Journal of Communicable Diseases
Volume 54, Issue 4 - 2022, Pg. No. 85-103
Peer Reviewed & Open Access Journal

Review Article

The Potential of Plants of Family *Fabaceae* with Emphasis on Putri Malu Medicinal Plant '*Mimosa Pudica*' (*Fabaceae*) as an Antimalarial & an Insecticide for Malaria Vectors: A Review

MH Zacka Aditama[1], Nisa Fauziah[2], Afiat Berbudi[2], Hesti Lina Wiraswati[2]

[1]Postgraduate Student, Universitas Padjadjaran, Bandung, Indonesia.
[2]Department of Biomedical Science, Faculty of Medicine, Universitas Padjadjaran, Bandung, Indonesia. Advanced Biomedical Laboratory, Faculty of Medicine, Universitas Padjadjaran, Bandung, Indonesia. Infection Study Center, Faculty of Medicine, Universitas Padjadjaran, Bandung, Indonesia.
DOI: https://doi.org/10.24321/0019.5138.2022108

I N F O

Corresponding Author:
Hesti Lina Wiraswati, Faculty of Medicine, Universitas Padjadjaran, Bandung, Indonesia.
E-mail Id:
hesti.lina@unpad.ac.id
Orcid Id:
https://orcid.org./0000-0003-2462-6633
How to cite this article:
MH Zacka Aditama, Fauziah N, Berbudi A, Wiraswati HL. The Potential of Plants of Family Fabaceae with Emphasis on Putri Malu Medicinal Plant 'Mimosa Pudica' (Fabaceae) as an Antimalarial & an Insecticide for Malaria Vectors: A Review. J Commun Dis. 2022;54(4):85-103.

Date of Submission: 2021-12-25
Date of Acceptance: 2022-12-27

A B S T R A C T

Background: Due to the prevalence of malaria worldwide and cases of resistance to malaria drugs, finding new drug candidates is important in malaria control. Due to its traditional use and phytochemical content, this review was conducted on the medicinal plant *Mimosa pudica* and its family, Fabaceae.

Method: This review collected original articles in online databases using several keywords combined with boolean operators. The articles about the antimalarial and insecticidal effects of *Mimosa pudica* and other *Fabaceae* species were included in the study.

Results: Forty-two articles described 45 species from the *Fabaceae* family exhibiting antimalarial and/ or insecticidal potential including Mimosa pudica. The studies showed that crude extract of M. pudica showed activity against P. *falciparum* or P. *berghei* and insecticidal activity against *Anopheles subpictus* and *Anopheles stephensi*. More advanced studies were carried out on other *Fabaceae* species, evaluating their activity with crude extracts and fractions, isolated compounds, and silver nanoparticles (AgNPs).

Conclusions: The most promising antiplasmodial activity of M. pudica was shown by aqueous, methanol, and water/ methanol extracts from the aerial part against P. *falciparum* FCR-3 strain. In addition, aqueous or ethanolic extracts from the leaves of M. pudica revealed their potential against A. *subpictus* and A. stephensi.

Keywords: *Anopheles*, Antimalaria, Antiplasmodial, *Fabaceae*, Insecticidal, *Mimosa Pudica*, *Plasmodium*

Introduction

Malaria is one of the most prevalent infectious diseases in the tropical world, with a total of 228 million global cases in 2018, according to World Health Organization (WHO).[1] WHO guidelines explain how to control malaria by controlling the malarial pathogen (*Plasmodium*) and its vector (*Anopheles*) with Artemisin-based Combination Therapy (ACT), Long-Lasting Insecticidal Nets (LLINs) and Indoor Residual Spraying of Insecticides (IRN).[2,4] However, *Plasmodium* and *Anopheles* developed resistance to drugs used against them. Despite that, ACT, LLINs, and IRS remained to be the first choice of control of WHO as they remained the most effective method, and the resistance towards them has not spread widely.[4,10] Still, some action is needed to prevent further spreading and malignant resistance.

Finding new drug candidates is vital to overcoming malaria resistance. Medicinal plants are an essential source of new drug candidates. The antimalarial drug to date, artemisinin, is also sourced from medicinal plants (*Artemisia annua*).[11] Mimosa pudica contained phytochemicals that showed antimalarial or insecticidal activities.[12,15] This study aims to gain information regarding the potential effects of this plant from published original research articles. Furthermore, this plant grows quickly, is found abundantly across tropical areas, and is even capable of growing in less fertile soil, making it easy to be cultivated.[12,16,17] This plant has been used as a traditional medicine in many countries.[12] To the best of our knowledge, a specific review study on this particular topic has not been done before, making this study the first recorded review study on this topic.

Review Method

This study was conducted on the species *Mimosa pudica* and its family, *Fabaceae*. Information on the insecticidal and antiplasmodial effects of this plant has been presented in two tables.

The search strategy used several keywords combined with boolean operators in online databases, as stated in Table 1. This review includes original articles about the effects of *Mimosa pudica* or other *Fabaceae* species towards *Plasmodium* or *Anopheles*. On the other hand, a review article, an article that could not be fully accessed, or an article published before 2016 were excluded from this study, except for the articles about Mimosa pudica, since the study about this plant is limited.

Table 1.Keywords and Databases Used

Keywords	Databases
("fabaceae" OR "peas" OR "legumes" OR "mimosa pudica" OR "lajwanti" OR "shameplant") AND ("antimalarial" OR "antiplasmodial" OR "plasmodium" OR "anopheles")	Google Scholar
	Science Direct
	Medline
	Springer Links
	Cochrane
("fabaceae" OR "polong" OR "mimosa pudica" OR "putri malu") AND ("antimalarial" OR "antiplasmodial" OR "plasmodium" OR "anopheles")	Google Scholar Indonesia
	Portal Garuda

Result

Forty-two articles met the inclusion and exclusion criteria (Figure 1). Thirty-four focused on the effects on *plasmodium*, four of which revealed the effects of Mimosa pudica, and another thirty showed the effects of *Fabaceae* species. Eight other articles focused on the effect on *Anopheles*, three of which revealed the effects of Mimosa pudica, and five articles showed the effects of other *Fabaceae* species. Original articles found in other languages (Bahasa-Indonesian language) were also used as found in Google Scholar. Common papers in different languages were not used as they were considered duplicates.

We reported 45 *Fabaceae* species including Mimosa pudica. Of these, 37 species were evaluated for their antimalarial potency, six for their insecticidal activity, and two species, Cassia occidentalis and Mimosa pudica, for both activities.

Tables 2 and 3 present a summary of the latest research on the effect of plant extracts of M. pudica and other Fabaceae species on *Plasmodium* and *Anopheles* malaria vectors. The widely used parts of this species are the roots, leaves, and bark. M. pudica samples were generally used in the form of crude extracts with ethanol, methanol, or water as solvents. Mean while, other *Fabaceae* species were used as crude extracts with water, methanol, hexane, ethanol, and

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.2022108

ethyl acetate as solvents. The most identified metabolites were alkaloids, flavonoids, tannins, and saponins. Other metabolites such as quinone, terpenoid, phenol, chloroform, and glycoside groups were also identified. Of these, 35 active compounds from 10 species were isolated (Table 3).

The studies on *Burkea africana*, *Ormocarpum* cochinchinense, and *Mimosa pudica* are the only studies that explained the mechanism of its metabolites. However, the pathway stated in their article was gathered from other literature and was not discovered in their investigations. Several studies have used plant-based-synthesised silver nanoparticles (AgNPs), in addition to using natural products to increase drug effectiveness. The materials used were from Indigofera oblongifolia, *Ormocarpum* cochinchinense, and *Mimosa pudica* (Tables 2 and 3).

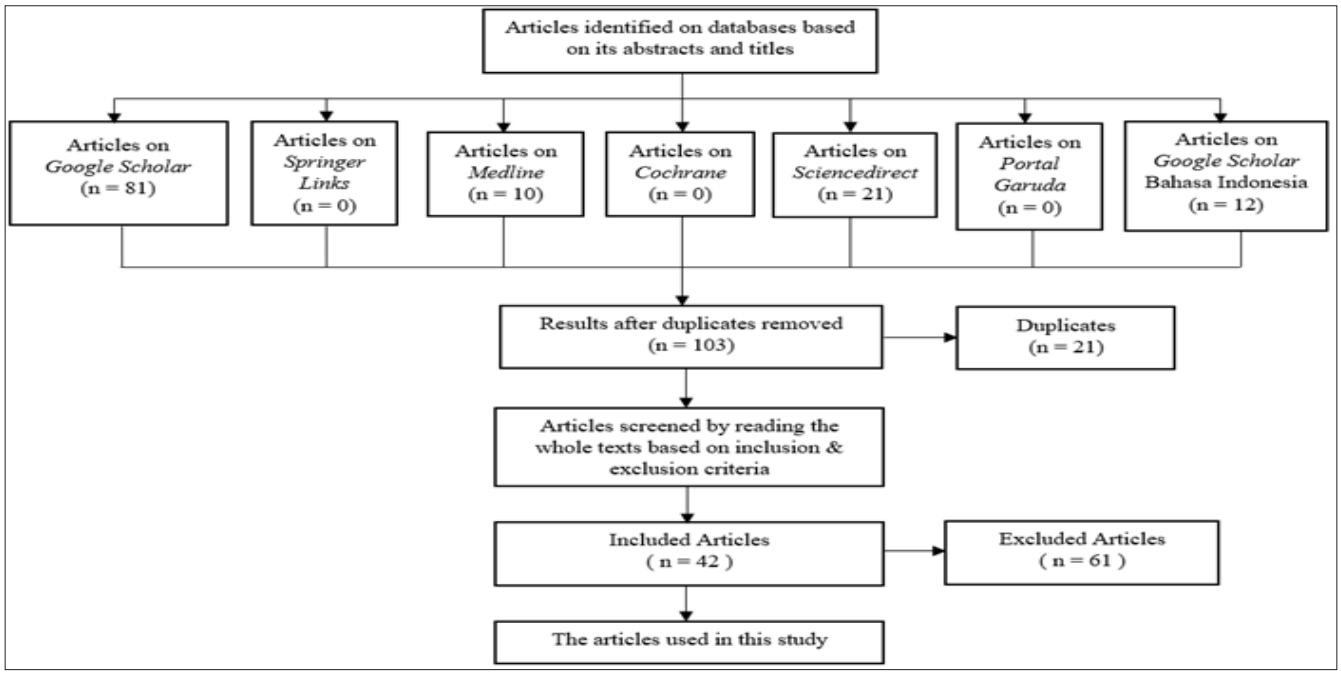

Figure 1.PRISMA Flow Diagram of the Process of Article Selection

Table 2.Results from Studies on Mimosa Pudica

S. No.	Authors (Year)	Target Species	Study Design	Sample Used	Results	Active Phytochemicals	Additional Information
1.	N Aarthi & K Murugan (2011)[18]	Plasmodium *berghei*	In vivo	Ethanol extract from leaves	% Suppression: 38.3% Dose: 800 mg/ kg/day	Alkaloids and flavonoids	N/A
2.	N Singh et al. (2015)[19]	CQS *Plasmodium falciparum* 3D7 strain	Ex vivo	Ethanol extract from whole plant	IC50: 51 µg/ mL	N/A	N/A
		CQR *Plasmodium falciparum* INDO strain	Ex vivo	Ethanol extract from whole plant	N/A	N/A	N/A
3.	OO Ogbole, PA Segun, & PS Fasinu (2018)[20]	CQS *Plasmodium falciparum* D6 strain	In vitro	Methanol extract from leaves	% Suppression: 35% Dose: 15.9 µg/ mL	N/A	N/A

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.2022108

4.	QL Tran et al. (2003)[21]	*Plasmodium falciparum* FCR-3 strain	In vitro	Aerial part-derived: 1.Aqueous extract 2.Methanol extract 3.Aqueous: Methanol extract (1:1)	EC50: 4.4 µg/mL 6.2 µg/mL 4.0 µg/mL	N/A	This is the first recorded study on the antimalarial potency of *M. pudica*
5.	S Marimuthu et al. (2011)[22]	*Anopheles subpictus larvae*	In vivo	Leaves-derived: 1.Aqueous extract 2.AgNPs	LC50: 45.82 µg/mL 13.9 µg/mL	Silver AgNPs, terpenoids, flavonoids	Using AgNPs rather than extraction, fractionation, or isolation of active compounds
6.	N Aarthi et al. (2011)[23]	*Anopheles stephensi* larvae Instar I	In vivo	Ethanol extract from leaves	LC50: 0.723 µg/mL	Alkaloids, flavonoids, phenols, steroids	N/A
		Anopheles stephensi larvae Instar II	In vivo	Ethanol extract from leaves	LC50: 1.150 µg/mL	Alkaloids, flavonoids, phenols, steroids	N/A
		Anopheles stephensi larvae Instar III	In vivo	Ethanol extract from leaves	LC50: 1.540 µg/mL	Alkaloids, flavonoids, phenols, steroids	N/A
		Anopheles stephensi larvae Instar IV	In vivo	Ethanol extract from leaves	LC50: 2.073 µg/mL	Alkaloids, flavonoids, phenols, steroids	N/A
		Anopheles stephensi pupa	In vivo	Ethanol extract from leaves	LC50: 2.835 µg/mL	Alkaloids, flavonoids, phenols, steroids	N/A
7.	S Amilah & E Fitria (2015)[24]	*Anopheles sp.* larvae Instar III	In vivo	Ethanol extract from leaves	LC50: 1.88 g/L	Alkaloids, saponins, flavonoids	Mechanism of action stated, derived from other literatures

EC50: Half Maximal Effective Concentration, IC50: Half Maximal Inhibitory Concentration, LD50: Half Maximal Lethal Dose, N/A: Not-Available

ED50: Half Maximal Effective Dose, IC50: Half Maximal Inhibitory Concentration, LD50: Half Maximal Lethal Dose, N/A: Not Available

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.2022108

Table 3.Results from Studies on other Fabaceae Species

S. No.	Fabaceae Species	Target Species	Study Design	Sample Used	Results	Active Phytochemicals	Additional Inform-ation	References
1.	Acacia karroo	*CQS Plasmodium falciparum 3D7 strain*	In vitro	Leaves-derived: 1. Methanol extract 2. Fraction 4	IC50: 9 µg/mL 8.2 µg/mL	Phenol, 2,4-bis(1,1-dimethylethyl)-; benzenepropanoic acid, 3,5-bis(1,1-dimethylethyl)-4-hydroxy-; mome inositol; and 3' ,5' -dimethoxyacetop-henone	N/A	C Sachdeva et al. (2020)[25]
		CQR I falcip-arum INDO strain	In vitro	Leaves-derived: 1. Methanol extract 2. Fraction 4	IC50: 14 µg/mL 4.8 µg/mL			
		Plasmodium berghei ANKA strain	In vivo	Methanol extract from leaves	% Suppre-ssion: 57%			
2.	Acacia nilotica	*Plasmodium falciparum* 3D7 strain	In vitro	Ethanol extract from bark	IC50 = 208.33 µg/mL	Tannins, alkaloids, saponins	N/A	M Ohashi et al. (2018)[26]
		Plasmodium berghei	In vivo	Ethanol extract from bark	% Suppre-ssion: 26.35%	N/A	The method used was different from other in vivo studies (not 4-day suppressive test)	NT Dabo et al. (2016)[27]
		Artesunate sensitive *Plasmodium falciparum* 3D7 strain	In vitro	Ethanol extract from: 1. Bark 2. Pods 3. Leaves	IC50: 4.28 µg/mL IC50: 4.16 µg/mL IC50: 1.29 µg/mL	N/A	N/A	MB Sadiq et al. (2017)[28]
3.	Afzelia africana	*Plasmodium falciparum* 3D7 strain	In vitro	Ethanol extract from bark	IC50: 222.36 µg/mL	Alkaloids, tannins, flavonoids, saponins	N/A	M Ohashi et al. (2018)[26]

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.2022108

4.	Baphia nitida	*Plasmodium falciparum* 3D7 strain	In vitro	Ethanol extract from bark	IC50: > 1000 µg/mL	Tannins, flavonoids, saponin glycosides	N/A	M Ohashi et al. (2018)[26]
5.	Bauhinia rufescens	*Plasmodium* berghei ANKA strain	In vivo	Extract from leaves	% Suppression: 50.6%	Flavonoids, tannins, triterpenes, saponins, and alkaloids	Means of extraction not mentioned	LN Bonkian et al. (2018)[29]
6.	Burkea africana	CQS *Plasmodium falciparum* 3D7 strain	In vitro	Bark-derived: 1. Ethanol extract 2. Dichloro-methane fraction	IC50: 28.69 µg/mL 6.44 µg/mL	N/A	The fraction showed a promising effect on the resistant strain, which means that it has a different mechanism of action from the drugs.	IC Ezenyi et al. (2021)[30]
		Multidrug resistant *Plasmodium falciparum* W2 mef strain	In vitro	Bark-derived: 1. Ethanol extract 2. Dichloro-methane fraction	IC50: 25.19 µg/mL 6.3 µg/mL			
7.	Caesalpenia bonducella	*Plasmodium* berghei ANKA strain	In vivo	Dichloro-methane extract from roots	% Suppression: 55.96%	Less to medium polar compounds		RS Nondo et al. (2016)[31]
8.	Cassia alata	CQS *Plasmodium falciparum* D10 strain	In vitro	Extract CH_2Cl_2/ MeOH (1:1) from leaves	IC50: 7.02 µg/mL	N/A	N/A	O Da et al. (2016)[32]
		Plasmodium berghei ANKA strain	In vivo	Extract CH_2Cl_2/ MeOH (1:1) from leaves	% Suppression: 45.2%			
		Plasmodium falciparum 3D7 strain	In vitro	Ethanol extract from leaves	IC50: 57.60 µg/mL	Flavonoids and glycosides	N/A	M Ohashi et al. (2018)[26]

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.2022108

9.	Cassia occidentalis	*Plasmodium falciparum* 3D7 strain	In vitro	Ethanol extract from leaves, seeds, and whole plant	IC50: > 1000 µg/mL (for all parts)	Anthraquinone, flavonoids	N/A	M Ohashi et al. (2018)[26]
		Anopheles stephensi Liston eggs	In vivo	Leaves-derived: 1. Hexane extract 2. Ethyl acetate extract 3. Methanol extract	Egg mortality rate: 85% 96.1% 94.9%	N/A	N/A	V Raja et al. (2016)[33]
10.	Cassia podocarpa	*Plasmodium falciparum* 3D7 strain	In vitro	Ethanol extract from leaves	IC50: > 1000 µg/mL	Anthraquinone	N/A	M Ohashi et al. (2018)[26]
11.	Cassia siamea	*Plasmodium falciparum* 3D7 strain	In vitro	Ethanol extract from leaves	IC50: > 1000 µg/mL	Anthraquinones, flavonoids	N/A	M Ohashi et al. (2018)[26]
12.	Cassia sieberiana	*Plasmodium* falciparum 3D7 strain	In vitro	Ethanol extract from roots & leaves	IC50: 432.48 µg/mL (roots) IC50: > 1000 µg/mL (leaves)	Galactosides, flavonoids Flavonoids, alkaloids	N/A	M Ohashi et al. (2018)[26]
13.	Cassia tora	Anopheles gambiae larvae Instar III-IV	In vivo	Seeds-derived: 1. Ethyl acetate extract 2. Fraction 3 3. Fraction 4 4. Aurantio-obtusin isolated compound 5. Obtusin-isolated compound	LD50: 2.5 µg/mL LD50: 5 µg/mL LD50: 7 µg/mL LD50: 10 µg/mL LD50: 10.2 µg/mL	Aurantio-obtusin and obtusin	Obtusin may not be the compound responsible for the effect in the extracts	VC Mbatchou et al. (2017)[34]

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.2022108

14.	Copaifera reticulata	CQS *Plasmodium* falcip-arum 3D7 strain	In vitro	Oleoresin	IC50: 2.54 µg/mL	β-caryophyllene &	Using oleoresin rather than extraction, fractionation, or isolation of active compounds	GA de Souza et al. (2016)[35]
		CQR *Plasmodium falciparum* W2 strain	In vitro	Oleoresin	IC50: 1.66 µg/mL	β-bisabolene		
		Plasmodium berghei ANKA strain	In vitro	Oleoresin	% Suppression: 96%			
15.	Cylicodiscus gabunensis	*Plasmodium* falci-parum Dd2 strain	In vitro	Bark-derived: 1. Ethanol extract 2. Hexane extract 3. Ethyl acetate fraction 4. Buthanol fraction 5. Aqueous fraction 6. CGEBU-F10 fraction 7. CGEBU-F10-7 fraction	IC50: 20.8 µg/mL IC50: 32.1 µg/mL IC50: 16.1 µg/mL IC50: 10.4 µg/mL IC50: 25.8 µg/mL IC50: 6.5 µg/mL IC50: 4.7 µg/mL	Gallic acid, ethyl gallate, benzoic acids	Fractio-nation and isolation of active compound has been done	O Aldulaimi et al. (2017)[36]
16.	Dalbergia katangensis	*Plasmodium* berghei ANKA MRA 311 strain	In vivo	Leaves-derived: 1. Methanol extract 2. Aqueous extract	% Suppression: 74.81% 73.38%	Terpenoids, steroids, polyphenols, flavonoids, anthraquinones	N/A	BC Valentin et al. (2020)[37]
17.	Detarium microcarpum	CQS *Plasmodium* berghei	In vivo	Methanol extract from leaves	% Suppression: 80.92%	Alkaloids, saponins, flavonoids, triterpenes, tannins	N/A	AR Abdullahi et al. (2020)[38]
18.	Dialium angolense	*Plasmodium* berghei ANKA MRA 311 strain	In vivo	Leaves-derived: 1. Methanol extract 2. Aqueous extract	% Suppression: 70.81% 70.38%	Anthraquinones, flavonoids, polyphenols, terpenoids	N/A	BC Valentin et al. (2020)[39]

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.2022108

19.	Dichrostachys cinerea	CQS *Plasmodium* berghei NK-65 strain	In vivo	Bark-derived: 1. Ethanol extract 2. Chloroform fraction 3. Ethyl acetate fraction 4. Buthanol fraction	% Suppression: 59.66% 74.71% 23.41% 70.38%	Phenols, flavonoids, tannins	N/A	LA Fadipe et al. (2020)[40]
		CQS Plasmodium *falciparum* D6 strain	In vitro	Whole stem-derived: 1. Dichloromethane extract 2. Methanol extract Stem bark-derived: 1. Dichloromethane extract 2. Methanol extract	IC50: 11.47 µg/mL 2.96 µg/mL IC50: 2.37 µg/mL > 1000 µg/mL	Steroids, flavonoids, saponins, cardiac glycosides, flavonoids, tannins, triterpenoids, saponins	N/A	PA Kweyamba et al. (2019)[41]
		CQR Plasmodium *falciparum* Dd2 strain	In vitro	Whole stem-derived: 1. Dichloromethane extract 2. Methanol extract Stem bark-derived: 1. Dichloromethane extract 2. Methanol extract	IC50: > 1000 µg/mL > 1000 µg/mL IC50: 11.92 µg/mL > 1000 µg/mL	Steroids, flavonoids, saponins, cardiac glycosides, flavonoids, tannins, triterpenoids, saponins	N/A	PA Kweyamba et al. (2019)[41]
		Plasmodium berghei	In vivo	Dichloromethane extract from bark	% Suppression: 53.12 %	Steroids, flavonoids, saponin	N/A	PA Kweyamba et al. (2019)[41]
20.	Dipteryx Lacunifera	CQR Plasmodium *falciparum* W2 strain	In vitro	Seed-derived: 1. Isolated isoliquiritigenin 2. Isolated 6,3′,4′-trihydroxyflavone 3. Diethyl ether fraction	% Suppression: 81.25% 88.98% 89.46%	Isoliquiritigenin 6,3′,4′-trihydroxyflavone	Suspected active compounds have been isolated	LS Alexandre et al. (2020)[42]

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.2022108

21.	Distemonanthus benthamianus	*Plasmodium* berghei ANKA strain	In vivo	Ethanol extract from bark	% Suppression: 56.43%	Tannins, glycosides, saponins, alkaloids, terpenes, flavonoids, coumarins	N/A	F Ayisi et al. (2021)[43]
22.	Eriosema montanum	CQS *Plasmodium falciparum* 3D7 strain	In vitro	Root-derived: 1.Extract CH_2Cl_2/ MeOH Root-derived isolation of: 2. Eucomic acid 3. 7-O -glucopyranosyl-isoprunetin 4. Genistin 5. Malonyl genistin 6. Isoprunetin 7. Isoluteolin 8. Genistein	IC50: 17.68 µg/mL IC50: 0.057 µg/mL 0.113 µg/mL 7.867 µg/mL > 10 µg/mL 0.042 µg/mL 0.121 µg/mL 7.736 µg/mL	Eucomic acid, isoflavonoid derivates (7-O -glucopyranosyl-isoprunetin, genistin, malonyl genistin, isoprunetin, isoluteolin, genistein)	Suspected active compounds have been isolated	JC Tomani et al. (2021)[44]
23.	Erythrina fusca	CQS *Plasmodium falciparum* 3D7 strain	In vitro	Bark-derived: 1. Methanol extract 2. nHexane fraction 3. $CHCl_3$ fraction 4. Aqueous fraction	IC50: 13.64 µg/mL 21.44 µg/mL 22.55 µg/mL 4.94 µg/mL	Phaseolin, phytol, β-amyrin, lupeol, and stigmasterol	Fractionation has been done	SA Sazed et al. (2021)[45]
		CQR *Plasmodium falciparum* Dd2 strain	In vitro	Bark-derived: 1. Methanol extract 2. nHexane fraction 3. $CHCl_3$ fraction 4. Aqueous fraction	IC50: 8.22 µg/mL 4.88 µg/mL 13.77 µg/mL 18.77 µg/mL	Phaseolin, phytol, β-amyrin, lupeol, and stigmasterol	Fractionation has been done	SA Sazed et al. (2021)[45]
24.	Erythrina schliebenii	*Plasmodium* berghei ANKA strain	In vivo	Aqueous extract from bark	% Suppression: 28.64%	N/A	N/A	RS Nondo et al. (2016)[31]
25.	Indigofera ammoxylum	CQS *Plasmodium falciparum* 3D7 strain	In vitro	Ethyl acetate extract from: 1. Leaves 2. Bark	IC50: > 50 µg/mL > 50 µg/mL	N/A	N/A	A Ledoux et al. (2018)[46]

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.2022108

26.	Indigofera oblongifolia	*Plasmodium* chabaudi	In vivo	AgNP from methanol extract derived from leaves	% Suppression 99%	N/A	Outstanding result near the control's value from AgNP	S Al-Quraishy et al. (2020)[47]
27.	Indigofera spicata	*Plasmodium* berghei ANKA strain	In vivo	Methanol extract from roots	% Suppression: 53.42%	Alkaloids, flavonoids, tannins	N/A	EM Birru et al. (2017)[48]
28.	Kotschya speciosa	Anopheles gambiae larvae	In vivo	Ethanol extract from: 1. Leaves 2. Roots	LC50: 75.83 µg/mL 252.03 µg/mL	Phenols	N/A	I Daniel et al. (2020)[49]
29.	Kotschya strigosa	Anopheles gambiae larvae	In vivo	Ethanol extract from: 1. Leaves 2. Roots	LC50: 37.08 µg/mL 237.31 µg/mL	Phenols	N/A	I Daniel et al. (2020)[49]
30.	Kotschya thymodora	Anopheles gambiae larvae	In vivo	Ethanol extract from: 1. Leaves 2. Roots	LC50: 16.35 µg/mL 53.35 µg/mL	Phenols	N/A	I Daniel et al. (2020)[49]
31.	Kotschya uguenensis	Anopheles gambiae larvae	In vivo	Leaves-derived: 1. Ethanol extract 2. Isolated ent-halim-1(10)-ene-15-oic acid 3. Isolated 3-O-methyl-D-chiro-inositol	LC50: 94.01 µg/mL 30.05 µg/mL 80.73 µg/mL	ent-halim-1(10)-ene-15-oic acid 3-O-methyl-D-chiro-inositol	Suspected active compounds have been isolated	B Samwel et al. (2019)[50]
32.	Mezoneuron benthamianum	CQS *Plasmodium falciparum* 3D7 strain	In vitro	Leaves-derived: 1. Hydroethanolic extract 2. Precipitate 3. Isolated ethyl gallate 4. Isolated quercetin 5. Isolated 13b-OH-pheophorbide a	IC50: 32.6 µg/mL 6.4 µg/mL 6.2 µg/mL 9.5 µg/mL 5.1 µg/mL	Ethyl gallate, quercetin, 13b-OH-pheophorbide A	Suspected active compounds have been isolated	O Jansen et al. (2017)[51]

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.2022108

33.	Mucuna pruriens	CQS *Plasmodium* berghei NK - 65 strain	In vitro	Ethanol extract from leaves	Significant parasitaemia decrease	n-hexadecanoic acid	Not using the same results as others	OE Ezim et al. (2021)[52]
		Plasmodium falciparum 3D7 strain	In vitro	Seeds-derived: 1. Ethanol extract 2. Aqueous extract	%Viability: 63.80 % 65.86 %	Phenolic compounds	Not using the same results as others	MA Jimoh et al. (2020)[53]
34.	Mundulea sericea	CQR *Plasmodium falciparum* W2 strain	In vitro	CH_2Cl_2/ MeOH extract from roots. Leaves-derived isolated: 1. Lupinifolinol 2. Lupinifolin 3. Mundulinol	IC50: 0.6 µg/mL IC50: 2.0 µM 12.1 µM 5.9 µM	Lupinifolinol Lupinifolin Mundulinol	Isolation of suspected active compounds has been done.	C Chepkirui et al. (2021)[54]
		CQS *Plasmodium falciparum* 3D7 strain	In vitro	CH_2Cl_2/ MeOH extract from roots. Leaves-derived isolated: 1. Lupinifolinol 2. Lupinifolin 3. Mundulinol	IC50: 1.8 µg/mL IC50: 6.6 µM 3.6 µM 2.4 µM	Lupinifolinol Lupinifolin Mundulinol	Isolation of suspected active compounds has been done.	C Chepkirui et al. (2021)[54]
35.	Ormocarpum cochinchinense	Anopheles stephensi	In vivo	Aqueous extract AgNP from aqueous extract	LC50:164.72 µg/mL LC50:10.43 µg/mL	AgNPs	Mechanism of action of AgNPs is stated	M Govindarajan & G Benelli (2016)[55]
36.	Parkia clappertoniana	*Plasmodium falciparum* 3D7 strain	In vitro	Ethanol extract from: 1. Leaves 2. Bark	IC50: 501.23 µg/mL > 1000 µg/mL	Saponin, flavonoid, tannins	N/A	M Ohashi et al. (2018)[26]
37.	Piliostigma thonningii	*Plasmodium falciparum* 3D7 strain	In vitro	Ethanol extract from: 1. Leaves 2. Bark	IC50: > 1000 µg/mL 514.63 µg/mL	Tannins, alkaloids, flavonoids	N/A	M Ohashi et al. (2018)[26]

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.2022108

38.	Prosopis juliflora	*Plasmodium* berghei NK-65 strain	In vivo	Chloroform extract from: 1. Leaves 2. Pods	% Suppression: 35% 35%	Julifloridine & juliprosopine	Suspected active compounds identified	R Batista et al. (2018)[56]
39.	Pterocarpus erinaceus	*Plasmodium* berghei ANKA strain	In vivo	Methanol extract from leaves	% Suppression: 75%	N/A	N/A	O Noufou et al. (2016)[57]
40.	Pterocarpus santalinoides	*Plasmodium falciparum* 3D7 strain	In vitro	Ethanol extract from bark	IC50: 907.52 µg/mL	Alkaloids, flavonoids, tannins	N/A	M Ohashi et al. (2018)[26]
41.	Senna occidentalis	CQS *Plasmodium falciparum* 3D7 strain	In vitro	Leaves-derived: 1. Hexane extract 2. Methanol extract 3. Aqueous extract	IC50 & % Suprression: 3.47 µg/mL & 75.52% 3,79 µg/mL & 71.60 % 4.03 µg/mL & 56.94 %	Anthraquinones phenols, tannins alkaloids, flavonoids	N/A	AM Daskum et al. (2019)[58]
42.	Senna singueana	CQS *Plasmodium* berghei ANKA strain	In vivo	Ethanol extract from leaves	% Suppression: 47.32%	N/A	Showed great adjuvant properties when tested alongside chloroquine	MG Hiben et al. (2016)[59]
43.	Sophora denudata	CQS *Plasmodium falciparum* 3D7 strain	In vitro	Ethyl acetate Extract from: 1.Leaves 2.Barks	IC50: > 50 µg/mL 17.88 µg/mL	N/A	N/A	A Ledoux et al. (2018)[46]
44.	Tamarindus indica	CQS *Plasmodium falciparum* 3D7 strain	In vitro	Ethanol extract from: 1.Leaves 2. Barks	IC50: > 1000 µg/mL > 1000 µg/mL	Saponins, tannins, glycoside, phenols, flavonoids	N/A	M Ohashi et al. (2018)[26]

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.2022108

Discussion

This review presents information in 2 groups: (1) studies related to the plasmodial and insecticidal activity of Mimosa pudica, and (2) from other species of the *Fabaceae* family. The information obtained includes the part of the plant used, the type of extract/ fraction/ isolated compound used, the type of study conducted (in vitro, in vivo, or ex vivo), and the toxicity parameters (IC50, EC50, LC50, LD50, or percentage suppression) against *Plasmodium* sp. or *Anopheles* sp. Isolation and further purification of the extract are needed to study a specific effect of a medicinal plant because of its phytochemical properties.[60]

Antimalarial Potency of Mimosa Pudica

Initial studies on *Mimosa pudica* were carried out using aqueous, methanol, and aqueous/ methanol extracts of aerial part-derived for antiplasmodial effect against *Plasmodium falciparum* FCR-3 strain. The methanol extract from leaves of M. pudica was also investigated against P. *falciparum* strain D6. The ethanol extract has an antiplasmodial effect against P. *berghei* and P. *falciparum* 3D7 or INDO strains. Among all the tests, aqueous, methanolic, and water/ methanol extracts of aerial part-derived showed the most promising results against P. *falciparum* FCR-3 strain, considering its IC50 value was less than 10 µg/mL.[30,59] The phytochemical screening of ethanolic extract revealed the presence of flavonoids and alkaloids. Phytochemical screening of other extracts or further purification of active compounds has not been carried out (Table 2).

Other *Fabaceae* families used leaves, bark, pods, roots, stems, and whole plants to investigate their antiplasmodial activity against P. *falciparum*, P. chabaudi, or P. *berghei*. The methanol extracts of Acacia karroo, Dalbergia katangensis, Detarium microcarpum, Dialium angolense, Dichrostachys cinerea, Erythrina fusca, Indigofera spicata, Pterocarpus erinaceus, and Senna occidentalis have shown promising results against P. *falciparum* or P. *berghei* with IC50 less than 10 µg/mL or suppressing percentage of more than 50%.[3,59] The most promising result is methanol extract from leaves of Dichrostachys cinerea against P. *falciparum* D6 strain with IC50 2.37 µg/mL and Detarium microcarpum that suppressed 80.92% P. *berghei* (Table 3). The ethanol extracts from Acacia nilotica, Dichrostachys cinerea, and Distemonanthus benthamianus have shown promising results against P. *falciparum* and P. *berghei*. The most promising result has been shown by ethanol extract from leaves of Acacia nilotica against Artesunate sensitive *Plasmodium falciparum* strain 3D7 with IC50 value of 1.29 µg/mL (Table 3).

Aqueous extract from leaves of Dalbergia or Dialium angolense showed plasmodial activity against P. *berghei* strain ANKA MRA 311 with 70% suppression. Still, the extract from the bark of Erythrina schliebenii is less active against P. *berghei* strain ANKA MRA 311 with 28.64% suppression. Aqueous leaf extract also has good activity against P. *falciparum* 3D7 strain on Senna occidentalis. A few other extracts have also revealed good antiplasmodial performance, such as CH_2Cl_2/ MeOH extract from leaves of Cassia alata against P. *falciparum* strain D10, dichloromethane extract from the bark of Dichrostachys cinerea against P. *berghei*, CH_2Cl_2/ MeOH extract from the roots of Mundulea sericea against P. *falciparum* 3D7 strain, and hexane extract from the leaves of Senna occidentalis against P. *falciparum* 3D7 strain with IC50 under 10µg/mL (Table 3).

Further purification increased the plasmodial activity many folds, such as the dichloromethane fraction from the bark of Burkea africana and the isolated compound from Eriosema montanum or Mezoneuron benthamianum. The expected results were also shown by the aqueous and n-hexane fraction of Erythrina fusca against P. *falciparum* 3D7 and Dd2 strains, respectively. However, further purification did not show any increased activity in the methanol fraction of Acacia karroo. It even showed decreased activity in fractions 3-4 and in compounds isolated from the ethyl acetate extract of Cassia tora, although the IC50 value was still promising (Table 3).

Isoliquiritigenin and 6,3',4-trihydroxyflavone-isolated compounds were reported to have antiplasmodial activity against P. *falciparum* W2 strain with 80% suppression. In addition, researchers have also succeeded in isolating eucomic acid, 7-O-glucopyranosyl-isoprunetin, isoprunetin, isoluteolin, genistin, genistein, ethyl gallate, quercetin, 13b-OH-pheophorbide a, lupinifolinol, lupinifolin, and mundulinol to fight P. *falciparum* 3D7 or W2 strains with IC50 less than 10 µg/mL (Table 3).

In summary, the methanol and aqueous extract showed good antiplasmodial activity of M. pudica. Studies on other *Fabaceae* suggest that methanol extract of M. pudica could be evaluated against another *Plasmodium*, as indicated by Indigofera oblongifolia against P. chabaudi or by Acacia karoo against P. *falciparum* 3D7 and INDO strains.[25,47] Further studies against P. *falciparum* FCR-3 strain can be carried out using fractions or isolated compounds. Unfortunately, antiplasmodial potential against P. *falciparum* has only been reported by M. pudica and not by other *Fabaceae* species. On the other hand, an aqueous extract of M. pudica could also be tested against P. *berghei* ANKA MRA 311 strain as shown by Dalbergia katangensis or Dialium angolense.[37,39] Furthermore, aqueous extract and its fraction of M. pudica can be evaluated against P. *falciparum* 3D7 strain as in Senna occicentalis.[58]

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.2022108

Insecticidal Potency of *Mimosa Pudica* towards Malarial Vectors

Researchers have reported the insecticidal activity of *Mimosa pudica* against Anopheles subpictus and Anopheles *stephensi*. The action of the aqueous extract of M. pudica against A. *subpictus* is lower than their ethanol extract against A. stephensi (LC50 45,82 µg/mL and 0.723 – 2.835 µg/mL, respectively) (Table 2). The aqueous extract of O. cochinchinense (*Fabaceae* family) also showed their activity against A. stephensi, but the action is lower than M. pudica (LC50 value of 164.72 µg/mL) (Table 3). These data indicate that the ethanol extract of M. pudica is more promising against A. stephensi than the other family members (8-45 times higher). Another report revealed that ethanol extract from leaves of other family members (K. speciosa, K. strigosa, K. thymodora, and K. uguenensis) had good insecticidal activity against A. gambiae with LC50 value of 16.35-94.01 µg/mL. Therefore, it is interesting to know the effect of ethanol extract from leaves of M. pudica against other vectors such as A. gambiae.

Further purification of the ethanol extract of M. pudica is needed to improve drug effectiveness. Another study reported that the insecticidal activity of ent-halim-1(10)-ene-15-oic acid from the ethanolic extract of Kotschya uguenensis leaves could increase its insecticidal activity three times against A. gambiae.[50] Insecticidal activity against A. gambiae was also shown by the ethyl acetate extract from seeds of another member of *Fabaceae* family, Cassia tora. The study used a crude extract, isolated ethyl acetate fractions, and isolated compounds aurantio-obtusin and obtusin. Interestingly, a crude extract obtained the most promising LD50 value rather than its fractions or isolated compounds (LD50 of crude extract: 2.5 µg/mL; fraction 5-7 µg/mL; isolated compounds 10-10.2 µg/mL) (Table 3). The result of this study revealed that a combination of compounds works more effectively than one active compound. Thus, ethyl acetate extract from the seeds of M. pudica against A. gambiae can also be used for future studies.

Plant-Synthesised Silver Nanoparticles

The green nanoparticle approach is promising in increasing drug sensitivity, one of which is using plant extracts with silver nanoparticles (Ag-NPs). This nanoparticle synthesis method is interesting considering its low cost, ability to accommodate large-scale production, use of simple techniques, and it being environmentally friendly.[61,62] In this review, we showed that the toxicity of extracts of *Mimosa pudica* or its family with nanoparticles was higher than without nanoparticles (Tables 2 and 3). The aqueous extract of *Mimosa pudica* with silver nanoparticles was more effective against Anopheles subpictus larvae than without silver nanoparticles (Table 2). The same thing was also shown by Ormocarpum cochinchinense, where aqueous extracts with silver AgNPs were more effective against Anopheles *stephensi* than without AgNPs (Table 3). As an antiplasmodial, AgNPs with methanol extract of Indigofera oblingifolia can suppress 99% of P. chabaudi (Table 3). AgNPs with aqueous extracts of plant species from other families (such as Azadirachta indica and Ocimum sanctum) also showed good results against P. *falciparum* 3D7 strain.[62] In addition, AgNPs are also known to exert a protective effect on liver tissue injury induced by P. chabaudi through regulating the iron regulatory genes or reducing parasitaemia in *Plasmodium* chabaudi-infected mice.[63,64] The unique metabolites of plant extracts can affect the properties of AgNPs formed, including nano size, high conductivity, and optical properties, which make them essential in increasing drug sensitivity. The nano size might make AgNPs penetrate more easily against *Plasmodium* sp. or *Anopheles* sp. larvae. Thus, biosynthesis of AgNPs with aqueous, methanol, and ethanol extracts of *Mimosa pudica* against P. falciparum strains D6 or P. *berghei* could be carried out in future studies. For insecticidal effect, biosynthesis of AgNPs with aqueous or ethanolic extract of M. pudica can also be carried out to increase its ability to fight A. *subpictus* and A. stephensi larvae.

Conclusion

This review summarises the antiplasmodial and insecticidal potential of Mimosa pudica. The most promising antiplasmodial activity was shown by aqueous, methanol, and aqueous/ methanol extract from the aerial part of M. pudica against P. *falciparum* FCR-3 strain. Meanwhile, aqueous or ethanolic extracts from leaves of M. pudica revealed the ability against A. *subpictus* and A. stephensi larvae. Future studies may aim to investigate the activity of the methanol extract of M. pudica against P. chabaudi or P. *falciparum* 3D7 and INDO strains. The conducted research can describe the action of methanol fraction or isolated compounds against P. *falciparum* FCR-3 strain. The aqueous extract of M. pudica can be evaluated against P. *berghei* ANKA MRA 311 strain or P. *falciparum* 3D7 strain. Extraction with other solvents can also be carried out, such as n-hexane or butanol extract to fight P. *falciparum* Dd2 strain, and the extract and ethyl acetate fraction to fight against *Anopheles* gambiae larvae. The use of plant-based-synthesised silver nanoparticles (AgNPs) needs to be intensified for further studies to increase the effectiveness of extracts against *Plasmodium* sp. or *Anopheles* sp.

Acknowledgement

The study was supported by the Faculty of Medicine, Universitas Padjadjaran and the Directorate for Research, Community Service, and Innovation (DRPMI), Universitas Padjadjaran.

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.2022108

Source of Funding: None

Conflict of Interest: None

References

1. World Health Organization [Internet]. World malaria report 2019. WHO Regional Office for Africa; 2019 [cited 2022 May 8]. Available from: https://www.who.int/news-room/fact-sheets/detail/malaria
2. World Health Organization [Internet]. WHO guidelines for malaria. Geneva; 2021 [cited 2022 May 8]. 210 p. Available from: https://apps.who.int/iris/rest/bitstreams/1332432/retrieve
3. The Indonesian Ministry of Health. Buku Saku Tatalaksana Malaria 2019. Sub Directorate of Malaria P2PTVZ Directorate of the Indonesian Ministry of Health [Internet]. 2019 [cited 2022 May 8].1-44. Available from: https://litbangkespangandaran.litbang.kemkes.go.id/perpustakaan/index.php?p=show_detail&id=4016
4. World Health Organization [Internet]. Malaria prevention works; 2017 [cited 2022 May 8]. 24 p. Available from: https://www.who.int/malaria/publications/atoz/malaria-prevention-works/en/
5. Sovi A, Keita C, Sinaba Y, Dicko A, Traore I, Cisse MB, Koita O, Dengela D, Flatley C, Bankineza E, Mihigo J, Belemvire A, Carlson J, Fornadel C, Oxborough RM. *Anopheles* gambiae (s.l.) exhibit high intensity pyrethroid resistance throughout Southern and Central Mali (2016-2018): PBO or next generation LLINs may provide greater control. Parasit Vectors [Internet]. 2020 [cited 2022 May 8];13(1):239. Available from: https://doi.org/10.1186/s13071-020-04100-7 [PubMed] [Google Scholar]
6. Naß J, Efferth T. Development of artemisinin resistance in malaria therapy. Pharmacol Res [Internet]. 2019 [cited 2022 May 8];146:104275. Available from: https://pubmed.ncbi.nlm.nih.gov/31100335/ [PubMed] [Google Scholar]
7. Nsanzabana C. Resistance to Artemisinin Combination Therapies (ACTs) do not forget the partner drug! Trop Med Infect Dis [Internet]. 2019 Feb 1 [cited 2022 May 8];4(1):26. Available from: https://pubmed.ncbi.nlm.nih.gov/30717149 [PubMed] [Google Scholar]
8. World Health Organization [Internet]. Artemisinin resistance and artemisinin-based combination therapy efficacy. WHO; 2019 [cited 2022 May 8];6. Available from: https://apps.who.int/iris/handle/10665/274362 [Google Scholar].
9. Thomas D, Tazerouni H, Sundararaj KG, Cooper JC. Therapeutic failure of primaquine and need for new medicines in radical cure of *Plasmodium* vivax. Acta Trop [Internet]. 2016 [cited 2022 May 8];160:35-8. Available from: https://www.sciencedirect.com/science/article/pii/S0001706X16302029 [Google Scholar]
10. Takala-Harrison S, Laufer MK. Antimalarial drug resistance in Africa: key lessons for the future. Ann N Y Acad Sci [Internet]. 2015 Apr [cited 2022 May 8];1342:62-7. Available from: https://pubmed.ncbi.nlm.nih.gov/25891142 [PubMed] [Google Scholar]
11. White NJ, Hien TT, Nosten FH. A brief history of Qinghaosu. Trends Parasitol [Internet]. 2015 Dec [cited 2022 May 8];31(12):607-10. Available from: https://pubmed.ncbi.nlm.nih.gov/26776328 [PubMed] [Google Scholar]
12. Joseph B, George J, Mohan J. Pharmacology and traditional uses of Mimosa pudica. Int J Pharm Sci Drug Res. 2013;5(2):41-4. [Google Scholar]
13. Rudrapal M, Chetia D. Plant flavonoids as potential source of future antimalarial leads. Syst Rev Pharm. 2017;8(1):13-8. [Google Scholar]
14. Okpako I, Onyesom I. Antiplasmodial activity of the ethanolic extract and flavonoid fraction of the stem of Phyllanthus amarus in experimental mice. Afr Sci. 2019;20(4):175-80. [Google Scholar]
15. Uzor PF. Alkaloids from plants with antimalarial activity a review of recent studies. Evid Based Complement Alternat Med. 2020;2020:8749083. [PubMed] [Google Scholar]
16. Ahmad H, Sehgal S, Mishra A, Gupta R. *Mimosa pudica* L. (Laajvanti): an overview. Pharmacogn Rev [Internet]. 2012 Jul [cited 2022 May 8];6(12):115-24. Available from: https://pubmed.ncbi.nlm.nih.gov/23055637 [PubMed] [Google Scholar]
17. Supandi, Saputra YH, Anwar C, Kinanto, Kodir RA, Kurnia D, Fauziah N, Laelalugina A, Wiraswasti HL. Potential of reclamation area of coal mining sites in medical field. Int J Adv Res Eng Technol. 2020;11(8):714-20. [Google Scholar]
18. Aarthi N, Murugan K. Antimalarial activity and phytochemical screening of ethanolic leaf extract of Phyllanthus niruri and Mimosa pudica. Int J Pharm Res Dev. 2011;3(3):198-205. [Google Scholar]
19. Singh N, Kaushik NK, Mohanakrishnan D, Tiwari SK, Sahal D. Antiplasmodial activity of medicinal plants from Chhotanagpur plateau, Jharkhand, India. J Ethnopharmacol [Internet]. 2015 [cited 2022 May 8];165(July 2019):152-62. Available from: http://dx.doi.org/10.1016/j.jep. 2015.02.038 [PubMed] [Google Scholar]
20. Ogbole OO, Segun PA, Fasinu PS. Antimicrobial and antiprotozoal activities of twenty-four Nigerian medicinal plant extracts. South Afr J Bot [Internet]. 2018 [cited 2022 May 8];117:240-6. Available from: https://doi.org/10.1016/j.sajb. 2018.05.028 [Google Scholar]

21. Tran QL, Tezuka Y, Ueda JY, Nguyen NT, Maruyama Y, Begum K, Kim HS, Wataya Y, Tran QK, Kadota S. In vitro antiplasmodial activity of antimalarial medicinal plants used in Vietnamese traditional medicine. J Ethnopharmacol. 2003;86(2-3):249-52. [PubMed] [Google Scholar]
22. Marimuthu S, Rahuman AA, Rajakumar G, Santhoshkumar T, Kirthi AV, Jayaseelan C, Bagavan A, Zahir AA, Elango G, Kamaraj C. Evaluation of green synthesized silver nanoparticles against parasites. Parasitol Res. 2011;108(6):1541-9. [Google Scholar]
23. Aarthi N, Vasugi C, Panneerselvam C, Kumar KP, Madhiyazhagan P, Murugan K. Toxicity and smoke repellency effect of *Mimosa pudica* L. against the malarial vector Anopheles *stephensi* (Diptera: Culicidae). Bioscan. 2011;6(2):211-4.
24. Amilah SS, Fitria E. LC50 Dari ekstrak daun Putri malu (*Mimosa pudica* L.) aerhadap larva nyamuk demam berdarah (Aedes aegypti L.) dan larva nyamuk malaria (*Anopheles* sp.). J Mat dan Ilmu Pengetah Alam Unipa [Internet]. 2015 [cited 2022 May 8];8(01):5-8. Available from: http://jurnal.unipasby.ac.id/index.php/stigma/article/view/248. Indonesian. [Google Scholar]
25. Sachdeva C, Mohanakrishnan D, Kumar S, Kaushik NK. Assessment of in vitro and in vivo antimalarial efficacy and GC-fingerprints of selected medicinal plant extracts. Exp Parasitol [Internet]. 2020 [cited 2022 May 8];219(May):108011. Available from: https://doi.org/10.1016/j.exppara. 2020.108011 [PubMed] [Google Scholar]
26. Ohashi M, Amoa-Bosompem M, Kwofie KD, Agyapong J, Adegle R, Sakyiamah MM, Ayertey F, Owusu K, Tuffour I, Atchoglo P, Tung NH, Uto T, Aboagye F, Appiah AA, Appiah-Opong R, Nyarko AK, Anyan WK, Ayi I, Boakye DA, Koram KA, Edoh D, Yamaoka S, Shoyama Y, Ohta N. In vitro antiprotozoan activity and mechanisms of action of selected Ghanaian medicinal plants against Trypanosoma, Leishmania, and *Plasmodium* parasites. Phytother Res. 2018;32(8):1617-30. [PubMed] [Google Scholar]
27. Dabo NT, Ofori M, Edo D, Nyarko AK, Bimi L. In vivo anti-malarial potentials of some plants extracts on ICR-mice, Mus musculus. Bayero J Pure Appl Sci [Internet]. 2016 [cited 2022 May 8];9(1):53-61. Available from: http://www.ajol.info/index.php/bajopas/article/view/139690/129400 [Google Scholar]
28. Sadiq MB, Tharaphan P, Chotivanich K, Tarning J, Anal AK. In vitro antioxidant and antimalarial activities of leaves, pods and bark extracts of Acacia nilotica (L.) Del. BMC Complement Altern Med. 2017;17(1):372. [PubMed] [Google Scholar]
29. Bonkian LN, Yerbanga RS, Koama B, Soma A, Cisse M, Valea I, Tinto H, Ouedraogo JB, Guigemde TR, Traore/Coulibaly M. In vivo antiplasmodial activity of two Sahelian plant extracts on *Plasmodium berghei* ANKA infected NMRI mice. Evid Based Complement Alternat Med. 2018;2018:6859632. [PubMed] [Google Scholar]
30. Ezenyi IC, Okpoko CK, Ufondu CA, Okhale SE, Adzu B. Antiplasmodial, antinociceptive and antipyretic potential of the stem bark extract of Burkea africana and identification of its antiplasmodial-active fraction. J Tradit Complement Med [Internet]. 2021 [cited 2022 May 8];11(4):311-7. Available from: https://doi.org/10.1016/j.jtcme.2020.12.004 [PubMed] [Google Scholar]
31. Nondo RS, Erasto P, Moshi MJ, Zacharia A, Masimba PJ, Kidukuli AW. In vivo antimalarial activity of extracts of Tanzanian medicinal plants used for the treatment of malaria. J Adv Pharm Technol Res. 2016;7(2):59-63. [PubMed] [Google Scholar]
32. Da O, Yerbanga RS, Traore/Coulibaly M, Koama BK, Kabre Z, Tamboura S, Dakuyo ZP, Sekhoacha MP, Matsabisa MG, Nikiema JB, Ouedraogo JB, Ouedraogo GA. Evaluation of the antiplasmodial activity and lethality of the leaf extract of Cassia alata L. (*Fabaceae*). Pak J Biol Sci. 2016;19(4):171-8. [PubMed] [Google Scholar]
33. Raja V, Ravindran JK, Eapen A, William JS. Laboratory evaluation of crude leaf extracts of Cassia occidentalis Linneaus (Caesalpinaceae) as an oviposition determinant and ovicide against vector mosquitoes Anopheles *stephensi* Liston, Culex quinquefasciatus Say and Aedes aegypti Linneaus (Diptera: Culicidae). J Mosq Res. 2016;6(33). [Google Scholar]
34. Mbatchou VC, Tchouassi DP, Dickson RA, Annan K, Mensah AY, Amponsah IK, Jacob JW, Cheseto X, Habtemariam S, Torto B. Mosquito larvicidal activity of Cassia tora seed extract and its key anthraquinones aurantio-obtusin and obtusin. Parasit Vectors. 2017;10(1):562. [PubMed] [Google Scholar]
35. De Souza GA, da Silva NC, de Souza J, de Oliveira KR, da Fonseca AL, Baratto LC, Oliveira EC, Varotti FP, Moraes WP. In vitro and in vivo antimalarial potential of oleoresin obtained from Copaifera reticulata Ducke (*Fabaceae*) in the Brazilian Amazon rainforest. Phytomedicine. 2017;24:111-8. [PubMed] [Google Scholar]
36. Aldulaimi O, Uche FI, Hameed H, Mbye H, Ullah I, Drijfhout F, Claridge TD, Horrocks P, Li WW. A characterization of the antimalarial activity of the bark of Cylicodiscus gabunensis Harms. J Ethnopharmacol [Internet]. 2017 [cited 2022 May 8];198:221-5. Available from: http://dx.doi.org/10.1016/j.jep.2017.01.014 [PubMed] [Google Scholar]
37. Valentin BC, Salvius BA, Joseph KB, Philippe ON, Jean-Baptiste LS. Antiplasmodial, antioxidant and

toxicological study of leaves extracts of Dalbergia katangensis Lecheneaud (*Fabaceae*) from Eastern DR Congo. GSC Adv Res Rev. 2020;4(2):34-45. [Google Scholar]
38. Abdullahi AR, Sani M, Abdussalam US, La B. Antiplasmodial activity and safety assessment of methanol leaf extract of Detarium microcarpum (*Fabaceae*). J Pharm Sci Drug Dev. 2020;2(1):2-9.
39. Valentin BC, Salvius BA, Henry MM, Joseph KB, Philippe ON, Jean-Baptiste LS. In vivo antiplasmodial and toxicological studies of Dialium angolense Welw. Ex Oliv. (*Fabaceae*) leaves extracts, a medicinal plant from Eastern Congo. World J Biol Pharm Health Sci [Internet]. 2020 [cited 2022 May 8];4(2):32-42. Available from: https://doi.org/10.30574/wjbphs.2020.4.2.0090 [Google Scholar]
40. Fadipe LA, Ajemba C, Lawal BA, Ahmadu AA, Ibikunle GF. Phytochemical and in-vivo antimalarial investigations of Dichrostachys cinerea (L.) Wight & Arn. (*Fabaceae*) root bark. Trop J Nat Prod Res. 2020;4(11):1007-14. [Google Scholar]
41. Kweyamba PA, Zofou D, Efange N, Assob JC, Kitau J, Nyindo M. In vitro and in vivo studies on anti-malarial activity of Commiphora africana and Dichrostachys cinerea used by the Maasai in Arusha region, Tanzania. Malar J [Internet]. 2019 [cited 2022 May 8];18(1):119. Available from: https://doi.org/10.1186/s12936-019-2752-8 [PubMed] [Google Scholar]
42. Alexandre LS, Oliveira MS, Dittz D, Sousa RW, Ferreira PMP Pessoa C, Varotti FP, Sanchez BA, Banfi FF, Chaves MH, Vieira Jr GM. Flavonoids, cytotoxic, and antimalarial activities of Dipteryx lacunifera. Rev Bras Farmacogn. 2020;30(4):544-50. [Google Scholar]
43. Ayisi F, Mensah CN, Borquaye LS. Antiplasmodial potential and safety evaluation of the ethanolic stem bark extract of Distemonanthus benthamianus Baill. (Leguminosae). Sci Afr [Internet]. 2021 [cited 2022 May 8];12:e00809. Available from: https://doi.org/10.1016/j.sciaf.2021.e00809 [Google Scholar]
44. Tomani JC, Bonnet O, Nyirimigabo A, Deschamps W, Tchinda AT, Jansen O, Ledoux A, Mukazayire MJ, Vanhamme L, Frederich M, Muganga R, Souopgui J. In vitro antiplasmodial and cytotoxic activities of compounds from the roots of Eriosema montanum Baker f. (*Fabaceae*). Molecules. 2021;26(9):2795. [PubMed] [Google Scholar]
45. Sazed SA, Islam O, Bliese SL, Hossainey MR, Shawon J, Mahmud A, Soma MA, Rashid MA, Rahman MS, Ghosh P, Alam MS. Exploratory analysis into the in vitro and in silico activity of E. fusca Lour. (*Fabaceae*) elucidates substantial antiplasmodial activity of the plant. Preprints [Internet]. 2021 [cited 2022 May 8]. Available from: https://link-springer-com.proxy.libraries.uc.edu/content/pdf/10.1007%2F978-3-642-19199-2.pdf [Google Scholar]
46. Ledoux A, Cao M, Jansen O, Mamede L, Campos PE, Payet B, Clerc P, Grondin I, Girard-Valenciennes E, Hermann T, Litaudon M, Vanderheydt C, Delang L, Neyts J, Leyssen P, Frédérich M, Smadja J. Antiplasmodial, anti-chikungunya virus and antioxidant activities of 64 endemic plants from the Mascarene Islands. Int J Antimicrob Agents. 2018;52(5):622-8. [PubMed] [Google Scholar]
47. Al-Quraishy S, Murshed M, Delic D, Al-Shaebi EM, Qasem MA, Mares MM, Dkhil MA. *Plasmodium* chabaudi-infected mice spleen response to synthesized silver nanoparticles from Indigofera oblongifolia extract. Lett Appl Microbiol. 2020;71(5):542-9. [PubMed] [Google Scholar]
48. Birru EM, Geta M, Gurmu AE. Antiplasmodial activity of Indigofera spicata root extract against *Plasmodium berghei* infection in mice. Malar J. 2017;16(1):198. [PubMed] [Google Scholar]
49. Daniel I, Innocent E, Sempombe J, Mugoyela V, Samwel B. Mosquito larvicidal activity of polar extracts from three Kotschya species against *Anopheles* gambiae s.s. Int J Mosq Res. 2020;7(3):29-33. [Google Scholar]
50. Samwel B, Innocent E, Machumi F, Kisinza WN, Heydenreich M. Isolation and characterization of mosquito larvicidal compounds from leaves of Kotschya uguenensis (Taub) F Whote. Int J Herb Med. 2019;7(6):1-4. [Google Scholar]
51. Jansen O, Tchinda AT, Loua J, Esters V, Cieckiewicz E, Ledoux A, Toukam PD, Angenot L, Tits M, Balde AM, Frederich M. Antiplasmodial activity of Mezoneuron benthamianum leaves and identification of its active constituents. J Ethnopharmacol [Internet]. 2017 [cited 2022 May 10];203:20-6. Available from: http://dx.doi.org/10.1016/j.jep.2017.03.021 [PubMed] [Google Scholar]
52. Ezim OE, Alagbe OV, Idih FM. Antimalarial activity of ethanol extract of Mucuna pruriens leaves on Nk65 chloroquine sensitive strain of *Plasmodium berghei*. J Complement Altern Med Res. 2021;13(4):1-7. [Google Scholar]
53. Jimoh MA, Idris OA, Jimoh MO. Cytotoxicity, phytochemical, antiparasitic screening, and antioxidant activities of Mucuna pruriens (*Fabaceae*). Plants (Basel). 2020;9(9):1249. [PubMed] [Google Scholar]
54. Chepkirui C, Ochieng PJ, Sarkar B, Hussain A, Pal C, Yang LJ, Coghi P, Akala HM, Derese S, Ndakala A, Heydenreich M, Wong VK, Erdélyi M, Yenesew A. Antiplasmodial and antileishmanial flavonoids from Mundulea sericea. Fitoterapia. 2021;149:104796. [PubMed] [Google Scholar]
55. Govindarajan M, Benelli G. One-pot fabrication of

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.2022108

silver nanocrystals using Ormocarpum cochin chinense biophysical characterization of a potent mosquitocidal and toxicity on non-target mosquito predators. J Asia Pac Entomol [Internet]. 2016 [cited 2022 May 12];19(2):377-85. Available from: http://dx.doi.org/10.1016/j.aspen.2016.04.003 [Google Scholar]

56. Batista R, Santana CC, Azevedo-Santos AV, Suarez-Fontes AM, Ferraz JL, Silva LA, Vannier-Santos MA. In vivo antimalarial extracts and constituents of Prosopis juliflora (*Fabaceae*). J Funct Foods [Internet]. 2018 [cited 2022 May 15];44:74-8. Available from: https://doi.org/10.1016/j.jff.2018.02.032 [Google Scholar]
57. Noufou O, André T, Richard SW, Yerbanga S, Maminata T, Ouédraogo S, Anne EH, Irene G, Pierre GI. Anti-inflammatory and anti-plasmodial activities of methanol extract of Pterocarpus erinaceus Poir. (*Fabaceae*) leaves. Int J Pharmacol. 2016;12(5):549-55. [Google Scholar]
58. Daskum AM, Godly C, Qadeer MA, Ling LY. Effect of Senna occidentalis (*Fabaceae*) leaves extract on the formation of β - hematin and evaluation of in vitro antimalarial activity. Int J Herb Med. 2019;7(3):46-51. [Google Scholar]
59. Hiben MG, Sibhat GG, Fanta BS, Gebrezgi HD, Tesema SB. Evaluation of Senna singueana leaf extract as an alternative or adjuvant therapy for malaria. J Tradit Complement Med [Internet]. 2016 [cited 2022 May 10];6(1):112-7. Available from: http://dx.doi.org/10.1016/j.jtcme. 2014.11.014 [PubMed] [Google Scholar]
60. Abubakar AR, Haque M. Preparation of medicinal plants: basic extraction and fractionation procedures for experimental purposes. J Pharm Bioallied Sci [Internet]. 2020 [cited 2022 May 10];12(1):1-10. Available from: https://pubmed.ncbi.nlm.nih.gov/32801594 [PubMed] [Google Scholar]
61. Chung IM, Park I, Seung-Hyun K, Thiruvengadam M, Rajakumar G. Plant-mediated synthesis of silver nanoparticles: their characteristic properties and therapeutic applications. Nanoscale Res Lett [Internet]. 2016 [cited 2022 May 15];11(1):40. Available from: http://dx.doi.org/10.1186/s11671-016-1257-4 [PubMed] [Google Scholar]
62. Sardana M, Agarwal V, Pant A, Kapoor V, Pandey KC, Kumar S. Antiplasmodial activity of silver nanoparticles: a novel green synthesis approach, Asian Pac J Trop Biomed. 2018;8(5):268-72. [Google Scholar]
63. Metwally DM, Alajmi RA, El-Khadragy MF, Al-Quraishy S. Silver nanoparticles biosynthesized with Salvia officinalis leaf exert protective effect on Hepatic tissue injury induced by *Plasmodium* chabaudi. Front Vet Sci. 2021;7:620665. [PubMed] [Google Scholar]
64. Murshed M, Dkhil MA, Al-Shaebi EM, Qasem MA, Mares MM, Aljawdah HM, Alojayri G, Abdel-Gaber R, Al-Quraishy S. Biosynthesized silver nanoparticles regulate the iron status in the spleen of *Plasmodium* chabaudi–infected mice. Environ Sci Pollut Res. 2020;27:40054-60. [PubMed] [Google Scholar]

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.2022108