

Harnessing indigenous knowledge on ethnomedicinal plants for malaria treatment in South Manokwari, West Papua, Indonesia

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Abstract. *Siburian RHS, Angrianto R, Syufi Y, Nugroho B, Tapilatu ME, Tapilatu JR. 2025. Harnessing indigenous knowledge on ethnomedicinal plants for malaria treatment in South Manokwari, West Papua, Indonesia. Biodiversitas 26: 3408-3422.* Malaria, an endemic disease in Papua, Indonesia, including South Manokwari, West Papua, has become a critical public health issue due to increasing drug resistance resulting from the routine use of antimalarial drugs. This issue highlights the importance of exploring medicinal plants as potential sources of new antimalarial agents. This study aims to document ethnomedicinal plants used for malaria treatment in South Manokwari District, using ethnobotanical and anthropological approaches. Data were collected through interviews with 88 participants aged 18 years and older, consisting of 34% male and 66% female. A total of 57 species of medicinal plants from 25 families were identified for malaria treatment. Relative Frequency of Citation (RFC) values ranged from 3.41 to 31.82, and the Fabaceae family was the most represented, with 8 species used for medicine, followed by Meliaceae and Myrtaceae families, each with 5 species. Preference ranking identified *Andrographis paniculata* (RFC: 31.82) as the top choice, followed by *Carica papaya* (RFC: 29.55) and *Alstonia scholaris* (RFC: 23.86). Plant parts used included leaves, stems, bark, roots, fruits, flowers, and seeds. Methods of application varied and included drinking, massaging, bathing, inhalation, and evaporation, with drinking being the most common method. The bioactive compounds in these plants are expected to contribute valuable references for the development of new antimalarial agents. Therefore, the conservation and future availability of their natural compounds should be prioritized.

Keywords: Ethnomedicinal, malaria, potential plant medicine, South Manokwari

INTRODUCTION

Malaria is a disease caused by a parasitic infection, typically transmitted through the bite of an infected *Anopheles* mosquito. Mild infection cases often present with flu-like symptoms, including fever and headaches (Sarwar 2016). However, severe infections can cause patients to experience very high fever, shock, seizures, pulmonary edema, significant bleeding, and respiratory distress (Mace et al. 2021). The disease is caused by protozoan parasites of the genus *Plasmodium* (Sato 2021). According to the studies conducted by Nugroho et al. (2020), Habtamu et al. (2022), Kahar et al. (2024), and Salutondok et al. (2024), the four *Plasmodium* species most commonly found in malaria patients are *P. falciparum*, *P. vivax*, *P. ovale*, and *P. malariae*. Transmission occurs through the bite of an infected female *Anopheles* mosquito (Townson 2017; Markwalter et al. 2024). Once in the body, the parasite infects hepatocytes and develops into exoerythrocytic merozoites, which enter the bloodstream and attack erythrocyte cells (Ezema et al. 2023). Intraerythrocytic trophozoites develop through a series of morphological changes during nuclear division, eventually

rupturing the host erythrocytes and releasing merozoites into the bloodstream, thus perpetuating the infection cycle (Gautam et al. 2020). The duration of the life cycle ranges from 24 to 72 hours, depending on the species. Some merozoites develop into sexual forms (gametocytes), which are taken up by mosquitoes during blood feeding, which later mature and develop into sporozoites, enabling transmission of the infection to new hosts (Kumar 2017b). Geographically, the prevalence of *Plasmodium* species varies across region (Tatem et al. 2017). In this context, continued transmission in areas with limited healthcare infrastructure has prompted renewed interest in alternative treatments for malaria, including the use of traditional medicine (Obeagu and Obeagu 2024).

Malaria is a major public health problem in many regions around the world. According to Venkatesan (2024), the global malaria mortality rate is 14:3 deaths per 100,000 population at risk. The World Health Organization (WHO) (2023) also reported that global malaria cases have exceeded pre pandemic COVID-19 pandemic, with an estimated 249 million cases occurring across 85 countries in 2022. This problem also occurs in Indonesia, particularly in Papua region (Rozi et al. 2025). Data from the Indonesian

Ministry of Health show that 418,546 malaria cases were reported in 2024, with the provinces of Papua and West Papua contributing the highest number of locally transmitted cases in the country. However, in the West Papua region, malaria cases have shown a declining trend in recent years. In 2022, there were 13,079 reported cases, decreasing to 10,170 in 2023 and further dropping to 3,716 in 2024. Despite this overall regional decline, data from South Manokwari District in 2023 indicate that malaria remains a significant public health concern, with a notably high number of cases reported, 23,974 in total. Due to deficiencies in the health system, malaria transmission in the Papua region remains high (Fadilah et al. 2022). As an endemic area, malaria in South Manokwari poses not only serious health risks but also impacts the socio-economic profile of the local population (Ain et al. 2024). Malaria treatment using modern antimalarial medicine has helped resolve a significant number of malaria cases in Papua, such as quinine, chloroquine, malarex, primaquine, and artemisinin derivatives (Ashley et al. 2014; Kloprogge et al. 2015; Sikora et al. 2019; Versita et al. 2021). However, some patients experience side effects from these treatments. For example, patients with glucose-6-phosphate dehydrogenase (G6PD) deficiency are at risk of developing acute hemolytic anemia (Ashley and Phyo 2018; Shibeshi et al. 2020; Tseha 2021). Moreover, the prolonged and widespread use of antimalarial drug has contributed to increasing drug resistance (Nguyen et al. 2023).

Treatment using natural products holds significant potential, as it draws on local knowledge of herbal medicine (Tobing et al. 2024). Several researchers (Suharno et al. 2016; Ibo and Arifa 2021; Womsiwor et al. 2024; Hutami et al. 2025) have recorded various medicinal plants in Papua, describing the administration and

preparation methods. South Manokwari remains one of the regencies with a relatively high number of malaria cases. To identify the most valuable plants and document their traditional uses, this study conducted a quantitative investigation. The exchange ethnomedicinal knowledge between immigrant and local communities in this area is expected to support the discovery of new drugs with the potential to treat malaria and address resistance to existing chemical treatments. The indigenous knowledge of medicinal plants and their usage methods is strongly influenced by the diseases most commonly encountered (Taek et al. 2018). The development of traditional medicine in treating malaria is urgently needed, not only as a preventive approach but also as a practical treatment, especially given the limited access to healthcare services in many areas of Papua. Therefore, it is essential to study ethnomedicinal knowledge related to the treatment of malaria, particularly regarding the types of plants used, the specific plant parts utilized, and the methods of preparation and administration. This information can serve as a valuable foundation for the development of potential new antimalarial agents.

MATERIALS AND METHODS

Study area

This study was conducted in South Manokwari District, one of the regencies of Manokwari District in West Papua Province, Indonesia (Figure 1), which was established under Law No. 23 of 2012. This area is located at 0.15°-3.025° latitude and 132°-134° longitude with an area of 2789.12 km² (Siburian et al. 2020).

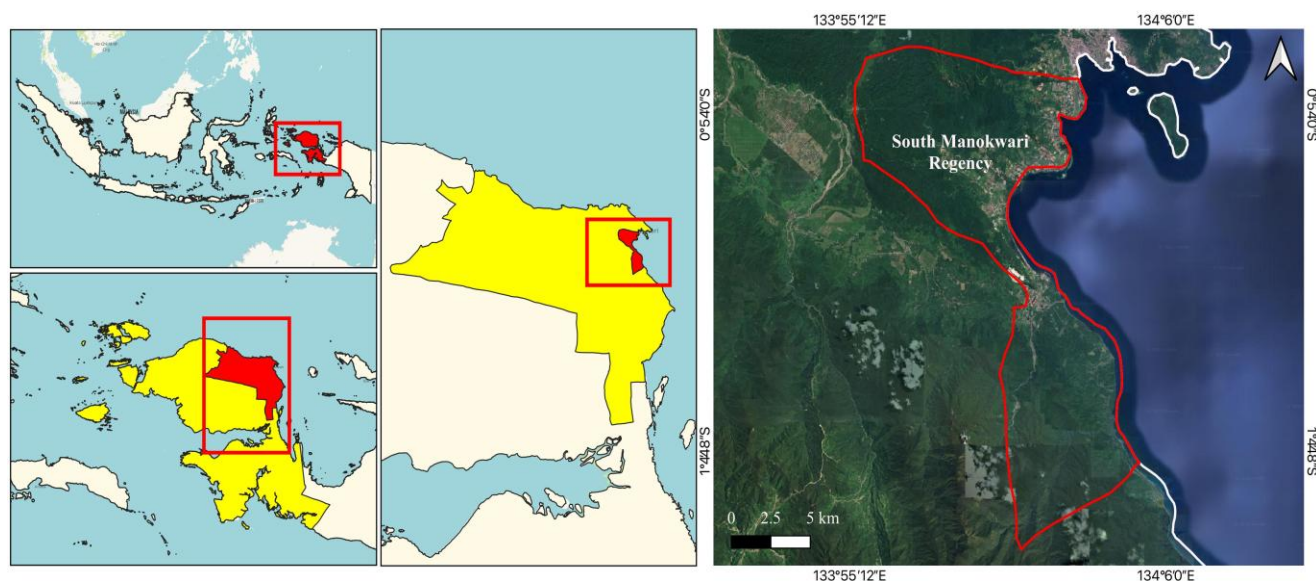


Figure 1. Study area in South Manokwari District, West Papua, Indonesia

South Manokwari District is characterized as a lowland tropical rainforest with diverse topography, ranging from sloping to steep, and is predominantly composed of alluvial soils, except in the calcareous mountainous regions (Angrianto et al. 2019; Gerits et al. 2021). It has a humid tropical climate, with an average annual rainfall of 153 mm and an average humidity of 86.3% (Bureau of Statistics South Manokwari District 2024). This study was conducted using a qualitative observational design with an ethnopharmacological approach. This approach integrates ethnographic and pharmacological aspects to explore traditional knowledge and the use of medicinal plants in the community (Dean 2024). A total of 88 participants aged 18 years were included, all of whom had knowledge of medicinal plant use for malaria treatment. The participants included both local residents and immigrants who had lived for at least 5 years in South Manokwari. Participants were surveyed by using snowball sampling techniques.

Procedures

This study was conducted with ethical approval obtained from the Faculty of Forestry of the University of Papua (146/UN42.6/KU.03.01/VII/2025). Prior to data collection, informed consent was obtained from all participants, including verbal and written explanations of the purpose, methods, and their rights to withdraw at any time without consequence. Participants were assured of confidentiality, and their identities were kept confidential in all reporting. The ethnomedicine survey was conducted through a combination of open and closed interviews along with group discussions to collect information on the use of plants for malaria treatment, as well as their cultural significance. A structured questionnaire was developed to support data collection. The interviews and discussions focused on following topics, including: (i) Demographic data of participants, including age, gender, educational background, and other relevant details; (ii) Benefits obtained from the forest; (iii) Names of the plants used in malaria treatment (common name, species, and family); (iv) Parts of the plant used as medicinal ingredients (leaves, bark, fruit, seeds, twigs, flowers, and roots); (v) Methods of processing the medicinal plants; (vi) Whether there is a specific season for collecting these plant parts. Validation and cross-checking of the collected information were conducted using relevant literature sources.

Plant specimens were identified in two ways: some were identified directly at the study location, while unidentified specimens were collected and prepared as herbarium vouchers. Unidentified specimens were later identified using reference vouchers stored at the Manokwariense Herbarium.

Data analysis

Data for this study were collected through participant observation and in-depth interviews with a total of 88 participants, who were selected using purposive sampling based on their extensive knowledge of malaria ethnomedicine. Key participants including traditional healers, elders, and individuals who frequently involved in the preparation or application of medicinal plants. Data

were analyzed using both qualitative and quantitative methods by Microsoft Excel 2019 (Microsoft Corporation, Washington, USA) used for data processing. A particular focus was given to the calculation of Relative Frequency of Citation (RFC) (Tardío and Pardo-de-Santayana 2008) to evaluate the level importance and specificity of plant use among participants. This index provides a quantitative information base to identify the most culturally important and frequently cited plant species for malaria treatment in the South Manokwari region. The RFC is calculated by dividing the number of participants who mentioned the species by the total number reviewed in this study (N). The RFC formula used is as follows:

$$RFC = \frac{FC}{N} \times 100$$

Where,

RFC : Relative Frequency of Citation

FC (family) : The number of informants reporting the plant family

N : Total number of informants interviewed

RESULTS AND DISCUSSION

Participant demographics

Both local and immigrant communities in South Manokwari District, possess traditional knowledge related to malaria treatment using medicinal. A total of 88 participants were interviewed, consisting of 30 men and 58 women. Gender often plays a role in ethnobotanical knowledge, with women commonly recognized as primary custodians of medicinal plant traditions. This pattern has been observed in various rural and traditional communities in Brazil (Conde et al. 2017), Dominica (Quinlan et al. 2016), Saudi Arabia (Alqethami et al. 2020), and Nepal (Kutal et al. 2021). Participants had varying educational backgrounds: 57.96% had completed elementary to junior high school education, 21.59% had a high school diploma, and 20.45% were undergraduates (Table 1).

The level of community education significantly influences their understanding of the use of medicinal plants in this area. At higher levels of education, people tend to rely more on pharmaceutical treatments than on alternative medicine or ethnomedicine (Ambu et al. 2020; Ssenku et al. 2022; Hapid et al. 2023).

Table 1. Demographic data of the participants (N: 88)

	Group	N	Percentage (%)
Gender	Male	30	34.09
	Female	58	65.91
Age	19-24	12	13.64
	25-49	28	31.82
	Over 50 years	48	54.54
Educational background	Primary level	51	57.96
	Secondary level	19	21.59
	High educational level	18	20.45

The largest percentage of participants (54%) were over 50 years old, followed by those aged 25 to 49 years (32%) and the youngest group, aged 19 to 24 years (14%). Age is positively associated with ethnomedicinal knowledge, as older individuals tend to possess more extensive knowledge of medicinal plants (Eshete and Molla 2021). Elderly people tend to have more knowledge in comparison to individuals from young people (Sharma et al. 2019). In addition, the knowledge of people living near forests or in rural villages demonstrated greater knowledge of medicinal plants compared to people living in urban areas. Similar knowledge gaps were also observed in several other regions (Navia et al. 2022; Zhou et al. 2023; Siburian and Angrianto 2024).

Diversity of medicinal plants for malaria

The results indicate that 57 plant species from 25 families are used for the prevention and treatment of malaria, either as single-plant remedies or in combination with other plant species. The number of plant species is lower compared to the results of Budiarti et al. (2020a), who reported 72 identified species from 40 families used for malaria treatment across Papua Island, Indonesia.

There were 27 plant species reported in the previous study that were not mentioned by participants in this study. This highlights the possibility that many medicinal plants remain unexplored and need further investigation, particularly regarding the diversity of their potential bioactive compounds for antimalarial treatments in Papua. This region's diverse topography significantly contributes to its high plant biodiversity (Murdjoko et al. 2020, 2021).

Among all the identified plant species, those from the Fabaceae, Myrtaceae, and Meliaceae families were most widely used by the community as ingredients for malaria treatment, as shown in Figure 2. Previous studies have also highlighted the significance of the Fabaceae family. For example, the Fabaceae family, approximately 665 species, around 101 species are used by the Zimbabwean community for medicinal purposes (Maroyi 2023). Similarly, Aditama et al. (2022) and Girmaw and Ashagrie (2023) also reported that the species from Fabaceae family commonly used in traditional medicine to various diseases, including malaria and its symptoms.

The primary habitat of plants for malaria treatment in the South Manokwari area is forest trees, which account for 59.65% of the identified species. All medicinal plants used in traditional pharmacology play a significant role in the discovery of new therapeutic molecules to combat malaria. Among these, information obtained through ethnomedicinal approaches serves as a valuable resource in the search for new antimalarial drugs (Pirintos et al. 2022). The local community in this area maintains a close relationship with the forest, making medicinal plants more accessible and affordable for them. In addition, medicinal plants are commonly used in society due to their availability, local wisdom, and cultural beliefs, as well as low side effects (Beyene et al. 2016). This area is located within the Mahkota Permata Tanah Papua landscape ecosystem, which stretches from Tambrau District, Arfak

Mountains, and South Manokwari to Bintuni Bay (Murdjoko et al. 2020).

Therefore, the wise management and conservation of ethnomedicinal plants is a strategic priority for future sustainable development. Comprehensive data on ethnomedicinal plants used for malaria treatment in this area are shown in Table 2. The most common mode of administration of the plants in the area include boiling, grinding into a paste, or consuming the raw seed. This processing method is similar to those observed in other areas in Indonesia, such as in Jepara, Central Java (Oktafiani et al. 2021), and Cianjur, West Java (Iskandar et al. 2020). The most widely used preparation of herbal medicines in the study is by boiling the plant material to make a decoction, which is then consumed. Similar practices have been reported in various parts of the world, including Southern Nigeria (Iyama and Idu 2015), Ethiopia (Alebie et al. 2017), and the Southern Lowlands of Laos (Elliott et al. 2020). The most common mode of preparation used is oral, accompanied by the addition of honey, salt, or other ingredients to improve taste or reduce toxicity (Nigussie and Wale 2022). Plants commonly used as oral remedies include *Andrographis paniculata*, *Strobilanthes crispus*, *Carica papaya*, *Arcangelisia flava*, and *Alstonia scholaris*, which are known to possess antiparasitic activity, in addition to anti-inflammatory and analgesic properties. A study conducted among the Moi tribe in Papua also reported *A. flava*, *C. papaya*, and *Orthosiphon aristatus* as traditional antimalarial remedies (Hutami et al. 2025). The result showed that antimalarial herbal remedies were primarily administered orally (71.9%), with less common methods including bathing (10.5%), massage (5.3%), and steam therapy (3.5%). This result aligns with findings reported by Indradi et al. (2023), who reported that oral administration is the most common method of antimalarial drug use in Papua. Furthermore, traditional medicine that was specifically used in treating malaria in Indonesia, is often self-made or purchased from local vendors and traditional healers (Torri 2016).

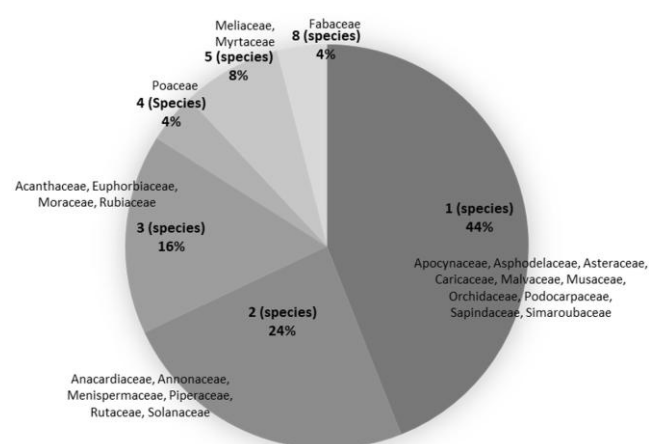


Figure 2. Medicinal plant family and the number of family species

Table 2. Ethnomedicinal plants for malaria treatment, including modes of administration, preparation methods, and citation frequency

Scientific name (family)	Common name	Family name	Habit of plant	Mode of administration	Mode of preparation	RFC
<i>Andrographis paniculata</i>	King of bitters	Acanthaceae	Shrubs	Decoction, Boil	Oral	31.82
<i>Asystasia gangetica</i>	Chinese violet	Acanthaceae	Shrubs	Decoction, Boil	Oral	4.55
<i>Strobilanthes crispus</i>	Kecibeling	Acanthaceae	Shrubs	Decoction, Boil	Oral	14.77
<i>Mangifera indica</i>	Mango	Anacardiaceae	Trees	Decoction, Boil	Oral	5.68
<i>Annona muricata</i>	Soursop	Annonaceae	Trees	Decoction, Boil	Oral	10.23
<i>Annona squamosa</i>	Custard apple	Annonaceae	Trees	Decoction, Boil	Oral	9.09
<i>Alstonia scholaris</i>	Milkwood	Apocynaceae	Trees	Decoction, Boil	Oral	23.86
<i>Aloe vera</i>	True aloe	Asphodelaceae	Succulents	Paste	Massage	5.68
<i>Musa paradisiaca</i>	Banana	Musaceae	Herbs	Cook as a food mixture	Oral	4.55
<i>Areca catechu</i>	Areca nut	Asteraceae	Trees	Chewed	Oral	7.95
<i>Carica papaya</i>	Papaya	Caricaceae	Herbs	Decoction, Boil	Oral	29.55
<i>Cymbopogon citratus</i>	West Indian lemon grass	Poaceae	Grass	Juice	Oral	9.09
<i>Anacardium occidentale</i>	Cashew nut	Anacardiaceae	Trees	Boil	Bath, oral	17.05
<i>Sterculia foetida</i>	Hazel sterculia	Malvaceae	Trees	Boil	Bath	4.55
<i>Brucea javanica</i>	Macassar kernels	Simaroubaceae	Shrubs	Decoction, Boil	Oral	7.95
<i>Aleurites moluccana</i>	Candlenut tree	Euphorbiaceae	Trees	Paste	Massage	5.68
<i>Jatropha curcas</i>	Jatropha	Euphorbiaceae	Trees	Decoction, Paste	Oral, Massage	4.55
<i>Ricinus communis</i>	Castor oil plant	Euphorbiaceae	Shrubs	Decoction, Paste	Massage	13.64
<i>Inocarpus papuanus</i>	Inocarpus	Fabaceae	Trees	Decoction, Boil	Oral	13.64
<i>Albizia amara</i>	Siris tree	Fabaceae	Trees	Decoction, Boil	Oral	13.64
<i>Paraserianthes falcataria</i>	Moluccan albizia	Fabaceae	Trees	Decoction, Boil	Oral	13.64
<i>Mimosa pudica</i>	Shame plant	Fabaceae	Shrubs	Decoction, Boil	Oral	13.64
<i>Pterocarpus indicus</i>	Amboyna wood	Fabaceae	Trees	Decoction, Boil	Oral	13.64
<i>Cassia alata</i>	Candle bush	Fabaceae	Trees	Decoction, Boil	Oral	13.64
<i>Albizia gummifera</i>	Peacock flower	Fabaceae	Trees	Decoction, Boil	Oral	13.64
<i>Calliandra portoricensis</i>	Snowflake acacia	Fabaceae	Shrubs	Decoction, Boil	Oral	13.64
<i>Azadirachta indica</i>	Nimtree	Meliaceae	Trees	Decoction, Boil	Oral	13.64
<i>Lansium domesticum</i>	Langsat	Meliaceae	Trees	Paste	Oral	9.09
<i>Melia azedarach</i>	Chinaberry tree	Meliaceae	Trees	Decoction, Boil	Oral	9.09
<i>Swietenia macrophylla</i>	Big-leaf mahogany	Meliaceae	Trees	Raw seed	Oral	9.09
<i>Swietenia mahagoni</i>	Small-leaf mahogany	Meliaceae	Trees	Raw seed	Oral	9.09
<i>Arcangelisia flava</i>	Yellow root	Menispermaceae	Woody vine	Decoction, Boil	Oral	9.09
<i>Fibraurea tinctoria</i>	Fibre bark	Menispermaceae	Woody vine	Decoction, Boil	Oral	9.09
<i>Morus alba</i>	White mulberry	Moraceae	Trees	Decoction, Boil	Oral	9.09
<i>Artocarpus altilis</i>	Breadfruit	Moraceae	Trees	Decoction, Boil	Oral	9.09
<i>Ficus variegata</i>	Variiegated rubber plant	Moraceae	Trees	Decoction, Boil	Oral	9.09
<i>Psidium guajava</i>	Guava	Myrtaceae	Trees	Boil	Bath, oral	9.09
<i>Eugenia sp.</i>	Brush cherries	Myrtaceae	Trees	Boil	Bath	9.09
<i>Syzygium malaccense</i>	Mountain apple	Myrtaceae	Trees	Decoction	Bath	9.09
<i>Syzygium guineense</i>	Water pear	Myrtaceae	Trees	Decoction	Steam therapy	9.09
<i>Syzygium cumini</i>	Java plum	Myrtaceae	Trees	Decoction	Steam therapy	3.41
<i>Coelogyne asperata</i>	Rough Coelogyne	Orchidaceae	Epiphyte	Boil	Bath	4.55
<i>Peperomia pellucida</i>	Pepper elder	Piperaceae	Herbs	Boil	Bath	4.55
<i>Piper betle</i>	Betel vine	Piperaceae	Woody vine	Boil	Bath	4.55
<i>Andropogon nardus</i>	Citronella grass	Poaceae	Grass	Decoction, Boil	Oral	12.50
<i>Cymbopogon citratus</i>	Lemongrass	Poaceae	Grass	Decoction, Boil	Oral	12.50
<i>Imperata cylindrica</i>	Cogon grass	Poaceae	Grass	Decoction, Boil	Oral	12.50
<i>Podocarpus neriifolius</i>	Lowland Podocarp	Podocarpaceae	Trees	Decoction, Boil	Oral	12.50
<i>Morinda citrifolia</i>	Indian mulberry	Rubiaceae	Shrubs	Decoction, Boil	Oral	12.50
<i>Nauclea orientalis</i>	Cheseewood	Rubiaceae	Trees	Decoction, Boil	Oral	12.50
<i>Neolamarckia macrophylla</i>	Large-leaved neolamarckia	Rubiaceae	Trees	Juice	Oral	12.50
<i>Citrus aurantiifolia</i>	Lime	Rutaceae	Trees	Decoction, Boil	Oral	12.50
<i>Melicope latifolia</i>	Broad	Rutaceae	Trees	Paste, Boil	Massage, Bath	12.50
<i>Dodonaea angustifolia</i>	Sand olive	Sapindaceae	Trees	Paste, Boil	Massage, Bath	12.50
<i>Capsicum frutescens</i>	Cayenne pepper	Solanaceae	Shrubs	Decoction, Boil	Oral	5.68
<i>Physalis minima</i>	Native gooseberry	Solanaceae	Herbs	Decoction, Boil	Oral	7.95
<i>Curcuma longa</i>	Turmeric	Zingiberaceae	Rhizomes	Decoction, Boil	Oral	17.05

RFC was used to identify the most frequently used plant species for malaria treatment in the study area. RFC values ranged from 3.41 to 31.82 (Table 2), with *Syzygium cumini* being the least cited (RFC: 3.41) and *A. paniculata* (RFC: 31.82), followed by *C. papaya* (RFC: 29.55). The overall RFC value in this study is a higher value than the previous study by Budiarti et al (2020a) in West Papua and Papua, with RFC values ranging from 0.01-0.21. In this study, *A. paniculata* was reported to be the most cited species for malaria treatment, consistent with findings from other regions in Indonesian such as Baturraden, Central Java, and Sumbang, West Java (Utaminingrum et al. 2020). High RFC value reflect the number of participants who cited a particular plant, emphasizing its cultural importance. The documented ethnomedicinal uses in this study provide strong support for the medicinal potential of these species. Medicinal plants with high RFC values should be prioritized for further phytochemical and pharmacological investigations to identify their active constituents that may be used for drug development.

Knowledge of plant parts, as well as preparation and application techniques, is greatly influenced by the community's ability to process and utilize them. The results of this study indicate that among the 25 plant families used in malaria treatment, leaves were the most frequently used plant part, accounting for 39.53% (Figure 3). The families Anacardiaceae, Annonaceae, Euphorbiaceae, Fabaceae, Meliaceae, Myrtaceae, and Poaceae were identified as the most commonly utilized, with plant parts including leaves and roots, as well as bark, flowers, fruits, seeds, and stems. These results are consistent with previous studies in other regions, such as Nigeria (Ibeh and Nworji 2022) and Colombia (Pájaro-González et al. 2022), which also reported frequent use of leaves, roots, fruits, and bark from several of the same plant families.

Leaves are the most commonly used part of the plant in ethnomedicine. In addition to their availability, leaves have a soft texture, high water content, and are rich in secondary metabolites. Several studies have reported that *C. papaya* leaves contain pharmacologically active antimalarial compounds, with significant levels of secondary metabolite content such as phenolics and flavonoids (Susanti et al. 2024; Arwansyah et al. 2025).

The medicinal plants reported by participants in South Manokwari possess varied phytochemical compositions and antimalarial activities, as presented in Table 3. Plant species of *C. papaya*, *A. paniculata*, *A. flava*, and *A. scholaris* are commonly used in traditional medicine. Among them, *C. papaya* leaves has been recognized in local community not only for malaria treatment but also for dengue fever, jaundice, digestive disorders, diuretic purposes, immunomodulation, antifungal treatment, hemorrhoids, and bruises (Hariono et al. 2021; Oraebosi and Good 2021; Eze et al. 2022; Arwansyah et al. 2025). The content of leaves has been reported to inhibit the development of *Plasmodium berghei* in infected test mice by up to 66.25% (Das et al. 2022; Patel 2023). This

inhibitory effect can be significantly enhanced when *C. papaya* leaves are combined with several other types of medicinal plants, suggesting a collaborative potential. In addition to leaves, the fruit of *C. papaya* is rich in fiber, calcium, potassium, vitamin C, thiamine, niacin, folates, vitamin A, riboflavin, and iron, which are particularly beneficial during malaria recovery (Krishna et al. 2008; Gunde and Amnerkar 2016).

Andrographis paniculata is another species widely used by the community. This plant has been considered effective in malaria treatment due to its mechanism of parasite suppression, strong antioxidant activity, and enzyme inhibition, which play roles in hindering parasite invasion (Intharuksa et al. 2022; Apsari et al. 2025). Anti-inflammatory action of this plant can help relieve symptoms such as fever and systemic inflammatory response syndrome (Isunu et al. 2022).

The bark of *A. flava* traditionally consumed by boiling and drinking. This plant has been reported to exhibit various pharmacological properties, including antimicrobial, antidepressant, antidiarrheal, antidiabetic, cardioprotective, and antimalarial effects (Sami and Nur 2024). Alkaloid content and cytotoxicity activity of this plant has been reported to suppress and support the repair of infected cells (Mutiah et al. 2020). In addition to *A. flava*, the bark of *A. scholaris* is also frequently used for malaria treatment. The boiled bark extract has been described to repair cell damage caused by *Plasmodium* infections, and inhibit enzymes involved in parasite proliferation (Kaihenia et al. 2023; Dhakad et al. 2025). Furthermore, the antioxidant compounds of this plant are also believed to contribute in the recovery of cells infected with *Plasmodium* (Singh et al. 2023).

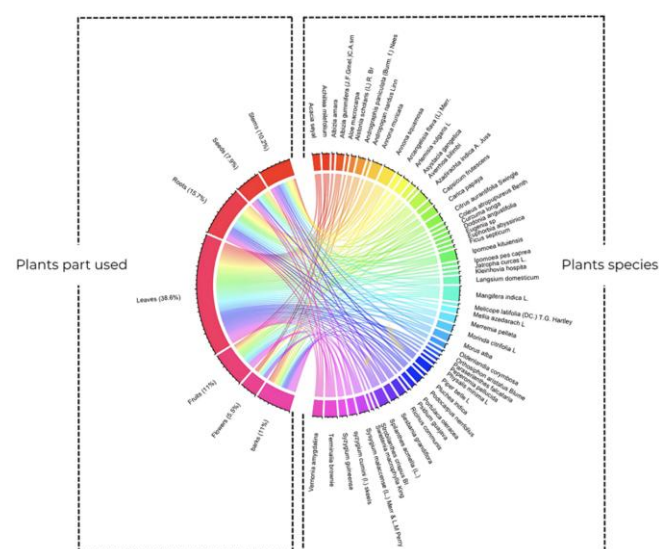


Figure 3. Distribution of plant families by categories of plant parts used

Table 3. Phytochemical components and antimalarial properties of medicinal plants traditionally used for malaria treatment in South Manokwari, West Papua, Indonesia

Scientific name	Phytochemicals	Antimalarial activity
<i>Andrographis paniculata</i>	Dioctyl adipate, menthol, and n-hexane extract (Prakoso et al. 2019)	Compounds exhibit strong inhibitory activity against heme polymerization, with IC ₅₀ values of 1.15±0.41 mg/mL for dioctyl adipate, 0.31±0.01 mg/mL for menthol, and 0.07±0.03 mg/mL for the n-hexane extract (Prakoso et al. 2019)
<i>Albizia amara</i>	Macrocyclicspermine alkaloids, saponins, quinones, and oleanolic acids (Indravathi et al. 2016)	There are no reports of antimalarial activity for <i>A. amara</i> . However, <i>A. lebbeck</i> from the same genus exhibited IC ₅₀ values of 8.2 µg/mL against the MRC2 strain and 5.1 µg/mL against the RKL9 strain in a <i>P. berghei</i> -infected mouse model (Kalia et al. 2015)
<i>Albizia gummifera</i>	n-Butanol, aqueous, and chloroform extracts, along with amphotericin B (Nigussie et al. 2015)	No reported antimalarial activity for <i>A. gummifera</i>
<i>Aleurites moluccana</i>	Niacin, thiamine, and vitamin E, along with minerals including sodium, potassium, calcium, magnesium, iron, and zinc (Lim 2012; Hakim et al. 2022)	No reported antimalarial activity for <i>A. moluccana</i>
<i>Aloe vera</i>	Aloin and aloe-emodin (Kumar et al. 2017)	Demonstrated antiplasmodial activity with EC ₅₀ values ranging from 0.289 to 1056 µg/mL (Kumar et al. 2017)
<i>Alstonia scholaris</i>	Petroleum ether and methanol (Gandhi and Vinayak 1990)	Methanol extract of <i>A. scholaris</i> showed a dose-dependent extension of survival in the treated animals (Gandhi and Vinayak 1990)
<i>Anacardium occidentale</i>	Hydroalcoholic and methanol (Kaushik et al. 2023; Tejumade et al. 2023)	The hydroalcoholic leaf extract of <i>A. occidentale</i> inhibited 75.45±0.35% of PfTk activity and suppressed 99.31±0.08% of <i>P. falciparum</i> at 50 µg/mL, with an IC ₅₀ value of 4.17±0.22 µg/mL (Kaushik et al. 2023). The methanol leaf extract of <i>A. occidentale</i> inhibited β-hematin with IC ₅₀ of 36.1±0.52 µg/mL (Tejumade et al. 2023)
<i>Andropogon nardus</i>	Hydromethanolic (Fatehi et al. 2023)	No reported antimalarial activity for <i>A. nardus</i>
<i>Annona muricata</i>	Flavonoids, triterpenes, terpenoids, anthocyanin, saponins, and tannins (Nwonuma et al. 2023)	The flavonoids apigenin and luteolin exhibit antiplasmodial and hypolipidemic effects by targeting key <i>Plasmodium</i> proteins (Nwonuma et al. 2023)
<i>Annona squamosa</i>	Amino acids, terpenes, lipids, steroids, flavonoids, ascorbic acid, tannins, vitamins and alkaloids	Aporphine alkaloids from bark of <i>Annona squamosa</i> showed moderate antiplasmodial activity against both chloroquine-resistant (Dd2) and chloroquine-sensitive (D10) strains (Saha 2011)
<i>Arcangelisia flava</i>	Alkaloids, flavonoids, furano-diterpene, hydroxyquinoline, phenylpropanoids, phenols, fatty acids, and stigmastane (Pratama et al. 2023)	The water extract of <i>A. flava</i> containing stigmastane, showed IC ₅₀ of 601 ppm (Hapsari et al. 2019)
<i>Areca catechu</i>	Flavonoids, alkaloids, saponins, tannins, and polyphenols (Salutan and Billacura 2015)	150 mg/kg/day ACL-BuOH inhibited 39.1% <i>P. berghei</i> in mice with a 60% survival rate (Jiang et al. 2009)
<i>Artocarpus altilis</i>	Tannins, polyphenols, flavonoids, leucoanthocyanins, steroids, and triterpenes (Soifoini et al. 2021)	The record showed antimalarial activity test compound of <i>A. altilis</i> strongly inhibited <i>P. falciparum</i> growth, with IC ₅₀ value of 1.05 µM. (Hidayati et al. 2020)
<i>Asystacia gangetica</i>	Alkaloids, phenolics, flavonoids, coumarins, tannins, terpenoids, steroids, and glycosides (So-In et al. 2025)	No reported antimalarial test on <i>A. gangetica</i>
<i>Azadirachta indica</i>	Glycosides, alkaloids, tannins, flavonoids, terpenoids, and saponin (Deshpande et al. 2014)	The leaf extract of <i>A. indica</i> has showed activity constituents against <i>P. falciparum</i> in vitro model (Deshpande et al. 2014)
<i>Brucea javanica</i>	Terpenoids, saponins, flavonoids, steroids, phenols, glycosides, alkaloids, and anthraquinones (Chumkaew and Srisawat 2014)	The acetone extract of the <i>B. javanica</i> roots showed antimalarial activity with an IC ₅₀ value of 0.28 µg/mL (Chumkaew and Srisawat 2014)
<i>Calliandra portoricensis</i>	Cardiac glycosides, anthraquinones, flavonoids, phenols, saponins, steroids, and tannins (Oyebode et al. 2018)	No reported antimalarial test on <i>C. portoricensis</i>
<i>Capsicum frutescens</i>	Phenol, flavonoid, and proanthocyanidins (Olatunji and Afolayan 2019)	The record showed antiplasmodial in vitro <i>C. frutescens</i> activity against <i>P. berghei</i> (Habte and Assefa 2020)

<i>Carica papaya</i>	Steroids, saponins, tannins, flavonoids, terpenoids, glycosides, reducing sugars, proteins, phenolic compounds, and alkaloids (Eze et al. 2022)	The record showed <i>in vitro</i> <i>C. papaya</i> have antimalarial activity against early <i>P. berghei</i> infection in mice (Zelege et al. 2017)
<i>Cassia alata</i>	Glycosides, anthraquinone, proteins, cardiac glycosides, steroids, alkaloids, phlobotannin, phenols, saponins, tannins, flavonoids, and carbohydrates (Edegbo et al. 2023)	The extract of the <i>C. alata</i> was tested antimalarial activity against <i>P. falciparum</i> , showed significant result with IC ₅₀ value below 1 µg/mL (Kayembe et al. 2012)
<i>Citrus aurantiifolia</i>	Alkaloids, flavonoids, saponins, tannins, and cardiac glycosides (Etebong et al. 2019)	The record shows that <i>C. aurantiifolia</i> has antiplasmodial effect (Etebong et al. 2019)
<i>Coelogyne asperata</i>	No reported phytochemical test on <i>C. asperata</i>	No reported antimalarial test on <i>C. Asperata</i>
<i>Curcuma longa</i>	Phenolic and flavonoids (Srivastava et al. 2022)	Records show <i>C. longa</i> extract has ethanol antimalarial effect against <i>P. berghei</i> (Dawet et al. 2024)
<i>Cymbopogon citratus</i>	Phytosterols, anthocyanin, amino acids, organic acid, phenolic compounds, volatile components, fatty acids, fumesol, flavonoids, isovaleranic aldehyde, methylheptenone, valeric esters, L-linanol, furfural, isopulegol, p-coumaric acid (Oladeji et al. 2019)	The record showed <i>C. citratus</i> possess higher antimalarial activity than either the herbal infusion or chloroquine (Chukwuocha et al. 2016)
<i>Dodonaea angustifolia</i>	Flavonoids, pinocembrin, and terpenoids (Melaku et al. 2017)	The record showed three isolated compounds of <i>D. angustifolia</i> have significant antiplasmodial activities (Melaku et al. 2017)
<i>Eugenia</i> sp.	Flavonoids, tannins, triterpenes, and sesquiterpenes (de Souza et al. 2018)	No reported antimalarial test on <i>Eugenia</i> sp.
<i>Fibraurea tinctoria</i>	Protoberberine alkaloids and furanoditerpenoids (Purwaningsih et al. 2023)	The extract showed antimalarial activity against <i>P. falciparum</i> , with IC ₅₀ ranging from 0.4-1.1 µg/mL (Nguyen-Pouplin et al. 2007)
<i>Ficus variegata</i>	Alkaloids, phenols, flavonoids, saponins, tannins, terpenoids, steroids, glycosides, and anthocyanine (Putra et al. 2020)	There are no reports of antimalarial activity for <i>F. variegata</i> . However, <i>F. benamina</i> from the same genus have shown anti-plasmodial of malaria activity (Singh et al. 2018)
<i>Imperata cylindrica</i>	Palmitic acid, campesterol, and stigmaterol (Lalthanpui and Lalchandama 2020)	No reported antimalarial test on <i>I. cylindrica</i>
<i>Inocarpus papuanus</i>	Alkaloid likely in some spp. (Webb 1955)	No reported antimalarial test on <i>I. papuanus</i>
<i>Jatropha curcas</i>	Flavonoids, alkaloids, saponins, steroids, tannins, coumarins, and phenols (Rampadarath et al. 2016)	The extracts showed IC ₅₀ > 50 µg/mL. Though frequently mentioned in ethnomedicine, no <i>in vitro</i> activity against <i>P. falciparum</i> was observed (Kaou et al. 2008)
<i>Lansium domesticum</i>	Triterpenoid, onoceranoid-type triterpenoids, triterpenoid glycosides, cycloartanoid-type triterpenoids, tetranortriterpenoids, dukunolides, mexicanolides, domesticulides, kokosanolides, langsatides, sesquiterpenoid, steroids (Mayanti et al. 2022)	The extract of the species was tested against antimalarial activity against <i>P. falciparum</i> , showed significant IC ₅₀ of 9.9 µg/mL (Mayanti et al. 2022)
<i>Mangifera indica</i>	9,12-octadecadienoic acid, 9-oxabicyclo nonane, hexadecadienal, oleic acid, 9,12-octadecadienal, methyl ester, and spirohexane (Asanga et al. 2023)	The <i>M. indica</i> compounds produced a significant reduction in <i>P. berghei</i> , attributed to linoleic acid esters in the plant (Asanga et al. 2023).
<i>Melia azedarach</i>	Flavonoid polyphenol, hydrocarbon, triterpene, monoterpene phenol, phytosterol, palmitic acid, fatty acid ester, methyl ester, triterpene, triterpenoids (Kar et al. 2022)	The extract showed antimalarial effects of methanol against <i>P. berghei</i> (Kar et al. 2022)
<i>Melicope latifolia</i>	O-methylotadrenolon, alloevodionol, isopimpinellin, alloxanthoxyetin, methylevodionol, and N-methylflindersine (Widyawaruyanti et al. 2021)	There are no reports of antimalarial activity for <i>M. latifolia</i> . However, <i>M. moluccana</i> within the same genus, exhibited antimalarial activity of leptanoineC(1) and haplopine-3,3'-dimethylallyl ether against <i>P. falciparum</i> with IC ₅₀ values of 0.18ppm and 2.28µg/mL (Wahjoedi et al. 2020)
<i>Mimosa pudica</i>	Flavonoids, alkaloids, Silver AgNPs, terpenoids, phenols, steroids, and saponins (Aditama et al. 2022)	The extract showed antimalarial effects against <i>P. falciparum</i> with IC ₅₀ values less than 10µg/mL (Ezenyi et al. 2021)
<i>Morinda citrifolia</i>	Polyphenols, mucilage, and terpenoids (Sina et al. 2021)	The extract showed antimalarial effects of ethanol contained in <i>M. citrifolia</i> against <i>P. berghei</i> (Rahayu et al. 2021)
<i>Morus alba</i>	Flavonoids, glycosides, tannins, polysaccharides,	The methalonic extract of <i>M. alba</i> showed antimalarial

	and lectins (Younus et al. 2016)	effects of <i>P. falciparum</i> with IC ₅₀ value of 0.02µg/mL (Ariantari et al. 2012)
<i>Musa paradisiaca</i>	Hemiterpenoid glucoside (1,1-dimethylallyl alcohol), syringin, (6S, 9R)-roseoside, benzyl alcohol glucoside, (24R)-4α,14α,24-trimethyl-Sacholesta-8,25(27)-dien-3β-ol (Martin et al. 2000)	The extract from <i>M. paradisiaca</i> showed antiplasmodium against <i>P. falciparum</i> with IC ₅₀ of 84.22µg/mL (Anbazhagan et al. 2017)
<i>Nauclea orientalis</i>	Carbohydrates, alkaloids, flavonoids, phenols, tannins, and saponins (Ngau et al. 2024)	The extract from <i>N. orientalis</i> showed antiplasmodium against <i>P. falciparum</i> with hexana IC ₅₀ of 1.93µg/mL and metanol IC ₅₀ of 3.91µg/mL (Budiarti et al. 2020b)
<i>Neolamarckia macrophylla</i>	Limited information on <i>N. macrophylla</i> However, within the same genus, the species of <i>N. cadamba</i> contains ten indole alkaloids, neolamarckine A-E, cadamine, 3β-isodihydrocadambine, angustine, naulafine, and harmane (Qureshi et al. 2021)	No reported antimalarial test on <i>N. macrophylla</i>
<i>Paraserianthes falcataria</i>	Tannin, alkaloid, flavonoid, saponin, steroid, and triterpenoid (Baihaqi et al. 2020)	No reported antimalarial test on <i>P. falcataria</i>
<i>Peperomia pellucida</i>	Alkaloids, flavonoid, steroid, saponins, and triterpenoid (Bialangi et al. 2016)	The n-hexane, ethyl acetate, and water fractions of the extract exhibited antimalarial activity with IC ₅₀ of 12.80, 2.90, and 10.74 mg/mL, respectively (Bialangi et al. 2016)
<i>Physalis minima</i>	Flavonoids, saponins, alkaloids, phenol, and tannins (Pradeepkumar et al. 2022)	The alcoholic extract of the plant showed antimalarial activity in vivo against <i>P. berghei</i> (Kallianpur et al. 2016)
<i>Piper betle</i>	Alkaloids, flavonoids, coumarins, tannins, terpenoids, cardiac glycosides, and saponins (Sonphakdi et al. 2024)	The extract of <i>P. betle</i> showed antiplasmodium against <i>P. berghei</i> (Al-Adhroey et al. 2010)
<i>Podocarpus neriifolius</i>	Terpenoids, phytosterols, flavonoids, saponins, tannins, phlobatannins, phenolic, carbohydrates, fats and fixed oils, coumarins, quinones, and volatile oils (Mohamed et al. 2023)	There are no reports of antimalarial activity for <i>P. neriifolius</i> . However, within the same genus, the species of <i>P. polystachyus</i> contains antimalarial activity against <i>P. falciparum</i> (Rawa et al. 2022)
<i>Psidium guajava</i>	Polyphenols, flavonoids, saponins, tannins, terpenoids, glycosides, flavones, cardiac glycosides, cardenolides, phlobatanins, and steroids (Bulugahapitiya et al. 2021)	Methanolic and ethanolic extract of <i>P. guajava</i> showed IC ₅₀ values in the range of 0.048 to 0.965µM against the <i>P. falciparum</i> (Yadav et al. 2020)
<i>Pterocarpus indicus</i>	Carbohydrates, alkaloids, cardiac glycosides, tannins, saponins, fats, oils, terpenoids, flavonoids, and resins (Islam et al. 2023)	Antimalarial activity tests were conducted on parasite cultures, with IC ₅₀ values 7.14, 4.0, and 0.65 g/mL of n-hexane, ethyl acetate, and 96% ethanol extracts were (Retnosari et al. 2023)
<i>Ricinus communis</i>	Steroids, saponins, alkaloids, flavonoids, and glycosides (Kumar 2017a)	The <i>R. communis</i> was recorded for possible antimalarial activity against <i>P. berghei</i> (NK65) infections in mice (Liadi et al. 2019)
<i>Sterculia foetida</i>	Alkaloids, glycosides, flavonoids, phenols, saponins, terpenoids, and tannins (Jafri et al. 2019)	There are no reports of antimalarial activity for <i>S. foetida</i> . However, within the same genus, <i>S. setigera</i> from the same genus showed antimalarial activity in a <i>P. berghei</i> -infected mice (Yakubu et al. 2024)
<i>Strobilanthes crispus</i>	Phenolics and flavonoids (Ghasemzadeh et al. 2015)	No reported antimalarial test on <i>S. crispus</i>
<i>Swietenia macrophylla</i>	Limonoid, coumarin, fatty acid ester, steroid, polyphenol, essential oil, and lignan (Telrandhe et al. 2022)	<i>S. macrophylla</i> methanol extract has been reported to be highly effective against <i>P. falciparum</i> (Telrandhe et al. 2022)
<i>Swietenia mahagoni</i>	Tannins, flavonoids, alkaloids, carbohydrates, glucosides, glycosides, and saponins (Nadi 2015)	The antimalarial bioassays of 34,5-tri- <i>O</i> -caffeoylquinic acid from <i>S. mahagoni</i> has been reported to be the most active against <i>P. falciparum</i> with IC ₅₀ of 8.8µgM (Nugraha et al. 2022)
<i>Syzygium cumini</i>	Carbohydrates, amino acids, tannins, saponins, phytosterols, terpenoids, phenols, and flavonoids (Agarwal et al. 2019)	The record showed that the butanol fraction of <i>S. cumini</i> fruit has antimalarial potential against <i>P. berghei</i> in mice (Faisal et al. 2025)
<i>Syzygium guineense</i>	Terpenoids, alkaloids, triterpenes, flavonoids, anthraquinones, tannins, glycosides, saponins, and phenols (Tadesse and Wubneh 2017)	The record showed that <i>S. guineense</i> leaf extract possess antimalarial activity in mice (Tadesse and Wubneh 2017)
<i>Syzygium malaccense</i>	p-cymene,β-caryophyllene, β-pinene, and α-terpineol (Karioti et al. 2007)	Record shown low antimalarial potential, rather suggesting the use of <i>S. malaccense</i> as antioxidant and antimicrobial (Pazzini et al. 2021)

Medicinal plants are used globally, including in South America, where out of 389 species, only nine have demonstrated both *in vitro* and *in vivo* antimalarial activity (Ceravolo et al. 2024). In Nigeria, 62 plant species are traditionally used to treat malaria, yet only 11 species have isolated phytochemicals with antimalarial activity (Evuomwan et al. 2023). While monotherapy using plant remedies remains common, increasing access to information and the evolving capacity of community ethnopractitioners have led to the emergence of combination therapies. The practice of mixing different plant species into a malaria treatment concoction, or combining plant parts such as leaves and bark, or fresh and fruits has been documented in several studies (Atanu et al. 2021; Arwansyah et al. 2025). In South Manokwari, it is common for the community to combine several plant species and various plant parts. These plants have been tested for generations in traditional medicine contexts and typically do not show significant side effects. However, further preclinical, clinical, and toxicological studies are necessary to establish scientific evidence and evaluate the effectiveness of these treatments through a combination of scientific perspectives (Sharma et al. 2014). A combination approach may include ingesting a plant-based concoction followed by sauna therapy using boiled plant materials, and then massage with plant-based substances such as tubers. Such integrative treatments reflect holistic healing practice that combine ethnomedicine with potential for scientific advancement.

Challenges and potential of developing ethnomedicinal plant malaria treatment

Modernization and current technological development have had a major impact on the ethnomedicine industry, which existed long before the advent of conventional medicine. However, the growth of ethnomedicine development has been relatively slow, largely due to its high degree of regional diversification and adaptation to specific local characteristics (Wanzala and Minyoso 2024). Limited documentation and information regarding safety standards, plant efficacy, ethnopractitioner capacity, and the impact of climate change on the availability of medicinal plant species present ongoing challenges.

Malaria remains a public health challenge in South Manokwari. Current treatment strategies in this area still rely heavily on Artemisinin Combination Therapy (ACT). However, malaria drug resistance continues to pose a challenge for certain communities, compounded by demographic factors and the local population's reliance on forests and non-timber forest products for health and livelihood. Malaria control in this area is complex, underscoring the importance of implementing a sustainable collaboration strategy (Pradhan et al. 2022).

There is an urgent need for innovative antimalarial treatments, particularly those rived from plant-based compounds that can effectively bind to human biological receptors. Papua's rich plant diversity presents a promising frontier for its exploration. The discovery of new malaria treatments from Papuan plants could represent a breakthrough. However, this must be balanced with efforts

to prevent overharvesting and protect wild plant populations, ensuring their long-term species survival (Rathore et al. 2022; Haq et al. 2023).

Several ethnomedicinal plants identified in this study as malaria treatment include species of conservation concern. Some, such as *P. indicus* and *S. macrophylla* are classified as Endangered (E) by the International Union for Conservation of Nature (IUCN). Although these two species are not among the most frequently cited, incorporating them into conservation efforts is critical to prevent future population decline and overharvesting. Other species are categorized as Least Concern (LC) or Vulnerable (V), while some are listed as Data Deficient (DD), indicating a lack of information on their conservation status. The use of threatened species raises serious concerns about unsustainable harvesting practices. Therefore, strategic and sustainable management efforts are crucial to ensure the continued availability of these plants for medicinal use, while maintaining healthy population levels in their natural habitats. These efforts should involve local communities and foster collaboration with government agencies and Non-Governmental Organizations (NGOs) to prevent their extinction.

Natural compounds such as quinine (from *Cinchona*) and artemisinin (from *Artemisia*) have been developed to treat malaria. Artemisinin derivatives such as artesunate, artemether, and dihydroartemisinin are key antimalarial treatment (Pradhan et al. 2022). However, the *Plasmodium* parasite has developed clinical resistance in certain geographic areas, contributing to the global spread of drug resistance (Hanboonkunupakarn et al. 2022; White and Chotivanich 2024). Artemisinin resistance is now considered a serious threat to global malaria control efforts.

The inventory, identification, and development of new antimalarial compounds are crucial. Ethnomedicine offers significant potential, leveraging its vast traditional knowledge, ethnopractitioners' skills, and a generational heritage preceding modern medical science (Prakash et al. 2023). In the South Manokwari community, knowledge of medicinal plants used to treat malaria is primarily passed through informal education, typically passed down by parents or close relatives who teach how to utilize locally available natural resources. This inherited knowledge consists of ideas and values considered wise and is deeply embedded in community practices (Casagrande et al. 2023). Collaborating with local practitioners and integrating traditional knowledge into scientific research can foster innovation in the development of new synthetic drugs. This collaboration enhances the wider healthcare system by synergizing traditional practices with modern medical approaches.

In summary, South Manokwari, a malaria-endemic region in Papua, where local communities still rely on ethnomedicinal knowledge for treatment. Among the most frequently cited species, *A. paniculata* and *C. papaya* are frequently cited, highlighting their cultural importance and antimalarial potential. In particular, leaves are the most frequently used plant part in traditional medicines, emphasizing its medicinal value and accessibility. Given their prominence in traditional practices, both *A. paniculata*

and *C. papaya* show strong potential for further pharmacological validation. Interdisciplinary research is urgently needed to isolate and assess the bioactive compounds of these species and evaluate their efficacy and safety for medicinal development.

At the same time, conservation strategies must be integrated to protect medicinal species, particularly threatened species under high risk of overharvesting or habitat loss. Such strategies may include the establishment of community-based conservation areas, cultivation programs, and sustainable harvesting guidelines. Additionally, the systematic documentation of indigenous knowledge through engagement with local vendors, traditional healers, and elders, is essential to preserve traditional practices. Recognizing and integrating indigenous knowledge into local health systems not only strengthens culturally relevant health services, but also support inclusive and sustainable malaria control. Ultimately, combining both cultural and scientific efforts offers a holistic approach to improving health and biodiversity in South Manokwari.

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