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Medicinal Plants for Treatment of Prevalent Diseases²

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Abstract⁴

This chapter focuses on reviewing publications on medicinal plants used in the treatment of common diseases such as malaria, cholera, pneumonia, tuberculosis and asthma. Traditional medicine is still recognized as the preferred primary health care system in many rural communities, due to a number of reasons including affordability and effectiveness. The review concentrated on current literature on medicinal plants, highlighting on information about ethnobotany, phytochemistry and pharmacology. The search for publications on medicinal plants with scientifically proven efficacy was carried out using electronic databases such as Science Direct, Google Scholar, SciFinder and PubMed. In all, about 46 species of different families with potent biological and pharmacological activities were reviewed. All the plants reviewed exhibited potent activity confirming their various traditional uses and their ability to treat prevalent diseases.⁵

Keywords: medicinal plants, malaria, diarrhea, tuberculosis, asthma⁶

1. Introduction⁷

Traditional medicine is still recognized as the preferred primary health care system in many communities, with over 60% of the world's population and about 80% in developing countries depending directly on medicinal plants for their medical purposes [1]. This is due to a number of reasons including affordability, accessibility and low cost [2].⁸

The use of plants to cure several kinds of human diseases has a long history. Various parts of plants such as leaf, stem, bark, root, etc. are being used to prevent, allay symptoms or revert abnormalities back to normal. Since the practice of “herbal remedies” does not adhere strictly to facts accrued using scientific approaches, orthodox medicine sees “herbal medicines” as an alternative medicine. However, most of the pharmaceutical products currently dispensed by physicians have a long history of use as herbal remedies, including opium, aspirin, digitalis and quinine. Modern medicine today utilizes active compounds isolated from higher plants, and about 80% of these active ingredients indicate a positive correlation between their modern therapeutic use and the traditional uses [3].⁹

The search for, and use of drugs and dietary supplements obtained from plants have increased in recent years. Scientist such as pharmacologists, microbiologists, botanists, and phytochemists are combing the Earth for phytochemicals and clues that could be developed into medicines for various diseases treatment. This study therefore reviewed electronic database (Google Scholar, SciFinder, PubMed, etc.) for medicinal plants that have potent activity in treating some prevalent and common ailments like malaria, diarrhea, tuberculosis, pneumonia and asthma.

2. Medicinal plants with demonstrated anti-malarial activity²

Malaria is one of the world's most important parasitic disease and a leading cause of death especially in developing countries [4]. It is endemic in about 100 developing countries, leading to about 1.2 million estimated deaths each year in Africa [5], with pregnant women and children below 5 years being mostly affected [6]. A wide range of medicinal plants is employed for the treatment of malaria, since majority of the people who get infected cannot afford the existing expensive orthodox medicines [7]. The problem of resistance to existing antimalarial agents by parasite has necessitated the search for new and potent agents, and the focus of researchers is on natural products especially medicinal plants since active compounds like quinine and artemisinin were isolated from plants and have been lead compounds for antimalarial drug development [8, 9]. Various medicinal plants have been investigated for their anti-malarial activity and some with demonstrated potent *in vitro* activity have been reviewed below.

2.1 *Cryptolepis sanguinolenta*⁴

C. sanguinolenta (Lindl.) Schlechter (Apocynaceae) is known by Ghanaians as 'Ghana quinine' and specifically by the Asantes and Ewes as 'Nibima' and 'Kadze,' respectively [10]. It is a twining and scrambling thin-stemmed shrub, indigenous to Africa, with much ethno-medicinal importance and interest in the West African sub-region [11]. It is used traditionally for the treatment of malaria, upper respiratory and urinary tract infections, diarrhea, hypertension and as cicatrizant of wounds [12, 13]. The ethanolic and aqueous extracts of *C. sanguinolenta* exhibited an *in vitro* antiplasmodial activity against multi-drug resistance *Plasmodium falciparum* (K1) strain, with all the extracts inhibiting 90% of parasite growth at concentrations below 23 µg/mL. The ethanolic roots and leaves extracts showed potent activity with IC₅₀ of 0.895 ± 0.02 and 3.01 ± 0.02 µg/mL, respectively. While the aqueous roots and leaves extracts had IC₅₀ of 2.32 ± 0.3 and 13.5 ± 0.7 µg/mL, respectively [14]. Evaluating the clinical efficacy of a tea bag formulation of the root of *C. sanguinolenta* in patients with uncomplicated malaria showed that within 72 h, Fifty percent (50%) of the patients had their *P. falciparum* parasitaemia cleared, and all patients, by Day 7. By Day 3, all presenting symptoms such as fever, chills, nausea and vomiting were completely no more. The overall cure rate when one tea bag of *C. sanguinolenta* was taken three times a day for 5 days was 93.5%, due to two cases of recrudescence on Days 21 and 28 [15].

2.2 *Terminalia ivorensis*⁶

T. ivorensis A. Chev. belongs to the family Combretaceae and is commonly known as 'black afara' and by the Asantes as 'amire.' It is a large deciduous forest tree of 15–46 m high, normally grown as timber plantation in many tropical countries [16]. In traditional medicine, various parts of the plant is used to treat malaria, yellow fever, pile, stomach ulcer, wounds and other infections [17, 18]. A study by Komlaga

et al. [19] revealed an active *in vitro* antiplasmodial activity of *T. ivorensis* aqueous leaf extract, against *P. falciparum* chloroquine-sensitive (3D7) and chloroquine resistant (W2) strains with IC₅₀ of 0.64 ± 0.14 and 10.52 ± 3.55 µg/mL, respectively. The ethanolic stem bark extract also showed an *in vitro* antimalarial activity against chloroquine-resistant strains of *P. falciparum* with an IC₅₀ of 6.949 µg/mL [20]. ²

2.3 *Elaeis guineensis* ³

E. guineensis Jacq (Arecaceae), popularly known as oil palm is a monocotyledonous plant which belongs to the coccoid group of palms. It grows up to 15 m high with a lifetime of over 100 years and occurs throughout the tropical rainforest belt of West Africa [21]. *E. guineensis* is commonly used for treating gonorrhea, rheumatism, headache, wounds [22]. An *in vitro* anti-plasmodial assay revealed that, the ethanolic extract of *E. guineensis* leaves has potent antimalarial activity with IC₅₀ of 1.195 µg/mL, against chloroquine-resistant *P. falciparum* [20]. ⁴

2.4 *Phyllanthus emblica* ⁵

P. emblica L. of the family Euphorbiaceae is a deciduous medium-sized plant (10–18 m high), native to tropical south eastern Asia and widely distributed in most subtropical and tropical countries. It is commonly known as Indian gooseberry, rich in vitamin C, minerals and amino acids which helps to build up lost vitality and vigor [23, 24]. Various parts of the plant is used traditionally for the treatment of diarrhea, inflammation, diabetes, jaundice, cough, asthma, peptic ulcer, skin diseases, leprosy, intermittent fevers, headache, anemia, dizziness, snakebite and scorpion-sting [25]. In an SYBR green I-based fluorescence assay to assess the anti-plasmodial potential of *P. emblica*, the methanol leaf extract exhibited potent activity against CQ-sensitive (3D7) and CQ-resistant (Dd2 and INDO) strains of *P. falciparum* with IC₅₀ of 3.125, 4.8 and 5 µg/mL, respectively. Also the ethyl acetate leaf extract showed activity with IC₅₀ of 7.25, 15 and 9 µg/mL against 3D7, Dd2 and INDO *P. falciparum* strains, respectively [26]. ⁶

2.5 *Syzygium aromaticum* ⁷

S. aromaticum (L.) Merril. & Perry, syn. *Eugenia caryophyllata*, an ancient and valuable spice is a member of the family Myrtaceae and is commonly known as clove. It is mostly used as a spice to flavor all kinds of foods and has other medicinal values including anthelmintic, anti-asthma and other allergic disorders, anti-inflammatory, antioxidant, antiviral and anti-parasitic properties [27]. A study by Bagavan et al. [26], revealed the antimalarial activity of methanol extract of *S. aromaticum* flower buds with IC₅₀ of 6.25, 9.5 and 10 µg/mL against *P. falciparum* CQ-sensitive (3D7) and CQ-resistant (Dd2 and INDO) strains, respectively. ⁸

2.6 *Goniothalamus marcanii* ⁹

G. tamirensis Pierre ex Finet & Gagnep is an accepted synonym for the species and is from the family Annonaceae. It occurs naturally in tropical and subtropical parts of Southeast Asia. 80%-EtOH extracts showed an *in vitro* antimalarial activity (IC₅₀ = 6.3 µg/mL) against the drug resistant K1 strain of *P. falciparum* [28]. ¹⁰

2.7 *Casearia sylvestris* ¹¹

C. sylvestris var. *lingua* (Cambess.) Eichler, (Salicaceae) is an evergreen shrub or small tree with long, slender branches and a very dense globose crown. Usually ¹²

4–6 m tall, but can grow up to 20 m high, with wide distribution throughout South America. It has been employed in traditional medicine for treating snake bites, wounds, inflammation, fevers, gastric ulcers and diarrhea [29]. The hexane extracts of *C. sylvestris* stem wood, stem bark, root bark, leaf and root wood as well as ethanol extract of the root bark, exhibited potent *in vitro* antiplasmodial activity against chloroquine-resistance FcB1/Colombia *P. falciparum* strain with IC₅₀ values of 0.9 ± 0.2 , 1.0 ± 0.4 , 1.2 ± 0.4 , 1.3 ± 0.1 , 2.3 ± 0.5 and 7.7 ± 1.1 µg/mL, respectively [30].

2.8 *Cupania vernalis*

C. vernalis Cambess. (Sapindaceae) is a semi-deciduous tree with elongated and dense crown, which can grow up to 10–22 m tall. It can be found in almost all forest formations in Brazil, South America, Argentina, Uruguay, Paraguay and Bolivia. The tree serves as source of tannins and wood locally, and in traditional medicine as diuretic, stimulant, expectorant, natural surfactant, sedative and for treating stomach-ache and dermatitis [31]. The hexane and ethanol leaf extracts showed active antimalarial activity against chloroquine-resistance (FcB1/Colombia) *P. falciparum* with IC₅₀ of 0.9 ± 0.3 and 6.6 ± 0.2 µg/mL, respectively [30].

2.9 *Xylopia emarginata*

X. emarginata Mart. is a species of plant in the Annonaceae family. It is native to Cerrado vegetation in Brazil. It is an evergreen tree with a very narrow, almost columnar crown which can grow up to 10–20 m tall and 30–40 cm in diameter. It usually grows in large clusters, forming a homogeneous mass. It is a species characteristic of swamp forest, and does not grow in the driest places. It is used as a condiment in food, a carminative and aphrodisiac in traditional medicine [32]. *X. emarginata* hexane root bark and stem bark extracts were able to inhibit *P. falciparum* (chloroquine-resistance FcB1/Colombia strains) with IC₅₀ of 4.9 ± 0.2 and 5.2 ± 0.4 µg/mL, respectively [30].

2.10 *Xylopia aromatica*

X. aromatica (Lam.) Mart. belongs to the family Annonaceae and the accepted name is *X. xylopioides*. It is a tree native to Cerrado grassland vegetation, particularly in the states of Goiás and Minas Gerais, in eastern Brazil. It is a medium-sized tree with long, hanging branches that can make the crown look like a Christmas tree. Leaves are alternate, narrow, pointed, in a flat plane and arranged regularly along the branches. It is a common roadside and farmland species of the Pacific slope, not in the forest [33]. The root wood and root bark hexane extracts demonstrated an *in vitro* antimalarial activity against chloroquine-resistance (FcB1/Colombia) strains of *P. falciparum* with IC₅₀ of 4.7 ± 0.9 and 6.8 ± 0.6 µg/mL, respectively [30].

2.11 *Aspidosperma macrocarpon*

A. macrocarpon Mart. (Apocynaceae) is a deciduous tree with an open crown growing up to 3–25 m tall and 25–35 cm in diameter. It is a timber tree, native to Brazil, Venezuela, Bolivia, Paraguay and Peru. Traditionally, it is employed in the treatment of fever [33]. The *in vitro* antiplasmodial study of the ethanol extract revealed an effective activity against *P. falciparum* (chloroquine-resistance FcB1/Colombia) with an IC₅₀ of 4.9 ± 1.1 µg/mL [30].

2.12 *Azadirachta indica* ²

A. indica A. Juss is commonly known as neem tree or Indian lilac and belongs to the mahogany family Meliaceae. It is an evergreen, fast-growing tree that can reach a height of 15–20 m with few of them growing up to 35–40 m, but in severe drought it may shed most of its leaves or nearly all leaves. It is typically grown in tropical and semi-tropical regions. Neem is effective against certain fungi that infect humans and hence used to treat skin diseases like eczema, psoriasis [34]. The 80% methanol leaf extract showed *in vitro* anti-plasmodial activity against chloroquine and pyrimethamine sensitive, 3D7 strain, and chloroquine resistant and pyrimethamine sensitive, Dd2 strain, with IC₅₀ of 5.8 and 1.7 µg/mL, respectively [35]. ³

2.13 *Harrisonia abyssinica* ⁴

H. abyssinica Oliv. of the family Rutaceae, is a spiny, evergreen shrub that branches from the base and can become a spreading or much-branched tree. It usually grows up to 6–13 m tall and commonly found in Tropical Africa, in the areas of Sierra Leone, Cameroon, Sudan, Ethiopia, Uganda, Kenya, Angola, Zambia and Mozambique [33]. The methanolic stem bark extract inhibited chloroquine resistant *P. falciparum* strain Dd2, with IC₅₀ value of 4.7 ± 0.113 while in chloroquine sensitive *P. falciparum* strain 3D7, the IC₅₀ value was 10 ± 0.114 µg/mL [35]. ⁵

2.14 *Maytenus senegalensis* ⁶

M. senegalensis Lam. Exell which belongs to the family Celastraceae is an African shrubs or trees widely distributed throughout Central and South America, Southeast Asia, Micronesia and Australasia, the Indian Ocean and Africa, growing up to 15 m high with spines up to 7 cm long. Traditionally, it is an anti-inflammatory herbal drug and is useful in treating toothaches [36]. The stem bark methanol extract showed anti-plasmodial activity with IC₅₀ of 3.9 and 10 µg/mL when treated *in vitro* on chloroquine sensitive, 3D7 and chloroquine resistant, Dd2 strains, respectively [35]. ⁷

3. Medicinal plants with demonstrated activity against *Vibrio cholera* ⁸

Cholera is an acute intestinal disease caused by a facultative anaerobic, Gram-negative, comma-shaped rod bacterium, known as *V. cholerae*. Cholera is a life threatening disease transmitted by the fecal-oral route. The organisms adhere to and colonize the small bowel within a short incubation period, where they secrete cholera enterotoxin leading to severe and watery diarrhea accompanied with vomiting, dehydration and eventually death if not treated promptly [37]. Various antibiotics have been effective for the treatment of cholera; however, the worldwide problem of microbial resistance to existing antimicrobial medicines has led to most antibiotic failure. Researchers are therefore shifting their focus to natural products, especially medicinal plant, with effective antimicrobial properties. Some medicinal plants with potent anti-cholera activity are reviewed below. ⁹

3.1 *Terminalia chebula* ¹⁰

T. chebula Retz. (Combretaceae) commonly known as black or chebulic myrobalan is a medium to large deciduous tree growing up to 30 m tall, with a trunk of 1 m in diameter. It leaves are oval, alternate to subopposite in arrangement and is ¹¹

a native to South Asia, from India and Nepal east to southwest China, Sri Lanka, Malaysia and Vietnam. Traditionally, it has been used for treatment of indigestion, diarrhea and diabetes [38]. The plant extract used to treat Cholera worked effectively against the strains of *V. cholera* the causative agent. The methanol fruit extract of *T. chebula* had strong bactericidal activity with MIC ranging from 0.125 to 1.5 mg/mL and MBC ranging from 0.25 to 2 mg/mL, against multi-drug resistance strains of *V. cholerae* (serotypes O1, O139, and non-O1, non-O139) [39].

3.2 *Syzygium cumini*

S. cumini (L.) Skeels (Myrtaceae), known as Jam is an evergreen tropical tree, native to the Indian Subcontinent, adjoining regions of Southeast Asia, China and Queensland. It Grows up to 30 m and can live more than 100 years, with a dense foliage which provides shade and is grown just for its ornamental value. The leaves are pinkish when young, and changes to dark green with a yellow midrib as they mature [40]. The seeds have traditionally been used to treat diarrhea, dysentery, piles, indigestion and diabetes. *S. cumini* methanol seed extract exhibited a bactericidal anti-cholera activity against multi-drug resistance strains of *V. cholerae* (serotypes O1, O139, and non-O1, non-O139), with MICs and MBCs ranging from 1.25–3 mg/mL [39]. Also Sharma et al. [41] reported the *in vitro* anti-vibrio activity of the ethanolic stem bark extract against different strains of *V. cholera* with MICS ranging from 2.5 to 20 mg/mL.

3.3 *Saraca indica*

S. indica auct. L. commonly known as Asoka-tree or Ashok is a plant belonging to the Detarioideae subfamily of the Fabaceae family. Asoka tree is an evergreen tree with a spreading crown which can grow up to 24 m tall and 34 cm in diameter. The original plant specimen came from Java. Some traditional uses of the plant include treatment of dyspepsia, fever, burning sensation, colic, ulcers, menorrhagia, leucorrhoea, pimples [42]. *S. indica* evoked strong bactericidal activity against different strains of multi-drug resistance *V. cholera*, with MBCs ranging from 1 to 4 mg/mL [39]. A study by Sharma et al. [41] also showed the anti-vibrio potential of the ethanolic stem bark extract, with MICs range of 2.5–10 mg/mL against 13 strains of *V. cholera*.

3.4 *Butea monosperma*

B. monosperma (Lam.) Taub. (Papilionaceae) is a native to tropical and subtropical parts of the Indian Subcontinent and Southeast Asia, ranging across India, Bangladesh, Nepal, Sri Lanka, Myanmar, Thailand, Laos, Cambodia, Vietnam, Malaysia and western Indonesia. Common names include flame-of-the-forest and bastard teak. It is a medium-sized dry season-deciduous tree, growing to 15 m tall. Leaves are pinnate, with (8–16 cm) petiole and three leaflets of 10–20 cm long. Its flowers are used in traditional medicine for the treatment of ulcer, inflammation, hepatic disorder and eye diseases [43]. The methanol flower extract showed anti-cholera activity with MIC and MBC ranging from 1.75 to 5 mg/mL against different strains of multi-drug resistance *V. cholera* [39].

3.5 *Euphorbia serpens*

E. serpens Kunth is a member of the Euphorbiaceae family. It is native to South America but it can be found on most continents as an introduced species and often a weed. This is an annual herb forming a mat of prostrate stems [44]. Purified

bioactive fraction of aqueous extract of *E. serpens* exhibited an anti-Vibrio activity ² at a Minimum Inhibitory Concentration of 3.92 mg/mL [45].

3.6 *Acacia farnesiana* ³

Vachellia farnesiana, also known as *A. farnesiana* (L.) Willd, commonly known ⁴ as sweet acacia or needle bush, is a species of shrub or small tree in the legume family, Fabaceae. The species grows to a height of 4.6–9.1 m and grows multiple trunks. *V. farnesiana* has been used in Colombia to treat malaria, in the Philippines the leaves are traditionally rubbed on the skin to treat skin diseases in livestock. In Malaysia, an infusion of the plant's flowers and leaves is mixed with turmeric for post-partum treatment [46]. The bark methanolic extract revealed a potent bactericidal activity against two strains of *V. cholera*, O139 (AI-1837) and O1 (569-B) with MBCs of 0.5 ± 0.1 and 0.9 ± 0.1 , respectively [47].

3.7 *Artemisia ludoviciana* ⁵

A. ludoviciana (Nutt.) White sagebrush of the family Asteraceae is native to North ⁶ America where it is widespread across most of the United States, Canada and Mexico. It is a rhizomatous perennial plant growing to height of 0.33–1 m. Medicinally, it is used for dermatological purposes and for treating cold [48]. The anti-cholera activity of the methanol whole plant extract was effective and bactericidal against O139 (AI-1837) and O1 (569-B) *V. cholera* strains. The minimum bactericidal concentrations against the two strains were 0.7 ± 0.2 and 1 ± 0.3 , respectively [47].

3.8 *Ocimum basilicum* ⁷

O. basilicum (L.) Basil (Lamiaceae) can be found in Tropical Asia. It is a ⁸ perennial growing up to 0.5 m tall and by 0.3 m in diameter. Medicinally it is used for the treatment of fever, colds, influenza, poor digestion, nausea, abdominal cramps, gastro-enteritis, migraine, insomnia, depression and exhaustion [49]. The methanol whole plant extract exhibited a bactericidal activity against *V. cholera* O139 (AI-1837) and O1 (569-B) strains with MBCs of 2 ± 0.6 and 3 ± 0.5 , respectively [47].

3.9 *Opuntia ficus* ⁹

O. ficus-indica (L.) of the family Cactaceae is species of cactus that has long been ¹⁰ domesticated. It is commonly known as prickly pear or Nopal cactus. It originated from Mexico and cultivated in other parts of the world including Mediterranean Basin, Middle East and northern Africa [50]. A study by Sánchez et al. [47], revealed the anti-cholera activity of the methanol cladode extract of *O. ficus*, with minimum bactericidal concentrations against O139 (AI-1837) and O1 (569-B) *V. cholera* strains to be 3 ± 0.05 and 3 ± 0.1 , respectively.

3.10 *Lawsonia inermis* ¹¹

L. inermis Linn. (Apocynaceae) commonly known in India as Henna is a flower- ¹² ing plant and the sole species of the genus Lawsonia. It is a tall shrub or small tree, standing 1.8–7.6 m tall, glabrous and multi-branched, with spine-tipped branchlets. The henna plant is native to northern Africa, western and southern Asia, northern Australia, and thrives well in semi-arid zones and tropical areas. It is useful medicinally for burning sensation, leprosy, skin diseases, amenorrhoea, and dysmenorrhea

and as abortifacient [51]. The ethanolic leaf extract exhibited an *in vitro* anti-vibrio activity with MICs ranging from 2.5 to 10 mg/mL against 13 strains of *V. cholera* [41].

4. Medicinal plants with demonstrated anti-tuberculosis activity²

Tuberculosis (TB) is an airborne infectious disease which does not only affect the lungs but also other parts of the body such as the brain and spine [52]. The main cause of TB is *Mycobacterium tuberculosis*. Other *M. tuberculosis* complex that causes TB include *M. bovis*, *M. africanum*, *M. canetti* and *M. microti* [53]. The predominant symptoms of active TB are fever, night sweat, weight loss and chronic cough with blood containing sputum. However, most TB infections are latent which may progress into active disease if left untreated [52]. Treatment of TB is very tedious and requires a long course with multiple antibiotics involved. However, this fastidious bacteria have become resistant to most antibiotics, and hence researchers are working tirelessly to come up with new and effective products especially from natural products such as medicinal plant. Some medicinal plants that have been investigated to possess active anti-tuberculosis activity are reviewed below.

4.1 *Anogeissus leiocarpa*⁴

A. leiocarpa (Combretaceae) commonly called African birch is a tall deciduous tree which is indigenous to the savannas of tropical Africa. Traditionally, its stem and root barks are used to treat gonorrhea, worm infestation, cough, asthma and tuberculosis [54]. The susceptibility of clinical isolates of *M. tuberculosis* to the methanolic extract of *A. leiocarpa* was investigated using the broth dilution method. The results demonstrated anti-mycobacterial property (MIC 78 µg/mL). *A. leiocarpa* fraction showed an increased anti-mycobacterial activity (MIC 7.8 µg/mL) [55].

4.2 *Terminalia avicennioides*⁶

T. avicennioides (Combretaceae) is a tree commonly found in West Africa. Its root bark, fruit and mistletoes are used traditionally to treat diarrhea, hemoptysis, sore throat, TB, asthma and cough [54]. The *in vitro* antibacterial studies using broth dilution method of methanolic extract of *T. avicennioides* showed a significant anti-mycobacterial activity (MIC 78 µg/mL) against clinical isolates of *M. tuberculosis*. The n-hexane and ethyl acetate fractions obtained from the crude methanol extract of *T. avicennioides* showed inhibitory activity (MIC 200 and 625 µg/mL, respectively) against attenuated strains of *M. bovis*. A further study of *T. avicennioides* fraction obtained demonstrated anti-mycobacterial activity (MIC 4.7 µg/mL) [55].

4.3 *Capparis brassii*⁸

C. brassii (Capparidaceae), the narrow-leaf caper bush is distributed in the coastal forest and mixed woodland from tropical West Africa to South-East Africa. The root bark is used to treat TB in folk medicine [54]. The methanol extract of *C. brassii* has demonstrated some level of anti-mycobacterial activity (MIC 1.25 mg/mL) against clinically isolated strains of *M. tuberculosis* [55].

4.4 *Combretum* spp.¹⁰

Combretum (Combretaceae) commonly called the bush willows has about 370 species of shrubs and trees, predominant in southern and tropical Africa,

Madagascar, Asia and tropical America. Traditionally, its root and stem barks are used to treat cough, bronchitis and TB [54]. The methanol extract exhibited anti-mycobacterial activity (MIC 1.25 mg/mL) against *M. tuberculosis* clinical isolates when evaluated in vitro using the broth microdilution method [55]. ²

4.5 *Solanum torvum* ³

S. torvum (Solanaceae) also called turkey berry is an upright bushy and spiny perennial plant which is native to the Caribbean, southern Mexico, tropical and central America. However, it is also widely naturalized in the warmer and coastal regions of New South Wales, northern and eastern Australia, tropical Africa, Asia, Papua New Guinea, South-Eastern USA and on several pacific islands. The juice from this plant is used for the treatment of fever, sore throat, dropsy, rheumatism, gonorrhea, stomach ache, chest ailment, and asthma, while leaves and fruits can also be used to control a wide range of microbial activity [56]. The crude leave extract of *S. torvum* has demonstrated a significant inhibitory activity against two stains of *M. tuberculosis* (H37Ra and H37Rv) with MIC of 156.3 and 1250 µg/mL, respectively [57]. ⁴

4.6 *Galenia africana* ⁵

G. africana (Aizoaceae) is an upright green to yellow-green aromatic woody perennial shrublet commonly found on the western and southern edges of Karoo [16]. The ethanolic extract of *G. africana* demonstrated anti-mycobacterial activity (MIC 1.2 mg/mL) against *M. tuberculosis*. A further study of flavone, 5,7,2'-trihydroxyflavone which was isolated from *G. africana* showed an increased activity (MIC 0.1 mg/mL) against *M. tuberculosis* [58]. ⁶

4.7 *Allium sativum* ⁷

A. sativum (Amaryllidaceae) popularly called garlic is a bulbous plant, native to northern and eastern Iran and Central Asia [59], however, garlic can grow in the wild and in places where it has become naturalized. During World War I and II, garlic was used as an antiseptic to prevent gangrene [60]. Aside its reported nutritional value, garlic can demonstrate antimicrobial effect at temperature as high as 120°C. The aqueous and ethanolic extracts of *A. sativum* has shown anti-tuberculosis activity (MIC 0.05 and 0.1 mg/mL, respectively) against *M. tuberculosis*, H37Ra via the use of Microplate Alamar Blue Assay (MABA) [61]. A study by Gupta et al. [62] also showed the inhibitory activity of *A. sativum* against multidrug resistant isolates DKU-156 and JAL-1236, as well as sensitive *M. tuberculosis* H37Ra with percentage inhibition of 72, 72 and 63%, respectively. ⁸

4.8 *Allium cepa* ⁹

A. cepa commonly called onions is from the family Liliaceae. Onions have several pharmacological activity such as antidiabetic, antioxidant, anticancer, cardiovascular, antimicrobial and others [63]. The minimum inhibitory concentration by which the ethanolic and aqueous extracts of the tissue of *A. cepa* inhibited the growth of *M. tuberculosis* H37Ra was recorded to be 0.1 mg/mL for both extracts [61]. Another *in vitro* study showed a 79% proportion of inhibition of aqueous extract of the bulb of *A. cepa* against MDR isolate JAL-1236 [62]. ¹⁰

4.9 *Cinnamomum verum*¹

C. verum, (formerly *C. zeylanicum*) of the family Lauraceae, commonly known as cinnamon tree is an evergreen small tropical plant native to Sri Lanka, it is also cultivated in Madagascar and Seychelles on commercial scale [33]. Its anti-tuberculosis activity reported by Sivakumar and Jayaraman, [61] revealed that, the aqueous and ethanolic extracts of the bark of *C. verum* exhibited anti-mycobacterial activity (MIC 0.1 and 0.2 mg/mL, respectively) against *M. tuberculosis* H37Ra.

4.10 *Acalypha indica*³

A. indica popularly known as Indian nettle is from the family Euphorbiaceae. In Africa, it is distributed in Nigeria, from eastern part of Sudan to Somalia and south through DR Congo and East Africa to Southern Africa. It also occurs in South-East Asia, India, Oceania and widely in the Indian Ocean islands. Traditionally, it is used as an antifungal and antibacterial agent for both human and plant pathogens. It is also used as an expectorant to treat pneumonia and asthma [33]. The *in-vitro* study of the aqueous leave extract of *A. indica* against MDR isolate DKU-156, JAL-1236 and sensitive *M. tuberculosis* H37Rv, demonstrated 95, 68 and 68% inhibition, respectively [62].

5. Medicinal plants with demonstrated activity against pneumonia⁵

Pneumonia is a respiratory tract infection characterized by the inflammation of one or both lungs as a results of the accumulation of pus in the alveoli. Pneumonia which can be caused by bacteria, viruses or fungi can be mild, severe or life threatening. Bacterial pneumonia can be caused by *Streptococcus pneumoniae* which is the commonest cause, *Staphylococcus aureus*, *Moraxella catarrhalis*, *Klebsiella pneumoniae*, *Haemophilus influenza*, *Chlamydophila pneumonia* and *Legionella pneumophila*. *Pneumocystis jirovecii pneumonia* (PCP) is a fungal pneumonia commonly found in immunocompromised patients. Viral pneumonia can also be caused by adenovirus, Varicella zoster, Influenza virus and respiratory syncytial virus [64, 65]. Traditionally, medicinal plants have been employed for treating pneumonia and hence the need to prove, scientifically, their folkloric uses. Researchers have investigated such plant, and below is a review on some of the reported plants with demonstrated activity.

5.1 *Echinops adenocaulos*⁷

In Ethiopian herbal medicine, members of the genus *Echinops* from family Asteraceae are used for the treatment of diarrhea, intestinal worm infestation, hemorrhoids, migraine and different forms of infections [66]. Zamzam water extract of *E. adenocaulos* demonstrated an antibacterial activity against multidrug resistance *S. pneumoniae* with a minimum inhibitory concentration (MIC) of 0.781 mg/mL [67].

5.2 *Verbascum fruticulosum*⁹

Various species of *Verbascum*, of the family Scrophulariaceae, have been used to treat pulmonary diseases in traditional medicine as a results of its antibacterial activity against *Klebsiella pneumonia* and *Staphylococcus aureus* [68]. The *in vitro* antimicrobial activity of aqueous extract of *V. fruticulosum* against multidrug resistant clinical isolate of *S. pneumoniae* showed a high antibacterial activity with MIC value of 0.195 mg/mL [67].

5.3 *Parietaria judaica*²

P. judaica commonly known as pellitory of wall from family Urticaceae has been valued for its use as a diuretic, balm for wounds and burns and also as a soother for chronic cough in herbal medicine [69]. The micro-broth dilution method was used to study the inhibitory activity of aqueous extract of *P. Judaica*. The extract was able to inhibit multidrug resistant *S. pneumonia* at an MIC value of 3.125 mg/mL [67].

5.4 *Urtica urens*⁴

U. urens commonly known as dwarf nettle or annual nettle from family Urticaceae is used medicinally for the treatment of pulmonary diseases [70]. A study by Saleh Fares et al. [67] on the inhibitory activity of the aqueous extract of this plant against multidrug resistant clinical isolates of *S. pneumoniae*, using micro-broth dilution method, gave an MIC of 6.25 mg/mL. This illustrates its potential to be used as medicine in the treatment pneumonia caused by multidrug resistant *S. pneumoniae*.

5.5 *Beta vulgaris*⁶

B. vulgaris popularly known as sugar beet from family Amaranthaceae is a sugar producing plant. Sugar-producing plants contain bioactive compounds, which are active against microbes and hence are able to protect the sugar from fermenting or from undergoing any alteration [71]. The study of the antimicrobial activity of the crude ethanolic leaf (lamina and midrib) extracts as well as fractions (n-hexane and chloroform) against *K. pneumonia*, showed zones of growth inhibition at different concentrations tested. At 1 mg/12 μ L, the lamina and midrib crude extracts recorded 19 and 9 mm inhibition zone. The chloroform lamina and midrib fraction recorded 12 and 14 mm at concentration 1 mg/6 μ L, while at concentration 1 mg/12 μ L, their inhibition zones were 15 and 20 mm, respectively. Also the n-hexane lamina and midrib fractions had 20 and 16 mm inhibition zones (1 mg/6 μ L), while 36 and 32 mm zones of inhibition (1 mg/12 μ L) were recorded, respectively [72].

6. Medicinal plants with demonstrated anti-asthmatic activity⁸

Asthma is a complex inflammatory disease and congestive respiratory disorder brought about by airway narrowing. It symptoms may include episodic wheezing, cough and chest tightness resulting in airflow block. It leads to changes in the levels of eosinophils, mast cells, lymphocytes, cytokines and other inflammatory cell products. There is increased prevalence worldwide especially in industrialized countries and among children with increased morbidity and mortality rate [73, 74]. Medicinal plants have been screened for properties that enhance their activity as anti-asthmatic agents, since current medications have adverse side effects. Few of such plants with demonstrated activity are reviewed below.

6.1 *Curcuma longa*¹⁰

C. longa L. is a rhizomatous herbaceous perennial flowering plant of the ginger family, Zingiberaceae. It is native to the Indian subcontinent and Southeast Asia, and requires temperatures between 20 and 30°C and a considerable amount of annual rainfall to thrive. Methanolic extracts (curcumin-II at 200 mg/kg and

curcumin-I at 100 mg/kg) of the finger rhizomes of *C. longa* reduced significantly ($P < 0.01$) estimated white blood cells count in ovalbumin (OVA) sensitized Wistar rat models for both long and short term. At a higher dosage, curcumin-II (200 mg/kg) tends to protect intact mast cells from degranulation [3]. This suggests that curcumin can be used as complementary medicine in the treatment of Asthma.

6.2 *Aerva lanata*²

A. lanata (L.) A. L. Juss. ex Schult (Amaranthaceae) is a perennial herb, frequently becoming more or less woody at the base. The stems can be erect to prostrate, sometimes scrambling or climbing into other plants for support. It is widespread in the tropics and subtropics of Africa through Asia to the Philippines and New Guinea. It is used traditionally for treating cough, sore throat, indigestion, wounds, and diabetics and as a vermifuge for children [75]. The ethanol extract of aerial parts of *A. lanata* at 100 µg/mL significantly ($***p < 0.01$) exhibited percentage decreased contraction in the isolated goat tracheal chain preparation model. Also in clonidine induced mast cell degranulation, the extract at 30 and 60 mg/kg administered orally, showed percentage protection of 64.2 and 68.9%, respectively [76].

6.3 *Cynodon dactylon*⁴

C. dactylon (L.) Pers, of the family Poaceae is a short-lived, prostrate, perennial grass. It is widely naturalized in the temperate to tropical zones of Europe, Africa, Asia, the Pacific and the Americas. Its habitat is along roadsides and in exposed rocky or sandy sites. It use in traditional medicine to stop bleeding in minor injuries, for weak vision and eye disorders, piles, asthma, tumors among others [77]. The findings of Savali et al. [78], indicated that isolated *C. dactylon* compound was potent and has significant ($p < 0.01$ and $p < 0.001$) inhibitory effect on compound 48/80 induced anaphylactic reaction and mast cell activation. Also, compound 48/80 induced increased level of nitric oxide in rat serum and rat peritoneal mast cells were significantly inhibited.

6.4 *Piper betle*⁶

P. betle L. (Piperaceae) commonly referred to as Betel pepper, is an evergreen climbing shrub producing woody stems, 5–20 m long, and distributed in Southeast Asia—probably originally from Malaysia. It is traditionally used to cure cough, cold, pruritis, asthma and rheumatism [79]. Ethanol and aqueous extract of leaves at doses 100 and 200 mg/kg possesses anti-asthmatic activity on histamine induced bronchoconstriction in guinea pig and histamine induced dose dependent contraction of guinea pig tracheal chain [80].

6.5 *Lepidium sativum*⁸

L. sativum L. (Brassicaceae) also referred to as Garden cress is a profusely-branched, erect, annual plant growing up to 80 cm tall [81]. It commonly grown in many regions of Saudi Arabia and the Eastern Province. The seeds are used to cure bronchitis, asthma, cough, and useful as abortifacient, antibacterial, aphrodisiac, diuretic, expectorant, gastrointestinal stimulant, gastroprotective, laxative and

stomachic [82]. The bronchodilatory effect of ethanolic seed extract and ethyl acetate, n-butanol and methanol fractions, against histamine and acetylcholine induced acute bronchospasm in guinea pigs, exhibited significant inhibition of bronchospasm, with n-butanol fraction showing a significant ($p < 0.001$) protection comparable to the reference standards used in the study [83]. Rehman et al. [84] also confirmed the bronchodilatory effect of *L. sativum* crude extract by investigating the various pathways for its activity in airway disorders. It was revealed that, the extract's activity was mediated through a combination of anticholinergic, Ca^{++} antagonist and phosphodiesterase inhibitory pathways.

6.6 *Curculigo orchioides* ³

C. orchioides Gaertn. (Hypoxidaceae) is a stemless evergreen perennial herb producing a cluster of leaves from the roots and spreading to form a clump. It grows up to 50 cm tall. It ranges from East Asia—South China, Japan, Indian sub-continent, Myanmar, Thailand, Cambodia, Laos, Vietnam, Malaysia, Indonesia, Philippines, New Guinea, W. Pacific. Alcoholic extract of *C. orchioides* rhizomes at doses (100–400 mg/kg) shows mast cell stabilizing and antihistaminic activity on Compound 48/80-induced mast cell degranulation and systemic anaphylaxis [85]. Also Pandit et al. [86] established the usefulness of the ethanol extract in treating asthma, as it was reported to exhibit significant relaxant effect ($p < 0.01$) at concentrations 100 and 25 $\mu\text{g/mL}$ in isolated goat tracheal chain and isolated guinea pig ileum preparations respectively. In an *in vivo* study using histamine induced bronchoconstriction in guinea pigs, egg albumin induced passive paw anaphylaxis in rats and haloperidol-induced catalepsy in mice, there was significant ($p < 0.01$) protection at lower doses. Again, maximum increase in leucocytes and lymphocytes (99%) and maximum decrease in eosinophils up to 0% at dose 375 mg/kg p.o. was reported in milk-induced total leukocytes and differential leukocyte counts.

6.7 *Casuarina equisetifolia* ⁵

C. equisetifolia L. (Casuarinaceae) also commonly known as Common Ru, is an evergreen tree with a finely branched, feathery crown usually growing from 6 to 35 m and 20–100 cm in diameter. The tree is widely planted throughout the tropics, and ranges from East Asia to Bangladesh, Myanmar, Thailand, Vietnam, Malaysia, Indonesia, Philippines, Australia and the Pacific [87]. The methanol extract of wood and bark (10–80 mcg/mL) exhibited a significant dose dependent ($p < 0.05$) antihistaminic activity by inhibiting the histamine induced contraction of trachea. The wood extract (100 mg/kg, i.p.) significantly reduced clonidine induced catalepsy ($p < 0.05$) and mast cell degranulation ($p < 0.001$) [88].

7. Conclusion ⁷

All the plants reviewed exhibited potent activity confirming their various traditional uses and their ability to treat prevalent diseases. There is therefore the need to subject these plants to further studies, by isolating active compounds which can be processed into new and potent medicines and the need to study their mechanisms of action.



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