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Plant Derived Antimalarial Agents

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Abstract
Malaria is a serious parasitic disease caused by Plasmodium species and transmitted by female Anopheles mosquito. According to World Malaria Report (WHO 2014), there are approximately 250 million malaria cases and near about 1 million people die each year due to malaria. With the increase levels of malaria parasite drug resistance, the herbal knowledge of indigenous communities for malaria treatment can play an important role in identification of new antimalarial plants that is yet to be discovered. In this review, we have highlighted many of those plants all over the world which are being used for the treatment of mlaria and can be the potential source for the development of new antimalarial drugs.

Keywords: Malaria, Plasmodium, Drug resistance, Plants, Parasite

1. Introduction
Malaria is the most prevailing insect borne disease that has victimized about half of the modern civilization and is endemic across more than hundred countries [1]. Malaria is the most common prima health problem in tropical and developing countries of sub-saharan Africa and South East Asia, accountable for the death of one-two million people each year and about 300-500 million people being infected. The fatal rates for this disease are extremely high and it is estimated that nearly half of the world population is at risk [2].
Malaria is caused by Plasmodium parasites, transmitted by female Anopheles mosquitoes, called malaria vector. There are four parasitic species that cause malaria in humans ie. *Plasmodium falciparum*, *Plasmodium vivax*, *Plasmodium valariae* & *Plasmodium ovale*; among them *Plasmodium falciparum* and *Plasmodium vivax* are the most commonly species clinically but P. falciparum is the most deadly leading to fatal complications including cerebral malaria. P. falciparum also infects the liver before invading RBC of the mammalian host. Clinical symptoms of malaria include acute febrile illness accompanied with fever, chills, headache & vomiting, anaemia, respiratory distress, cerebral malaria that can eventually lead to death [3].
The first and most common antimalarial drug, that is still used today, is quinine, isolated from the bark of Cinchona species in 1820 [4]. Another antimalarial drug chloroquine was synthesized in 1940 and was the only drug used for the treatment of malaria [5]. Artemisinine, isolated from *Artemisia annua*, is the most important, discovered and characterized by Chinese scientists that is being used thousands of years to treat malaria. There has been very little improvement in the control of malaria, inspite of various control programs. Control of malaria is complex as the Anopheles mosquito have developed resistance to many insecticides & the appearance of drug resistance strains of Plasmodium [6]. Therefore new drugs or drug combinations are urgently needed that should have novel modes of action or be chemically different from the drugs in current use. Inorder to deal with the expanding problem of drug resistance which continues to challenge malaria control efforts, new antimalarial drugs are needed.
Conventional remedies plays an important role in the economy and viable growth of developing nations. Their life is purely dependant on traditional knowledge system of herbal plants for curing various ailments. The indigenous people are exploiting a range of herbals for effective treatment of various diseases involving malaria. Ethno-medicinal and ethnobotanical studies have provided vast scope and possibility for the development and synthesis of new drugs. Modern drugs have been deducted from folklore and traditional medicine. There are about 1200 plant species from 160 families used to treat malaria [7]. According to WHO, about 60 % of world's people use herbal medicine for treating their sickness [8].

Various cultural traditions are associated with the use of wild plants as medicinal herbs to cure specific ailment since ancient times. This medico lore is passed over generations traditionally all over the world. Globally, numerous medicinal plants are used by the traditional healers for the treatment of malaria. However, this practice is not acknowledged wholly by current medicine. Large number of plant species have been identified as antimalarial plants. Several plant varieties have been identified through ethnobotanical and ethnopharmacological studies as antimalarial medicinal plants. This review is an attempt to present a comprehensive account of numerous medicinal plants used in the treatment of malaria. A thorough literature survey highlights that plant kingdom has enormous resources which can be exploited for unidentified novel compounds with antimalarial activity.

Table 1: Plants with antiplasmodial activity

Sr No	Plant	English name/ Local Name	Family	Natural habitat	Parts used	Active constituents
1.	*Acanthospermum hispidum* [9]	Bristly starbur	Asteraceae	Central & South America	Aerial parts	Alkaloids, flavonoids
2.	*Acalypha wilkensiana* [10]	Copper plant	Euphorbiaceae	Pacific islands	Leaves	Alkaloids, flavonoids, saponins, tannins
3.	*Acokanthera schimperi* [11]	Arrow poison tree	Apocynanceae	Africa	Leaves	Glycosides
4.	*Adhatoda zeylanica* [12]	Vasa	Acanthaceae	Malabar nut	Leaves	Alkaloids, flavonoids, tannins, saponins
5.	*Ageratum connyzoides* [13]	Billy goat weed	Asteraceae	Brazil, Kenya	Aerial parts	Alkaloids, flavonoids, coumarins, essential oils
6.	*Ajuga integrifolia* [14]	Bugleweed	Lamiaceae	Ethopia, Asia	-----	Terpenoids, iridoid glycosides, flavonoids, essential oils
7.	*Ajuga remota* [15]	Armagusa	Labiateae	Ethopia, Africa	Aerial parts	Flavonoids, alkaloids, tannins, terpenoids
8.	*Allanblackia floribunda* [16]	Tallow tree	Clusiaceae	Africa	Aerial parts	Flavonoids, xanthanoids, essential oil
9.	*Allophylus africanus* [17]	False Currant	Sapindaceae	Africa	Whole plant	Flavonoids, polyphenols, essential oils
10.	*Albizia zygia* [18]	West African walnut	Leguminoseae	Africa	Aerial parts	Flavonoids
11.	*Alstonia macrophylla* [19]	Hard Milkwood	Apocynaceae	India, Malaysia, Thailand	Bark	Alkaloids, flavonoids, terpenoids, saponins, tannins
12.	*Ampelozizyphus amazonicus* [20]	Saracura mira	Rhamnaceae	Amazon region	Stem, root	Saponins, terpenoids, steroids
13.	*Annona squamosa* [21]	Wild sweetsop	Annonaceae	S. America	Aerial parts	Alkaloids, glycosides, flavonoids
14.	*Angelica purpuraefolia* [22]	Bai jhi	Apiaceae	S. America, Africa	Rhizome	Khellactone, triterpenes
15.	*Anisochilus harmandii* [23]	Kapurli	Lamiaceae	Asia	Aerial parts	Terpenoids, flavonoids
16.	*Aphanamixis grandifolia* [24]	Rohitukka tree	Meliaceae	Asia	Bark	Terpenoids
17.	*Aristolochia griffithi* [25]	Birth wort	Aristolochiaceae	N.E. India	Root	Alkaloids,
18.	*Artemisia annua* [26]	Sweet wormwood	Asteraceae	Asia, N. America	Aerial parts	Flavonoids, essential oils, sesquiterpene lactones
19.	*Artemisia armeniaca* [27]	Sagebrush	Asteraceae	Iran	Aerial parts	Essential oils, flavonoids
20.	*Asparagus africanus* [28]	African asparagus	Asparagaceae	Africa	Whole plant	Alkaloids, terpenoids
21.	*Aspidasperma olivaceum* [29]	Copperpod	Apocynaceae	Brazil	Leaves, Bark	Alkaloids
22.	*Aspilia pruliseta* [30]	----------	Asteraceae	Uganda	Aerial parts	Terpenoids
23	*Azadirachta indica* [31]	Neem	Meliaceae	India	Whole plant	Terpenoids, essential oils
24	*Bambusa vulgaris* [32]	Cana brava	Poaceae	Asia	Aerial parts	Flavonoids, lactones
25	*Berberis aristata* [33]	Indian barberry	Berberidaceae	India	Roots	Alkaloids, tannins
26	*Berginia ciliata* [34]	Hairy Berginia	Saxifragaceae	Africa	Leaves	Alkaloids, terpenoids, phenols
27	*Beilschmiedia zenkeri* [35]	Akolodo	Lauraceae	Cameroon, Congo	Aerial parts	Alkaloids, flavonoids
28	*Bixa orellana* [36]	Achiote	Bixaceae	N & S. America	Whole plant	Essential oils
29	*Brassica nigra* [37]	Indian mustard	Brassicaceae	Asia	Seeds	Flavonoids, polyphenols, essential oils
30	*Bridelia ferrugenia* [38]	Kizni	Euphorbiaceae	Africa, Nigeria	Stem bark	Alkaloids, saponins, flavonoids
31.	*Brucea mollis* [39]	Karbi	Simaroubaceae	India, Nepal Malaysia	Root	Alkaloids, terpenoids, quassinoids
32.	*Caesalpinia*	Fever nut	Caesalpiniaceae	Tanzania	Whole part	Alkaloids, terpenoids, glycosides,

	bonducella [40]					saponins
33	*Caesalpinia sappan* [41]	Heartwood	Fabaceae	Brazil	Seeds	Alkaloids, terpenoids, glycosides, saponins
34	*Caesalpinia minax* [42]	-------	Caesalpiniaceae	South East Asia	Seeds	Diterpene alkaloids
35	*Caesalpinia volkensii* [43]	Kikuyu	Fabaceae	Tanzania, Kenya	Stem bark	Flavonoids, tannins
36	*Carica papaya* [44]	Papaw	Caricaceae	India, Africa, America	Leaves	Alkaloids, flavonoids, glucosides
37	*Canthium multiforum* [45]	Laager	Rubiaceae	Cameroon	Whole plant	Alkaloids, terpenoids, tannins
38	*Canella winterana* [46]	Wild cinnamon	Canellaceae	West Indies	Leaves	Essential oils, sesquiterpenoids
39	*Cedrelopsis grevei* [47]	Katrafay	Meliaceae	Madagascar	Leaves	Essential oils
40	*Clausena anisata* [48]	Horsewood	Rutaceae	Africa	Leaves	Alkaloids, essential oils
41.	*Cassia fistula* [49]	Golden shower	Fabaceae	India, Amazon, Sri Lanka	Leaves, fruit, bark	Flavonoids, anthraquinones
42.	*Cassia siamea* [50]	Kasood tree	Fabaceae	S.E. Asia	Leaves	Alkaloids
43	*Cassia sieberiana* [51]	Drumstick tree	Caesalpinioideae	Africa	Root, stem	Flavonoids, alkaloids, stilbenes
44	*Carapa guianensis* [52]	Crabwood	Meliaceae	Amazon region, America	----------	Essential oil
45	*Christia vespertilionis* [53]	Red butterfly wing	Fabaceae	S.E.Asia	Roots, leaves, stem	Tritepenes, alkaloids, phenols
46	*Chukrasia tabularis* [54]	White cedar	Meliaceae	India, China, Bangladesh	Stem bark	Limonoids, tetranorriterpenoids
47	*Cissampelos pareira* [55]	Velvet leaf	Menispermaceae	Asia, Africa	Roots	Alkaloids, terpenoids, tannins
48	*Citropsis articulata* [56]	African cherry orange	Rutaceae	Africa	Root bark	Alkaloids, terpenoids, saponins, tannins
49	*Citrus medica* [57]	Citron	Rutaceae	S.E Asia	Aerial parts	Essential oil
50	*Citrus limetta* [58]	Sweet lime	Rutaceae	S.E.Asia	Fruit peel	Flavonoids, glycosides, phenols, essential oils
51.	*Clerodendrum rotundifolium* [59]	Bagflower	Lamiaceae	Asia, Africa, America	Aerial parts	Alkaloids
52.	*Clerodendrum viscosum* [60]	Thuner	Lamiaceae	Asia, Africa, America	Whole plant	Alkaloids, sesquiterpene lactones
53	*Clausena harmandiana* [61]	Prong faa	Rutaceae	Thailand	Aerial parts	Alkaloids, coumarins, essential oils
54	*Corydalis dubia* [62]	Re -skon	Papaveraceae	Bhutan, India	Whole plant	Alkaloids
55	*Corymbia watsoniana* [63]	Yellow bloodwood	Myrtaceae	Australia	Flower	Triketones
56	*Croton gratissimus* [64]	Lavender croton	Euphorbiaceae	Africa	Leaves	Cembranolides
57	*Croton macrostachyus* [65]	Broad leaved cotton	Euphorbiaceae	Kenya, Ethopia, Nigeria	Leaves	Alkaloids, flavonoids, terpenes, saponins
58	*Cryptolepis sanguinolenta* [11]	Nibima, Kadze	Periplocaceae	Africa	Roots	Alkaloids
59	*Cryptocarya rigidifolia* [66]	----------	Lauraceae	Africa, Indonesia	Root wood	Tetrahydropyrone derivatives
60	*Cryptocarya nigra* [67]	Medang	Lauraceae	Indonesia	Stem bark	Alkaloids
61.	*Cuminum cyminum* [68]	Cumin	Apiaceae	India, Pakistan, Iran	Seeds	Essential oils, alkaloids, flavonoids, saponins, coumarins
62.	*Dasymaschalon obtusipetalum* [69]	Jing wang	Annonaceae	Thailand	Twigs	Alkaloids
63	*Datisca glomerata* [70]	Durango	Datiscaceae	N.America	Whole plant	Triterpene hydrocarbon derivatives, cucurbitacin glycosides
64	*Dendrobium venustum* [71]	----------	Orchidaceae	Thailand, Combodia	Whole plant	Phenolic compounds
65	*Dicoma tomentosa* [72]	Hookiah bel	Asteraceae	Africa, Asia	Whole plant	Sesquiterpene lactone
66	*Dillenia andamanica* [73]	----------	Delleniaceae	Australia, Indian islands	Whole plant	Flavonoids, triterpenoids, saponins, phenolics
67	*Duranta repens* [74]	Golden dew drop	Verbenaceae	Mexico, S. America	Whole plant	Iridoid glycosides, flavonoids, alkaloids
68	*Echinops kebericho* [75]	Amhar	Asteraceae	Ethopia	Roots	Essential oils
69	*Eleucine indica* [76]	Yard grass	Poaceae	Warmer areas of world	Whole plant	Phenolic compounds, flavonoids
70	*Enantia polycarpa* [77]	Osopupa	Annonaceae	Nigeria	Stem bark	Alkaloids
71.	*Enkleia siamensis* [78]	Chamar jasmine	Thymelaeaceae	Australia	Roots	Flavonoids

72.	*Eremostachys macrophylla* [79]	----------	Lamiaceae	Iran	Aerial parts, rhizome	Essential oils
73	*Erythrina burttii* [80]	Rattlepod	Fabaceae	Kenya, Ethopia	Root, stem bark	Flavonoids
74	*Erythrina fusca* [81]	lucky bean tree	Fabaceae	Asia, Africa	Stem bark	Flavonoids, pterocarpans,
75	*Erythrina indica* [82]	Indian coral	Fabaceae	Asia	Stem	Alkaloids, flavonoids, streroids
76	*Erythrina schliebenii* [40]	Mlindimila	Fabaceae	Tanzania	Stem, bark	Flavonoids, alkaloids, terpenoids
77	*Faidherbia albida* [83]	Winter thorn	Mimosiodae	Africa, Nigeria	Stem bark	Alkaloids, tannins, saponins
78	*Ficus thonningii* [84]	Wild fig	Moraceae	Africa, Nigeria	Whole plant	Flavonoids, alkaloids, terpenoids, tannins, essential oils
79	*Flacourtia indica* [85]	Batoku palm	Salicaceae	Asia, Africa	Aerial parts	Poliothrysoside
80	*Garcinia mangostana* [86]	Purple mangosteen	Clusiaceae	Asia, Africa, Australia	Aerial parts	Xanthones
81.	*Garcinia xanthochymus* [87]	Yellow mangosteen	Clusiaceae	Asia, Africa, Australia	Aerial parts	Benzophenones
82.	*Geissospermum vellosii* [88]	Bergibita	Apocynaceae	Brazil	Stem bark	Alkaloids
83	*Goniothalamus elegant* [89]	Kao nang nee	Annonaceae	Africa, Asia	Bark	Tetrahydropyran derivatives
84	*Goniothalamus australis* [90]	China pine	Annonaceae	Australia	Aerial parts	Alkaloids, lactones
85	*Glycyrrhiza glabra* [91]	Licorice	Fabaceae	Asia, Europe	Roots	Flavonoids, saponin glycosides
86	*Holarrhena pubescens* [40]	Tellicherry bark	Apocynaceae	Africa, India	Roots	Triterpenoids, steroids, alkaloids
87	*Himatanthus articulates* [92]	Sucuba	Apocynaceae	Brazil	Stem bark	Triterpenoids, iridoids
88	*Horsfieldia spicata* [93]	Belu itam	Myristacaceae	Asia	Whole plant	Procyanidins
89	*Hunteria zeylanica* [94]	Lahoi	Apocynaceae	Asia, Africa	Bark	Alkaloids
90	*Hypericum lanceolatum* [95]	----------	Hypericaceae	Africa	Stem bark	Terpenoids, xanthones, flavonoids
91	*Icacina senegalensis* [96]	False yam	Icacinaceae	Africa	Leaves	Alkaloids, saponins, tannins, terpenoids
92.	*Indigifera oblongifolia* [97]	Jhil	Papilionaceae	Africa	Leaves	Alkaloids, tannins
93	*Jasminum syringifolium* [74]	Jasmine	Oleaceae	Andaman & Nicobar Islands	Leaves	Essential oils
94	*Jatropha ribifolia* [98]	Pohl	Euphorbiaceae	America	Whole plant	Terpenoids, coumarins, essential oils
95	*Keetia leucantha* [99]	Buje	Rubiaceae	Africa	Twigs	Essential oils, tripenic acids
96	*Kniphofia foliosa* [100]	Torch lily	Asphodelaceae	Africa	Rhizome	Quinones
97	*Lettowianthus stellatus* [101]	----------	Annonaceae	Tanzania, Kenya	Fruits	Geranylbenzoquinoids, aporphinoid alkaloids
98	*Liriodendron tulipifera* [102]	Lily tree	Magnoliaceae	N.America	Bark, leaves	Alkaloids, sesquiterpenoids
99	*Lippia javanica* [103]	Lemon bark	Verbenaceae	Africa	Aerial parts	Lippialactone
100	*Lophira alata* [86]	Red ironwood	Ochnaceae	Africa	Aerial parts	Chalcones, biflavonoids
101	*Lycoris radiata* [104]	Red magic lily	Amaryllidaceae	China, Korea	Bulbs	Alkaloids
102	*Magnifera indica* [44]	Mango	Anacardiaceae	Asia	Aerial parts	Flavonoids, polyphenols, glycosides
103	*Mammea Africana* [55]	African apple	Callophyllaceae	Africa	Aerial parts	Alkaloids, flavonoids, diterpenoids
104	*Mallotus oppositifolius* [105]	Geisel	Euphorbiaceae	Africa	Leaves	Phloroglucinols
105	*Markhamia tomentosa* [106]	Fula pulaar	Bignoniaceae	Africa	Stem bark	triterpenoid saponins
106	*Maytenus mekongensis* [107]	----------	Celasteraceae	Asia, Africa	Roots	Sesquiterpene alkaloids
107	*Meconopsis simplicifolia* [108]	Blue poppy	Papaveraceae	Nepal	Aerial parts	Alkaloids
108	*Mitrephora diversifolia* [109]	----------	Annonaceae	Australia	Roots	Azafluorenone Alkaloids
109	*Momordica foetida* [59]	Wild cucumber	Cucurbitaceae	Africa	Leaves	Alkaloids, flavonoids, terpenoids,

						steroids
110	*Muntafara sessilifolia* [110]	Baker	Apocynacaea	Madagascar	Stem bark	Indole Alkaloids
111.	*Myrtus communis* [111]	True myrtale	Myrtaceae	Iran	Aerial parts	Coumarins, flavonoids, essential oils
112.	*Nardostachys chinensis* [112]	--------	Valerianaceae	S.E Asia	Whole plant	Sesquiterpenoids
113	*Nauclea latifolia* [113]	African peach	Rubiaceae	Africa	Stem bark	Alkaloids, tannins, saponins
114	*Neoboutonia macrocalyx* [114]	Lace leaf	Euphorbiaceae	Africa	Stem bark	Triterpenoids
115	*Neonauclea purpura* [115]	Purple Neo Cheesewood	Rubiaceae	Asia, Australia	Stem bark	Alkaloids
116	*Newbouldia laevis* [116]	Balanta, akoko	Bignoniaceae	Africa	Aerial parts	Flavonoids, alkaloids, saponins
117	*Ocimum basilicum* [117]	Basil	Lamiaceae	Asia	Leaves	Flavonoids, essential oils
118	*Ocimum sauve* [118]	Wild basil	Lamiaceae	Africa	Leaves	Essential oils
119	*Ocimum sanctum* [32]	Holy basil	Lamiaceae	India	Leaves	Phenols, terpenoids
120	*Ormocarpum kirkii* [119]	Curled caterpillar bush	Leguminoseae	Tanznia, Zimbabwe	Roots	Flavonoids, coumarins
121.	*Otostegia integrifolia* [120]	Abyssinian rose	Lamiaceae	Ethopia	Leaves	Diterpenoids
122.	*Panicum maximum* [121]	Guinea grass	Poaceae	Africa, Palestine	Leaves	Essential oil, flavonoids
123	*Pedilanthus tithymaloides* [74]	Red bird flower	Euphorbiaceae	India, North America	Aerial parts	Phytosterols, flavonoids
124	*Pentas bussei* [122]		Rubiaceae	Tanzana, Kenya	Roots	Naphthohydroquinones
125	*Picrorhiza scrophulariiflora* [123]	Figwort	Plantaginaceae	India, Nepal, China	Whole plant	Secoiridoid & caffeoyl glycosides
126	*Piper nigrum* [124]	Black pepper	Piperaceae	Asia	Fruit	Alkaloids, essential oils, flavonoids
127	*Piper peltatum* [125]	Monkeys hand	Piperaceae	N.America	Aerial parts	Essential oils
128	*Piptocoma antillana* [126]	Velvet shrub	Asteraceae	Latin America	Leaves, twigs	Terpenoids, seqsuiterpene lactone
129	*Physalis angulata* [127]	Balloon cherry	Solanaceae	America	Whole plant	Flavonoids, alkaloids, steroids
130	*Polyalthia longifolia* [128]	False ashoka	Annonaceae	India, Sri lanka	Stem	Alkaloids, steroids, tannins, flavonoids
131.	*Plectranthus barbatus* [126]	Forskohlii	Lamiaceae	S.America, Asia	Root bark	Flavonoids, diterpenoids
132.	*Pleurospermum amabile* [129]	----------	Apiaceae	Bhutan	Whole plant	Phenylpropanoids, furanocoumarins
133	*Plumbago zeylanica* [130]	Doctor bush	plumbaginaceae	America, Mexico	Roots	Alkaloids, steroids, tannins, triterpenoids, flavonoids, saponins
134	*Piper umbellate* [131]	Cow foot leaf	Piperaceae	S.America	Aerial parts	4-nerolidylcathecol
135	*Phyllanthus amarus* [132]	Black catnip	Phyllanthaceae	America, Asia	Aerial parts	Alkaloids, flavonoids, tannins, terpenoids
136	*Phyllanthus urinaria* [133]	Gripeweed	Phyllanthaceae	Asia	Whole plant	Alkaloids, flavonoids, tannins, terpenoids
137	*Psidium acutangulum* [134]	Para guava	Myrtaceae	French Guinea	Aerial parts	Triterpenoids
138	*Punica granatum* [135]	Pomegranate	Lythraceae	Africa, Asia	Whole plant	Flavonoids, anthocyanins
139	*Quassia amara* [136]	Bitter ash wood	Simaroubaceae	Africa	Leaves	Quassinoids
140	*Ritchiea capparoides* [137]	----------	Capparidaceae	Africa, Nigeria	Leaves	Alkaloids, saponins, tannins, sesquiterpenes
141.	*Rumex crispus* [138]	Curly dock	Polygonaceae	Asia, America	Aerial parts	Flavonoids, anthraquinones, naphthalenes
142.	*Salvia rhytidea* [139]	Persian sage	Lamiaceae	Iran, Afghanistan	Roots	Diterpenoids
143	*Salacia longipes* [140]	Oliver	Celasteraceae	Africa	Seeds	Sesquiterpenoids
144	*Schizanthus tricolor* [141]	Poor man's orchid	Solanaceae	Chile, Argentina	Aerial parts	Alkaloids
145	*Senna occidentalis* [122]	Mogdad coffee	Fabaceae	America, Asia	Leaves	Anthraquinone glycoside, fatty oils, glycosides, flavonoids, tannins
146	*Schima wallichi* [142]	Needlewod tree	Theaceae	India, Nepal, Bhutan	Leaves	Quinones, glycosides, coumarins, flavonic glycosides
147	*Sophora molis*	Low mountain	Fabaceae	Asia, Australia	Roots	Flavonoids

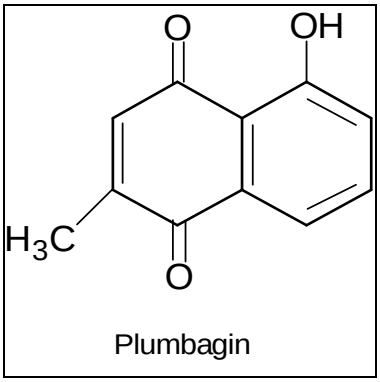
	[143]	laurel				
148	*Stephania abyssinica* [144]	Beiyanzi	Menispermaceae	Kenya, Zimbabwe	Leaves	Alkaloids
149	*Strychnos malacoclados* [145]	----------	Loganiaceae	Africa	Stem bark	Alkaloids
150	*Symphonia globulifera* [146]	Chewstick	Clusiaceae	America, Africa	Leaves	Benzophenones, xanthones
151.	*Tachia grandiflora* [147]	Mahot noir	Gentianaceae	Brazil	Roots, leaves	Xanthenoids, monoterpenoids
152	*Telfairia occidentalis* [148]	Fluted gourd	Cucurbitaceae	Africa, Nigeria	Leaves, seeds	Alkaloids, flavonoids, saponins, tannins
153	*Teucrium ramosissimum* [149]	----------	Lamiaceae	----------	Aerial parts	Sesquiterpenoids, flavonoids; essential oils
154	*Thalictrum foliolosum* [25]	Meadow rue	Ranunculaceae	N.E.India	Aerial parts	Alkaloids, phenols, triterpenoids, sapnins, phytosterols
155	*Tinospora cordifolia* [55]	Guduchi	Menispermaceae	Asia	Aerial parts	Alkaloids, glycosides, seaquiterpenoids
156	*Toddalia asiatica* [150]	Orange cucumber	Rutaceae	Africa, Asia	Root bark	Flavonoids, alkaloids, steroids, saponins, coumarins
157	*Trichilia megalantha* [151]	African nut tree	Meliaceae	Africa	Leaves, roots	Quassinoids, alkaloids, flavonoids
158	*Tridex procumbens* [143]	Tridex daisy	Compositae	America, Asia	Aerial parts	Flavonoids, steroids, triterpenoids, alkyl esters
159	*Vernonia amygdalina* [152]	Bitterleaf	Asteraceae	Africa	Leaves	Tannins, saponins, flavonoids, alkaloids, steroids, phenols
160	*Vernonia guineensis* [153]	Ewuro-olopaa-kan	Asteraceae	Africa	Whole plant	Tannins, saponins, flavonoids, alkaloids, steroids, phenols
161.	*Viola websteri* [154]	---------	Violaceae	Asia	Whole plant	Alkaloids, quassinoids, sesquiterpenes
162	*Withania somnifera* [28]	Winter cherry	Soanaceae	India	Aerial parts	Alkaloids, steroidal lactones
163	*Xylocarpus granatum* [155]	Cannonball mangrove	Meliaceae	Asia, Africa, Australia	Fruits	Flavonoids, alkaloids, tannins, teriterpenes, steroids
164	*Zanthoxylum chalybeum* [59]	Knob wood	Rutaceae	Africa	Stem bark	Coumarins, alkaloids, essential oils
165	*Zanthoxylum monophyllum* [156]	Yellow prickle	Rutaceae	Africa	Leaves, bark	Coumarins, alkaloids, essential oils

Table 2: Active chemical constituents from some antimalarial plants

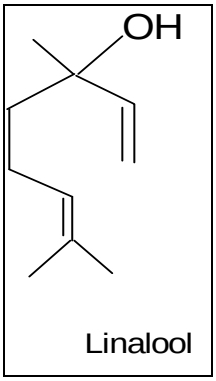
Sr No.	Plant Name	Chemical Constituents	Reference
1.	Acanthospermum hispidum	Guaianolides 1 & 2, Acanthospermal B, N-heptacosanol, Triacontane, N-butil eicosante	157
2.	Adhatoda vasica	Vasicine, Vasicinone, Vasicol, Vasicinolone	158
3.	Adhatoda zeylanica	Vasicine, Vasicinone	159
4.	Ageratum connyzoids	Echinatine, Lycopsamine, Precocene I & II, Spinasterol	160
5.	Ajuga remota	Harpagide, Cyasterone, Sangosterone; 2,3-diacetylharpagide	161
6.	Aphanamixis grandifolia	Nemoralisin D, E, F	162
7.	Allophyllus africanus	Hanocokinoside, alloeudesmenol, allotaraxerolide	163
8.	Angelica purpuraefolia	Hydroxylomatin, khellactone	164
9.	Albizia zygia	4,7- dihydroxyflavanone; 3,4,7 trihydroxyflavone; 3-O-methylfisetin	165
10.	Annona squamosa	Squamocin, Motrilin, Annotemoyin-2	166
11.	Artemisia annua	Myrcene, 1,8- cineole, linalool, borneol, scopoletin, β-caryophyllene, casticin, chrysosplenol, chrysosplenetin, α-pinene	167-168
12.	Aspidosperma olivaceum	Aspidoscarpine, Uleine, Apparicine, Olivacine	169
13.	Azadirachta indica	Azadirachtin, Gedunin, Nimbidin, Nimbin, Nimbolide	170
14.	Bixa orellana	Lutein, Norbixin, Trans bixin, Tormentic acid, Spathulenol, Ishwarane, β-humulene, Stigmasterol, Sitosterol	171
15.	Berberis aristata	Berbamine, Barberine, Oxyberberine, Karachine, Pakistanine, Oxycanthine	172
16	Bergenia ciliata	Bergenin, Gallicin, Gallic acid, catechin	173
17	Bridelia ferruginea	Quercetin, Quercetin 3- glucoside, Rutin, Myrcetin 3- glucoside, Myrcetin 3-rhamnoside	174
18	Brucea mollis	Bruceolline E, Bruceolline F, Bruceine D, Yadanziolide B	175
19	Canthium multiforum	Scopoletin, Hymexelsin, 6,7-dimethoxucoumarin	176
20	Canella winterana	B-caryophyllene, β-farnesene	177
21	Citrus limetta	Sabinene, Linalool, Geraniol, γ-terpenene, β-bisabolene, Myrcene	178
22	Caesalpinia bonducella	Bonducellin, Caesalpinin, α & β-caesalpin, Caesaldekarin C & F	179
23	Cissampelos pareira	Cissampelosine, Grandirubrine, Isoimerubrine, Cissamine, l-curine	180

24	Cassia fistula	Sennoside A, B; Fistulic acid, Chrysophanol	181
25	Chukrasia tubularis	Sitosterol, Quercetin, Scopoletin, Cedrelone, Tabulalin, Tabulalide A-D, Melianone, Chukrasin A & B	182
26	Clausena anisata	Calusamine D-G, Heptaphyllene, Girinimbine, Ekeberginine, Furanoclausamines A & B, Indicolactone	183
27	Corydalis dubia	Dubiamine, Scoulerine, Protopine, Capnoidine, Hydrastine, Becuculline	184
28	Caessalpinia sappan	Caesalpin J & P, Sappanol, Protosappaninn A, B, C, E1, E2	185
29	Citropsis articulate	Trigonelline, Rutarin, Seselin, Suberosin, Omubioside	186
30	Cedrelopsis grevei	β-farnesene, β- elemene, α-copaene	187
31	Croton macrostachys	Crotepoxide, Lupeol, betulin, Crotomacrine, Trachylina-18-oic acid	188
32	Clausena harmandania	Harmandianamines A, B, C; Clausamine A, B; Clausine D & F; Heptaphylline	189
33	Corymbia watsoniana	Watsonianones A, B, C	190
34	Cryptolepis sanguinolenta	Isocryptolepine, Cryptospirolepine, Cryptolepine	191
35	Cryptocarya rigidifolia	Cryptorigidifoliols A-E, F-K	192
36	Datisca glomerata	Datiscacin	193
37	Dendrobium venustum	Densiflorol B, Gigantol, Phoyunnanin	194
38	Dicoma tomentosa	Germacranolides, Melampolides, urospermal A	195
39	Duranta repens	Ursolic acid, Durantoside I, II	196
40	Enkleia siamensis	Ormocarpin, Carthamidin, Daphnoretin	197
41	Eremostachys macrophylla	Hexadecanoic acid, Isobutyl phthalate, Ethyl linoleate, Germacrene D, α-cadinol	198
42	Erythrina burttii	Burttinol A, B, C, D	199
43	Goniothalamus australis	Goniothalines A, B; Caldensine, Altholactone, Asimilobine	200
44	Glycyrrhiza glabra	Glycyrrhizin, Glycyrrhizic acid, Glucuronic acid, Glabridin, Hispagabridin A & B	201
45	Garcinia mangostana	Mangostin, β-mangostin, Gartanin, 1-isomangostin, 3-isomangostin, Clabaxanthone	202
46	Holarrhena pubescens	Lupeol, Betulinic acid, Betulinaldehyde, Holadiene, Pubescine, Kurchamide, Kurchinine	203
47	Hemitanthus articulates	Plumieride, Isoplumieride, Plumericin, Isoplumericin, Lupeol cinnamate, Lupeol acetate	204
48	Horsfielda spicata	Myristicyclins A & B	205
49	Hunteria zeylanica	Vobasine, Eburnamine, Tuboxenine, Epiyohimbol, Dihydrocorynantheol, Yohimbol	206
50	Indigofera oblongifolia	Indigin, Indigoferic acid, β-sitosterol, 3-hydroxybenzoic acid	207
51	Jatropha ribifolia	Ribifolin, α- pinene, β- pinene, α-phellandrene, D- verbenon, Pinocamphone	208-209
52	Keetia leucantha	Caryophyllene, Cubinol, Heptacosanone, Squalene, Phytol, Oleic acid, α-cadinol	210
53	Kniphofia foliosa	Knipholone anthrone, Joziknipholones A & B	211
54	Lettowianthus stellatus	Iriodenine, Lettowianthine, 11-methoxy lettowianthine	212
55	Liriodendron tulipifera	Atherospermidine, Oxoxylopine, Medioresinol	213
56	Lipia javanica	Tagetone, Lianlool, camphor, Caryophyllene oxide, β- myrcene	214
57	Lophira alata	Lophiroflavan A, Lophirochalcone, Lophiroflavans B & C	215
58	Lycoris radiata	Trispherine, Homolycorine, Oduline, Lycorenine	216
59	Mangifera indica	Mangiferolate A, B; Isoambolic acid, β-selinene, β- caryophyllene	217
60	Markhamia tomentosa	Tormentic acid, β-sitosterol, Pomolic acid, Oleanolic acid, 3-acetyl pomolic acid	218
61	Meconopsis simplicifolia	Protopine, Norsanguinarine, Dihydrosanguinarine, Oxysanguinarine	219
62	Mitrephora diversifolia	5,8-dihydroxy-6-methoxyonychine; 5-hydroxy-6-methoxyonychine	220
63	Muntafara sessilifolia	Tabernaelegantine B & D, 3-oxo-tabernaelegantine A	221
64	Nardostachys chinensis	Ferulic acid, Chlorogenic acid methyl ester, 8-hydroxypinoresinol-4-O-β-glucopyranoside	222
65	Nauclea latofolia	Strictosamide, Naucleamide A, F; 10-hydroxystrictosamide	223
66	Neoboutonia macrocalyx	Simplexin, Montanin, Neoboutomacroin	224
67	Ocimum basilicum	Eugenol, Vanilin, Thujopsene, Galaxolide 1, Dibutyl phthalate, 1,4-diethyl benzene	225
68	Piper nigrum	Piperine, Piperamine, Piperamide, Pipericide, Piperlein B, sarmentine	226
69	Plumbago zeylanica	Plumbagin, Zeylanone, Elliptinone, Droserone, Isozeylanone, 3,3-biplumbagin	227
70	Phyllanthus amarus	Amariin, Corilagin, Geraniin, Niranthin, Amarulone	228
71	Plectranthus barbatus	Forskolin, α-amyrin, Deactylforskolin, Forskoditerpenoside A-E	229
72	Pentas bussei	BusseihydroquinonesA-D, Dihydronaphthoquinone	230
73	Piptocoma antillana	5-epiisogoyazensolide	231
74	Quassia amara	Isoquassin, Quassin, neoquassin, Quassinol, Quassol	232
75	Symphonia globulifera	Guttiferone B-D, Symphonone A-I, Symphonin, Maclurin, Symphoxanthone	233
76	Senna occidentalis	Aspartic acid, Emodin taxalbumin	234
77	Tachia grandiflora	Decussatin, Amplexine	235
78	Thalictrum foliolosum	Thalfoliolosumines A & B	236
79	Toddalia asiatica	Trans caryophyllene, Pentadecanal, Sibirinol, 1,5- cyclododecadiene, E-dodec-3-en-5-yn-1-ol	237
80	Tinispora cordifolia	Tinosporine, Berberine, Syringin, Tinocordiside, tinosporon, Columbin, Furanolactone	238
81	Tridex procumbens	β-amyrone, procumbentin, palmitoleic acid, stearic acid	239
82	Withania somnifera	Withanine, Withasomnine, Peudo withanine, Visamine, Withaferin A, Withanolides	240
83	Zanthoxylum chalybeum	Usambanoline	241

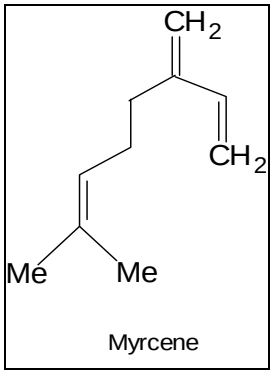
Structures of compounds isolated from antimalarial plants



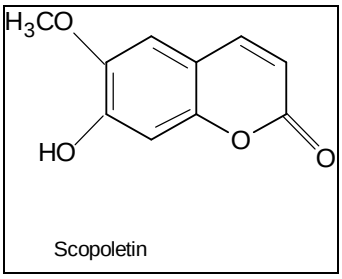
Plumbagin



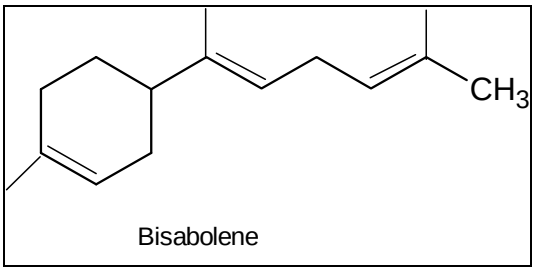
Linalool



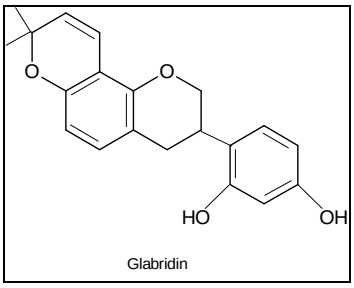
Myrcene



Scopoletin



Bisabolene



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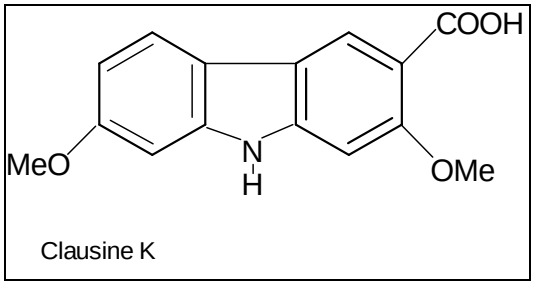
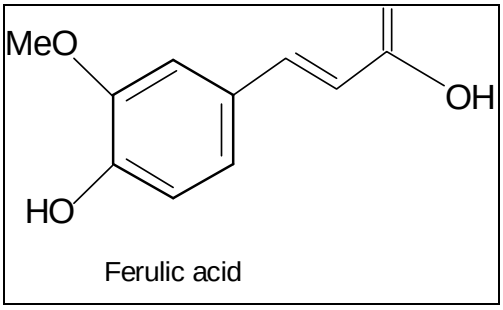
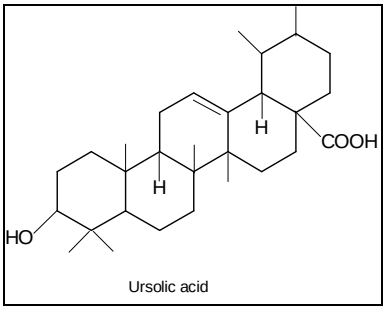


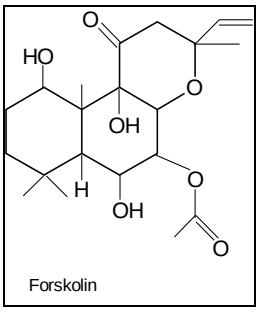
Clausine K



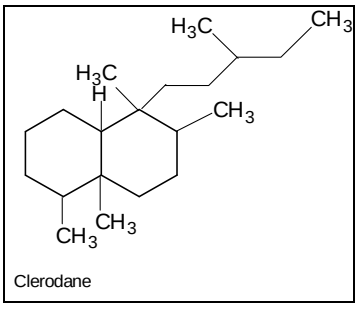
Ferulic acid



Ursolic acid



Forskolin



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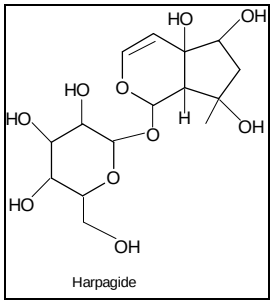
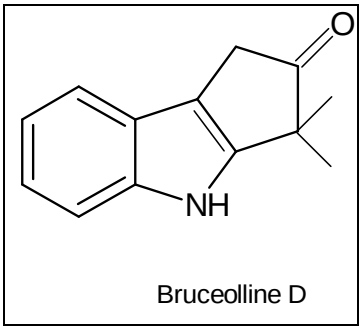
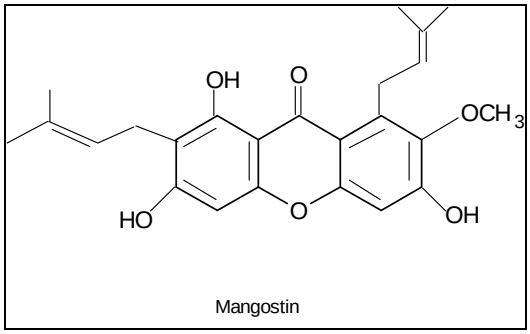


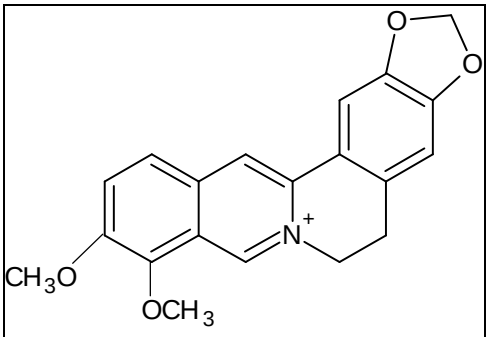
Harpagide



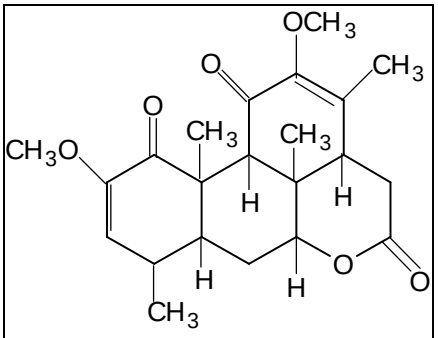
Bruceolline D



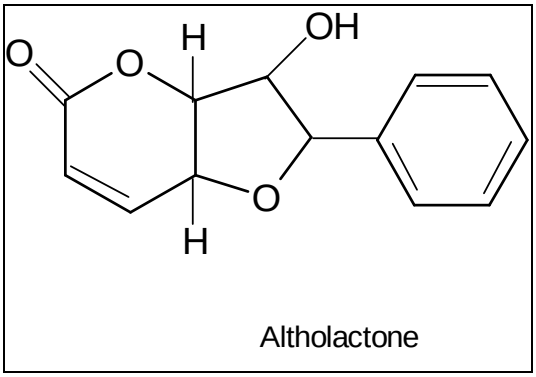
Mangostin



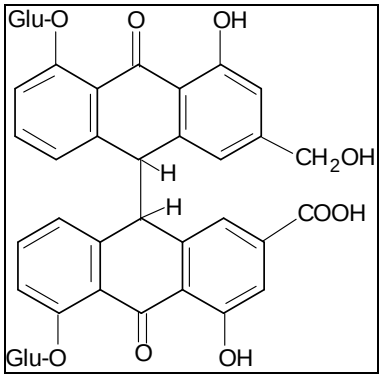
Berberine



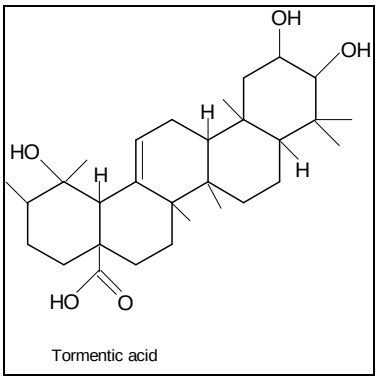
Quassin



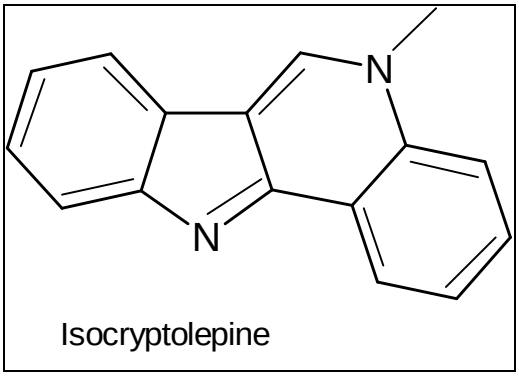
Altholactone



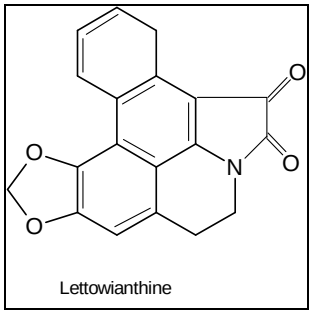
Sennoside A



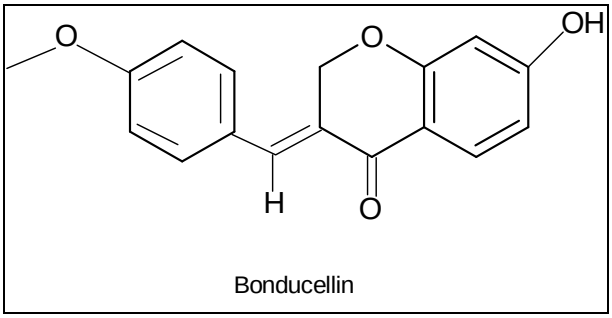
Tormentic acid



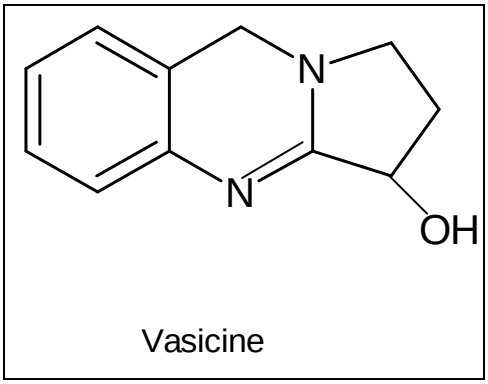
Isocryptolepine



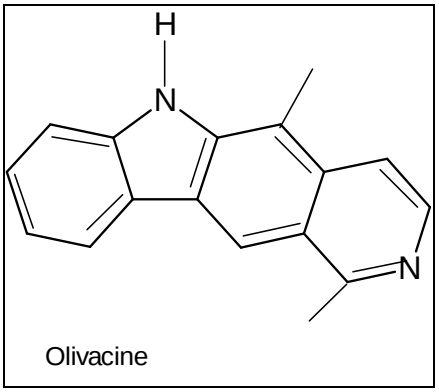
Lettowianthine



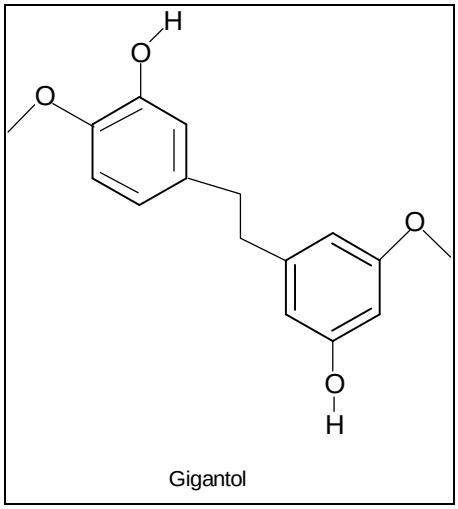
Bonducellin



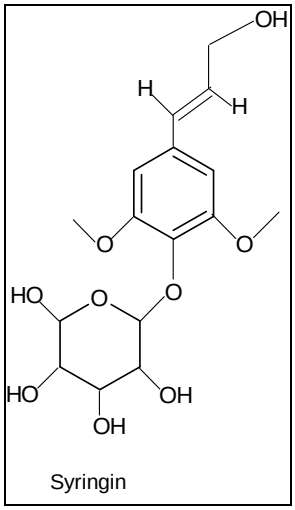
Vasicine



Olivacine



Gigantol



Syringin

Images of antimalarial plants

Ajuga remota Artemisia annua

Berginia ciliata Caesalpinia bonducella

Carapa guinensis Garcinia mangostana


Lettowianthus stellatus Lycoris radiata


Panicum maxicum Rumex crispus


Stephania abyssinica Tridex procumbens


Vernonia amygdalina Withania somnifera


Xylocarpus granatum Zanthoxylum chalybeum

Conclusion

Malaria is still the most destructive infection and this disease is getting worse due to increasing resistance of Plasmodium falciparum against most antimalarial drugs. Plants are being used in medicine since time immemorial, because they have fitted the immediate personal need, they are accessible and inexpensive. Thus this review highlights the information on different medicinal plants for the treatment of malaria. However these require further detailed investigation with ethnopharmacological approach. There is need to advance the work on plants that will reveal suitable suitable molecules as templates for designing new derivatives with improved properties. The search for antimalarials from plants must continue to fight the disease.

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