de la Torre et al. (2012), the ethnobotany study and traditional knowledge of plants are essential parts of its development into medicine in the future [51]. This has a significant contribution to the modern medicine as seen today. In the present study, 25% of herbal

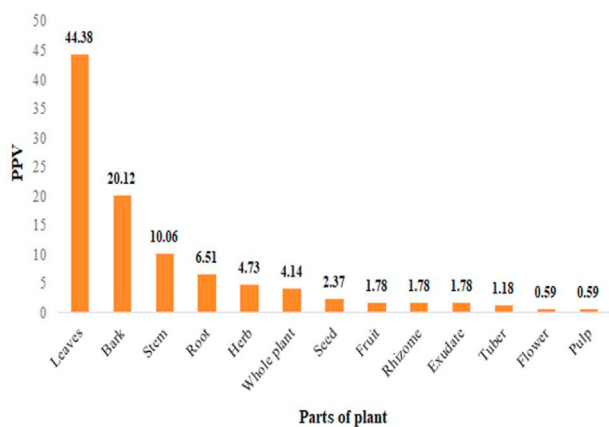


Figure 4. Part of plant value (PPV) of medicinal plants used for malaria traditional treatment in Papua Island.

medicines in modern pharmacopeia were plant-based while others are synthetic drugs using chemical compounds also isolated from plants [52]. Therefore, the recording and documentation of traditional knowledge are necessary in preserving this abundant information for the next generation. Documenting traditional knowledge provides a comprehensive database for the development of new phytochemical, pharmacological, and clinical studies. It also protects the culture and ecological value of a plant.

3.4. Part of plant species used in traditional treatment of malaria

The concoctions traditionally used in treatment of malaria in Papua Island are composed of several types of plant parts. Based on the PPV results, majority of people, put at 44.38%, used leaves in Papua as their ingredients for traditional treatment of malaria. This was followed by the bark at 20.12%, stem at 10.06%, roots at 6.51%, herbs at 4.73%, whole plant at 4.14%, and seeds at 2.37%. In addition, each of fruit, rhizome, and exudate at 1.78%, tubers at 1.18%, and each of flower and fresh fruit at 0.59%, as shown in Figure 4.

In general, the parts of plants usually used in traditional medicine include leaves, bark, stem, fruit, roots, and tubers [53]. These results are similar with many antimalarial ethnobotany studies which also showed that leaves are more used than other plant parts [54, 55, 56, 57, 58, 59, 60, 61]. The high frequency in the use of leaves as a medicinal ingredient is due to its abundance, availability, high productivity, and the fact that it is more comfortable to obtain compared with other plant parts [13, 62, 63]. Additionally, leaves are the most exploited part of plants because it provides advantages in terms of the technical acquisition, processing, and suitable for earth conservation [57, 64]. Furthermore, each part of the plant has different effects depending on its chemical composition. Since the leaves are the center of photochemical reactions, they tend to store more organic resources which could be metabolized into secondary metabolites, such as alkaloids, glycosides, flavonoid, phenolic compounds, steroid and terpenoid [13, 65, 66, 67]. According to Uzor (2020), these several secondary metabolites could become the medicinal properties for antimalaria [68].

4. Conclusion

The traditional knowledge and traditional medical practice with the use of plant-based medicine, especially in treating malaria, is a vital part of the people in Papua Island. This is probably due to the high cases of malaria and the remoteness of areas in both Papua and West Papua provinces. The ease and simplicity in finding and preparing plant concoctions are also an important reason why people depend more on traditional medicine.

The results of this study showed that the Western Part of Papua Island in Indonesia has a wide diversity of medicinal plants used in treating malaria. The traditional healers provided in detail the plant species and parts used in preparing the antimalarial concoctions. The data from traditional healers widely distributed in 35 ethnicities in Papua and West Papua, reported 72 species from 40 plant families. The most widely used plants for malaria treatment was *Alstonia scholaris* from *Apocynaceae* family and *Carica papaya* from *Caricaceae* family, which could be subjected to further research. There is need to carry out a systematic review in order to select the plant species from the data in this study, with high priority for further development.

Moreover, there is a work in progress in analyzing numbers of plant species selected from Papua Island and to screen these antimalarial activities through in vitro assay used antiplasmodial bioassays and Heme Polymerization Inhibition Assay. However, the results would be published separately.

Declarations

Author contribution statement

M. Budiarti: Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

A. Maruzu: Performed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

R. Mujahid: Conceived and designed the experiments; Performed the experiments; Contributed reagents, materials, analysis tools or data.

A.N. Sari: Contributed reagents, materials, analysis tools or data.

W. Jokopriyambodo, T. Widayat and S. Wahyono: Conceived and designed the experiments; Performed the experiments.

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Declaration of interests statement

The authors declare no conflict of interest.

Additional information

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