EXPLORING MEDICINAL PLANTS

Antimalarial Medicinal Plants

Edited by

Azamal Husen

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Antimalarial Medicinal Plants

Malaria continues to affect a large population of the world, especially in third world countries. The spread of drug-resistant parasites demonstrates the need for antimalarial agents with various modes of action. The search for remedies derived from medicinal plants for the treatment of malaria is reliant on accurate ethnobotanical and ethnopharmacological information obtained from traditional medical practitioners. *Antimalarial Medicinal Plants* provides information on bioactive compounds and therapeutic potentials of several antimalarial plant species found around the globe. This book evaluates these plant species with respect to their biology, diversity, distribution, and pharmacological values.

A volume in the *Exploring Medicinal Plants* series, this book highlights trends, technologies, processes, and services important to and necessary for efficient production, use, and understanding of medicinal qualities of antimalarial plants. It critically examines claims made by traditional medical practitioners with scientific validations for safe herbal drug formulation. It is a reference work for researchers of herbal medicine, traditional healers, pharmacists, and students associated with plant sciences and economic botany.

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Series Editor: Azamal Husen, Wolaita Sodo University, Wolaita, Ethiopia

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Contents

Preface

Malaria is a serious and challenging, life-threatening infectious disease. This parasitic infectious disease is caused by protozoan parasites, namely, *Plasmodium falciparum*, *P. vivax*, *P. malariae*, *P. ovale*, *P. knowlesi*, and *P. cynomolgi*. The parasite is transmitted from human to human through the bite of an infective *Anopheles* mosquito. *Plasmodium* travels through the blood, matures and reproduces in the liver, and causes malaria disease. The common symptoms of malaria are fever and headache, and in severe cases, malaria leads to death. For its cure, normally, artemisinin-based medicines are used. However, antimalarial drug resistance has emerged as a great challenge to the malaria control programme. *P. falciparum* resistance to artemisinins has already been noticed. Thus, because malaria affects a large population of the world, the spread of drug-resistant parasites and the limited number of effective drugs for the treatment warrant discovery of new antimalarial drugs with new modes of action.

It has also been noticed that since the earliest times, mankind has used medicinal plants in order to cure various diseases and relieve suffering. Similarly, the search for new remedies from medicinal plant species used for the treatment of malaria depends on the accurate and specific ethnobotanical and ethnopharmacological information obtained from traditional medical practitioners. As we know, in these days, people are seeking an alternative to modern medical treatments, turning to phytomedicines for the treatment of malaria, and to cure various diseases and relieve suffering. Thus, in this connection, plant-based pharmaceuticals play a significant role. Numerous plant species belonging to the *Aristolochia*, *Aspidosperma*, *Cinchona*, *Croton*, *Momordica*, *Piper, Senna, Solanum, Stachytarpheta*, *Tabebuia, Swertia*, etc. genera have shown immense antimalarial activity and are reviewed in detail. Moreover, this book critically examines and reviews the claims made by traditional medical practitioners and scientific validations. Other information on aspects concerning diversity, biology, phytochemistry, harvest and conservation techniques, genetic improvement, *in vitro* practice for higher antimalarial agents, and so on have been presented.

Taken together, the aim of the book is to provide an overview of the most important and selected antimalarial plant species around the world and the natural products obtained from these plants. This book provides valuable information to scientists, researchers, and students working especially on medicinal plants or in areas of ethnomedicine, natural products, economic botany, plant biochemistry, biotechnology, pharmacognosy, industrial chemistry, and other allied subjects. This book would also help in testifying on the various reports on antimalarial plants and their other potential uses in new drug discovery based on their bioactive molecules, and may also attract the attention of pharmaceutical companies, industrialists, and health policymakers.

I am grateful to all contributors for readily accepting my invitation, sharing their knowledge in specialized areas of research, and readily adjusting the suggestions for improving the shape of their contributions. With great pleasure, I also extend my sincere thanks to Randy Brehm, Tom Connelly, and all associates at Taylor & Francis Group, LLC/CRC Press, for their active cooperation. Finally, my special thanks go to Shagufta, Zaara, Mehwish, and Huzaifa for providing their time, and overall support, to put everything together.

Azamal Husen

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Azamal Husen is a Professor at Sankalchand Patel University, Visnagar, India; and Adjunct Professor at Graphic Era (Deemed to be University), Dehradun, Uttarakhand, India. He is also working as a Visiting Professor at University Putra Malaysia, Selangor, Malaysia; and acting as a Foreign Delegate at Wolaita Sodo University, Wolaita, Ethiopia. Previously, he served as Professor and Head of the Department of Biology, University of Gondar, Ethiopia. He also worked as a Visiting Faculty of the Forest Research Institute and the Doon College of Agriculture and Forest at Dehra Dun, India. His research and teaching experience of 25 years encompasses biogenic nanomaterial fabrication and application; plant responses to nanomaterials; plant adaptation to harsh environments at the physiological, biochemical, and molecular levels; herbal medicine; and clonal propagation for the improvement of tree species.

He has conducted research sponsored by the World Bank, the National Agricultural Technology Project, the Indian Council of Agriculture Research, the Indian Council of Forest Research Education, and the Japan Bank for International Cooperation. Husen has published extensively (over 250) and served on the Editorial Board and as a reviewer of reputed journals published by Elsevier, Frontiers Media, Taylor & Francis, Springer Nature, RSC, Oxford University Press, Sciendo, the Royal Society, CSIRO, PLOS, MDPI, John Wiley & Sons, and UPM Journals. He is on the advisory board of Cambridge Scholars Publishing, UK. He is a fellow of the Plantae group of the American Society of Plant Biologists, and a member of the International Society of Root Research, Asian Council of Science Editors, and the International Natural Product Sciences. He is Editor-in-Chief of the *American Journal of Plant Physiology*, and a Series Editor of *Exploring Medicinal Plants* (Taylor & Francis Group, USA); *Plant Biology, Sustainability, and Climate Change* (Elsevier, USA); and *Smart Nanomaterials Technology* (Springer Nature, Singapore). He has been awarded the distinguished honour of being recognized as one of the 'World's Top 2% Scientists' for the year 2022, and again for the year 2023 by Stanford University, USA. This recognition has also been prominently featured in the Elsevier Data Repository.

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1 Diversity and Geographic Distribution of Some Antimalarial Plant Species

Salman Khan, Kolagani Chandramohan, and Azamal Husen

1.1 INTRODUCTION

Worldwide, humans are exposed to various types of diseases, of which some are natural and some are anthropogenic-driven (Murray and Lopez, 1996). Malaria is such an important disease which has global impact on humans. It is widespread in tropical areas, such as Africa, China, India, and other Asian countries (O'Neill et al., 1985). Castro and Peterka (2023) reported the increasing trends of malaria cases specifically in indigenous and artisanal mining areas of Brazilian Amazon. It is due to increased deforestation and mining (Figure 1.1). In the year 1980, more than 5 million cases per annum were documented from Africa (O'Neill et al., 1985). Dash et al. (2008) mentioned that as per WHO (World Health Organization), India's contribution to malaria is about 70% in South-East Asian countries.

Anopheles spp. mosquitoes act as vector organisms for malaria-causing protozoan *Plasmodium* spp. The bite of the female *Anopheles* mosquito leads to the transfer of *Plasmodium* into human blood, causing malaria. In India, *Anopheles culicifacies*, *A. stephensi*, *A. dirus*, *A. fluviatilis*, *A. minius*, *A. sundaicus*, *A. annularis*, *A. varuna*, *A. jeyporiensis*, and *A. philippinensis* are reported to carry *Plasmodium* (Rao, 1984; Dash et al., 2008). The former six species are considered as primary vectors, and the rest are secondary.

Due to the global climate change, insects and other microorganisms are modifying their body and behaviour. Many insecticides are not effective against mosquitoes due to resistance development in them. Similarly, protozoans are being resistant to various chemotherapeutic potential agents (O'Neill et al., 1985).

There are so many factors which influence the dynamics of malarial cases, but the major reasons are population movement, climate change, deforestation, mining, agricultural activity, and floods (Figure 1.1). It is estimated that global warming tends to increase in global temperature, and this will change the growth rate of vector mosquitoes, increase blood digestion rate, and cause a surge in feeding rate (Dash et al., 2008).

Various programmes and projects for minimizing malarial cases have been formulated by many agencies, including WHO and the government of India. Programme such as PfCP (*Plasmodium falciparum* containment programmes), urban malarial schemes, global malaria eradication programmes, national malarial eradication programmes, and others are effective in minimizing the cases (Sharma, 1996).

1.2 GEOGRAPHIC DISTRIBUTION OF MALARIA IN THE WORLD

Dash et al. (2008) reported that 36% of the world population is affected by malaria. Around 107 countries and their nearby areas have shown malarial cases worldwide. India, being diverse in

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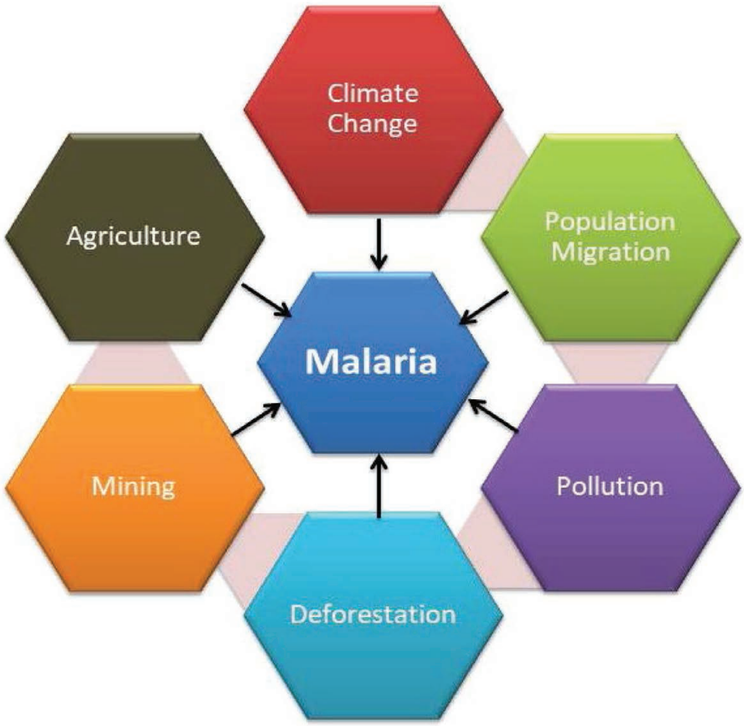

FIGURE 1.1 Factors driving dynamics of malarial cases in humans.

climate, topography, and biodiversity, provides the ideal environment for vector growth and its spread (Das et al., 2012).

- **In world other than India:** Africa, Mexico, South-East Asia, South America, Australia, Europe, Iran, etc. (Richards et al., 2001; Dash et al., 2008; Das et al., 2012; Narain and Nath, 2018).
- **In India:** Chhattisgarh, Gujarat, Haryana, Jharkhand, Madhya Pradesh, North-East India, Orissa, Uttarakhand, and West Bengal (Sharma et al., 1983; Misra, 1996; Bhattacharya et al., 2006; Kumar et al., 2007; Dash et al., 2008).

1.3 DESCRIPTION OF MAJOR ANTIMALARIAL PLANTS OF INDIA

Muñoz et al. (2000a, 2000b) identified the natural biological compound used by Mostene and Chacobo tribes against malaria derived from plants in Bolivia. They mentioned species such as *Apuleia leiocarpa*, *Bauhinia guianensis*, *Nectandra cuspidata*, *Parattanthelium amazonum*, *Tanaecium jaroba*, *Qualea paraensis*, *Derris amazonica*, and *Sclerolobium guianense*. A similar report on medicinal plants with antimalarial potential used by the Tacana Indians was also presented by Deharo et al. (2001) from Bolivia. Mahato and Sen (1997) and Matte (2023) mentioned that biochemical compound terpenoid exhibits tremendous antimalarial properties. O'Neill et al. (1985) reported antimalarial properties in *Artemisia annua* due to the presence of artemisinin. It was also reported that the most important families of plants which show great potential against malaria are Amaryllidaceae and Simaroubaceae. Spencer et al. (1947) surveyed and formulated a document mentioning a list of antimalarial plants belonging to 33 genera. Muregi et al. (2007) mentioned that *Vernonia lasiopus*, *Toddalia asiatica*, *Ficus sur*, *Rhamnus prinoides*, and *R. staddo* possess significant antimalarial properties. Mahagany (*Swietenia mahagoni*) seeds possess great antimalarial activity against *Plasmodium berghei* due to the presence of flavonoids and its derivates (Sari et al., 2023). Similarly, Chinchilla et al. (2012) listed 25 important *in vitro* antimalarial plant species from Costa Rica. These include *Cinnamomum chavarria*, *Hampea appendiculata*, *Nectandra membranacea*, *Persea povedae*, *Psidium guajava*, *Senna papillosa*, and *Siparuna thecaphora*. Mariath et al. (2009) formulated a detailed list of 476 antimalarial plants belonging to 103 plant families, such as Anacardiacea, Aracaceae, Bixaceae, Brassicaceae, Fabaceae, Lauraceae, Moraceae, Rhamnaceae, and Velloziaceae, from the American continent. Şener et al. (2003) provided details on important alkaloids extracted from the different species of Amaryllidaceae family. Similarly, Bray et al. (1990) mentioned the antimalarial potential of few important species of family Meliaceae.

Various researchers have also identified and reported important medicinal plants having higher antimalarial properties. Koudouvo et al. (2011) reported 52 plant species related to 29 families having antimalarial properties from the Togo Maritime Region. From West and Central Africa, alkaloids extracted from different antimalarial plants were described by Ancolio et al. (2002). It includes *Combretrum micranthum*, *Feretia apodanthera*, *Guiera senegalensis*, *Morinda*sp., *Pycnanthus angolensis*, and *Securidaca longepedunculata*. Abosi and Raseroka (2003) provided details on the antimalarial potential of the leaves and roots of *Vernonia amygdalina*. Achenbach (1992) mentioned the antimalarial property of *Hoslundia opposita*, which grows in East and West Africa. From Cameroon (Central Africa), 217 antimalarial plants' descriptions were given by Titanji et al. (2008). They also mentioned that about 100 bioactive compounds were isolated from 26 different species of plants from Cameroon.

Similarly, Tona et al. (1999) reported nine plants with antimalarial properties from the Democratic Republic of Congo. Likewise, Kaou et al. (2008) mentioned nine different antimalarial plant species from Africa. Azas et al. (2002) reported an experiment on the use of a combination of medicinal plants crude extract for antimalarial activity in Mali. Asase and Oppong-Mensah (2009) surveyed and identified about 29 antimalarial plants belonging to 24 different families from Ghana. Important medicinal plants (Figures 1.2 and 1.3) and various chemical features are shown in Figure 1.4.

Other than in Africa, many plants are being used as antimalarial/antiplasmodial agents. Researchers such as Mojab (2012) mentioned antimalarial plants from Iran, such as *Artemisia* spp., *Cichorium intybus*, *Glycyrrhiza glabra*, *Prosopis juliflora*, and *Solanum surattense*. Zhang et al. (2002) reported the novel antimalarial alkaloid (decursivine) extracted from the leaves and stem of *Rhaphidophora decursiva*. In India, Kamaraj et al. (2012) reported a list of 23 medicinal antimalarial plants which were used in the village area. They reported the following species with great antimalarial properties in different parts of the plant due to the activity of secondary metabolites: *Adhatoda vasica*, *Aegle marmelos*, *Andrographis lineata*, *Argemone Mexicana*, *Cassia nictitans*, *Coriandrum sativum*, *Cuminum cyminum*, *Datura metel*, *Diospyros melanoxylon*, *Eclipta prostrata*, *Lantana camara*, *Momordica charantia*, *Nelumbo nucifera*, *Piper nigrum*, and *Tagetes erecta*. Rahman et al. (1999) mentioned about the antimalarial properties of *Andrographis paniculata*, *Piper sarmentosum*, and *Tinospora crispa* from Malaysia. Garavito et al. (2006) reported the presence and activity of Colombian medicinal plants as antimalarial agents belonging to the families Annonaceae, Euphorbiaceae, Menispermaceae, Miosaceae, Piperaceae, and Solanaceae. Nguyen-Pouplin et al. (2007) identified and reported 49 different species of plants having antimalarial properties. Moreover, researchers from Indonesia have reported 72 species of plants belonging to 40 families as antimalarial potential species (Budiarti et al., 2020). Details of the major plant species, common name, their distribution, important chemical compound, from the world are discussed in Table 1.1.

1.4 BIOCHEMICAL COMPOUNDS

1.4.1 Alkaloids

They are an important biological compound which is extracted from various parts of the plant. They are capable of treating various diseases, including malaria. They have physiologically active

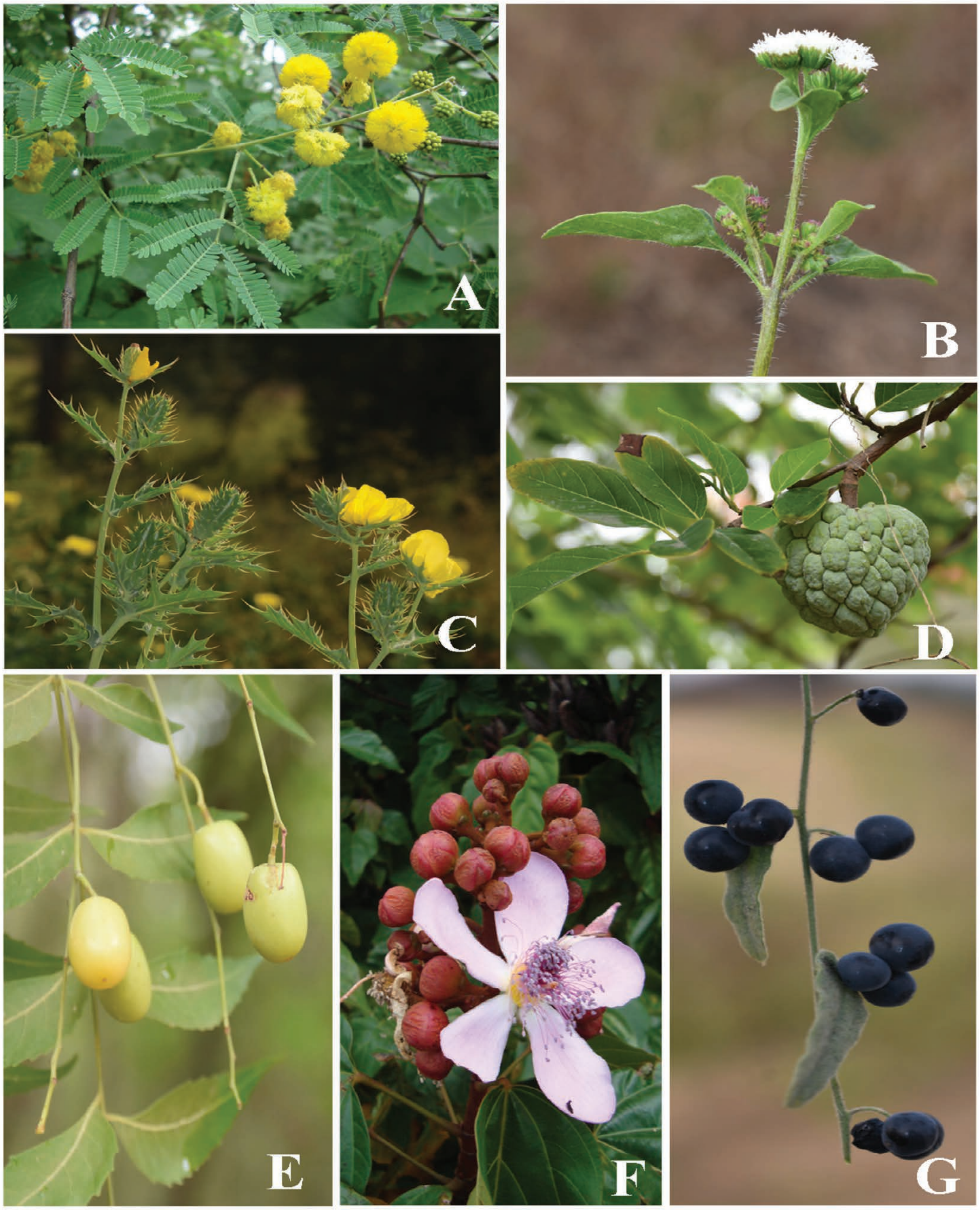

FIGURE 1.2 (a) *Vachellia nilotica* (L.) PJH Hurter and Mabb.; (b) *Ageratum conyzoides* L.; (c) *Argemone mexicana* L.; (d) *Annona squamosa* L.; (e) *Azadirachta indica* A. Juss.; (f) *Bixa orellana* L.; (g) *Cissampelos pareira* L.

nitrogen bases in a heterocyclic ring obtained from amino acids (Figure 1.4). The alkaloid groups that have antimalarial potency include terpenoidal and steroidal alkaloids, indole alkaloids, phenanthroindolizine alkaloids, isoquinoline, benzylisoquinoline and hasubanane alkaloids, naphthoisoquinoline alkaloids, aporphine and morphinandienone alkaloids, proterberine alkaloids,

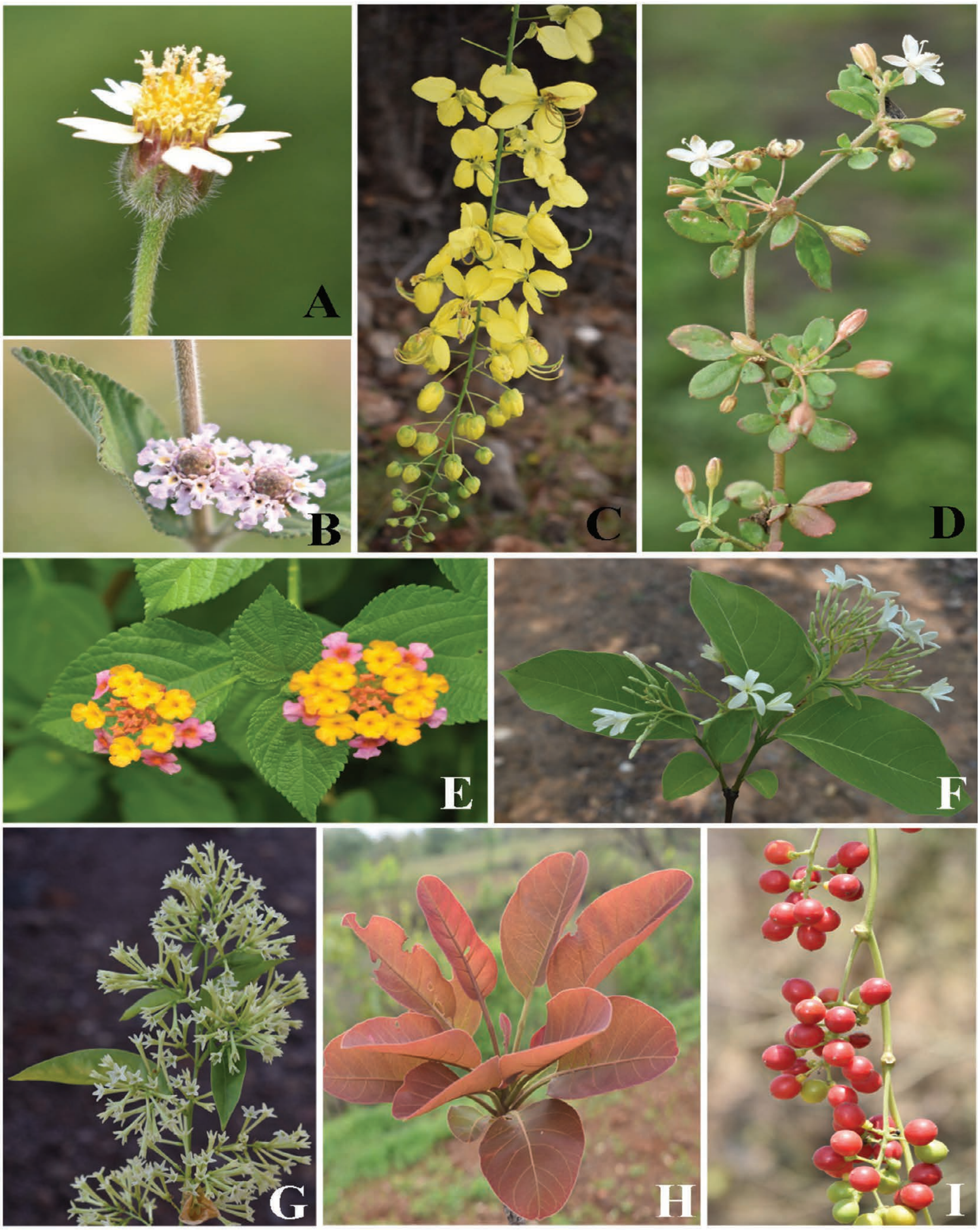

FIGURE 1.3 (a) *Tridax procumbens* L.; (b) *Lippia javanica* (Burm.f.) Spreng.; (c) *Cassia fistula* L.; (d) *Glinus oppositifolius* (L.) Aug.DC.; (e) *Lantana camara* L.; (f) *Holarrhena pubescens* Wall. ex G. Don; (g) *Cestrum nocturnum* L.; (h) *Terminalia bellirica* (Gaertn.) Roxb.; (i) *Tinospora cordifolia* (Willd.) Hook.f. and Thomson.

amaryllidaceae alkaloids, cyclopeptide alkaloids, quinoline alkaloids, pyridocoumarin alkaloids, acridone alkaloids, and macrocyclic alkaloids (Uzor, 2020). Few examples of major alkaloids are anonaine, augustine, caesalminines A and B, carpaine, crinamine, lycorine, tubulosine, microthecaline, N-methyltelobine, obtusipetadione, simplicifolianine, virekine, etc. (Saxena et al., 2003).

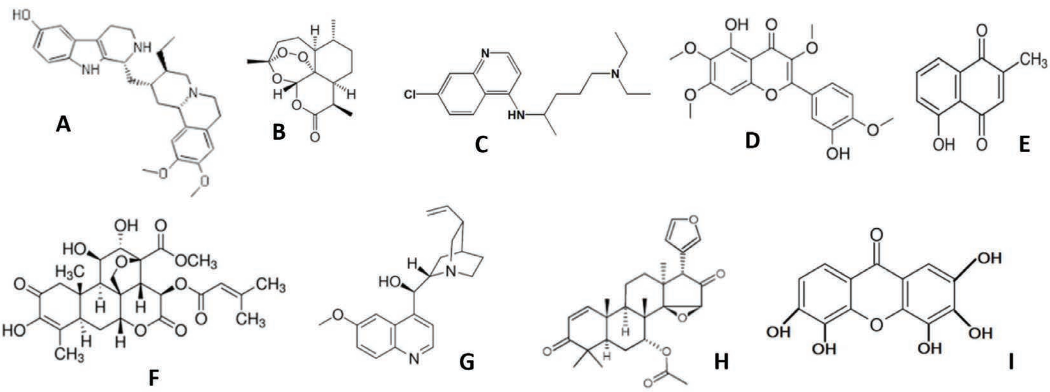

FIGURE 1.4 (a) Alkaloid, (b) artemisinin, (c) chloroquine, (d) flavonoid, (e) quinone, (f) quassinoid, (g) quinine, (h) triterpenoid, and (i) xanthone.

1.4.2 Chloroquine

It is a type of aminoquinoline which is primarily used for the treatment of malaria. It has many other uses, such as antiviral, extraintestinal amoebiasis treatment, antirheumatic, anti-parasitic, anti-inflammatory, etc. (Scholar, 2007). The structure of chloroquine is discussed in Figure 1.4. However, chloroquine resistance against malarial parasite is also reported from various countries. The chemical formula of chloroquine is $C_{18}H_{26}ClN_3$. Other names of chloroquine are Artichin, Chlorochine, Resochin, Sanoquin, Solprine, and others (Scholar, 2007).

1.4.3 Artemisinin

It is a type of sesquiterpenes lactone having an endoperoxide bridge derived from plants like *Artesimia annua* (Guo, 2016). The chemical formula of artemisinin is $C_{15}H_{22}O_5$. Its synonyms are artemisinine, artemisininum, and quinghaosu. Artemisinin is mostly used in malaria treatment worldwide. It is also used as an anti-infectious agent and has capabilities to treat cancer. A novel derivative of artemisinin based on the structural configuration is dihydroartemisinin (Guo, 2016).

1.4.4 Quinine

It is a medication that is used to treat malaria solely or in combination with other medicines (Achan et al., 2011). The chemical formula of quinine is $C_{20}H_{24}N_2O_2$ (Figure 1.4). Apart from malaria, it is also used to treat piroplasmosis. Like with other chemical compounds, resistance to quinine is also developed in malarial parasites. Its synonyms include chinine, chinin, and cinchonidine. It can be obtained from the bark of *Cinchona* spp. (Muñoz et al., 2000a).

1.4.5 Quinones

Quinones are a biochemical compound that has a complex structure and shows antimalarial activities. They are either 1,4-diketocyclohexa-2,5-dienoid or 1,2-diketocyclohexa-3,5-dienoid. Naphthoquinones are one of the important structures of quinones in which the asexual erythrocytic

TABLE 1.1
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Species	Common/Local Name	Family	Bioactive Compound	Plant Part Used	Distribution	Key References
Acacia nilotica	Babul	Fabaceae	Terpenoids	Leaves	India	Matte, 2023
Acalypha fruticosa	Birch-leaved cattail	Euphorbiaceae	Sesquiterpenoids	Leaves	Africa, India	Alshawsh et al., 2009
Acalyphawilkensiana	Copper plant	Euphorbiaceae	Alkaloids, flavonoids, saponins, tannins	Leaves	Pacific islands	Udobang et al., 2010
Acanthospermum hispidum	Bristly starbur	Asteraceae	Alkaloids, flavonoids	Aerial parts	Central and South America	Ganfon et al., 2012
Achillea millefolium	Yarrow	Asteraceae	Sesquiterpenes	Whole plant	North America, Europe, Asia	Saxena et al., 2003
Acokanthera schimperi	Arrow poison Tree	Apocynaceae	Glycosides	Leaves	Africa	Mohammed et al., 2014
Acridocarpus alternifolius	Papao	Malpighiaceae	Flavonoids	Leaves	Ghana	Laryea and Borquaye, 2019
Adhatoda spp.	Vasa	Acanthaceae	Alkaloids, flavonoids, tannins, saponins	Leaves	Malabar nut	Bora et al., 2007; Kamaraj et al., 2012
Aegle marmelos	Bel, golden apple	Rutaceae	Anthraquinone	Leave, bark	India	Kamaraj et al., 2012
Ageratum conyzoides	Billygoa weed	Asteraceae	Alkaloids, flavonoids, coumarins, essential oils	Aerial parts	Brazil, Kenya	Nour et al., 2010
Ajugaintegrifolia	Bugleweed	Lamiaceae	Terpenoids, iridoid glycosides, flavonoids, essential oils	Roots, root bark	Ethiopia, Asia	Asnake et al., 2015
Ajugaremota	Armagusa	Lamiaceae	Flavonoids, alkaloids, tannins, terpenoids	Aerial parts	Ethiopia, Africa	Njoroge and Bussmann, 2006; Gitua et al., 2012
Albiziazygia	West African walnut	Fabaceae	Flavonoids	Aerial parts	Africa	Abdalla and Laatsch, 2012
Allanblackia floribunda	Tallow tree	Clusiaceae	Flavonoids, xanthanoids, essential oil	Aerial parts	Africa	Azebaze et al., 2015
Allophylus africanus	False currant	Sapindaceae	Flavonoids, polyphenols, essential oils	Whole plant	Africa	Oladosu et al.,2013
Aloe spp.	Mugwanugu	Asphodelaceae	Alkaloids, flavonoids	Various parts	Kenya	Njoroge and Bussmann, 2006; Singh et al., 2022
Alstonia angustifolia	Pulai	Apocynaceae	Alkaloids	Leaves and bark	Asia	Saxena et al., 2003
Alstonia boonei	Ahun	Apocynaceae	Alkaloids, triterpenoids	Stem bark, leaves	Nigeria	Idowu et al., 2010
Alstoniamacrophylla	Hard milkwood	Apocynaceae	Alkaloids, flavonoids, terpenoids, saponins, tannins	Bark, stem bark, root bark	India, Malaysia, Thailand	Saxena et al., 2003; Cheenpracha et al., 2013

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List of Important Medicinal Plants throughout the World Having Antimalarial Properties

Species	Common/Local Name	Family	Bioactive Compound	Plant Part Used	Distribution	Key References
Amomum kravanh	Bai Dou Kou	Zingiberaceae	Myrtenol	Fruit	South-East Asia	Saxena et al., 2003
Ampelozizyphus amazonicus	Saracura mira	Rhamnaceae	Saponins, terpenoids, steroids	Stem, root	Amazon region	do Carmo et al., 2015
Anadenanthera colubrina	Cebil, willca	Fabaceae	Flavonoids	Bark	Africa	Muñoz et al., 2000b
Ancistrocladus spp.	Cameroonian vine	Ancistrocladaceae	Korupensamine, alkaloids	Leaf, tubers, root bark, stem	Africa	Saxena et al., 2003
Andira inermis	Brown heart	Fabaceae	Flavonoids, xanthones	Leaves, stem	Africa, America	Saxena et al., 2003
Andrographis lineata	Striped chiretta	Acanthaceae	Flavonoids	Whole plant	India	Kamaraj et al., 2012
Andrographis paniculata	Sambiroto	Acanthaceae	Andrographolide	Whole plant	Malaysia	Rahman et al., 1999
Angelica purpuraefolia	Bai jhi	Apiaceae	Khellactone, triterpenes	Rhizome	South America, Africa	Chung et al., 2010
Anisochilus harmandii	Kapurli	Lamiaceae	Terpenoids, flavonoids	Aerial parts	Asia	Lekphrom et al., 2010
Annona squamosa	Wild sweetsop	Annonaceae	Alkaloids, glycosides, flavonoids	Aerial parts	South America	Johns et al., 2011
Anthemis nobilis	Roman chamomile	Asteraceae	Sesquiterpenes	Aerial parts	North America, Western Europe	Saxena et al., 2003
Aphanamixis grandifolia	Rohitukka tree	Meliaceae	Terpenoids	Bark	Asia	Astulla et al., 2011
Apuleia leiocarpa	Garapa	Fabaceae	Quinone	Leaves	Brazil, Uruguay, Argentina, Paraguay	Muñoz et al., 2000a
Argemone mexicana	Mexican prickly poppy	Papaveraceae	Allocryptopine, protopine, berberine	Leaves, seeds	Nigeria, Brazil	Idowu et al., 2010; Kamaraj et al., 2012
Aristolochia griffithii	Birth wort	Aristolochiaceae	Alkaloids	Root	NE India	Das et al., 2016
Arrabidaea florida	Fridericia Mart	Bignoniaceae	Quinone	Leaves	America	Muñoz et al., 2000b
Artemisia abrotanum	Southernwood	Asteraceae	Sesquiterpenes	Leaves	Europe, Asia	Saxena et al., 2003
Artemisia absinthium	Common wormwood	Asteraceae	Sesquiterpenes	Leaves	Europe, Asia, Middle East	Saxena et al., 2003
Artemisia annua	Sweet wormwood	Asteraceae	Artemisinin, sesquiterpenes	Aerial part	Africa	O'Neill et al., 1985; Saxena et al., 2003; Youyou et al., 2015
Artemisia armeniaca	Sagebrush	Asteraceae	Essential oils, flavonoids	Aerial parts	Iran	Mojarrab et al., 2014

Artemisia indica	Wormwood	Asteraceae	Flavonoids, xanthones	Stem	India	Saxena et al., 2003
Asparagus africanus	African asparagus	Asparagaceae	Alkaloids, terpenoids, muzanzagenin	Whole plant	Africa	Saxena et al., 2003; Dikasso et al., 2006
Aspidosperma olivaceum	Copperpod	Apocynaceae	Alkaloids	Leaves, bark	Brazil	Chierrito et al., 2014
Aspilia pluriseta	Dwarf Aspilia	Asteraceae	Terpenoids	Aerial parts	Uganda	Sebisubi et al., 2010
Azadirachta indica	Neem	Meliaceae	Terpenoids, essential oils, triterpenoids	Whole plant	India, Nigeria	Saxena et al., 2003; Chianese et al., 2010; Idowu et al., 2010
Azanza garckeana	Snot apple	Malvaceae	Flavonoids, alkaloids	Whole plant	Africa	Njoroge and Bussmann, 2006
Bambusa vulgaris	Cana brava	Poaceae	Flavonoids, lactones	Aerial parts	Asia	Valdés et al., 2010
Bauhinia guianensis	Escalera de mono	Fabaceae	Flavonoids	Stem bark	Bolivia, South America	Muñoz et al., 2000a
Beilschmiedia spp.	Akolodo	Lauraceae	Alkaloids, flavonoids	Aerial parts, wood	Cameroon, Congo, Asia	Saxena et al., 2003; Lenta et al., 2009
Berberis aristata	Indian barberry	Berberidaceae	Alkaloids, tannins	Roots	India	Chandel et al., 2015
Bergenia ciliata	Hairy bergenia	Saxifragaceae	Alkaloids, terpenoids, phenols	Leaves	Africa	Walter et al., 2013
Bidens pilosa	Nyamaradza	Asteraceae	Flavonoids	Leaves and twigs	Ghana	Laryea and Borquaye, 2019
Bixaorellana	Achiote	Bixaceae	Essential oils	Whole plant	America	Valdés et al., 2011
Boswellia elongata	Frankincense tree	Burseraceae	Flavonoids, terpenoids	Bark	Yemen	Alshawsh et al., 2009
Brassica nigra	Indian mustard	Brassicaceae	Flavonoids, polyphenols, essential oils	Seeds	Asia	Muluye et al., 2015
Bridelia ferruginea	Kizni	Phyllanthaceae	Alkaloids, saponins, flavonoids	Stem bark	Africa, Nigeria	Mbah et al., 2012
Brucea javanica	Macassar kernels	Simaroubaceae	Quassinoids, triterpenoids	Stem, leaves	Asia	O'Neill, 1985; Saxena et al., 2003
Bruceamollis	Karbi	Simaroubaceae	Alkaloids, terpenoids, quassinoids	Root	India, Nepal, Malaysia	Prakash et al., 2013
Brunsvigia spp.	Kandelaarblom	Amaryllidaceae	Alkaloids	Bulb	South-Eastern Asia	Saxena et al., 2003
Caesalpinia bonducella	Fever nut	Fabaceae	Alkaloids, terpenoids, glycosides, saponins	Whole part	Tanzania	Nondo et al., 2016
Caesalpinia minax	Peacock flower	Fabaceae	Diterpene alkaloids	Seeds	South-East Asia	Ma et al., 2014
Caesalpinia sappan	Heartwood	Fabaceae	Alkaloids, terpenoids, glycosides, saponins	Seeds	Brazil	Ma et al., 2015

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Caesalpinia volkensii	Kikuyu	Fabaceae	Flavonoids, tannins	Stem bark	Tanzania, Kenya	Njoroge and Bussmann, 2006; Ochieng et al., 2012
Cajanus cajan	Pigeon pea	Fabaceae	Cajachalcone	Leaves	Nigeria	Idowu et al., 2010
Canavalia beniensis	Jackbeans	Fabaceae	Alkaloids	Leaves, stem	Bolivia	Muñoz et al., 2000b
Canella winterana	Wild cinnamon	Canellaceae	Essential oils, sesquiterpenoids	Leaves	West Indies	Grace et al., 2010
Canthium multiflorum	Laager	Rubiaceae	Alkaloids, terpenoids, tannins	Whole plant	Cameroon	Akomo et al., 2009
Carapa guianensis	Crabwood	Meliaceae	Essential oil	Seeds	Amazon region, America	Pereira et al., 2014
Carica papaya	Papaw	Caricaceae	Alkaloids, flavonoids, glucosides	Leaves	India, Africa, America	Ofori-Attah et al., 2012
Cassia edulis	Mukawa	Fabaceae	Flavonoids	Root bark	Africa, South Asia, Australia	Njoroge and Bussmann, 2006
Cassia fistula	Golden shower	Fabaceae	Flavonoids, anthraquinones	Leaves, fruit, bark	India, Amazon, Sri Lanka	Grace et al., 2012
Cassia nictitans	Sensitive partridge pea	Fabaceae	Emodin, luteolin	Leaves	India	Kamaraj et al., 2012; Osunga et al., 2023
Cassia siamea	Kasood tree	Fabaceae	Alkaloids	Leaves	SE Asia	Deguchi et al., 2012
Cassia sieberiana	Drumstick tree	Fabaceae	Flavonoids, alkaloids, stilbenes	Root, stem	Africa	Abdulrazak et al., 2015
Cassipourea malosana	Muthathi	Rhizophoraceae	Alkaloids	Stem bark	Africa	Njoroge and Bussmann, 2006
Cedrelopsis grevei	Katrafay	Rutaceae	Essential oils	Leaves	Madagascar	Afoulous et al., 2013
Cestrum sp.	Jessamines	Solanaceae	Alkaloids, quassinoids, sesquiterpenes, triterpenoids, flavonoids	Leaves	Bolivia	Muñoz et al., 2000b
Chamaedorea elegans	Parlor palm	Arecaceae	Triterpenes	Leaves, stem, bark	Bolivia	Muñoz et al., 2000b
Christia vespertilionis	Red butterfly wing	Fabaceae	Triterpenes, alkaloids, phenols	Roots, leaves, stem	South-East Asia	Upadhyay et al., 2013
Chukrasia tabularis	White cedar	Meliaceae	Limonoids, tetranorriterpenoids	Stem bark	India, China, Bangladesh	Ogbole et al., 2016
Cichorium intybus	Chicory	Asteraceae	Lactucin, lactucopicrin	Root	America, Australia, India	Mojab, 2012
Cinchona spp.	Cinchona	Rubiaceae	Alkaloids	Bark	Sri Lanka, India, America, Africa	O'Neill et al., 1985; Muñoz et al., 2000a
Cinnamomum chavarria	Cinnamon	Lauraceae	Alkaloids	Bark, fruits, leaves	North America	Chinchilla et al., 2012

Cissampelos pareira	Velvet leaf	Menispermaceae	Alkaloids, terpenoids, tannins	Roots	Asia, Africa	Singh and Banyal, 2011
Cissus quadrangularis	Veldt grape	Vitaceae	Terpenoids	Leaves	Africa, tropical Asia	Matte, 2023
Cissus rotundifolia	Venezuelan treebine	Vitaceae	Flavonoids	Leaves	Yemen	Alshawsh et al., 2009
Citropsis articulata	African cherry orange	Rutaceae	Alkaloids, terpenoids, saponins, tannins	Root bark	Africa	Lacroix et al., 2011
Citrus limetta	Sweet lime	Rutaceae	Flavonoids, glycosides, phenols, essential oils	Fruit peel	South-East Asia	Mohanty et al., 2015
Citrus medica	Citron	Rutaceae	Essential oil	Aerial parts	South-East Asia	Idowu et al., 2010
Clappertonia ficifolia	Sahomia	Malvaceae	Flavonoids	Leaves	Ghana	Laryea and Borquaye, 2019
Clausena harmandiana	Prong faa	Rutaceae	Alkaloids, coumarins, essential oils	Aerial parts, roots	Thailand	Saxena et al., 2003; Thongthoom et al., 2010
Clausena anisata	Horsewood	Rutaceae	Alkaloids, essential oils	Leaves	Africa	Okokon et al., 2012
Clerodendrum rotundifolium	Bagflower	Lamiaceae	Alkaloids	Aerial parts	Asia, Africa, America	Adia et al., 2016
Clerodendrum Viscosum=C. infortunatum	Thuner	Lamiaceae	Alkaloids, sesquiterpene lactones	Whole plant	Asia, Africa, America	Moshi et al., 2012
Clutia abyssinica	Muthima mburi	Peraceae	Alkaloids	Various parts	Africa	Njoroge and Bussmann, 2006
Combretum micranthum	Kinkeliba	Combretaceae	Alkaloids	Leaves	Central and West Africa	Ancolio et al., 2002
Commiphora eminii	Mukungugu	Burseraceae	Flavonoids	Whole plant	Africa	Mutie et al., 2023
Coriandrum sativum	Cilantro	Apiaceae	Decenal, decanal, geranyl vinyl ether	Leaves	India	Kamaraj et al., 2012
Corydalis dubia	Crested lark	Papaveraceae	Alkaloids	Whole plant	Bhutan, India	Wangchuk et al., 2012
Corymbia watsoniana	Yellow bloodwood	Myrtaceae	Triketones	Flower	Australia	Carroll et al., 2013
Corynanthe pachyceras	Mende paa	Rubiaceae	Alkaloids	Stem bark	Africa	Saxena et al., 2003
Crinum amabile	Giant spider lily	Amaryllidaceae	Alkaloids	Bulb	South-East Asia	Saxena et al., 2003
Croton gratissimus	Lavender croton	Euphorbiaceae	Cembranolides	Leaves	Africa	Langat et al., 2011
Croton macrostachyus	Broad-leaved cotton	Euphorbiaceae	Alkaloids, flavonoids, terpenes, saponins	Leaves	Kenya, Ethiopia, Nigeria	Mohammed et al., 2014
Croton penduliflorus	Nyamaradza	Euphorbiaceae	Tannins, flavonoids	Leaves, twigs	Ghana	Laryea and Borquaye, 2019
Cryptocarya rigidifolia	Peumo	Lauraceae	Tetrahydropyrone derivatives	Root wood	Africa, Indonesia	Liu et al., 2015

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Cryptocarya nigra	Medang	Lauraceae	Alkaloids	Stem bark	Indonesia	Nasrullah et al., 2013
Cryptolepis sanguinolenta	Nibima, Kadze	Apocynaceae	Alkaloids	Roots	Africa	Saxena et al., 2003; Samy et al., 2011
Cucumis aculeatus	Gakungui	Cucurbitaceae	Nitidine	Fruits	Africa	Njoroge and Bussmann, 2006
Cuminum cyminum	Cumin	Apiaceae	Essential oils, alkaloids, flavonoids, saponins, coumarins	Seeds	India, Pakistan, Iran	Kamaraj et al., 2012; Zheljazkov et al., 2015
Curcuma longa	Haldi, Turmmeric	Zingiberaceae	Flavonoids, curcumin	Rhizomes	Asia, Africa	Okello and Kang, 2019
Cyclea barbata	Green grass jelly	Menispermaceae	Alkaloids	Roots	India, Java	Saxena et al., 2003
Cyperus rotundus	Nut grass	Cyperaceae	Sesquiterpenes	Twigs	Europe, South-East Asia	Saxena et al., 2003
Dasymaschalon obtusipetalum	Jing wang	Annonaceae	Alkaloids	Twigs	Thailand	Jaidee et al., 2015
Datisca glomerata	Durango	Datiscaceae	Triterpene, cucurbitacin	Whole plant	North America	Graziose et al., 2013
Datura metel	Indian thornapple	Solanaceae	Alkaloids, flavonoids	Leaf	India	Kamaraj et al., 2012
Datura stramonium	Apple of Peru	Solanaceae	Flavonoids	Leaves and twigs	Ghana	Laryea and Borquaye, 2019
Dehaasia incrassata	Margapali, Paitan	Lauraceae	Alkaloids	Leaves, bark	Asia, Africa	Saxena et al., 2003
Dendrobium venustum	The lovely Dendrobium	Orchidaceae	Phenolic compounds	Whole plant	Thailand, Cambodia	Sukphan et al., 2014
Derris amazonica	Timbo Branco	Fabaceae	Flavonoids	Roots	Brazil	Muñoz et al., 2000a
Dichroa febrifuga	Chinese quinine	Hydrangeaceae	Febriguine	Roots	China	O'Neill et al., 1985; Saxena et al., 2003
Dicoma tomentosa	Hookiah bel	Asteraceae	Sesquiterpene lactone	Whole plant	Africa, Asia	Jansen et al., 2012
Dillenia andamanica	Andaman Dillenia	Dilleniaceae	Flavonoids, triterpenoids, saponins, phenolics	Whole plant	Australia, India	Chander et al., 2016
Diospyros melanoxylon	East Indian ebony	Ebenaceae	Lupeol, betulin, β-sitosterol	Roots, bark, wood	India	Kamaraj et al., 2012
Dovyalis spp.	Kau apple	Salicaceae	Catechin, flavonoids	Fruits	Africa	Njoroge and Bussmann, 2006; Qanash et al., 2022
Duguetia hadrantha	Pindaiva	Annonaceae	Sampangine Alkaloids	Stem bark	South America	Saxena et al., 2003