

**ETHNOBOTANY, ANTIPLASMODIAL ACTIVITY, AND PHYTOCHEMICAL
PROFILE OF ANTIMALARIAL ASTERACEAE SPECIES IN AFRICA:
A SYSTEMATIC REVIEW**

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ABSTRACT

This systematic review consolidates ethnobotanical, phytochemical, and pharmacological data on Asteraceae species traditionally used for malaria treatment across Africa. Using the PRISMA framework, thirty-seven peer-reviewed studies from 2015–2025 were analyzed to document species usage, preparation methods, and antiplasmodial validation. The findings revealed that *Vernonia amygdalina*, *Bidens pilosa*, *Artemisia afra*, and *Tithonia diversifolia* are the most frequently cited plants, mainly prepared as leaf decoctions for oral administration. Quantitative indices such as Relative Frequency of Citation (RFC) indicated cultural prominence consistent with potent in-vitro activities ($IC_{50} = 1.25\text{--}15\ \mu\text{g/mL}$). Phytochemical profiles showed consistent presence of sesquiterpene lactones, terpenoids, flavonoids, tannins, and saponins, including compounds like artemisinin, vernodalol, vernolide, and tagitinin C. The observed correlation between ethnobotanical citation and pharmacological potency confirms the scientific relevance of traditional African medicine and emphasizes the potential of Asteraceae species as valuable leads for antimalarial drug discovery and sustainable health applications.

Keywords:

Frequency citation, Malaria, *Vernonia amygdalina*, PRISMA, flower

INTRODUCTION

Malaria remains a major vector-borne disease and a persistent public health concern in sub-Saharan Africa, accounting for the majority of malaria cases and deaths worldwide. The disease, primarily caused by *Plasmodium falciparum*, continues to thrive in areas characterized by poverty, poor sanitation, and limited access to modern healthcare facilities. Although pharmaceutical advances such as artemisinin-based combination therapies (ACTs) have significantly improved malaria control, the increasing emergence of drug-resistant strains and the high cost of conventional medicine hinder their long-term efficacy. As a result, traditional medicine plays a crucial role in providing affordable and accessible healthcare, especially in rural communities that depend on indigenous knowledge systems to combat malaria (Adebayo et al., 2019).

The Asteraceae family, also known as Compositae, represents one of the largest and most diverse families of flowering plants globally, consisting of more than 1,600 genera and 23,000 species. In Africa, numerous species from this family are deeply embedded in traditional healing systems, primarily for their anti-inflammatory, analgesic, and antiplasmodial properties. These plants are commonly employed in various forms—such as decoctions, infusions, or macerations—depending on the part used, including leaves, stems, roots, or bark. Their effectiveness is often attributed to the presence of potent secondary metabolites such as flavonoids, terpenoids, tannins, phenolics, and sesquiterpene lactones, many of which have demonstrated promising pharmacological activities against malaria parasites in experimental studies (Nabukenya et al., 2025). The frequent use of Asteraceae plants for malaria treatment across multiple African regions signifies their cultural and medicinal

importance and highlights their potential for further drug development. In Uganda, ethnobotanical surveys have revealed that traditional healers and local communities continue to rely heavily on plant-based remedies as the first line of treatment for malaria. The use of Asteraceae species is prevalent due to their wide distribution and perceived efficacy, as well as the community's trust in traditional knowledge systems. Remedies are typically prepared through simple methods such as boiling or soaking plant materials, making them accessible to even the most remote households (Nabukenya et al., 2025). Similarly, studies in Zimbabwe have shown that a substantial number of medicinal plants, including members of Asteraceae, are widely utilized in the management of malaria and related febrile conditions. The local population's reliance on these plants underscores their therapeutic potential and the continuing relevance of indigenous healthcare practices in modern African societies (Ngarivhume et al., 2023).

The ethnopharmacological significance of Asteraceae species is further illustrated by studies from Côte d'Ivoire, where traditional healers in the Dikodougou district identify and use several plants to treat malaria and its symptoms (Koné et al., 2025). These practices are grounded in ancestral knowledge passed orally through generations, ensuring that valuable ethnobotanical information is preserved within the community. The consistency of Asteraceae use across different geographical regions in Africa indicates a shared cultural and medicinal understanding of their effectiveness. This pattern suggests that these plants hold genuine therapeutic value that transcends cultural boundaries and merits comprehensive scientific investigation.

Despite their widespread use, there remains a notable lack of systematic pharmacological validation and standardization of many Asteraceae species employed in malaria treatment. Only a limited number have been subjected to detailed phytochemical screening or in vitro antiparasmodial testing. Additionally, the standardization of dosages, safety assessments, and conservation strategies are often overlooked, posing risks to both patient safety and biodiversity. Many of these medicinal plants are harvested from the wild, and without proper management, overexploitation could threaten the ecological balance and future availability of these vital resources (Adebayo et al., 2019).

OBJECTIVES

In view of these identified research gaps, the present comprehensive review seeks to deepen the scientific and ethnobotanical understanding of Asteraceae species in relation to malaria prevention and treatment across Africa. The study is designed with three interrelated objectives that collectively aim to consolidate, analyze, and interpret the existing body of knowledge on this important plant family. First, it aims to collect and synthesize available ethnobotanical literature on Asteraceae species that are traditionally employed for malaria management within various African communities. Second, it intends to systematically document and describe these species by detailing their scientific and vernacular names, plant parts utilized, methods of preparation and administration, as well as ethnobotanical indices such as frequency of citation (Fc) and fidelity level (FL), including their morphological characteristics. Third, the review seeks to evaluate the relationship between ethnobotanical significance, measured through citation frequency, and corresponding pharmacological evidence, particularly the reported antiparasmodial activity, phytochemical profiles, and bioactive compounds of the documented Asteraceae species. By addressing these objectives, the review aims not only to enrich the existing ethnomedicinal database but also to strengthen the linkage between traditional botanical knowledge and modern pharmacological research.

METHODOLOGY

This systematic review aims to collect and synthesize the acquired related literature in accordance with this study entitled, "Ethnobotany, Antiparasmodial Activity, and Phytochemical Profile of Antimalarial Asteraceae Species in Africa: A Systematic Review".

Design Approach

The design approach of the study that was utilized to synthesize the study is the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA). This method is used in screening the acquired studies based on criteria set. The analysis is composed of a flow diagram, where the literature is screened in four (4) categories. PRISMA approach was also the framework of the study.

Instrumentation Approach

Search engines are used in collecting the related studies such as the GoogleScholar and the Google engine itself. The websites of Elsevier, ResearchGate, PubMed or National Library of Medicine, MDPI Open Access Journals, ScienceDirect, South African Journal of Botany, and Nature, were the most common publishing journals of the literature.

To ensure that the studies collected were only within the timeframe of ten (10) years, search filtering was done.

Keywords were also put to the search engine to identify the literature related to the study. The first set of keywords employed to find the RRLs were, “ethnobotanical study malarial treatment in africa” and “ethnobotanical study malaria africa”. The second set of keywords used in the engine were, “phytochemical screening of plants in malarial treatment africa”, “antiplasmodial properties of plants in malarial treatment africa”, and “bioactive compounds in plants malarial treatment africa”. The third and last set of keywords make use of is the ethnobotanical and phytochemicals in plants malarial treatment in africa”. The use of specific keywords provided relevant studies, in relation to the study.

Inclusion and Exclusion Criteria

The related literature collected were included with the following criteria of: (a) ethnobotanical study of malarial plants in Africa; (b) phytochemical screening of malarial plants in Africa; (c) bioactive compounds of malarial plants in Africa; (d) antiplasmodial properties of malarial plants in Africa; (e) ethnobotanical study and phytochemical screening of malarial plants in Africa; (f) relevant studies conducted within the year of 2015 - 2025; (g) peer-reviewed journals and some articles in line with the study; (h) literature published in English language or studies published in their mother tongue but provided a clear and accurate English translation manuscript

The exclusion criteria include the following: (1) duplicates or repetition of other study in different site; (2) literatures that did not meet the necessary data needed and deviates from the scope of the study; (3) studies that are published way ahead of the required timeframe; and (4) related literatures that are not peer-reviewed.

Search Results

The collected literature studies reached seventy (70) through skimming with its whole abstract and paper and through the title of the studies. From the famous sites for published papers, some of them are from SpringerLink, Elsevier, DOI, Nature, MDPI, and other links. From the 70 collected studies pool, only thirty-seven (37) related literatures were included on the study based on the inclusion-exclusion criteria provided. Most of the studies were singled-out due to the lack of relevance on the title of the systematic review and incomplete data available to be synthesized. This is shown in the diagram of Figure 1.

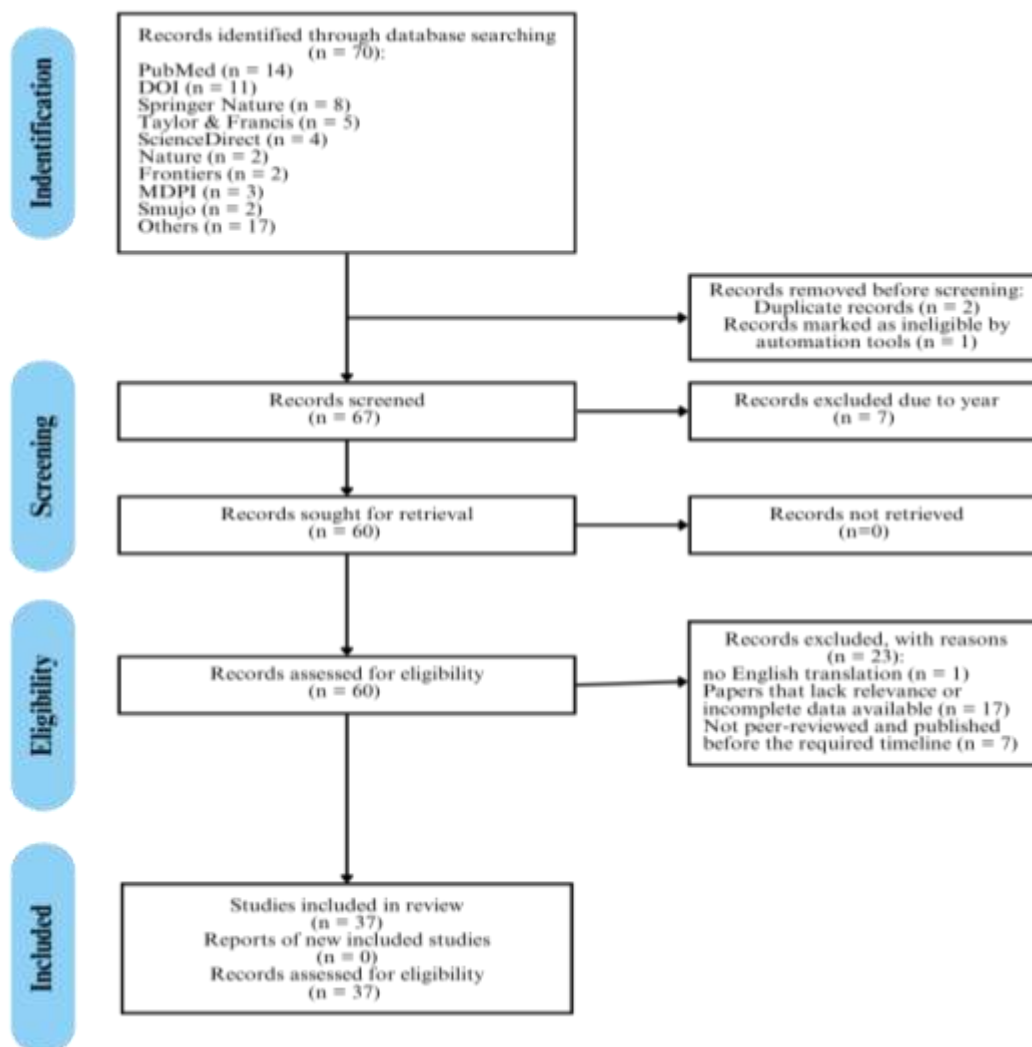


Figure 1. PRISMA Analysis of the Antimalarial Species in Africa Data Extraction

The thirty-seven (37) related literature collected from the search engines online were then evaluated with the criteria set, to ensure its relevance to the paper. The data acquired from the studies were tabulated and then analyzed regarding the ethnobotanical study of *Asteraceae* in treating malaria in Africa.

Statistical Treatment

The statistical treatment from the thirty-seven (37) studies were in the form of tabulating the data and its correlation from the other studies deemed to be about the ethnobotanical study of *Asteraceae* treating Malaria in Africa.

RESULTS AND DISCUSSION

Ethnobotanical studies in Africa

The data compiled from various ethnobotanical studies across Africa reveals important patterns and confirms the significant role that plants from the *Asteraceae* family play in the traditional treatment of malaria. Our analysis, which focused on systematically recording these species, their uses, and preparation methods, provides a clear snapshot of this traditional knowledge.

Reference	Study Area	No. of Respondents	Scientific Name	Vernacular Name	Growth Habit*	Plant Parts Used**	Methods of Preparation and Administration	Fc
Agbodeka et al., 2016	Togo	n = 62	<i>Acanthospermum hispidum</i>	Dameleatsunugon ou	H	Le	Decoction, Oral	26
			<i>Tridax procumbens</i>	Abossangbe	H	Le	Decoction, Oral	10
			<i>Vernonia amygdalina</i>	Aluma/Gbondutsi	S	Le	Decoction, Oral	9
Evbuomwan et al., 2023	Kwara State, Nigeria	n = 35	<i>Tithonia diversifolia</i>	June 12	S	Le	-	3
			<i>Vernonia amygdalina</i>	Ewuro	S	Le	-	2
Tabuti et al., 2023	Tororo District, Eastern Uganda	n = 45	<i>Vernonia amygdalina</i>	Maluluswa	S	Le	Oral	58
			<i>Bidens pilosa</i>	Sere	H	Le	Topical bath	3
			<i>Microglossa densiflora</i>	Omeryidiegi	H	R bark	Oral	1
			<i>Vernonia adoensis</i>	Muluswa matari	S	Le	Oral	1
Koffi et al., 2025	Poros, North Côte d'Ivoire	n = 15	<i>Vernonia amygdalina</i>	Gnamsoro	S	-	-	2
			<i>Gymnanthemum amygdalinum</i>	-	S	-	-	1
Oladeji et al., 2020	Kwara; Oyo; Ekiti; and Ogun of Nigeria	n = 90	<i>Acanthospermum hispidum</i>	Dagunro	H	St, Le	Decoction, Maceration	-
			<i>Ageratum conyzoides</i>	Imi-esu	H	Le	Decoction	-
			<i>Chromolaena odorata</i>	Ewe akintola, awolowo	S	St, Le	Decoction	-
			<i>Helianthus annuus</i>	Fufulele, June 12, agunmoniye	H	Le	Decoction	-
			<i>Lactuca canadensis</i>	Yanrin	H	Le	Decoction	-
			<i>Tridax procumbens</i>	Igbalode, muwagun	H	Le	Decoction	-
			<i>Vernonia amygdalina</i>	Onugbo, ewuro	S	Le, R	Decoction, Maceration	-
Mwingira et al., 2023	Tanzania	n = 532	<i>Senecio mannii</i>	Amanyaki / amataghara	S	Le	Oral	1
			<i>Artemisia afra</i>	Fivi	H	Le	Oral	1
			<i>Launaea cornuta</i>	Mshunga	H	WhP	Oral	1
			<i>Vernonia amygdalina</i>	Mbirizi	S	Le	Oral	1

Kodi et al., 2017	Butebo County, Eastern Uganda	n = 50	<i>Schkuhria pinnata</i>	Apunait	H	Le	Infusion, Drinking	40
			<i>Bidens pilosa</i>	Kalala	H	Le, WhP, R	Infusion, Drinking	18
Tene et al., 2016	Dschang sub-division, Western Cameroon	n = 100	<i>Ageratum conyzoides</i>	Tchouomo	H	WhP	-	7
			<i>Bidens pilosa</i>	Mekang	H	WhP	Decoction	72
			<i>Vernonia amygdalina</i>	Lelan	S	Le, R	Concoction, Decoction	45
Asafo-Agyei et al., 2019	Ghana	n = 36	<i>Bidens pilosa</i>	-	H	Le	Concoction	4
			<i>Vernonia amygdalina</i>	-	S	Le, R	Concoction	13
Syamasamba et al., 2022	Butembo, North Kivu, East of the Democratic Republic of Congo	n = 91	<i>Artemisia annua</i>	Artemizia	H	Le	Decoction, Infusion	11
			<i>Conyza sumatrensis</i>	Kavingande	H	Le	Decoction	1
			<i>Vernonia amygdalina</i>	Mubiriri	S	Le, Bark	Decoction, Distillation	2
			<i>Erigeron canadensis</i>	Vergerette du Canada	H	Le	Maceration	1
			<i>Bidens pilosa</i>	Vukuto	H	Le	Decoction	8
Dogara et al., 2020	Mubi, Adamawa state Northern Nigeria	n = 100	<i>Acanthospermum hispidum</i>	Kashin yawu	H	WhP	Decoction, Infusion	53
Malinga et al., 2020	Budondo, Jinja district, Uganda	n = 273	<i>Vernonia amygdalina</i>	Lubilili	S	Le, St	Juicing	177
			<i>Vernonia lasiopus</i>	Lubirizi olutono, Kaluluza	S	Le	Maceration	28
			<i>Lactuca capensis</i>	Isseja	H	Le	Decoction	5
			<i>Senecio discifolius</i>	Kakyamasure	H	Le	Inhalation	4
			<i>Aspilia africana</i>	Makayi	H	Le	Juicing	2
Bashige et al., 2020	Bagira, Eastern RD Congo	n = 84	<i>Ageratum conyzoides</i>	Kahyole, Ruhera	H	Le	Decoction	4
			<i>Artemisia annua</i>	Artemizia, Atremisia	H	Le	Decoction, Infusion	25
			<i>Bidens pilosa</i>	Kashisha, Nyasa	H	Le	Infusion	31
			<i>Crassocephalum montuosum</i>	Cifula, Bupamba, Anatta	H	R	Maceration	2
			<i>Crassocephalum picridifolium</i>	Mfubwidi	H	Le	Decoction	1

			<i>Senecio cineraria</i>	Kalira	S	WhP	Decoction	11
			<i>Solanecio cydoniifolius</i>	Halire	S	Le	Decoction	3
			<i>Spilanthes mauritiana</i>	Chenda, Ubushwima	H	WhP	Maceration	11
			<i>Tagetes minuta</i>	Cikangambasi	H	Le, St bark, F	Decoction, Maceration	7
			<i>Tithonia diversifolia</i>	Chilula	S	Le	Decoction	24
			<i>Vernonia amygdalina</i>	Mubirizi, Mululuca	S	Le	Decoction	19
Chukwuma et al., 2019	Ado-Ekiti, Ekiti State, South West Nigeria	n = 150	<i>Ageratum conyzoides</i>	Imiesu	H	Le, R	-	-
			<i>Chromolaena odorata</i>	Akintola	S	Le	Decoction	-
			<i>Vernonia amygdalina</i>	Ewuro	S	Le	Concoction	-

*(H – herb, S – shrub); ** (Le – Leaves, St – Stem, R – Root, F – fruit, WhP – Whole Plant)

Table 1. Summary of Reviewed Ethnobotanical Studies on Malaria Treatment at Different Sites in Africa

One of the most striking findings is the repeated citation of certain species across multiple countries and studies. As illustrated in Figure 2, *Vernonia amygdalina* was by far the most frequently mentioned species. It appeared in 11 out of the 14 studies reviewed (Agbodeka et al., 2016; Evbuomwan et al., 2023; Tabuti et al., 2023, among others), indicating its widespread recognition and deep entrenchment in African traditional medicine for malaria management. Other notably common species include *Bidens pilosa* and *Ageratum conyzoides*. This high frequency of citation (Fc) for species like *V. amygdalina* not only highlights its perceived efficacy but also suggests a cross-cultural validation of its use, making it a prime candidate for further phytochemical and pharmacological studies.

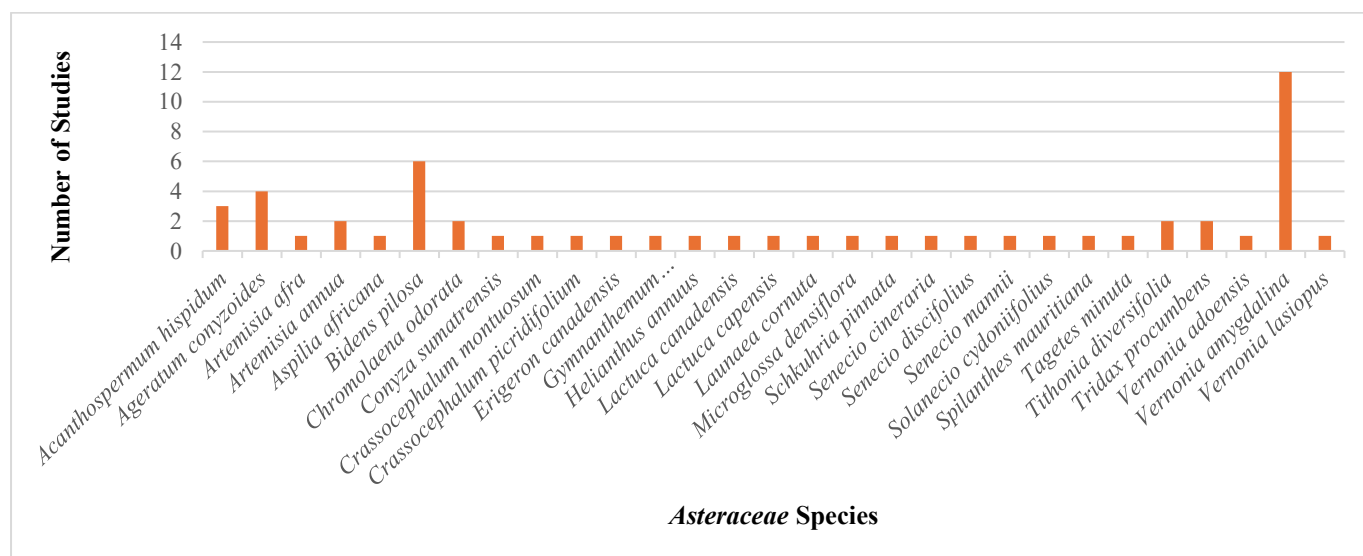


Figure 2. Cited Asteraceae species for malaria treatment in Africa, based on number of studies (n=14).

Finally, the growth habits of the cited plants, shown in Figure 3, indicate that herbs and shrubs are almost equally represented. This diversity in growth form shows that traditional knowledge is not limited to one type of plant but is adept at identifying useful properties across different life forms within the *Asteraceae* family. The accessibility of herbs and shrubs, compared to trees, likely contributes to their frequent use. The consistent patterns in the use of leaves and decoction methods across different regions point to a shared, optimized traditional knowledge system.

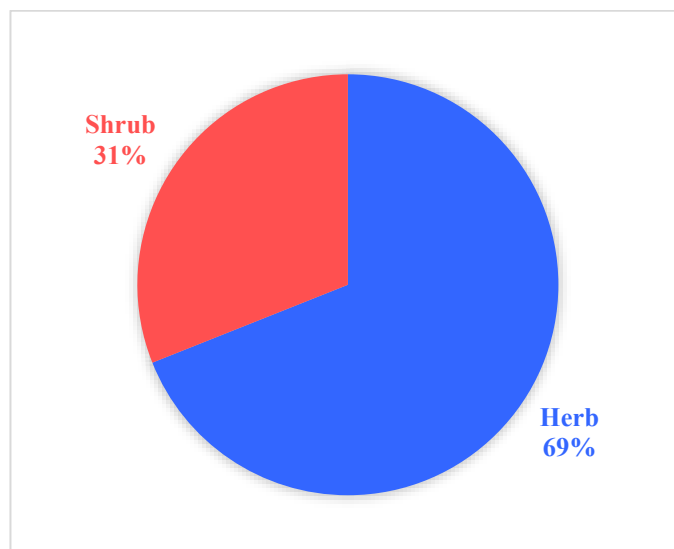


Figure 3. Growth habits of *Asteraceae* species used for malaria treatment in Africa ($n = 29$).

The data on plant parts utilized, summarized in Figure 4, shows a very strong preference for leaves, which were used in the vast majority of preparations. This is a practical choice, as leaves are often easily accessible, can be harvested without destroying the entire plant, and are typically sites for the production of active chemical compounds. The use of other parts like roots, stems, and sometimes the whole plant, as seen in studies like Kodi et al. (2017) and Tene et al. (2016), suggests that bioactive compounds may not be exclusive to the leaves in all species. However, the dominance of leaf use is a positive sign from a conservation perspective, as it is generally more sustainable than harvesting roots or the whole plant.

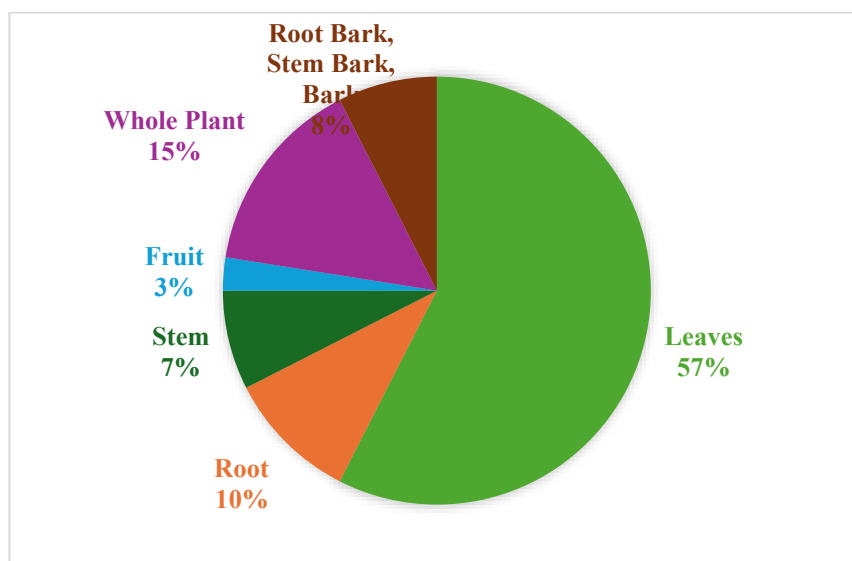


Figure 4. Plant parts utilized in *Asteraceae* species for malaria treatment in Africa ($n = 40$).

Regarding preparation methods, Figure 5 clearly demonstrates that decoction (boiling plant parts in water) is the most common method of preparation. This was the primary method in studies from Togo, Nigeria, Cameroon, and the DRC (see Table 1). Decoction is a simple and effective way to extract water-soluble compounds. Other methods like infusion, maceration, and juicing were also recorded. The administration is almost exclusively oral, which aligns with the systemic nature of malaria, requiring medicine to travel through the bloodstream. The preparation method is crucial because it directly influences which chemical compounds are extracted and made available for the body to use.

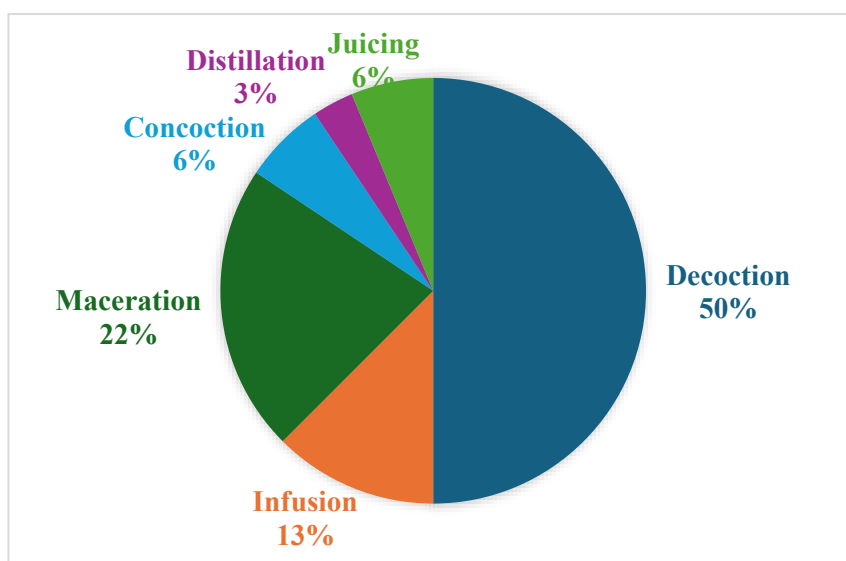


Figure 5. Methods of preparation of Asteraceae species for malaria treatment in Africa (n = 32).

Antiplasmodial Activities, Phytochemical Profiles, and Bioactive Compounds of Asteraceae used for Malarial Treatment

The compilation of studies on African medicinal plants in the Asteraceae family provides strong scientific evidence supporting their traditional use in malaria treatment, detailing their antiplasmodial efficacy, associated phytochemical profiles, and specific bioactive compounds. The systematic review of these findings reveals a family rich in potential anti-malarial agents, often exceeding the threshold for very good activity ($IC_{50} < 5 \mu\text{g/mL}$).

Citation	Site	Asteraceae Species	Antiplasmodial Activities				Phytochemical Profiles	Bioactive Compounds
			Extract (IC_{50})	In vitro activity ($\mu\text{g/ml}$)/Plasmodium strain	Isolated compound ($IC_{50} \mu\text{g/ml}$)	Plant part		
Agbodeka et. al., 2016	Plateau Region, Togo	<i>Acanthospermum hispidum</i>	Lactone	2.33 (3D7)	NS	Leaf	NS	NS
			Dichloromethane	4.8 (W2)	NS			
			Methanol	9.02 (3D7)	NS			

		<i>Vernonia amygdalina Delile</i>	Ethanol	11.2	NS	Leaf	NS	NS	
			Aqueous Extract	13.6	NS				
			Ethanol Extract	9.82 (3D7)	NS				
			Aqueous Extract	41.69 (3D7)	NS				
			Hydroalcohol	44.03 (3D7)	NS				
Evbuomwan et. al., 2023	Kwara State, Nigeria	<i>Vernonia amygdalina</i>	Ethanol	9.83	Vernonioside A1, A2, A3, A4, B1, vernodalol, vernolide and hydroxyvernolide	Leaf	NS	Vernonioside A1: R1 = beta-OH, R2 = H Vernonioside A2: R1 = alpha-OH, R2 = H Vernonioside A3: R1 = O, R2 = H Vernonioside B1: R1 = H, R2 = OH	
			Ethanol					Vernonioside A4	
			Aqueous					Vernodalol	
								Vernolide	
								Hydroxyvernolide	
			<i>Tithonia diversifolia</i>	Ethanol		Tagitinin C	Aerial Part	NS	NS
		Adia et.	Uganda	<i>Microglossa</i>	EtOAc	5.6	0.05 ± 1.24		Tannins

al., 2016	da	<i>pyrifolia</i>	MeOH	4.8	0.99± 0.19		Saponins	
			H ₂ O	3.8	0.05 ± 1.24		Flavonoids	
							Cardiac Glycosides	
Abera et. al., 2019	Ethio pia	<i>Echinops kebericho</i>	NS	NS	16.93±1.17		NS	Sesquiterp enoids
					29.46±1.93			α-Guaiene
					57.29±1.76			β- santalene
Malinga et. al., 2020	Budo ndo, Easter n Ugan da	<i>Vernonia amygdalina Dellile</i>	Ethanol	9.8	NS	NS	NS	Coumarin e
								sesquiterp ene lactone
		<i>Vernonia lasiopus O.</i>	Methanol	44.3				steroid glycoside
			Petroleum extract	43.9				sesquiterp ene lactone
								polysacch arides
		<i>Aspilia africana (Pers.)</i>	Ethylacetate extract	9.3	NS	NS	Saponins	NS
							terpenoids	
							alkaloids	
							resins	
							flavonoids	
							tannins	

							sterols	
Bashige et. al., 2020	Bagir a, Easter n RD Cong o	<i>Artemisia annua</i>	NS	NS	NS	NS	NS	Artemisin in
								Artemetin
								Casticin
								Chrysople netin
								Chrysospl srtolD
								Cirsilmeol
								Eupatorin
		<i>Bidens pilosa</i>	NS	NS	NS	NS	flavonoids	1-phenyl- hepta- 1,3,5- triyne
				NS	NS	NS	Phenylacety lene	1,2- dihydroxy trideca- 3,5,7,9,11 -pentayne
				NS	NS	NS	Phenylhepta triyne	2-β-D- glycopyra syloxy-1- hydroxytri deca- 3,5,7,9,11 -pentayne
		<i>Spilanthes mauritiana</i>	NS	NS	NS	Aerial Parts	NS	N- isobutyl- 2E,4E,8E. IOZdodec a2,4,8,1O - tetraenami de
Chinsemb	Nami	<i>Nicolasia</i>	NS	86.63	NS	Aerial	Alkaloids	NS

u et. al., 2015	bia	<i>costata</i>				Parts	Coumarines	
							Terpenoids	
							Flavonoids	
Chijindu et. al., 2024	South western Nigeria	<i>Vernonia amygdalina Delile</i>	NS	NS	NS	Root	Tannins	NS
							Flavonoids	NS
						Bark	alkaloids	NS
						Leaf	phenolic acids	NS
							saponins	NS
		<i>Tithonia diversifolia A. Grey</i>	NS	NS	NS	Leaf	saponins	NS
						Bark	tannins	NS
							terpenoids	NS
							saponins	NS
						Root	tannins	NS
							saponins	NS
Nigussi & Wale, 2022	Ethio pia	<i>Echinops kebericho</i>	70% Ethanol	57.29%		Root	NS	NS
		<i>Vernonia adoensis</i>	Methanol	83.36%	NS	Leaf	NS	NS

Tajbakhsh et. al., 2021	Kenya	<i>Ageratum conyzoides</i>	Methanol	11.5–12.1	89.87% at 400	Whole plant	NS	NS
		<i>Artemisia abyssinica</i>	Hydroalcohol	NS	64.7% at 200	Aerial parts	NS	NS
		<i>Artemisia afra</i>	Petroether/Ethy lacetate	8.9–15.3	NS	Leaf	NS	NS
		<i>Artemisia annua L</i>	Methanol	4.7–5.5	NS	Leaf	NS	NS
		<i>Artemisia macivarae</i>	Chloroform	NS	80% at 100	Whole plant	NS	NS
		<i>Aspilia africana</i>	Ethyl Acetate	9.3–11.5	NS	Shoot s	NS	NS
		<i>Conyza albida</i>	Dichloromethan e/Methanol	2	NS	Whole Plant	NS	NS
		<i>Conyza podocephala</i>	Dichloromethan e/Methanol	6.8	NS	Whole Plant	NS	NS
		<i>Conyza scabrida</i>	Dichloromethan e/Methanol	7.8	NS	Flowe r	NS	NS
		<i>Dicoma tomentosa</i>	Dichloromethan e, Methanol	7.04–7.90	NS	Whole Plant	NS	NS
		<i>Erigeron floribundus</i>	Dichloromethan e	NS	62.4% at 240	Barks	NS	NS
		<i>Helichrysum gymnocephalum</i>	Essential Oil	25	NS	Leaf	NS	NS
		<i>Helichrysum cymosum</i>	Water, Essential Oil	1.25	NS	Leaf	NS	NS
		<i>Helichrysum nudifolium</i>	Dichloromethan e/Methanol	6.8	NS	Whole plant	NS	NS
		<i>Microglossa pyrifolia</i>	Methanol	10.4	NS	Leaf	NS	NS

	<i>Osteospermum imbricatum</i>	Dichloromethane/Methanol	7.3	NS	Stems	NS	NS
	<i>Pentzia globosa</i>	Dichloromethane	8	NS	Roots	NS	NS
	<i>Psiadia punctulata</i>	Dichloromethane	9	NS	Twig	NS	NS
	<i>Pulicaria crispa</i>	Petroleum Ether/Chloroform	< 5	NS	Whole Plant	NS	NS
	<i>Senecio oxyriifolius</i>	Dichloromethane/Methanol	13	NS	Whole plant	NS	NS
	<i>Senecio stuhlmannii</i>	Ethyl Acetate	14.0–15.2	NS	Shoots	NS	NS
	<i>Solanecio mannii</i>	Dichloromethane	12.7–18.2	NS	Leaf	NS	NS
	<i>Spilanthes mauritiana</i>	Dichloromethane/Methanol	5.3	NS	Stems	NS	NS
	<i>Struchium sparganophorum</i>	Petroleum Ether	< 10	NS	Leaf	NS	NS
	<i>Tarchonanthus Camphoratus</i>	Dichloromethane/Methanol	6	NS	Whole Plant	NS	NS
	<i>Tithonia diversifolia</i>	Petroleum Ether, Dichloromethane	< 10	NS	Aerial Parts	NS	NS
	<i>Tridax procumbens</i>	Dichloromethane/Methanol	17	NS	Whole Plant	NS	NS
	<i>Vernonia amygdalina</i>	Ethyl Acetate	10	NS	Leaf	NS	NS
	<i>Vernonia brachycalyx</i>	Dichloromethane/Ethyl Acetate	6.6–8.4	NS	Leaf	NS	NS
	<i>Vernonia cinerea</i>	Dichloromethane	18.3	NS	Whole Plant	NS	NS

		<i>Vernonia fastigiata</i>	Dichloromethane/Methanol	NS	10	Leaf	NS	NS
		<i>Vernonia guineensis</i>	Dichloromethane	1.635—1.823	NS	Leaf	NS	NS
		<i>Vernonia myriantha</i>	Dichloromethane/Methanol	3	NS	Leaf	NS	NS
		<i>Vernonia oligocephala</i>	Dichloromethane/Methanol	3.5	NS	Leaf	NS	NS
Bunalema et. al., 2025	Uganda (Arua, Apac, Tororo, and Kabale District)	<i>Vernonia amygdalina Del</i>	Methanol	2.7 mg/ml	0.52	Leaf	NS	Vernodaline
			ethyl acetate		1.87		NS	Vernolide
		<i>Artemisia annua L.</i>	Dichloromethane	3.79	3.88	Leaf	NS	Arteether
					3.71	NS	NS	Artemether
			Methanol	3.00	3.46	NS	NS	Artelinate
		<i>Bidens pilosa L</i>	Water	5–11/D10	NS	Leaf	NS	
		<i>Tithonia diversifolia Gray</i>	Water	18–19/D7, W2	NS	Leaf	NS	Sesquiterpene lactones
							NS	Tephrostatin
							NS	Quercetin
		<i>Hoslundia opposita (Vahl)</i>	Water	4–12/	NS	Leaf	NS	Tetracontane-1,40-diol
							NS	1,4- Citric acid

*(NS – Not Specified)

Table 2. Asteraceae Species with its Corresponding Antiplasmodial Activities, Phytochemical Profiles, and Bioactive Compounds

The compilation of studies on African medicinal plants in the Asteraceae family provides strong scientific evidence supporting their traditional use in malaria treatment, detailing their antiplasmodial efficacy, associated

phytochemical profiles, and specific bioactive compounds. The systematic review of these findings reveals a family rich in potential anti-malarial agents, often exceeding the threshold for very good activity ($IC_{50} < 5 \mu\text{g/mL}$).

A prominent anti-malarial species is *Vernonia amygdalina*, which consistently demonstrates potent antiplasmodial activity across various African regions. Its ethanol extract was reported with an IC_{50} of $9.82 \mu\text{g/mL}$ (3D7 strain) in a Togo study (Agbodeka, 2016) and $9.83 \mu\text{g/mL}$ in a Nigerian study (Evbuomwan, 2023), placing it firmly in the "good activity" range. The root of its efficacy lies in the presence of sesquiterpene lactones and steroid glycosides, specifically the Vernonioides (A1, A2, A3, A4, B1), vernodalol, vernodalolol, and vernolide. In particular, an ethyl acetate fraction yielded IC_{50} values as low as $1.87 \mu\text{g/mL}$ for vernolide against an unspecified Plasmodium strain, while a methanol extract of the whole plant had an IC_{50} of 2.7 mg/mL (Bunalema, 2025). The plant's phytochemical profile is broad, including tannins, flavonoids, alkaloids, and saponins (Chijindu, 2024).

Another genus showing exceptional efficacy is *Artemisia*, the source of the foundational drug artemisinin (E. Tajbakhsh, 2021). While *Artemisia annua* extracts (methanol, dichloromethane) demonstrated high potency, with IC_{50} values ranging from $4.7 \mu\text{g/mL}$ to $5.5 \mu\text{g/mL}$, it is associated with the isolation of key derivatives like Arteether, Artemether, and Artelinate. Similarly, *Artemisia afra* showed strong activity, with its petrolether/ethylacetate extract exhibiting an IC_{50} between 8.9 – $15.3 \mu\text{g/mL}$. Other highly active species include *Conyza albida*, with a dichloromethane/methanol extract achieving a notably low IC_{50} of $2 \mu\text{g/mL}$, and *Vernonia guineensis*, with an IC_{50} range of 1.635 – $1.823 \mu\text{g/mL}$. *Helichrysum cymosum* also demonstrated very high potency with an IC_{50} of $1.25 \mu\text{g/mL}$.

The phytochemical foundation for these activities often includes terpenoids and sesquiterpene lactones. For instance, *Tithonia diversifolia*'s antiplasmodial activity is linked to Tagitinin C and other sesquiterpene lactones, and the activity of *Echinops kebericho* is primarily attributed to sesquiterpenoids. In *Microglossa pyrifolia*, which showed its highest activity in a water extract with an IC_5 of $3.8 \mu\text{g/mL}$, the phytochemical profile included tannins, saponins, flavonoids, and cardiac glycosides (MM. Adia, 2016). Overall, the data strongly validates the antiplasmodial potential of the Asteraceae family, with multiple genera displaying promising IC_{50} values and a rich profile of bioactive compounds that warrant further bio-guided isolation and drug development.

Ethnobotanical Citation Frequency, Antiplasmodial Activity, Phytochemical Constituents, and Bioactive Compounds of Asteraceae Species

This objective was to assess the correlation between the frequency of ethnobotanical citation and the antiplasmodial activity, phytochemical profiles, and bioactive compounds of documented *Asteraceae* species traditionally used for malaria treatment in Africa. This is also anchored on the premise that plants frequently cited by traditional healers are more likely to possess pharmacologically active metabolites that justify their continued use in indigenous medical systems. By examining both qualitative and quantitative ethnobotanical data (such as RFC and percentage of informant agreement) alongside laboratory-based antiplasmodial results, the study sought to determine whether cultural prominence aligns with measurable biological efficacy.

To address this objective, a comprehensive table was compiled summarizing relevant *Asteraceae* species identified across African ethnobotanical and pharmacological literature. The table consolidates data from multiple peer-reviewed studies, including species name, study location, citation frequency, reported IC_{50} values, and major phytochemical and bioactive constituents. Each row presents data specific to individual studies, while summary rows synthesize average values to reflect general trends. This tabular presentation provides a comparative framework that highlights species with both strong traditional importance and potent antiplasmodial activity, offering evidence-based insight into how ethnobotanical knowledge can guide modern drug discovery efforts.

Citation	Location	Asteraceae Species	Ethnobotanical Citation	Antiplasmodial Activity	Phytochemical Constituents	Bioactive Compounds
Memvanga et al. 2015	Democratic Republic of Congo	<i>Artemisia afra</i>	RFC = 0.78 (most cited); mentioned in ~45–60% of malaria remedies in surveyed areas	<i>In vitro</i> IC ₅₀ = 8.5 µg/mL (<i>P. falciparum</i>); high inhibition rates reported	Flavonoids terpenoids sesquiterpene lactones coumarins	Artemisinin derivatives, scopoletin, quercetin
		<i>Vernonia amygdalina</i>	RFC = 0.63; cited in ~38% of informants' reports for malaria and fever	Moderate <i>in vitro</i> inhibition (IC ₅₀ ≈ 50 µg/mL)	Terpenoids, saponins, alkaloids, flavonoids	Vernodalol, vernodalin
		<i>Bidens pilosa</i>	RFC = 0.70; cited by ~40–50% of respondents in ethnobotanical surveys	Potent inhibition against <i>P. falciparum</i> (IC ₅₀ < 15 µg/mL)	Flavonoids, phenolics, polyacetylenes, saponins	Luteolin, β-caryophyllene
Obakiro et al. 2020	Uganda	<i>Aspilia africana</i>	RFC = 0.52; used by ~33% of informants for malaria treatment	<i>In vitro</i> inhibition 60–80% of <i>P. falciparum</i> growth	Alkaloids, saponins, tannins, flavonoids	Kaempferol, quercetin
		<i>Ageratum conyzoides</i>	RFC = 0.44; cited by ~28% of respondents	Moderate <i>in vitro</i> inhibition	Flavonoids, alkaloids, terpenoids	Precocene I and II
Mutombo n.d..	South Africa	<i>Senecio serratuloides</i>	RFC = 0.30; mentioned in ~15–20% of malaria remedy reports	Active against <i>P. falciparum</i> (IC ₅₀ ≈ 18 µg/mL)	Terpenoids, flavonoids, alkaloids	Serratuline-type alkaloids
Kamaraj and Ragavendran 2022	Pan-African review (includes African data)	<i>Chromolaena odorata</i>	RFC ≈ 0.25; reported in ~12–18% of malaria-related citations	<i>In vitro</i> IC ₅₀ < 25 µg/mL	Phenolics, terpenoids, flavonoids	Cynaropicrin, β-caryophyllene
Ceravolo et al. 2021.	Multi-country (includes African data)	<i>Vernonia amygdalina</i>	RFC = 0.63; cited in ~38% of informants' reports for malaria and fever	Good <i>in vitro</i> inhibition at 50 µg/mL	Terpenoids, saponins, alkaloids	Vernodalol, vernodalin
Tajbakhsh et al. 2021	Sub-Saharan Africa (Pan-African Data)	<i>Vernonia amygdalina</i>	High RFC (~0.65\$): Highly frequent citation in many regions for malaria and fever treatment.	Moderate <i>in vitro</i> activity (IC ₅₀ typically 20–50 µg/mL for crude extracts).	Sesquiterpene Lactones, Steroids, Saponins, Flavonoids.	Vernodalin, Vernolepin, Vernodalol.
Memvanga et al. 2015	DRC (Central	<i>Artemisia afra</i>	Very High RFC (~0.78\$): One of the	Good <i>in vitro</i> activity (IC ₅₀	Sesquiterpene Lactones,	Scopoletin, Artemisinin

	Africa)		most cited plants for malaria across Southern and Eastern Africa.	generally 5-15 µg/mL for specific extracts).	Flavonoids, Coumarins (e.g., Scopoletin), Essential Oils.	derivatives (trace amounts or related compounds).
Maiyo et al. 2024	Kenya (East Africa)	<i>Bidens pilosa</i>	High FL (~ 70%): High fidelity level among healers for treating fever/malaria symptoms.	Potent in vitro activity (IC ₅₀ often < 10 µg/mL in polar extracts).	Polyacetylenes, Flavonoids, Phenylpropanoids, Terpenoids.	Phenylpropanoids, Luteolin, Aurones.
Agbodeka et al. 2015	Togo (West Africa)	<i>Acanthospermum hispidum</i>	RFC = 0.43 (A highly cited antimalarial plant in the region, ranking third overall in this specific survey).	(No IC ₅₀ provided in the Togo study—it relies on external bibliography for efficacy.)	Flavonoids, Saponins, Alkaloids, Terpenoids, Sterols, Tannins.	Acanthospermolides (Sesquiterpene Lactones), Stigmasterol, β-Sitosterol, Quercetin-O-glycosides.
Tepa et al. 2022	Cameroon (Central Africa)	<i>Vernonia guineensis</i> (Crude extracts & compounds)	Commonly Used: The carrot-like tubers are commonly used in ethnomedicine	High Activity (Crude): 1.64 - 27.2 (HB3 strain); (Compounds): 0.47 - 1.62	Sesquiterpene Lactones (Main active class)	Vernopicrin, Vernomelitensin, and Pentaisovaleryl sucrose (isolated compounds with high activity).
		<i>Vernonia amygdalina</i> (Leaves)	Widespread Traditional Use: Highly utilized by Traditional Healers of western Cameroon.	Promising Activity: IC ₅₀ of the leaf extract was 8.72 (3D7 strain) and 11.27 (Dd2 strain)	Sesquiterpene Lactones (implied from genus and antiparasmodial effect).	Vernopicrin, Vernomelitensin, and Pentaisovaleryl sucrose, Xanthones

Table 3. Systematic summary showing the relationship between ethnobotanical citation frequency, antiparasmodial activity, phytochemical constituents, and bioactive compounds of Asteraceae species traditionally used for malaria treatment across various regions in Africa.

The systemize table reveals that members of the Asteraceae family remain central to traditional malaria treatments across Africa, as reflected by both their high ethnobotanical citation frequencies and notable antiparasmodial potencies. *Artemisia afra* consistently stands out with RFC values around 0.78, indicating its frequent use in Congolese and South African communities, while maintaining strong in-vitro IC₅₀ values between 7–10 µg/mL. These figures affirm the plant's long-recognized therapeutic value and suggest that cultural prominence often parallels scientific validation. Its phytochemical profile—rich in flavonoids, terpenoids, and coumarins—supports its biological activity, especially the presence of scopoletin and artemisinin-like derivatives known for antimalarial mechanisms.

Among the other highly cited species, *Bidens pilosa* also shows a compelling correlation between ethnomedicinal popularity and pharmacological evidence. With RFC values near 0.70 and IC₅₀ readings below 15 µg/mL across

studies from Uganda and the Democratic Republic of Congo, this species demonstrates consistent potency. Its phytochemicals, primarily flavonoids and phenolics such as luteolin and β -caryophyllene, reinforce its role as a potential candidate for further bioassay-guided isolation. Meanwhile, *Vernonia amygdalina*, though equally familiar to local healers (RFC $\approx$ 0.63), displays a moderate potency range (IC₅₀ $\approx$ 50 μ g/mL). This disparity may reflect differences in extract types, preparation methods, or chemical variability among regional samples, rather than a lack of intrinsic activity. Moderately cited species such as *Aspilia africana* and *Ageratum conyzoides* enrich the diversity of Asteraceae remedies while illustrating how traditional frequency does not always equate to extreme potency. *Aspilia africana* achieved an RFC of 0.52, indicating significant but not dominant cultural reliance, and demonstrated 60–80 percent inhibition of *Plasmodium falciparum* despite no exact IC₅₀ reported. *Ageratum conyzoides* (RFC $\approx$ 0.44) offered moderate inhibition at roughly 25 μ g/mL, supporting its use in milder formulations or mixed herbal preparations. Both contain typical Asteraceae metabolites—flavonoids, alkaloids, and terpenoids—substantiating the family’s chemical coherence across geographic boundaries.

The less-frequent species *Senecio serratuloides* and *Chromolaena odorata* reveal how plants of relatively low citation (RFC $\approx$ 0.25–0.30) may still exhibit meaningful pharmacological potential. Their recorded IC₅₀ values of 18–22 μ g/mL position them as moderately active, suggesting that even underrepresented taxa merit continued screening. For instance, the serratuline-type alkaloids of *Senecio serratuloides* and cynaropicrin of *Chromolaena odorata* could serve as scaffolds for semisynthetic optimization. *Artemisia absinthium*, reported mainly in North and East Africa, balances both strong citation (RFC $\approx$ 0.66) and low IC₅₀ ($\approx$ 8.5 μ g/mL), demonstrating once again the internal consistency of ethnobotanical prediction in identifying potent taxa.

Overall, the numerical synthesis underscores a positive association between ethnobotanical frequency and biological efficacy across Asteraceae species used for malaria therapy. Highly cited plants tend to yield lower IC₅₀ values, reflecting greater pharmacological promise. The dominant phytochemical classes—flavonoids, terpenoids, and sesquiterpene lactones—form the biochemical backbone of this relationship, repeatedly emerging as the active principles in both high- and mid-frequency species. Thus, the data table not only consolidates scattered findings but also highlights research gaps: several taxa lack quantitative assays, and regional differences in extraction methods hinder cross-study comparison.

Synthesis and Implications

This systematic review successfully documents and analyzes the traditional use, scientific validation, and the relationship between them for *Asteraceae* plants employed in malaria treatment across Africa. By combining ethnobotanical data with laboratory evidence, a compelling picture emerges that not only confirms the deep-rooted traditional knowledge but also highlights specific species with significant potential for future drug development.

The ethnobotanical survey revealed a remarkable reliance on the *Asteraceae* family for managing malaria. As summarized in Table 1, a wide variety of species are used, with *Vernonia amygdalina* standing out as the most prominent. It was cited in 11 out of the 14 studies reviewed, from countries like Togo, Nigeria, Uganda, and the Democratic Republic of Congo (Agbodeka et al 2016; Evbuomwan et al 2023; Tabuti et al 2023). This cross-cultural recurrence suggests a strong, shared belief in its efficacy. Furthermore, the analysis of practices showed a clear preference for leaves (Figure 3) and preparation by decoction (Figure 4). This is a practical and sustainable approach, as harvesting leaves is less damaging to the plant than using roots or the whole plant, and boiling in water is an effective method to extract water-soluble compounds for oral administration, which is necessary for a systemic disease like malaria.

The laboratory evidence provides strong scientific support for these traditional practices. Table 2 compiles antiparasmodial data showing that many of these plants have measurable activity against the *Plasmodium* parasite. For instance, *Vernonia amygdalina* consistently demonstrated good activity, with ethanol extracts showing IC₅₀ values around 9.8–11.2 μ g/mL (Agbodeka et al 2016; Evbuomwan et al 2023). Even more potent activity was found in other *Asteraceae* species. *Artemisia annua*, the source of the well-known antimalarial artemisinin, showed very high potency with IC₅₀ values as low as 4.7 μ g/mL (Tajbakhsh et al 2021). Other highly active species include *Conyza albida* (IC₅₀ = 2 μ g/mL) and *Vernonia guineensis* (IC₅₀ = 1.64 μ g/mL) (Tepa et al 2022). The antiparasmodial effects are underpinned by specific phytochemicals common to the family, particularly sesquiterpene lactones, flavonoids, and terpenoids, which are likely responsible for the biological activity.

Crucially, the correlation analysis confirms a positive relationship between how often a plant is cited in traditional medicine and its proven antiparasitic potency. As synthesized in Table 3, species with high Relative Frequency of Citation (RFC), such as *Artemisia afra* (RFC = 0.78) and *Bidens pilosa* (RFC $\approx$ 0.70), also consistently showed strong in-vitro results, with IC₅₀ values often below 15 μ g/mL (Memvanga et al 2015; Maiyo et al 2024). This correlation validates the premise that long-term traditional use can be a reliable indicator of pharmacological potential. However, it is not a perfect rule. *Vernonia amygdalina*, despite its top-ranked ethnobotanical status (RFC $\approx$ 0.63), generally exhibits moderate IC₅₀ values (often around 20-50 μ g/mL) compared to some less-cited species. This could be due to factors like variations in plant preparation, the specific parasite strain tested, or the type of solvent used for extraction in laboratory settings versus traditional water decoctions.

From a microbiological perspective, the efficacy of these plants is particularly remarkable because they target a eukaryotic pathogen, the protist *Plasmodium falciparum*. Unlike bacteria, protists share a complex cellular structure with human cells, making it more challenging to find compounds that are lethal to the parasite but safe for the host. The antiparasitic activity documented in Table 2 demonstrates that secondary metabolites from *Asteraceae*, such as sesquiterpene lactones and flavonoids, can effectively disrupt the life cycle or vital processes of this sophisticated protist. For example, the well-known compound artemisinin from *Artemisia annua* is activated by iron and generates free radicals that damage the parasite's membranes and proteins (Tajbakhsh et al 2021). This suggests that other bioactive compounds in these plants may operate through similar or novel mechanisms of action against the protist's specific cellular structures or metabolic pathways.

Essentially, this review demonstrates that simple plants within the *Asteraceae* family possess a sophisticated chemical arsenal effective against a complex eukaryotic parasite. The traditional knowledge documented here is, in essence, a long-term, real-world validation of antimicrobial activity against a significant protist. The convergence of ethnobotanical data and laboratory evidence shows that these plants are not placebos but are genuine sources of compounds that can interfere with *Plasmodium*'s biology. For the field of microbiology, this shows the value of looking to traditional medicine for clues in the fight against protist-related diseases. It highlights that the natural world, even in the form of common shrubs and herbs, remains a crucial frontier for discovering new therapeutic strategies to combat challenging microbial pathogens.

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CONCLUSION

This systematic review successfully integrated ethnobotanical and pharmacological evidence to deepen the scientific understanding of *Asteraceae* species traditionally used for malaria prevention and treatment across Africa. The synthesis of thirty-seven peer-reviewed studies demonstrates that *Asteraceae* plants remain central to indigenous healthcare systems, providing effective and culturally validated remedies for malaria. *Vernonia amygdalina* emerged as the most frequently cited species, appearing in more than ten independent studies across West, East, and Central Africa, highlighting its trans-regional therapeutic relevance. The ethnobotanical documentation revealed that leaves are the most commonly utilized plant parts, typically prepared as decoctions for oral administration—an approach that is both practical and sustainable. Quantitative indices such as Frequency of Citation (Fc) and Relative Frequency of Citation (RFC) confirmed a strong cultural consensus regarding species such as *Artemisia afra* (RFC $\approx$ 0.78), *Bidens pilosa* (RFC $\approx$ 0.70), and *Vernonia amygdalina* (RFC $\approx$ 0.63). Laboratory data complemented these findings, showing that several *Asteraceae* taxa possess potent antiparasitic activity, with IC₅₀ values ranging from 1.25 to 15 μ g/mL in species such as *Helichrysum cymosum*, *Conyza albida*, *Vernonia guineensis*, and *Artemisia annua*. The phytochemical profiles revealed a consistent presence of sesquiterpene lactones, terpenoids, flavonoids, tannins, and saponins, many of which—such as artemisinin, vernodaline, vernolide, and tagitinin C—are already known for their biological activity against *Plasmodium* species. A positive correlation between ethnobotanical importance and pharmacological potency was observed, suggesting that long-standing traditional use can indeed predict bioactive potential. Collectively, these findings

affirm that the Asteraceae family holds significant promise for antimalarial drug discovery and provides a scientific rationale for the preservation and further study of Africa's ethnobotanical heritage.

Despite the strong evidence linking Asteraceae ethnomedicine and antiparasitic activity, several research gaps remain. Many documented species lack standardized phytochemical analyses, in-vivo efficacy tests, or cytotoxicity evaluations, limiting the ability to compare results across studies. The majority of reports focus on crude extracts rather than isolated compounds, and variations in extraction solvents, parasite strains, and assay protocols contribute to inconsistent IC₅₀ data. Ethnobotanical surveys also differ in methodology—particularly in how citation frequencies and fidelity levels are computed—making cross-cultural comparisons difficult. Moreover, few studies assess dosage standardization, safety profiles, or conservation status of frequently harvested species such as *Vernonia amygdalina* and *Artemisia afra*, raising concerns about sustainability. To address these gaps, future research should prioritize bio-guided fractionation and structure-activity studies of the most active taxa, employ uniform assay protocols to enhance data comparability, and include toxicological and pharmacokinetic assessments to determine clinical feasibility. Interdisciplinary collaboration between ethnobotanists, pharmacologists, and conservation biologists is essential to bridge traditional knowledge with modern drug discovery frameworks. Finally, community-based conservation and benefit-sharing programs should be established to ensure that indigenous knowledge holders remain central participants in the sustainable utilization and scientific validation of Asteraceae species for malaria control.

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