Review Article

Traditional Medicinal Plants as a Source of Antituberculosis Drugs: A System Review

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Medicinal plants are the chief components in the different oriental formulations in different traditional medical systems worldwide. As a thriving source of medicine, the medicinal plants with antituberculosis (TB) properties inspire the pharmacists to develop new drugs based on their active components or semimetabolites. In the present review, the anti-TB medicinal plants were screened from the scientific literatures, based on the botanical classification and the anti-TB activity.

The obtained anti-TB medicinal plants were categorized into three different categories, viz., 159 plants critically examined with a total 335 isolated compounds, 131 plants with their crude extracts showing anti-TB activity, and 27 plants in literature with the prescribed formula by the traditional healers. Our systemic analysis on the medicinal plants can assist the discovery of novel and more efficacious anti-TB drugs.

1. Introduction

Globally, traditional medicines (TM) make a vital contribution to the health care industry. In some countries, TM is the main source of health care or even the sole health care service available, especially in the rural sector [1]. The popularity of TM is also increasing in the developed countries for many different reasons, one of which is that the effectiveness of these TM was proved by the ethnopharmacological research. Early in 1972, the World Health Organization (WHO) established a Department of Traditional Medicine (DTM). Later, WHO (2013) called on to strengthen its public services of the traditional medicine [1]. Recently, the International Classification of Traditional Medicine (ICTM) was added as a new chapter into the International Classification of Diseases—11 (ICD-11) [2]. This achievement currently refers to the Traditional Chinese Medicine (TCM) alone, which opens its doors to accommodate many other thriving traditional health care philosophies prevailing globally, such as Ayurveda and Traditional African medicine (TAM).

The spread of tuberculosis (TB) occurred from East Africa to the rest of the world with the migration of Homo sapiens, especially along the established trade routes with increased mingling and crowding of populations [3, 4]. Currently, there exist more than 10 million new cases of active disease and nearly 1.3 million deaths annually [5, 6]. In response to this spreading route, different countries developed their own traditional anti-TB formulations during the long courses in fighting this old plaque. Reports relating TB can be found in many ancestral data of the TM medical system, especially the TCM, Ayurveda, and TAM for its long history coexisting with human kinds for an estimated 70,000 years [7]. Investigations on the TM formulations show that the plants or herbs are the main composition of the traditional anti-TB formula, from which the active components or semimetabolites present a thriving source of new drugs. In the last 20 years, nearly 50% of drugs approved by the
FDA in the United States of America have been derivatives of the natural products, including natural plant products [8]. Among the 435,000 plant species reported worldwide [9], an estimated 70,000 species of plants are used for medicinal purposes [10]. Thus, selecting plants based on ethnobotanical knowledge can enhance the probability to find new compounds with anti-TB activity.

Before this review, some articles summarized the role of local medical plants but only few with anti-TB purpose [11, 12]. In this review, the anti-TB medicinal plants in different countries or regions are included to analyze their botanical classification, active botanical parts, extract method, and in vitro anti-TB activities in brief. Subsequently, the effective anti-TB plants are described with the following three branches: those with the isolated effective compounds, those with their crude plant extracts showing anti-TB effect, and those only found in the formula prescribed by traditional healers. Finally, we discuss the influencing factors on the development of traditional medicine and its future trend. This review is to inspire the development of possible new anti-TB agents derived from plants.

2. Brief Description of the Overall Anti-TB Medicinal Plants

We present the data by searching the main three databases: Wangfang Med, Chinese National Knowledge Infrastructure, and PubMed. Combinations of the following search terms are used: “tuberculosis,” “plant,” “herb,” “Chinese and western medicine,” and “random.” In the present review, only the nonrepetitive plant species with good in vivo or in vitro anti-TB effect were accepted, although the criterion of the effectiveness was quite different with the inhibition concentration expressed in several different ways in different Mycobacteria, especially the \( M. \) \( \text{tuberculosis} \) H37Rv and the clinical isolates. The plants employed for treating the fever in traditional medicine have not been included, as fever is taken to be a nonspecific indication of many infections that are not restricted to TB. The exception to this is where fever is treated in conjunction with other TB-related symptoms like coughing.

The classification of the traditional anti-TB medicinal plants in the present review belongs to 90 families including 230 genus and 277 species (Figure 1). The top 11 families with more than 7 plant species include Fabaceae (21 species in 18 genus), Asteraceae (20 in 16 genus), Euphorbiaceae (14 in 11 genus), Lamiaceae (13 in 11 genus), Rutaceae (14 in 10 genus), Combretaceae (9 in 4 genus), Piperaceae (9 in 1 genus), Zingiberaceae (8 in 3 genus), Annonaceae (7 in 6 genus), and Apiaceae (7 in 7 genus). Forty plant families are only reported once. A total of 6 \( Terminalia \) genus that belongs to the Combretaceae family have up to 6 anti-TB plant species, and about 9 anti-TB plant species belong to only one genus \( Piper \).

The literatures that we studied reported the anti-TB properties of the plant species from different plant parts (aerial parts, almonds, bark, bulbs, branches, fruits, flowers, heart woods, leaves, rhizomes, roots, stems, seeds, shoots, twigs, tubers, wood, whole plants, and even the ethnomedicinal recipes). With the leaves (83 cases), roots (61), aerial parts (52), barks (30), stems (14), whole plants (9), seeds (9), fruits (8), rhizomes (8), and flowers (7) are the top 10 most used anti-TB plant parts. For the same plant species, different parts of the plant presented a varied anti-TB effect. The useful plant parts of the genus \( Lantana \), \( Piper \), and \( Terminalia \) mainly focused on the leaves, leaves, and both leaves and roots, respectively.

It was observed that the extraction methods of the medicinal plants available in the literature significantly affected the anti-TB results. The general problems concerning the antibacterial screening of medicinal plant extracts have already been discussed in the literature [13]. There is still no single extraction method that is regarded as a standard for extracting the bioactive compounds from medicinal plants. One or more of the following solvents were mainly used in the studies: dichloromethane (268 times), methanol (65), ethanol (45), hexane (29), chloroform (18), ethyl acetate (11), water (11), and acetone (10), while diethyl ether, acetate, and hydroalcoholic solutions were seldom used. Since the extraction process deeply influences the results of the bioactivity tests and the subsequent isolation of bioactive compounds, selection of the best extraction method by consulting the traditional knowledge about the preparation of the herbal remedy remains crucial [14].

As noted earlier and evidenced by this review, many reports lack adequate statistical analysis of their results and appropriate controls for their anti-TB activity, while some studies lack the generic extraction schemes or tests against a panel of various species of \( Mycobacteria \) to avoid false positive results. In this review, the parallel cytotoxic evaluation on mammalian cell lines has not been provided, since our main aim was to summarize the crude extracts or compound precursors of the anti-TB medicinal plants, although this needs to be overcome in the future.

3. Compounds from the Plants with Anti-TB Activity

Different from the conventional process of drug discovery involving the screening of large molecular libraries for biological activities and/or in silico data mining approaches based on cheminformatics modeling, the bioactivity-guided fractionation was mostly employed in medicinal plants to isolate the bioactive compounds. They were extracted first from the specified parts of the plants, then fractionized and characterized by infrared spectroscopy, mass spectrometry, and nuclear magnetic resonance spectroscopy, to obtain the structural data. Finally, their bioactivities were verified in different mycobacteria.

Several groups summarized the active anti-TB natural products from the different organs and regions. Early in 2007, Copp and Pearce [15] summarized a total of 353 natural products (secondary metabolites) with reported growth inhibitory activity towards \( M. \) \( \text{tuberculosis} \) or related organisms from terrestrial and marine plants and animals and microorganisms. Abedinzadeh et al. [16] stressed the natural antimycobacterial peptides from bacteria, fungi, plants, and animals. Chinsembu [17] described the natural
antimycobacterial agents from endophytes and medicinal plants in different regions of Africa, Europe, Asia, South America, and Canada. The present review only focused on the medicinal plants and the plants with anti-TB components belonged to the 156 species, 123 genus, and 64 families, of which Fabaceae (13 species, 10 genus), Rutaceae (10 species, 7 genus), and Lamiaceae (9 species, 7 genus) were the top three families; accordingly, more genera belong to those family with anti-TB activity (Table 1).

Many plants consisted several components with anti-TB activity, and only the active compounds that were reported are listed in this review. Table 1 presents the list of 335 compounds, which were tested for their anti-TB activities. Those 335 compounds could be divided into mainly 11 classes, such as terpenes (37 types), ketones (31), acids (14), alcohols (10), esters (9), hydrocarbons (9), quinones (8), furans (7), phenols (6), and quinolones (3). The typical structures of the 335 compounds are sorted out in Figure 2. Of all the anti-TB natural compounds, the derivatives and analogs of phytol, flavones, and terpenoids were critically reviewed by Singh et al. [173] and Cantrell et al. [174] for their pharmacological activities of various diseases. These 335 compounds were natural products or secondary metabolites, and few of their synthetic modified derivatives have been mentioned in this review.

In fact, many semisynthetic derivatives proved to be more active than the parent compounds; for example, the methylation of natural compounds of mulinenic acid and 13-hydroxy-mulin-11-en-20-oic acid methyl ester decreased the minimum inhibitory concentration (MIC) by 8 times [42]; n-propyl ester and n-butyl ester of isomulinic acid decreased the MIC by 4 times [42]. The triacetylated methyl gallate decreased the MIC 2-4 times, since the acetylation increased the lipophilic nature of methyl gallate [19]. The

![Classification of traditional anti-TB medicinal plants with effective crude extracts and the compounds. (a) Botanical families consisting of the anti-TB medicinal plants. There are 108 families including 230 genus and 277 species in this summary. (b) Genus number (>2) of the anti-TB medicinal plant families.](image-url)
| Plant species         | Plant family      | Part used           | Extracts                  | Compound class     | Active constituents                                                                 | References |
|----------------------|-------------------|--------------------|---------------------------|--------------------|-------------------------------------------------------------------------------------|------------|
| Abrus precatorius    | Fabaceae          | Aerial parts       | Dichloromethane fraction  | Isoflavonquinone  | Abroquinone B (1) against *M. tuberculosis* H37Ra with MIC of 12.5 μg/ml by MABA<sup>ab</sup> | [18]       |
| Acacia farnesiana    | Mimosaceae        | Fruit              | Methanolic extract        | Parabens, flavonones | Methyl gallate (2) showed activity against the sensible strain *M. tuberculosis* H37Rv with MIC of 50 μg/ml, respectively. The (2S)-Naringenin 7-O-β-D-galloylglucopyranoside (3) showed activity against multidrug resistant *M. tuberculosis* G122 with MIC of 50 μg/ml by MABA | [19]       |
| Aglaia forbesii      | Meliaceae         | Leaf               | Dichloromethane fraction  | Benzopyran flavaglines | Desacyetylpyramidial D (4) against *M. tuberculosis* Ra with MIC of 25 μg/ml by MABA | [20]       |
| Allanblackia floribunda | Guttiferae      | Root bark          | Successively macerated in dichloromethane-methanol (1 : 1) and methanol for 4 h | Biflavonoids | Morelloflavone (5) with the MIC of 19.53 and 39.06 μg/ml against *M. smegmatis* and *M. tuberculosis*, respectively, by MABA | [21]       |
| Allium neapolitanum  | Alliaceae         | Bulb               | Chloroform extract        | Canthinone         | Canthin-6-one (6), 8-hydroxy-canthin-6-one (7), and 5(C)-hydroxy-octadeca-6(E)-8(Z)-dieniac acid (8) with MICs in the range 8–32 μg/ml against a panel of fast-growing Mycobacterium species by dilution method | [22]       |
| Allium sativum       | Liliaceae         | Bulb               | Petroleum ether extract   | Fatty acids        | Lauric acid (9) and myristic acid (10) with MIC of 22.2 and 66.7 μg/ml, respectively, against *M. tuberculosis* H37Ra by MABA | [23]       |
| Allophylus edulis     | Sapindaceae       | Leaf               | Hydrodistillation          | Cycloprop[e]azulen-4-ol | Viridiflorol (11) against *M. tuberculosis* H37Rv (ATCC27294) with MIC of 190.0 μg/ml by the microplate resazurin assay | [24]       |
| Alnus incana         | Betulaceae        | Bark               | Methanol extract          | Triterpenes        | Betulin (12), betulinic acid (13), and betulone (14) with MIC of 12.5, 84, and 57 μg/ml against *M. tuberculosis* H37Ra by the microplate resazurin assay | [25]       |
| Alpinia katsumadai   | Zingiberaceae     | Seed               | n-Hexane                  | Diarylheptanoids   | Trans,trans-1,7-diphenylhepta-4,6-dien-3-one (15) as efflux inhibitors against *M. smegmatis* mc² 155 by thiazolyl blue tetrazolium bromide method | [26]       |
| Amphipterygium adstringens | Anacardiaceae   | Stem bark          | Dichloromethane/ methanol (1 : 1) | Tirucallanes | (14β, 24E)-3-oxolanosta-7,24-dien-26-oic acid (16) and (14β,24E)-3-hydroxylanosta-7,24-dien-26-oic acid (17) with MIC of 64 and 32 μg/ml against *M. tuberculosis* H37Rv (ATCC 27294) by Bactec 460-TB apparatus | [27]       |
| Amyris elemifera     | Rutaceae          | Leaf               | Chloroform extract        | Texalin             | Texalin (18) with MIC of 25 μg/ml against *M. tuberculosis* H37Rv by Bactec 460-TB radiometric methodology | [28]       |
| Androsace umbellata   | Primulaceae       | Whole plants       | Ethanol extract            | Saxifragifolin     | Saxifragifolin D (19) reduced the intracellular replication of *M. tuberculosis* in THP-1-derived macrophages but not in A549 cells | [29]       |
| Plant species           | Plant family      | Part used         | Extracts          | Compound class               | Active constituents                                                                 | References |
|------------------------|-------------------|-------------------|-------------------|------------------------------|-------------------------------------------------------------------------------------|------------|
| Angelica sinensis      | Apiaceae          | Root              | Chloroform extract| Fatty diol                   | Falcarindiol (20), 9Z,17-octadecadiene-12,14-diyne-1,11,16-triol,1-acetate (21), and oplopandiol (22) with MIC of 26.7, 25.3, and 50.2 μg/ml, respectively, against M. tuberculosis H37Rv by MABA | [30]       |
| Anisochilus harmandii  | Lamiaceae         | Aerial parts      | Water             | Diterpenes                   | One pimarane-type diterpene named pimicar acid (23) and two abietane-type diterpenes named 9α,13α-epidioxyabiet-8-(14)-en-18-oic acid (24) and 15-hydroxydehydroabietic acid (25) with MIC of 50 μg/ml, respectively, against M. tuberculosis H37Ra by MABA (3R)-falcarnol (26) and (3R, 9R, 10S)-panaxydol (27) with MICs of 25.6 μM and 36.0 μM and IC50’s of 15.3 μM and 23.5 μM against M. tuberculosis H37Ra by microplate resazurin assay | [31]       |
| Aralia nudicaulis      | Araliaceae        | Rhizome           | Methanolic extract| Polyacetylene                | (3R)-falcarinol (26) and (3R, 9R, 10S)-panaxydol (27) with MICs of 25.6 μM and 36.0 μM and IC50’s of 15.3 μM and 23.5 μM against M. tuberculosis H37Ra by microplate resazurin assay | [32]       |
| Ardisia gigantifolia   | Primulaceae       | Leaves and stems  | Chloroform extract| Resorcinol                   | 5-alkylresorcinols (28), 5-(8Z-heptadecenyl) resorcinol (29), and 5-(8Z-pentadecenyl) resorcinol (30) with MIC of 34.4 and 79.2 μM against M. tuberculosis H37Rv (ATCC 27294) by MABA assay, respectively | [33]       |
| Argyreia speciosa      | Convolvulaceae    | Root              | Methanolic extract| Flavanoid sulphates          | Quercetin 3'-O methyl 3-sulphate (31) and kaempferol 7-O methyl 3-sulphate (32) against M. tuberculosis H37Rv with MIC values of 25 μg/ml, respectively, by MABA [(E)-2-(methyl (phenyl) amino) ethyl 2-(2-hydroxyundecanamido)-7 (33), 11-dimethyl-3-oxotetradec-4-enoate (34), and compound 1 inhibit mycobacterial biofilm formation, disperse the preformed biofilms, and disrupt the mature biofilms at concentration of 4, 8, and 32 μg/ml, respectively] | [34]       |
| Arisaema sinii         | Araceae           | Whole plant       | 80% ethanol       | Fatty acid ester             | Aristolactam I (35) with MIC of 12.5-25 μg/ml against drug resistant M. tuberculosis by fluorometrit MABA | [35]       |
| Aristolochia brevipes  | Aristolochiaceae  | Rhizome           | Dichloromethane extract | Benzo[f]-1,3-benzodioxolo[6,5,4-cd]jindol-5(6H)-one | Aristolactam I (35) with MIC of 12.5-25 μg/ml against drug resistant M. tuberculosis by fluorometrit MABA | [36]       |
| Aristolochia taliscana | Aristolochiaceae  | Hook roots        | Hexanic extract   | Neolignans                   | Licanin A (36), licanin B (37), and eupomatenoid-7 (38) with MIC of 3.12-12.5 μg/ml against M. tuberculosis strains: H37Rv, four mono-resistant H37Rv variants and 12 clinical MDR isolates by MABA | [37, 38] |
| Arracacen toleucensis  | Umbelliferae      | Aerial parts      | Dichloromethane-methanol (1:1) | Coumarins                     | Isoimperatorin (39), osthol (40), suberolin (41), and 8-methoxypsoralen (42) with MIC of 64, 32, 16, and 128 μg/ml against M. tuberculosis H37Rv (ATCC 27294) by MABA | [39]       |
| Artemisia capillaris   | Asteraceae        | Aerial parts      | Methanol extracts  | Stilbene derivatives         | Ursolic acid (43) and hydroquinone (44) with MIC of 12.5-25 μg/ml against M. tuberculosis MDR/XDR strains by MABA | [40]       |
### Table 1: Continued.

| Plant species               | Plant family | Part used | Extracts         | Compound class     | Active constituents                                                                 | References |
|-----------------------------|--------------|-----------|------------------|--------------------|--------------------------------------------------------------------------------------|------------|
| Artocarpus lakoocha         | Moraceae     | Root      | Dichloromethane extract | Benzofuran         | Lakoochin A (45) and lakoochin B (46) with MIC of 12.5 and 50 μg/ml against M. tuberculosis H37Ra by MABA | [41]       |
| Azorella compacta           | Umbelliferae | Aerial parts | n-Hexane       | Diterpenoid        | Azorellanol (47) and 17-acetoxy-13-alpha-hydroxy-azorellane (48) showed the strongest activity, with MIC of 12.5 μg/ml against both strains (M. tuberculosis H37Rv (ATCC 27294) and a clinical isolate CIBIN/UMF15:99) by MABA | [42, 43]  |
| Bauhinia purpurea           | Fabaceae     | Root      | Dichloromethane extract | Dibenz[b,f]oxepin | Bauhinoxepin J (5,6-dihydro-3-methoxy-1,4-dionedibenzo[b,f]oxepin (49) against M. tuberculosis H37Ra with a MIC of 24.4 μM by MABA | [44]       |
| Bauhinia saccocalyx         | Fabaceae     | Root      | Dichloromethane extract | Dibenz[b,f]oxepin | Bauhinoxepins A (3,3,5-trimethylbenzo[b]pyrano[6,11-diol] (50) and B (6-methoxy-7-methyl-2-(3-methylbut-2-enyl)dibenzo[b,f]oxepine-1,8-diol (51) against M. tuberculosis H37Rv with MIC of 6.25 and 12.5 μg/ml, respectively, by MABA | [45]       |
| Beilschmiedia erythrophloia | Lauraceae    | Root      | Methanol         | Endiandric acid    | Beilschminol C (52) and suberosol B (53) against M. tuberculosis H37Rv with MICs of 50 and 28.9 μg/ml, respectively, by MABA | [46]       |
| Beilschmiedia tsangii       | Lauraceae    | Leaf      | Methanol         | Epoxyfuranoid lignans | Three new epoxyfuranoid lignans, 4a,5a-epoxybeilschmin A (54) and B (55), and beilschmin D (56), together with known beilschmin A (57) and B (58) with MICs of 30, 40, 50, 2.5, and 7.5 μg/ml, respectively, against M. tuberculosis 90-211378 by proportion method on agar | [47]       |
| Blepharodon nitidum         | Asclepiadaceae | Whole plant | Ethanol extract | Hydroperoxycycloartanes | 24-Hydroperoxycycloart1-25-en-3β-ol (59) and 25-hydroperoxycycloart-23-en-3β-ol (60) with MIC of 12.5 and 25 μg/ml against drug-resistant clinical isolates by MABA | [48]       |
| Bocconia arborea            | Papaveraceae | Aerial parts | Chloroform extract | Dihydrochelirubine | Alkaloids 6-methoxydihydrochelirubine (61) and 6-methoxydihydrochelirubine (62) against M. tuberculosis H37Rv and MDR tuberculosis with MIC of 12.5-50 μg/ml by MABA | [49]       |
| Caesalpinia pulcherrima     | Fabaceae     | Root      | Dichloromethane   | Cassane-furanoditerpenoids | 6 Beta-benzoyl-7 beta-hydroxyvoucapen-5 alpha-ol (63) and 6 beta-cinnamoyl-7 beta-hydroxyvoucapen-5 alpha-ol (64) with MIC of 25 and 6.25 μg/ml against M. tuberculosis H37Ra by MABA | [50]       |
| Caesalpinia sappan          | Fabaceae     | Heartwood | Methanol         | Chalcone            | 3-Deoxyxyampphalcone (65) against both drug-susceptible and drug-resistant strains of M. tuberculosis at MIC50s of 3.125–12.5 μg/ml in culture broth and MIC50s of 6.25–12.5 μg/ml inside macrophages and pneumocytes | [51]       |
| Plant species          | Plant family | Part used       | Extracts          | Compound class         | Active constituents                                                                 | References |
|-----------------------|--------------|-----------------|-------------------|------------------------|-------------------------------------------------------------------------------------|------------|
| Calliandra californica| Fabaceae     | Root            | Ethyl acetate     | Cassane-type diterpenes| Escobarine A (66) and B (67) with MIC of 25-50 μg/ml against M. tuberculosis H37Rv  | [52]       |
| Callicarpa pilossissima| Verbenaceae  | Leaves and twigs| Methanol extract  | Diterpenoids           | 12-Deoxy-11,12-dihydro-seco-hinokiol methyl ester (68), callicarpic acid B (69), and alpha-tocopherol trimer B (70) with MICs ≤63.6 μM against M. tuberculosis H37Rv in vitro by MABA | [53]       |
| Calophyllum lanigerum | Clusiaceae   | All plant       | Methanol          | Coumarin               | (+)-Calanolide A (71) against M. tuberculosis with H37Rv with MIC of 3.13 μg/ml by the radiometric BACTEC | [54, 55]   |
| Camchaya calcarea     | Asteraceae   | Whole plant     | Dichloromethane   | Cycloeca[b]furan       | Goyazensolide (72), centraherin (73), lychnophorolide B (74), isogoyazensolide (75), isocentraherin (76), 5-epi-sisogoyazensolide (77), and 5-epi-isocentraherin (78) with MICs of 3.1, 3.1, 6.2, 1.5, 3.1, 3.1, and 3.1 μg/ml, against M. tuberculosis H37Rv, respectively, by MABA | [56]       |
| Celastrus vulcanicola | Celastraceae | Leaf            | Dichloromethane   | Sesquiterpenes         | 1α-Acetoxy-6β, 9β-dibenzoyloxy-dihydro-b-agarofuran (79) with MIC value of 6.2 μg/ml against sensitive and resistant M. tuberculosis strains by MTT method | [57]       |
| Chamaedorea tepejilote| Arecaeae     | Leaf            | Hexane extracts   | Pentacyclic triterpenes, fatty alcohols | Ursolic acid (43) and farnesol (80) against M. tuberculosis H37Rv (ATCC 27,294) with MIC of 50 μg/ml and 8 μg/ml, respectively, by MABA | [58, 59]   |
| Chrysanthemum morifolium| Asteraceae | Flower          | Methanol extract  | 3-Hydroxy triterpenoids | Maniladiol (81), 3-epilupeol (82), and 4,5a-epoxyhelianol (83) with MIC of 4 μg/ml, 4 μg/ml, and 6 μg/ml, respectively, against M. tuberculosis H37Rv by MABA | [60]       |
| Citrullus colocynthis | Cucurbitaceae| Fruit           | Methanolic extract| Triterpenes            | Ursolic acid (43) and cucurbitacin E 2-O-β-D-glucopyranoside (84) against M. tuberculosis H37Rv with MICs of 25 μg/ml, respectively, by BACTEC 460TB system | [61]       |
| Citrus aurantiifolia  | Rutaceae     | Fruit peels     | Hexane extract    | Furo[3,2-G]coumarin, fatty acid | Both 5,8-dimethoxypsoralen (85) and palmic acid (86) with the MIC of 25 μg/ml against M. tuberculosis H37Rv (ATCC 27,294) and M. tuberculosis H10 by MABA | [62]       |
| Clausena excavata     | Rutaceae     | Rhizome         | Chloroform extract| Coumarins, carbazole derivatives | Dentatin (87), nor-dentatin (88), clausenidin (89), 3-formylcarbazole (90), mukonal (91), 3-methoxy-3-formylcarbazole (92), 2-hydroxy-3-formyl-7-methoxy-carbazole (93), and clausazoline J (94) with MIC of 50, 100, 200, 100, 200, 50, 100, and 100 μg/ml against M. tuberculosis H37Rv by MABA | [63]       |
| Clavija procera       | Theophrastaceae| Stem and bark   | Ethanol extract   | Oleanane triterpene    | Oleane triterpenoid aegicerin (95) with MIC values ranged between 1.6 and 3.12 μg/ml against 37 different sensitive and resistant MTB strains by thiazolyl blue tetrazolium bromide method | [64]       |
| Plant species       | Plant family | Part used | Extracts             | Compound class         | Active constituents                                                                 | References |
|--------------------|--------------|-----------|----------------------|------------------------|--------------------------------------------------------------------------------------|------------|
| Clinacanthus siamensis | Acanthaceae  | Leaf      | Ethanol              | Amide                  | Trans-3-methylthioacrylamide (96) with the MIC of 200 μg/ml against M. tuberculosis H37Ra by MABA | [65]       |
| Cnidoscolus chayamansa  | Euphorbiaceae | Leaf      | Chloroform : methanol (1 : 1) | Pentacyclic triterpenes | Moretenol (97) and moretenyl acetate (98) showed MIC of 25 μg/ml against M. tuberculosis H37Rv and four mono-resistant strains | [66]       |
| Combretum molle      | Combretaceae  | Stem bark | Acetone              | Polyphenol             | Punicalagin (99) with MIC of 600 μg/ml against M. tuberculosis H37Rv by the agar proportionnal method | [67, 68]   |
| Cordia globifera     | Ehretiaceae   | Root      | A hexane-soluble extract | Quinones               | Globiferin (100) and cordiachrome C (101) with MICs of 6.2 and 1.5 μg/ml, respectively, against M. tuberculosis H37Ra by MABA | [69]       |
| Croton kongensis     | Euphorbiaceae | Leaf      | Dichloromethane      | Diterpenedione         | 16-Dien-9,15-dione (102), ent-8,9-seco-8,14-epoxy-7R-hydroxy-11α-acetoxy-16-kauren-9,15-dione (103), ent-8,9-seco-7R-hydroxy-11α-acetoxykaur-8 (14) with MICs of 25.0, 6.25, and 6.25 μg/ml, respectively, and possessed antimalarial activity with ICso ranges of 1.0-2.8 μg/ml against M. tuberculosis H37Ra by MABA | [70]       |
| Curcuma longa        | Zingiberaceae | Rhizomes  | Chloroform extracts  | Curcumin               | Curcuminoid demethoxycurcumin (104) with MIC of 200 μg/ml against M. tuberculosis H37Rv by BACTEC 460 | [71, 72]   |
| Curtisia dentata     | Curtisiaceae  | Leaf      | Ethanol extracts     | Triterpenes            | Ursolic acid acetate (105) and betulinic acid acetate (106) with MIC of 3.4 μg/ml and 19.8 μg/ml against M. tuberculosis H37Rv (ATCC 27294) by MABA | [73]       |
| Cynanchum atratum    | Asclepiadaceae | Roots    | Ethanol extract      | Isoquinolin            | (-)-Deoxypergularinine (107) with MIC of 12.5 μg/ml against M. tuberculosis H37Ra, H37Rv, MDR, and XDR strains by Bactec MGIT 960TM | [74]       |
| Derris indica        | Fabaceae      | Stem, root| Hexane : dichloromethane (1 : 1) | Flavonoids            | 3-Methoxy-(3″,4″-dihydro-3″,4″-dioxo-7″,8″-dimethylpyrano-(7,8 : 5″,6″)-flavone (108), 3,4-methylenedioxy-10-methoxy-7-o xo[2]benzopyran[4,3-b]benzopyran (109), karanjachromene (110), and pinnatin (111) against M. tuberculosis H37Ra with MICs of 25, 6.25, 12.5, and 12.5 μg/ml by MABA | [75, 76]   |
| Diospyros anisandra  | Ebenaceae     | Stem bark | n-Hexane extract     | Naphthalene            | Plumbagin (112) and 3,3″-biplumabgin (113) against M. tuberculosis H37Rv with MIC of 1.56 and 3.33 μg/ml by MABA | [7]        |
| Diospyros decandra   | Ebenaceae     | Bark      | Hexane               | Triterpenes            | 2-Oxo-3b,19a-dihydroxy-24-nor-urs-12-en-28-oic acid (114) with MIC of μg/ml against M. tuberculosis H37Ra by MABA | [77]       |
| Diospyros montana    | Ebenaceae     | Stem bark | Chloroform extract   | Quinonoids             | Plumbagin (112) > emodin (115) > menadione (116) > thymoquinone (117) > diospyrin (118) against M. tuberculosis H37Ra (ATCC 25177) and MDR-TB by MABA | [78, 79]   |
| Plant species                  | Plant family    | Part used       | Extracts          | Compound class   | Active constituents                                                                 | References |
|-------------------------------|-----------------|-----------------|-------------------|------------------|--------------------------------------------------------------------------------------|------------|
| Disthemonanthus benthamianus  | Fabaceae        | Stem bark       | Methanol extract  | Flavonoids       | Distemonanthoside (119), sitosterol 3-O-β-D-glucopyranoside, 4-methoxygallic acid (118), and quercetin (121), against a clinical isolate strain of *M. tuberculosis* AC 45 with MIC ranged from 31.25 to 125 μg/ml by MABA | [80]       |
| Dracaena angustifolia         | Dracaenaceae    | Leaf            | Dichloromethane extract | Triterpenes, fatty acids, fatty alcohols | Ergosterol-5,8-endoperoxide (122), linoleic acid (123), and E-phytol (124) with MICs ≤ 2 μg/ml against *M. tuberculosis* H37Rv (ATCC 27294) by MABA | [81]       |
| Ehretia longiflora            | Boraginaceae    | Root            | Methanolic extract | Quinone          | Ehretiquinone (125) and prenylhydroquinone (126) with MIC of 25 and 26.2 μg/ml against *M. tuberculosis* strain H37Rv by the agar proportion method | [82]       |
| Engelhardia roxburghiana      | Juglandaceae    | Root            | Methanol          | Quinone          | Engelharquinone (127), 3-methoxyjuglone (128), and (-)-4-hydroxy-1-tetralone (129) with MIC of 3.125, 3.125, and 6.25 μg/ml against *M. tuberculosis* 90-221387 and 0.2, 0.2, and 4.0 μg/ml against *M. tuberculosis* H37Ra by MABA | [83, 84]   |
| Eriosema chinense             | Fabaceae        | Root            | Ethnomedicinal extracts | Flavonoids       | Isoflavonoids, pasellidin (138) and erythobissin (139) with MICs between 8 μg/ml and 25 μg/ml against MTB; 3-phenyl coumarin derivative indicanine (138) with MIC of 18.5 μg/ml against *M. smegmatis* by agar proportion method | [85]       |
| Erythrina gibbosa             | Fabaceae        | Root            | Successively extracted with dichloromethane-methanol (1:1) and methanol | Isoflavonoids    | Indicanine B (141) with MIC of 18.5 μg/ml against *M. smegmatis* by agar proportion method | [86]       |
| Erythrina indica              | Fabaceae        | Root bark       | Methanol          | Isoflavonoids    | Isoflavonoids, pasellidin (138) and erythobissin (139) with MICs between 8 μg/ml and 25 μg/ml against *M. tuberculosis* H37Rv; 3-phenyl coumarin derivative indicanine (138) with MIC of 18.5 μg/ml against *M. smegmatis* by agar proportion method | [86]       |
| Erythrina senegalensis        | Fabaceae        | Ethnomedicinal recipes | 70% aqueous methanol | Isoflavonoids    | Isolavonoids, pasellidin (138) and erythobissin (139) with 3-phenyl coumarin derivative indicanine (138) with MIC of 18.5 μg/ml against *M. smegmatis* by agar proportion method | [86]       |
| Eucalyptus tordilliana        | Myrtaceae       | Leaf            | Hexane extract    | Fatty acid ester | Hydroxymyristic acid methylester (142) and a substituted pyrenyl ester (143), a sterol with MIC of 49.45 and 46.99 μg/ml against *M. tuberculosis* H37Rv (ATCC 27294) by MABA | [87]       |
| Euclea natalensis             | Ebenaceae       | Root            | Acetone extract   | Naphthoquinone   | Diospyrin (118) and 7-methyljuglone (144) against *M. tuberculosis* H37Rv (ATCC 27294) by BACTEC 460 with four- to sixfold reduction of MIC | [88]       |
| Plant species            | Plant family     | Part used          | Extracts       | Compound class       | Active constituents                                                                 | References |
|-------------------------|------------------|--------------------|----------------|----------------------|-------------------------------------------------------------------------------------|------------|
| Euphorbia ebracteolata  | Euphorbiaceae    | Roots              | 80% ethanol    | Diterpenoids         | Rosane-type diterpenoids 3 (145) and 8 (146) displayed moderate inhibitory effects on with the MIC of 18 μg/ml and 25 μg/ml, respectively, by MABA                                  | [89, 90]   |
| Euphorbia lagascae      | Euphorbiaceae    | Air-dried powdered plant | Methanol extract | Steroids             | Ergosterol peroxide (147), cycloart-23-en-3β,25-diol (148), vanillin (149), and 4-hydroxybenzaldehyde (150) against M. tuberculosis H37Rv ATCC 27294 strain using two different systems: BACTEC 460TB (Bectec 460) | [91]       |
| Exocarpos latifolius    | Santalaceae      | Stem               | Methanol extract | Fatty acid           | Exocarpic acid (E-octade-13-ene-9,11-diyinoic-acid) (151) with MIC of 20 μg/ml against M. tuberculosis H37Ra (ATCC 25177) by the thiazolyl blue tetrazolium bromide method | [92]       |
| Fatoua pilosa           | Moraceae         | Whole plant        | Methanol extract | Coumarin; chalcones  | Scopoletin (152), isobavachalcone (153) and (E)-1-[2,4-dihydroxy-3-(3-methylbut-2-enyl)phenyl]-3-(2,2-dimethyl-8-hydroxy-2H-benzopyran-6-yl)prop-2-en-1-one (154), copoletin (155), and umbelliferone (156) with MICs of 42, 18, 30, 42, and 58.3 μg/ml against M. tuberculosis H37Rv by the agar proportion method | [93]       |
| Ferula hermonis         | Apiaceae         | Root               | Ethanol extraction | Octahydroazulen     | Jaeschkeanadiol benzoate (teferidin) (157) and jaeschkeanadiol p-hydroxybenzoate (ferutin) (158) with MIC values of 3.125 and 1.56 μg/ml against M. bovis BCG Pasteur 1173P2 and 0.69 and 2 μg/ml against M. tuberculosis H37Rv, respectively, by fluorescence assay | [94]       |
| Garcinia livingstonei   | Guttiferae       | Leaf               | Acetone extract | Flavonoids           | Amentoflavone (159) and 4-monomethoxy amentoflavone (160) with MIC of 0.6 ad 1.4 mg/ml against M. smegmatis (ATCC 1441), with the positive control isoniazid (MIC = 1.70 mg/ml) by tetrazolium violet indicator | [95]       |
| Garcinia multilora      | Clusiaceae       | Heartwood          | Methanol        | Biflavones          | 6,6″′-Biapigenin hexamethylether (161), volkensilavone hexamethylether (162), and hexamethylether of GB-1a (163) against M. tuberculosis H37Rv with inhibition of 96%, 95%, and 87% at 1.25 μg/ml by BACTEC 460TB | [96]       |
| Garcinia nobilis        | Clusiaceae       | Stem bark          | Methanol        | Flavonoids          | 4-Prenyl-2-(3,7-dimethyl-2,6-octadienyl)-1,3,5,8-tetrahydroxyxanthone (164) with MIC of 8 μg/ml against M. tuberculosis H37Rv ATCC 27294 and M. tuberculosis clinical MTCS2 by MABA | [97]       |
| Goniothalamus laoticus  | Annonaceae       | Flower             | Ethyl acetate extract | Lactone derivative  | (+)-Altholactone (165) and howinin A (166) with MIC of 6.25 μg/ml, respectively, against M. tuberculosis H37Ra by MABA | [98]       |
| Harrisonia perforata    | Simaroubaceae    | Branches           | Ethanolic extract | Flavonoids          | Perforamone B (5-hydroxy-7-methoxy-2-methyl-8-(1-hydroxy-3-methyl-3-butenyl)chromone) (167) and D (2-hydroxymethylalloptaeroxylin) (168), peucin-7-methyl | [99]       |
| Plant species                  | Plant family | Part used       | Extracts       | Compound class | Active constituents                                                                 | References |
|-------------------------------|--------------|-----------------|----------------|----------------|-------------------------------------------------------------------------------------|------------|
| Helichrysum melanacme        | Asteraceae   | Shoots          | Acetonic extract | Chalcone       | Ether (169), and greveichromenol (170) with MICs of 25, 25, 50, and 50 μg/ml against \( M. \) tuberculosis H37Ra by MABA  
2,4,6-Trihydroxy-3'-prenylchalcone (171) and 4',6',5'-trihydroxy-6'-6''-dimethyldihydropyrano-[2''',3'''-2',3'] chalcone (172) [100] |           |
| Heracleum maximum            | Apiaceae     | Root            | Methanolic extract | Furanocoumarins | (3R,8S)-Falcarindiol (173) and 6-isopentenylxyloisobergapten (174) with MICs of 24 μM and 167 μM and IC<sub>50</sub> of 6 μM and 27 μM against \( M. \) tuberculosis H37Ra respectively [101] |           |
| Humulus lupulus               | Cannabaceae  | Strobile hops   | Hexane extract  | Fatty acid      | Unsaturated fat oleic and linoleic acids (175) with MIC of 4 and 16 μg/ml against \( M. \) fortuitum by thiazolyl blue tetrazolium bromide method [102] |           |
| Hydnocarpus anthelmintica    | Flacourtiaceae | Seeds           | 95% ethanol     | Fatty acid      | Anthelmintinins A (176), B (177), C (178) (11-cyclopent-1-en-1-yl)-11-oxoundecanoic acid, 2,3-dihydroxypropyl 9-[(R)-cyclopent-2-en-1-yl]nonanoate, 2,3-dihydroxypropyl 13-[(R)-cyclopent-2-en-1-yl]tridecanoate, and two known ones, namely, chaulmoogric acid (179) and ethyl chaulmoograte (180) with MIC of 5.54, 16.70, 4.38, 9.82, and 16.80 μM, respectively, by GFP-expressed \( M. \) tuberculosis H37Rv [103] |           |
| Hypericum perforatum         | Guttiferae   | Aerial parts    | Hexane and chloroform extracts | Pyranone | Hyperenone A (181) against \( M. \) tuberculosis H37Rv and \( M. \) bovis BCG with MIC of 75 μg/ml and 100 μg/ml, respectively, by thiazolyl blue tetrazolium bromide method [104] |           |
| Indigofera longeracemosa     | Fabaceae     | Stem            | Methanol extract | Diterpene       | Diterpene 12-methyl-5-dehydroacetylhydromine (182) with MIC of 0.38 μg/ml against \( M. \) tuberculosis H37Rv by proportion method [105] |           |
| Ipomoea leptophylla          | Convolvulaceae | Leaf           | Organic soluble extract | Triterpenes    | 3α,25-Epoxy-3R,21R-dihydroxy-22a-angeloyloxolean-12-ene-28-oic acid (183), camacic acid (184), and rehmannic acid (185) with MICs of 64, 64, and 32 μM, respectively, against \( M. \) tuberculosis H37Rv by BACTEC 460 radiometric system [106] |           |
| Juniperus communis           | Cupressaceae  | Needles and branches | Methanolic extracts | Diterpene       | Isocupressic acid (186) and commucic acid (187) displayed MICs of 78 μM and 31 μM against \( M. \) tuberculosis H37Ra, respectively, by microplate resazurin assay [107] |           |
| Juniperus procera            | Cupressaceae  | Leaf and bark   | 95% ethanol     | Diterpene       | Plumagin (112) and 7β-hydroxyabieta-8,13-dien-11,12-dione (188) with MIC < 12.5 μg/ml against \( M. \) tuberculosis H37Rv by visible growth [108] |           |
| Plant species       | Plant family | Part used | Extracts          | Compound class   | Active constituents                                                                 | References |
|---------------------|--------------|-----------|-------------------|------------------|--------------------------------------------------------------------------------------|------------|
| Kaempferia galanga | Zingiberaceae| Rhizomes  | Absolute ethanol  | Aromatic acid    | Ethyl p-methoxycinnamate (189) inhibited the growth of \( M. \) tuberculosis H37Ra and H37Rv with MICs of 48.5 and 24.2 mM by Bactec 460 system | [109]      |
|                     |              |           |                   |                  | 3,5,7,4′-Tetramethoxyflavone (190) and 5,7,4′-trimethoxyflavone (191) with MIC of 200 and 50 \( \mu \)g/ml, respectively, against \( M. \) tuberculosis H37Rv by MABA | [110]      |
| Kaempferia parviflora | Zingiberaceae| Rhizomes  | Water             | Flavonoids       | Three pentacyclic triterpenoids of 3-acetoxy-22-(2′-methyl-2Z-butenyloxy)-12-oleanen-28-oic acid (192), 3-hydroxy-22β-(2′-methyl-2Z-butenyloxy)-12-oleanen-28-oic acid (reduced lantadene A) (193), and oleanolic acid (194) with MIC of 50, 50, and 25 \( \mu \)g/ml against \( M. \) tuberculosis H37Rv by MABA | [111]      |
| Lantana hispida     | Verbenaceae  | Aerial parts| Hexane extract   | Pentacyclic triterpenoids | Ursolic acid (43) and oleanolic acid (194) against \( M. \) tuberculosis H37Rv by MABA | [58]       |
|                     |              |           |                   |                  | 5,7-Dihydroxy-3-methoxy-2-(4-methoxyphenyl)-4H-chromen-4-one (195); 5,6,7-trihydroxy-3-methoxy-2-(4-methoxyphenyl)-H-chromen-4-one (196); 6,8,4′-trimethyl-\( \alpha,\beta,\gamma\)-dimethyl,\( \alpha,\beta,\gamma\)-bis(3,4-dihydroxyphenyl) butane (17) with MIC of 50 \( \mu \)g/ml, respectively, against \( M. \) tuberculosis H37Rv (ATCC 27294) by Bactec 460-TB apparatus | [27]       |
| Lantana horrida     | Verbenaceae  | Aerial parts| Hexanic extracts  | Triterpenes      | Falcarindiol (198) with MIC of 20 \( \mu \)g/ml and sesquiterpene alcohol a-preanthapendol (199) with MIC of 60 \( \mu \)g/ml against \( M. \) tuberculosis H37Rv by spot culture growth inhibition assay | [112]      |
| Larrea divaricata   | Zygophyllaceae| Aerial parts| Dichloromethane/methanol (1:1) | Flavone, polyphenols | Lavonessnevadens (5,7-dihydroxy-6,8,4′-trimethoxyflavone) (200) and isothymusin (6,7-dimethoxy-5,8,4′-trihydroxyflavone) (201) against \( M. \) tuberculosis H37Rv by MABA | [113]      |
| Ligusticum officinale| Apiaceae    | Root      | n-Hexane extract  | Fatty alcohol    | 3β,25-Epoxy-3α,21α-dihydroxy-22β-(3-methylbut-2-en-1-oloyloxy) olean-12-ene-28-oic acid (202); 3β,25-epoxy-3α,21α-dihydroxy-22β-angeloyloxyolean-12-ene-28-oic acid (203); 3β,25-epoxy-3α,21α-dihydroxy-22β-tigloyloxyolean-12-ene-28-oic acid (204); and 3β,25-epoxy-3R-hydroxy-22β-(2-methylbutan-1-oloyloxy)olean-12-ene-28-oic acid (205), lantanillic acid (206), cammaric acid (184), lantanolic acid (207), and rehmannic acid (185) against \( M. \) tuberculosis H37Rv (ATCC 27294) using the radiorepiometric BACTEC 460 system | [106]      |
| Limnophila geoffrayi| Scrophulariaceae| Aerial parts| Chloroform extract| Flavonoids       | Citrusflavonoids (207) against \( M. \) tuberculosis H37Rv (ATCC 27294) using the radiorepiometric BACTEC 460 system | [113]      |
| Lippia turbinata    | Verbenaceae  | Aerial parts| Methanol-dichloromethane | Triterpenoids | Lantanillic acid (206), cammaric acid (184), lantanolic acid (207), and rehmannic acid (185) against \( M. \) tuberculosis H37Rv (ATCC 27294) using the radiorepiometric BACTEC 460 system | [106]      |
| Litsea hypophaeae   | Lauraceae    | Root      | Methanol          | Lactone, phenol  | Litseakolide L (208) and N-trans-feruloylmethoxystyramine (209) with MIC values of 25 | [76]       |
| Plant species                  | Plant family | Part used | Extracts         | Compound class | Active constituents                                                                 | References |
|-------------------------------|--------------|-----------|------------------|----------------|--------------------------------------------------------------------------------------|------------|
| Lophira lanceolata            | Ochnaceae    | Roots     | Methanol extract | Flavonoids     | and 1.6 μg/ml, respectively, against M. tuberculosis H37Rv by agar proportion method | [114]      |
|                               |              |           |                  |                | Dihydrolophirone A (210) and lophirone A (211) with MIC of 31.25 and 15.75 μg/ml against M. tuberculosis H37Rv by MABA | [114]      |
| Lunasia amara                 | Rutaceae     | Leaf      | Ethanol          | Phenyl quinoline | 4-Methoxy-2-phenylquinoline (212) and 4-methoxy-2-(3,4-ethylenedioxy) phenyl quinoline (213) with MICs of 16 μg/ml, respectively, against M. tuberculosis H37Rv by BACTEC radiometric method | [115]      |
| Marsypopetalum modestum       | Annonaceae   | Stem      | Ethanol          | Dithiopyridine | Dipyridithione (214) with MIC < 0.039 μg/ml, respectively, against M. tuberculosis H37Rv by MABA | [116]      |
| Micromelum hirsutum           | Rutaceae     | Stem bark | Dichloromethane extract | Carbazole | Micromolide ((−)-Z-9-octadecene-4-olide) (215) and five known alkaloids: lansine (216), 3-formylcarbazole (90), and 3-formyl-6-methoxycarbazole (217) with MIC of 1.5, 31.5, 14.3, 42.3, and 15.6 μg/ml, against M. tuberculosis H37Rv by agar proportion method | [117]      |
| Microtropis fokienensis       | Celastraceae | Root      | Methanol         | Sesquiterpenes | 1α-Acetoxy-2α-hydroxy-6β,9β,15-tribenzoylxy-β-dihydroagarofuran (218), 2α-acetoxy-1α-hydroxy-6β,9β,15-tribenzoylxy-β-dihydroagarofuran (219), ribiculin G (220), and triptogedin G-2 (221) with MICs of 19.5, 15.8, 14.6, and 26 μM against M. tuberculosis 90-221387 by agar proportion method | [118]      |
| Microtropis japonica          | Celastraceae | Stem      | Methanol         | Sesquiterpenes | 15-Acetoxyorbiculin G (222), celahin C (223), salasol A (224), and 8-acetoxymutangin (225) with MICs of 39.6 μM, 15 μM, 15 μM, and 10 μg/ml, respectively, against M. tuberculosis H37Rv by agar proportion method | [119, 120]|
| Morinda citrifolia            | Rubiaceae    | Leaves    | Hexane fraction  | Steroid        | E-Phytol (mixture of the two ketosteroids, stigmasta-4-en-3-one (226) and stigmasta-4,22-dien-3-one (227)) and the epidoxyoster campesta-5,7,22-trien-3β-ol (228) with MIC of 2.5 μg/ml and minus 2.0 μg/ml against M. tuberculosis H37Rv (ATCC 27294) by the growth index 13-Hydroxy-mulin-11-en-20-oic-acid methyl ester (229), isomulinic acid n-propyl ester (230), and isomulinic acid n-butyl ester (231) with MIC of 6.25 μg/ml, respectively, against M. tuberculosis H37Rv (ATCC 27294) by MABA Essential oil of limonene (232), 1,8 cineole (233), and α-pinene (234) against M. tuberculosis H37Rv with MIC of 2% (v/v) | [121, 122]|
| Mulinum crassifolium          | Apiaceae     | Aerial parts | n-Hexane       | Diterpenoid    |                                                                  | [43]       |
| Myrtus communis               | Myrtaceae    | Leaf      | Hydrodistillation | Monoterpenes   | Thymoquinone (TQ; 2-isopropyl-5-methyl-1, 4-benzoquinone) (117) with MIC of 12.5 μg/ml | [123]      |
| Nigella sativa                | Ranunculaceae | Seed     | Methanolic extract | Quinones       |                                                                  | [124]      |
| Plant species         | Part used                  | Part family       | Active constituents                                                                 | Compound class                          | References |
|-----------------------|----------------------------|-------------------|-------------------------------------------------------------------------------------|------------------------------------------|------------|
| Ocimum basilicum      | Aerial parts (leaves, fruits, and flowers) | Lamiaceae         | (E)-3′-Hydroxy-4′-1′-hydroxyethyl-4′-(2-hydroxy-3-oxo-2-propyl) phenyl-4′-methoxy cinnamate (235) against M. tuberculosis H37Rv by MABA (ATCC 27294) | Fatty acid ester                        | [125]      |
| Ocimum sanctum        | Leaf                       | Lamiaceae         | Ursolic acid (UA) 12-(26-oxic-acids) with MIC of 12.5 μg/ml against M. tuberculosis H37Rv by MABA (ATCC 27294) | Triterpenes                             | [40, 126] |
| Ocotea macrophylla    | Wood, leaf                 | Lauraceae         | (S)-3-Methoxynordomesticine hydrochloride (236) with MIC of 4 μg/ml against M. tuberculosis H37Rv by thiazolyl blue tetrazolium bromide method (127) | Apomorphine                             | [127]      |
| Oplopanax horridus    | Inner stem bark            | Araliaceae        | Sesquiterpenes Oplopandiol (237) and falcarindiol (198) with MIC of 61.5 μg/ml against M. tuberculosis (ATCC 35801) by MABA | Sesquiterpenes                          | [128]      |
| Oplopanax horridus    | Successively using hexane, dichloromethane, and methanol | Araliaceae        | Sesquiterpenes Oplopandiol (237) and falcarindiol (198) with MIC of 61.5 μg/ml against M. tuberculosis (ATCC 35801) by MABA | Sesquiterpenes                          | [128]      |
| Pedilanthus tithymaloides | Aerial parts               | Euphorbiaceae     | Canjojane (238) against M. tuberculosis H37Ra with MIC of 25 μg/ml by MABA           | Diterpenoid                             | [129]      |
| Phoradendron robinii  | Whole plant                | Santalaceae       | 5-Hydroxy-2-(4′-hydroxyphenyl)-7-methoxy-2,3-dihydro-4H-chromen-4-one (239) with MIC of 28 μg/ml against M. tuberculosis H37Ra by MABA (ATCC 27294) | Flavanone                               | [27]       |
| Physalis angulata     | Aerial parts               | Solanaceae        | Physalin D (240) with MIC of 31.2 μg/ml against M. tuberculosis H37Rv by MABA (ATCC 27294) |-Benzofuran                              | [130]      |
| Physalis angulata     | Aerial parts               | Solanaceae        | Physalin D (240) with MIC of 31.2 μg/ml against M. tuberculosis H37Rv by MABA (ATCC 27294) |-Benzofuran                              | [130]      |
| Plectranthus granulatus | Aerial parts               | Lamiaceae         | Benzofuran-Benzofuran-3-2-hydroxymethyl-5-ethyl-3′-(N,N-dimethylcarbamoyl) pyridinium (245) against M. tuberculosis H37Rv and 17 clinical isolates with benzofuran-3-2-hydroxymethyl-5-ethyl-3′-(N,N-dimethylcarbamoyl) pyridinium by microplate assay | Benzofuran                               | [133]      |
| Plectranthus granulatus | Aerial parts               | Lamiaceae         | Benzofuran-Benzofuran-3-2-hydroxymethyl-5-ethyl-3′-(N,N-dimethylcarbamoyl) pyridinium (245) against M. tuberculosis H37Rv and 17 clinical isolates with benzofuran-3-2-hydroxymethyl-5-ethyl-3′-(N,N-dimethylcarbamoyl) pyridinium by microplate assay | Benzofuran                               | [133]      |
| Plectranthus granulatus | Aerial parts               | Lamiaceae         | Benzofuran-Benzofuran-3-2-hydroxymethyl-5-ethyl-3′-(N,N-dimethylcarbamoyl) pyridinium (245) against M. tuberculosis H37Rv and 17 clinical isolates with benzofuran-3-2-hydroxymethyl-5-ethyl-3′-(N,N-dimethylcarbamoyl) pyridinium by microplate assay | Benzofuran                               | [133]      |
| Plant species          | Plant family     | Part used     | Extracts          | Compound class     | Active constituents                                                                 | References |
|-----------------------|------------------|---------------|-------------------|--------------------|-------------------------------------------------------------------------------------|------------|
| Plectranthus ornatus  | Lamiaceae        | Aerial parts  | Chloroform        | Royleanone         | 12.5 μg/ml, respectively, against *M. tuberculosis* H37Rv by MTT                    | [134, 135]|
|                       |                  |               |                   |                    | 7α-Acetoxy-6β-hydroxyroyleanone (MIC 0.0083 μM) (253) and 6,7-dehydroxyroyleanone (MIC 0.039 μM) (254) against *M. tuberculosis* H37Rv by thiazolyl blue tetrazolium bromide method |
| Plumbago indica       | Plumbaginaceae   | Root          | Petroleum ether    | Naphthalene        | Plumbagin (112) with MIC of 0.25 and 8 μg/ml against MDR-TB and 2 and 4 μg/ml against the XDR-TB isolates by thiazolyl blue tetrazolium bromide method |
| Plumeria bicolor      | Apocynaceae      | Leaves        | Chloroform extract | Naphthalene        | Plumericin (112) against active and MDR TB with MIC of 0.12, 0.15, 0.07, 0.13, and 0.14 μg/ml, respectively, better than isoplumericin |
| Polyalthia cerasoides | Annonaceae       | Root          | Extracted successively with hexane, ethyl acetate, and methanol | Apomorphine, fatty acid, sesquiterpenes | Bidebiline E (255), octadeca-9,11,13-triynoic acid (256), and α-humulene (257), with 6.25 μg/ml against *M. tuberculosis* H37Ra MABA |
| Polyalthia debilis    | Annonaceae       | Root          | Methanol          | Lactone derivative | Debilisones B (258), C (259), and E (260) with MIC of 25, 12.5, and 25 μg/ml, respectively, against *M. tuberculosis* H37Ra by MABA |
| Polyalthia evecta     | Annonaceae       | Root          | Extracted successively with hexane, dichloromethane, and methanol | Furan             | Furanoid polycetylene (261) with MIC of 3.1 μg/ml against *M. tuberculosis* H37Ra by MABA |
| Potamogeton malaianus | Potamogetonaceae | Whole plant   | Dichloromethane    | Diterpenes         | Potamogetonide (262), potamogetonol (263), potamogetonin (264), and 15,16-epoxy-12-oxo-8 (17),13 (16),14-labdatrien-20,19-olide (265) with MIC of 50-100 μg/ml against *M. tuberculosis* H37Ra by MABA |
| Pourthiaea lucida     | Rosaceae         | Leaf          | Methanol          | Alkohol            | a-Tocospirio A (266) and B (267), a-tocopherylquinone (268), and (E)-phytol (124) with MICs of 30, 50, 25, and 12.5 μg/ml against *M. tuberculosis* H37Rv by agar proportion method |
| Premna odorata        | Lamiaceae        | Leaf          | Methanol          | Aldehydes          | 1-Heneicosyl formate (269) with MIC of 8 μg/ml against *M. tuberculosis* H37Rv (ATCC27294) by MABA |
| Prunus cerasoides     | Rosaceae         | Root          | Successively with hexane, ethyl acetate, and methanol | Fatty acid         | Octadeca-9,11,13-triynoic acid (256) with MIC of 6.25 μg/ml against *M. tuberculosis* H37Ra by MABA |
| Punica granatum       | Punicaceae       | Peel of the fruit | Water            | Polyphenol         | Epigallocatechin-3-gallate (EGCG) (270) and quercetin (271) with MIC of MIC 32-256 μg/ml against nine *M. tuberculosis* isolates by thiazolyl blue tetrazolium bromide method | [143]     |
| Plant species               | Plant family | Part used       | Extracts               | Compound class | Active constituents                                                                 | References |
|---------------------------|--------------|-----------------|------------------------|----------------|-------------------------------------------------------------------------------------|------------|
| Radermachera boniana      | Bignoniaceae | Leaves and twigs | Ethyl acetate          | Sterol         | Ergosterol peroxide (147) and b-sitosterone (272) with MICs of 34.8 and 9.9 μM, respectively, against M. tuberculosis H37Rv by MABA | [144]     |
| Ranunculus ternatus       | Ranunculaceae| Roots           | Ethanol                | Benzophenones  | (benzophenones) Methyl (R)-3-[2-(3,4-dihydroxybenzoyl)-4,5-dihydroxyphenyl]-2-hydroxypropanoate (273) with MIC of 41.67 μg/ml against M. tuberculosis H37Rv by MABA | [145]     |
| Rumex hymenosepalus       | Polygonaceae | Root            | Dichloromethane/methanol (1:1) | Diphenylethylene | 5’-[(E)-2-(4-Acetoxyphenyl) ethenyl]-1,3-benzenediol(1a) (274) with MIC of 32 μg/ml against M. tuberculosis H37Rv (ATCC 27294) by Bactec 460-TB apparatus | [27]     |
| Rumex nepalensis          | Polygonaceae | Root            | Ethanol extracts       | Glycoside      | Rumexneuposide A (275), torachryson (276), nepodin-8-O-b-D-glucopyranoside (277), torachryson-8-O-b-D-glucopyranoside (278), and chrysophanol-8-O-b-D-glucopyranoside (279), which showed MICs of 20.7, 6.1, 26.6, 8.9, and 4.1 μM, respectively, by fluorescence assay | [146]     |
| Salvia africanaalutea     | Lamiaceae    | Aerial parts    | Ethanol extract        | Diterpene      | Abietane-type diterpene carnosic acid (280) with MIC of 28 μg/ml against M. tuberculosis H37Rv (ATCC27294) by a rapid radiometric method | [147]     |
| Salvia miltiorrhiza       | Lamiaceae    | Roots           | Acetone                | Tanshinones    | Tanshinone I (281), tanshinone IIA (282), and cryptotanshinone (283) with MIC in the range of 1.17–26.57 μg/ml against M. tuberculosis H37Rv by agar proportion method | [148, 149] |
| Sapium indicum            | Euphorbiaceae| Fruit           | Hexane extract         | Phorbol ester  | Sapitoxin A (284), sapitoxin B (285), 12-(2¢-N-methylaminobenzoyl)-4R-deoxy-5,20-dihydroxyphorbol-13-acetate (286), and 12-(2-methylaminobenzoyl)-4-deoxyphorbaklyde-13-acetate (287) with MIC of 3.12, 12.5, 25, and 25 μg/ml, respectively, against M. tuberculosis H37Ra by MABA | [150]     |
| Saussurea lappa            | Asteraceae   | Bark            | Ethanol extract        | Sesquiterpenoids | Saussureamine C (methyl 3-O-feruloylquinate) (288) against M. tuberculosis by inhibiting folC | [151]     |
| Scleropyrum wallichianum   | Santalaceae  | Twig            | Successively with n-hexane, chloroform, and methanol | Fatty acid | Scleropyric acid (289) with MIC of 25 μg/ml against M. tuberculosis H37Rv by MABA | [152]     |
| Solanum torvum            | Solanaceae   | Fruit            | Methanol extracts      | Xanthine       | Methyl caffeate (290) with MIC of 8 μg/ml against M. tuberculosis by agar proportion method | [153]     |
| Stephania dinklagei       | Menispermaceae| Aerial parts    | Chloroform extract     | Flavanone      | Flavanone pinostrabin (291) against M. tuberculosis H37Rv with MIC of 3.125 μg/ml by MABA | [49]     |
| Strobilanthes cusia       | Acanthaceae  | Leaf             | Methanol extracts      | Quinazoline    | Tryptanthrin (292) with MIC of 1 mg/ml against M. tuberculosis by BACTECH | [154, 155] |
| Plant species          | Plant family | Part used   | Extracts                          | Compound class  | Active constituents                                                                 | References |
|------------------------|--------------|-------------|-----------------------------------|-----------------|--------------------------------------------------------------------------------------|------------|
| Tabernaemontana citrifolia | Apocynaceae  | Leaf        | Chloroform extract                | Voacangine      | Ibogaine (293) and voacangine (294) with MIC of 50 μg/ml against M. tuberculosis H37Rv by Bactec 460-TB radiometric methodology | [28]       |
| Teloxys graveolens     | Chenopodiaceae | Aerial parts | Acetone extract                   | Flavanone      | Flavanone pinosirobin (291) against M. tuberculosis H37Rv with MIC of 12.5 μg/ml by MABA | [49]       |
| Terminalia avicennioides | Combretaceae | Root bark   | Sucessively with petroleum ether, ethyl acetate, chloroform, and methanol | Triterpenes     | Anjucnolic acid (295) and friedelin (296) which, respectively, had MICs against BCG of 156 μg/ml and 4.9 μg/ml, respectively, by broth microdilution method | [156, 157] |
| Terminalia brownii      | Combretaceae  | Root        | Methanol extract                  | Flavones, ellagic acid | Methyl (S)-flavogallonate (297), ellagic acid xyloside (298), and methyl ellagic acid xyloside (299) against M. smegmatis by measured spectrophotometrically at 620 nm | [158]       |
| Byrsonima fagifolia    | Malpighiaceae | Leaf        | Chloroform extract                | Amyrin          | α- and β-Amyrin (300), α-amyrin acetate (301), and dotriacontane (302) with MIC of 31.25, 62.5, and 62.5 μg/ml, respectively, against M. tuberculosis H37Rv (ATCC 27294) by MABA | [159]       |
| Terminalia laxiflora   | Combretaceae  | Root        | Methanol extract                  | Triterpenes, fatty alcohol, sterol | Friedelin (296), triacantanol (303), β-sitosterol (34), and sitostenone (35) with MIC of 250 μg/ml, 250 μg/ml, 500 μg/ml, and 500 μg/ml, respectively, against M. smegmatis by measured spectrophotometrically at 620 nm | [158]       |
| Terminalia superba     | Combretaceae  | Stem bark   | Methanol extract                  | Ellagic acid    | 3,4′-Di-O-methyllic acid 3′-O-β-D-xylopyranoside (306) and 4′-O-galloyl-3,3′-di-O-methyllic acid 4-O-β-D-xylopyranoside (307) with MIC of 4.88 μg/ml and 9.76 μg/ml, respectively, against M. tuberculosis H37Rv (ATCC 27294) by MABA | [160]       |
| Tetracera potatoria    | Dilleniaceae  | Stem bark   | Methanol/dichloromethane (1:1)    | Alcohol         | Tetraceranolate (308) and N-hydroxy imidate-tetracerase (309) with MIC of 7.8 μg/ml and 15 μg/ml, respectively, against M. smegmatis (ATCC 23246) by tetracarboxazol method | [161]       |
| Tetradenia riparia     | Lamiaceae     | Leaf        | Hydrodistillation                 | Royleanone      | 6,7-Dehydroroylanone (254) with MIC of 31.2 μg/ml against M. tuberculosis H37Rv by resazurin microtiter assay | [162]       |
| Thalia multiflora      | Marantaceae   | Aerial parts | Dichloromethane–methanol (1:1) followed by a 100% methanol | Steroids        | Stigmast-5-en-3β-ol-7-one (310), stigmast-4-en-6β-ol-3-one (311), stigmast-5,22-dien-3β-ol-7-one (312), and stigmast-4,22-dien-6β-ol-3-one (313) were found to be the most active compounds with MIC of 1.9, 4., 1.0, and 2.2 μg/ml, respectively, against M. tuberculosis by fluorescence assay | [163]       |
| Plant species         | Plant family   | Part used   | Extracts            | Compound class                        | Active constituents                                                                 | References |
|----------------------|----------------|-------------|---------------------|---------------------------------------|-------------------------------------------------------------------------------------|------------|
| Tiliacora triandra   | Menispermaceae | Root        | Dichloromethane     | Bisbenzylisoquinoline alkaloids       | Tiliacorinine (314), 2'-nortiliacorinine (315), and tiliacorine (316) are bisbenzylisoquinoline alkaloids with MIC of 3.1–6.2 mg/ml against M. tuberculosis different strains by MABA | [164]      |
| Tussilago farfara    | Asteraceae     | Aerial parts | Soxhlet extracted  | Aromatic acid                         | p-Coumaric acid (317) and 4-hydroxybenzoic acid (318) with MIC 31.3 μg/ml of 62.5 μg/ml against M. tuberculosis H37Rv by high throughput spot culture growth inhibition assay | [165]      |
| Ventilago madraspatana | Rhamnaceae  | Stem bark   | Methanol            | Anthraquinone                         | Emodin (115) with MIC of 4 μg/ml against M. tuberculosis H37Rv by MABA              | [78, 166]  |
| Zanthoxylum capense  | Rutaceae       | Leaf        | 80% ethanol         | Phenol, amide                         | Decarine (319) and an N-isobutylamidine, N-isobutyl- (2E,4E)-2,4-tetradecadienamide (320) with MIC of 1.6 μg/ml against M. tuberculosis H37Rv by measuring the optical density at 600 nm in a Tecan M200 plate spectrophotometer | [167]      |
| Zanthoxylum leprieurii | Rutaceae     | Stem bark   | Methanol extract    | Dihydroacridine                       | Hydroxy-1, 3-dimethoxy-10-methyl-9-acridone (321), 3-hydroxy-1, 5, 6-trimethoxy-9-acridone (322) with MIC of 5.1 and 1.5 μg/ml, respectively, against M. tuberculosis H37Rv by MABA | [168]      |
| Zanthoxylum schinifolium | Rutaceae   | Leaf        | Methanolic extracts | Coumarin                              | 7-[(2E)-3,7-dimethylocta-2,6-dienoyl]-8-methoxychromen-2-one (collinin) (323) with MIC 30 μg/ml of 3.13–6.25 μg/ml against both drug-susceptible and -resistant strains of M. tuberculosis by luminescent viability assay kit | [169]      |
| Zanthoxylum wutaiense | Rutaceae     | Root        | Methanol extract    | Benzofuran, furo[3,2-b]quinoline       | 7-Methoxyanodendroate (324), 7-methoxystaurophan (325), wutaianal (326), dictamine (327), and γ-fagine (328), with MIC of 35, 35, 30, and 30 μg/ml, respectively, against M. Tuberculosis H37Rv by the agar proportion method | [170]      |
| Zingiber cassumunar  | Zingiberaceae | Root        | Methanol            | Three fatty acid esters               | (E)-4-(3,4-Dimethoxyphenyl)but-3-en-1-yl linoleate (329), (E)-4-(3,4-dimethoxyphenyl)but-3-en-1-yl oleate (330), and (E)-4-(3,4-dimethoxyphenyl)but-3-en-1-yl palmitate (331), with MIC of 200, 100, and 200 μg/ml, respectively, against M. tuberculosis H37Rv by MABA | [171]      |
| Ziziphus cambodiana  | Rhamnaceae    | Root bark   | Acetate extract     | Triterpenes                           | 3-O-Vanillyleacetic acid (332), betulinaldehyde (333), betulic acid (334), and 2-O-E-p-coumaryl aliphatic acid (335) with MIC of 25, 25, 25, and 12.5 μg/ml, respectively, against M. tuberculosis H37Rv by MABA | [172]      |

MABA: microplate alamar blue assay; MIC: minimum inhibitory concentration.
abietane diterpenoid had an MIC of 1.2 $\mu$g/ml, while its C-12 acetate analogue was more active with an MIC of 0.89 $\mu$g/ml [175]. One of the most impressing natural products was (+)-calanolide A, a novel dipyranocoumarin from the Mal- sian tree *Calophyllum lanigerum* var. austrocoriaceum. This distinct compound was first reported with good activity against the strains of HIV-1, which was resistant to diverse other nonnucleosides as well as nucleoside (AZT) reverse transcriptase inhibitors [176, 177]. Later, the novel calanolides with the ring-D-modification were synthesized with selective activity against the replication and/or nonreplicating *M. tuberculosis* by targeting the Rv2466c [55]. In particular, analogues bearing 2-nitrofurano group at the ring D position markedly improved the in vitro efficacy and reduced the mammalian cell toxicity, when compared with the parent compound (+)-calanolide A [55]. Recently, Mu et al. demonstrated that the nitrofuranyl calanolides could be employed as novel fluorescent probes that can serve as a much needed high-throughput and low-cost detection method for detection of living *M. tuberculosis* and can precisely determine the MIC values for a full range of available drugs [178]. Thus, different modifications of the calanolide derivatives demonstrated three aspects (anti-HIV, anti-TB, and TB diagnosis) of potent usage in TB disease.

Of all the 335 natural plant compounds and its semisynthetic analogues, only few were found for their mechanistic role of their anti-TB activities. The calanolides target the Rv2466c, and hyperenone A inhibits the ATP-dependent MurE ligase, which involves in the cytoplasmic steps of peptidoglycan biosynthesis [104]. It was reported that saussureamine C (methyl 3-O-feruloylquinate) targets the folC [151] and eupractenoid B targets the acetyl transfer activity of GlnU [90]. The trans, trans-1, 7-diphenylhepta-4, 6-dien-3-one target the efflux pumps [26]. *In silico* analysis revealed that some fatty acids could bind at the cleft between the N-terminal and C-terminal lobes of the cytosolic domain of serine/threonine protein kinase B (PknB) [23]. The anti-TB plant medicinal compounds included in this review lack the molecular basis of the action and mechanisms of modulation on the metabolism of *M. tuberculosis* nor the immunomodulatory activities of those compounds.

4. Plants Showing Anti-TB Effect in Form of Crude Extracts

The plants whose active components were isolated and tested for their anti-TB activity as described in Section 3. This section summarizes the reported plants for their anti-TB activity only in the form of crude extracts. They are listed in Table 2 with the total amount of 128 plant species. The top five plant families were *Asteraceae*, *Euphorbiaceae*, *Fabaceae*, *Piperaceae*, and *Acanthaceae*, and the plant parts mainly used for extraction were root for *Fabaceae* family and leaf for *Asteraceae*, *Piperaceae*, and *Acanthaceae*, respectively. For *Euphorbiaceae* family, the plant parts of bark, fruit, leaf, root, and seed were reported with the anti-TB function.

Among the extraction methods, ethanol, hexane, and methanol were found to be the top three frequently used
### Table 2: Medicinal plants and their crude extracts showing *in vitro* anti-TB activity.

| Plant species | Plant family | Part used | Extracts | References |
|---------------|--------------|-----------|----------|------------|
| Acacia catechu | Liliaceae | Root | Hexane extracts with inhibition of mycobacterial (standard and clinical) growth | [179] |
| Acacia senegal | Fabaceae | Root | Aqueous extraction has potential antimycobacterial activity | [180] |
| Acalypha indica | Euphorbiaceae | Leaf | Aqueous extracts with inhibition of 95% at 4 percent \( \text{v/v} \) concentration in L-J medium for sensitive \( M. \) tuberculosis H37Rv | [181] |
| Acorus calamus | Acoraceae | Root | Methanol extracts with the oils inhibiting the growth of MTB B19-4 at 2 \( \mu \)g/ml | [180] |
| Aloe vera | Xanthorrhoeaceae | Leaf | Aqueous extract was found to be 41% at 4 percent \( \text{v/v} \) concentration in L-J medium for sensitive \( M. \) tuberculosis H37Rv | [181, 184] |
| Alstonia scholaris | Apocynaceae | Leaf | Methanol extracts have potential antimycobacterial activity and the synergistic group consisting of rifampicin in murine model | [185] |
| Amborella trichopoda | Amborellaceae | Fruit | Methanol extracts against \( M. \) bovis BCG (strain 11-73 P2) with MIC of 2.5 \( \mu \)g/ml | [186] |
| Ambrosia ambrosioides | Asteraceae | Aerial parts | Methanolic extracts against \( M. \) tuberculosis H37Rv with MIC of 790 \( \mu \)g/ml | [187] |
| Ambrosia confertiflora | Asteraceae | Aerial parts | Methanol, chloroform, dichloromethane, and ethyl acetate extracts against \( M. \) tuberculosis H37Rv with MIC of 200, 90, 120, and 160 \( \mu \)g/ml, respectively | [187] |
| Amphilerygium simplicifolium | Julianaceae | Leaf | Dichloromethane-methanol extracts (1.1) inhibit the \( M. \) tuberculosis H37Rv at 50 \( \mu \)g/ml with 90.5 ± 1.0% | [188] |
| Andrographis paniculata | Acanthaceae | Aerial parts | Hexane and methanol (1:5) extracts with maximum antimycobacterial activity at 250 \( \mu \)g/ml against all the tested strains of \( M. \) tuberculosis (H37Rv, MDR, and drug sensitive) | [189] |
| Andrographis paniculata | Acanthaceae | Leaf | Ethanol extracts with inhibition of mycobacterial (standard and clinical) growth | [7, 190] |
| Angiopteris evecta | Marattiaceae | Leaf | 80% methanol extract against \( M. \) tuberculosis H37Rv ATCC 25618 with an MIC of 400 \( \mu \)g/ml | [191] |
| Apodytes dimidiata | Icacinaceae | Leaf | Hexane extractions against the field strain of MDR-TB and against the \( M. \) tuberculosis H37Rv with MIC of 0.47 and 0.31 mg/ml, respectively | [192] |
| Artemisia ludoviciana | Asteraceae | Bark, leaf | Hexane extracts against MDR-TB clinical isolates with MIC of 25-100 \( \mu \)g/ml | [58, 193] |
| Artemisia nilagirica | Asteraceae | Leaf | Ethanol extracts against \( M. \) smegmatis with IC50 of 300 \( \mu \)g/ml | [194] |
| Belischmedia obscura | Lauraceae | Root | Ethyl acetate extracts against \( M. \) tuberculosis H37Rv with MIC of 31.25 \( \mu \)g/ml by MABAb | [195] |
| Bidens odorata | Asteraceae | Aerial parts | Hexane, dichloromethane, ethyl acetate, and ethanolic extracts against \( M. \) tuberculosis H37Rv (ATCC 27294) with MIC of 100, 12.5, 12.5, and 12.5 \( \mu \)g/ml | [196] |
| Bridelia micrantha | Euphorbiaceae | Bark | Acetone extracts against \( M. \) tuberculosis H37Ra with MIC of 25 \( \mu \)g/ml | [197] |
| Calluna vulgaris | Ericaceae | Aerial parts | Ethyl acetate extracts with 97% inhibition at 100 \( \mu \)g/ml against \( M. \) tuberculosis H37Rv (ATCC 27294) | [198] |
| Calophyllum brasiliense | Clusiaceae | Leaf | Dichloromethane-methanol extracts (1.1) inhibit the \( M. \) tuberculosis H37Rv at 50 \( \mu \)g/ml with 82.8 ± 0.4% | [188] |
| Capparis zeylanica | Capparidaceae | Leaf | Ethyl acetate extracts against \( M. \) tuberculosis H37Rv with the 32 mm minimum zone of inhibition | [199, 200] |
| Carya illinoensis | Juglandaceae | Bark | Hexane extracts against \( M. \) tuberculosis H37Rv with MIC of 30 \( \mu \)g/ml | [193] |
| Cassia sophera | Caesalpinia ceae | Seed | Methanol extracts against \( M. \) smegmatis with MIC of 125 \( \mu \)g/ml | [201] |
| Plant species            | Plant family     | Part used | Extracts                                                                 | References |
|-------------------------|------------------|-----------|--------------------------------------------------------------------------|------------|
| Chenopodium ambrosioides| Amaranthaceae     | Leaf      | 80% ethanol crude extracts against *M. tuberculosis* 37Ra (ATCC 25177™) with MIC of 5000 μg/ml | [184]      |
| Chrysactinia mexicana   | Asteraceae        | Root      | Ethyl ether extract against a drug-resistant strain of *M. tuberculosis* CIBIN/UMF15:99 with MIC of 62.5 μg/ml | [202]      |
| Citrullus colocynthis   | Cucurbitaceae     | Leaf      | Chloroform extracts against *M. tuberculosis* 37Rv with MIC of 2.5 mg/ml by MABA | [203]      |
| Citrus sinensis         | Rutaceae          | Fruit peel| Hexane extracts against two drug-resistant strains of *M. tuberculosis* with MIC of 25 and 50 μg/ml | [204]      |
| Cladonia arbuscula      | Cladoniaceae      | Root      | Hexane and ethyl acetate extracts with 96% and 99% inhibition at 100 μg/ml against *M. tuberculosis* 37Rv (ATCC 27294), respectively | [198]      |
| Cocculus hirsutus       | Menispermaceae    | Leaf      | Ethanol extracts against *M. tuberculosis* 37Rv (ATCC 27294) with MIC of 500 μg/ml | [196]      |
| Codiaeum peltatum       | Euphorbiaceae     | Stem      | Methanol extracts against *M. bovis* BCG (strain 11-73 P2) with MIC of 100 μg/ml | [186]      |
| Combretum aculeatum     | Combretaceae      | Aerial part| Aqueous extracts inhibiting *M. marinum* with MIC of 0.2 mg/ml | [205]      |
| Costus speciosus        | Zingiberaceae     | Stem, flower| Hexane partition from methanol extracts against *M. tuberculosis* 37Rv with MIC of 100 μg/ml | [206]      |
| Cremastrispora triflora | Rubiaceae         | Leaf      | Acetone extracts decreased 16-fold of MIC in combination with rifampicin against *M. aurum* and reduction of the MICs of the anti-TB drug ranged from 2-fold to 4-fold, 2-fold to 64-fold, and 2-fold to 64-fold for *M. smegmatis*, *M. aurium*, and *M. tuberculosis*, respectively | [207]      |
| Croton sylvaticus        | Euphorbiaceae     | Leaf, root, stem bark| Decoction, not known | [208]      |
| Curcuma caesia          | Zingiberaceae     | Rhizome   | Ethanol extract against *M. tuberculosis* 37Rv (ATCC 27294) with MIC of 31.25 μg/ml | [196]      |
| Cymbopogon citratus     | Poaceae           | Stem, rhizome| Hexane partition from methanol extracts of 200 μg/ml against *M. tuberculosis* 37Rv | [206]      |
| Cyperus rotundus        | Cyperaceae        | Root      | Ethanol extracts against *M. tuberculosis* 37Rv (ATCC 27294) with MIC of 62.5 μg/ml | [209]      |
| Davilla elliptica       | Dilleniaceae      | Leaf      | Chloroform extracts showed a promising antimycobacterial activity with a MIC of 62.5 μg/ml by MABA | [209]      |
| Dissotis rotundifolia   | Melastomataceae   | Leaf      | 80% ethanol crude extracts against *M. tuberculosis* 37Ra (ATCC 25177™) with MIC of 5000 μg/ml | [184]      |
| Dryopteris stewartii    | Dryopteridaceae   | Whole plant| Decoction, not known | [203]      |
| Echinopsis giganteus    | Asteraceae        | Root      | Methanol extracts against *M. tuberculosis* 37Ra and 37Rv with MIC of 32 and 16 μg/ml, respectively | [210]      |
| Empetreum nigrum        | Emperataceae      | Root      | Hexane extracts with 95% inhibition at 100 μg/ml against *M. tuberculosis* 37Rv (ATCC 27294) | [198]      |
| Erythrina abyssinica    | Fabaceae          | Root bark | Methanol extracts showed the highest activity on *M. tuberculosis* 37Rv (MIC 390 μg/ml) | [211]      |
| Euophoria nuda          | Orchidaceae       | Tubers    | Ethanol extracts against *M. tuberculosis* 37Rv (ATCC 27294) with MIC of 500 μg/ml | [196]      |
| Euphoria albomarginata  | Euphorbiaceae     | Shoots    | Extracts by n-hexane, dichloromethane, ethyl acetate, and methanol individually against *M. tuberculosis* 37Rv with MIC of 250-1000 μg/ml | [212]      |
| Euphoria hirta          | Euphorbiaceae     | Leaf      | Ethyl acetate extracts showed better activity with maximum of 64.73% reduction in relative light units against *M. tuberculosis* 37Rv | [213]      |
| Evodia elleryana        | Rutaceae          | Bark      | Ethyl acetate extracts with 95% inhibition of *M. tuberculosis* 37Ra grown in vitro (ATCC 25177) at 50 μg/ml | [214]      |
| Ficus sur               | Moraceae          | Root      | 80% ethanol against *M. tuberculosis* 37Ra (ATCC 25177) with MIC of 0.78 μg/ml | [215]      |
| Ficus citrifolia        | Moraceae          | Leaf      | 95% ethanol extracts against *M. tuberculosis* 37Rv (ATCC 27294) with 91% inhibition at 100 μg/ml | [216]      |
Table 2: Continued.

| Plant species               | Plant family | Part used | Extracts                                                                 | References |
|-----------------------------|--------------|-----------|---------------------------------------------------------------------------|------------|
| F. cernua                   | Asteraceae   | Leaf      | Hexane extracts against sensitive and resistant strains, respectively, with MIC of 25-50 μg/ml | [217]      |
| Foeniculum vulgare          | Umbelliferae | Aerial parts | Hexane extracts against M. tuberculosis H37Rv with MIC of 100 μg/ml | [204]      |
| Globularia alypum           | Globulariaceae | Leaf | Petroleum ether extracts against M. tuberculosis H37Rv with IC$_{50}$ of 77 μg/ml | [218]      |
| Glycyrrhiza glabra          | Fabaceae     | Root      | Ethanol extracts against M. tuberculosis H37Rv (ATCC 27294) with MIC of 250 μg/ml | [219]      |
| Guaiacum coulteri           | Zygophyllaceae | Flower | Methanol extracts against M. tuberculosis H37Rv with MIC of 1000 μg/ml | [188]      |
| Guiera senegalensis         | Combretaceae | Aerial parts | Aqueous extracts inhibiting M. marinum with MIC of 200 μg/ml | [205]      |
| Gymnosperma glutinosum      | Asteraceae   | Leaf      | Hexane extracts against M. tuberculosis H37Ra and H37Rv both at 31.2 μg/ml | [220]      |
| Helianthus annuus           | Asteraceae   | Stem      | Extracts by n-hexane, dichloromethane, ethyl acetate, and methanol individually against M. tuberculosis H37Rv with MIC of 250-500 μg/ml | [212]      |
| Heracleum maximum           | Apiaceae     | Root      | Aqueous extracts against M. bovis BCG by OD units | [183]      |
| Heteromorpha trifoliata     | Apiaceae     | Leaf      | Ethanol extracts against M. tuberculosis H37Rv with MIC of 80 μg/ml | [221]      |
| Hygrophilia auriculata      | Acanthaceae  | Root, leaf | Acetone extract against M. tuberculosis H37Rv by y the disc diffusion method | [222]      |
| Juglans mollis              | Juglandaceae | Bark      | Hexane extracts against M. tuberculosis H37Rv with MIC of 50 μg/ml | [193]      |
| Juglans regia               | Juglandaceae | Bark, leaf | Hexane extracts against M. tuberculosis strain H37Rv with MIC of 100 μg/ml | [193, 194]|
| Justicia adhatoda           | Acanthaceae  | Leaf      | Ethanolic extract against M. tuberculosis H37Rv by y the disc diffusion method | [223]      |
| Khaya senegalensis          | Meliaceae    | Bark, leaf | Ethanol extracts against M. tuberculosis H37Ra with MIC of 6.25 μg/ml | [224]      |
| Lantana camara              | Verbenaceae  | Leaf      | Methanol extracts against M. tuberculosis H37Rv with MIC of 20 μg/ml | [17]       |
| Lantana hispida             | Verbenaceae  | Leaf      | Hexane extracts against drug-resistant clinical isolates of M. tuberculosis with MIC of 100-200 μg/ml | [193, 194]|
| Laurelia novaezelandiae     | Monimiaceae  | Leaf, flower | Aqueous extract against M. smegmatis with IC$_{50}$ of 0.02 mg/ml | [225]      |
| Leucophyllum frutescens     | Scrophulariaceae | Root, leaf | Methanol extracts against a drug-resistant strain of M. tuberculosis CIBIN/UMF15:99 with MIC of 62.5 μg/ml | [202]      |
| Maerua edulis               | Capparaceae  | Root      | Hexane extracts against M. bovis BCG, M. tuberculosis H37Ra with MIC 31.2-62.5 μg/ml | [226]      |
| Mallotus philippensis       | Euphorbiaceae | Leaf, fruit | Ethanolic extracts of fruit and leaves against M. tuberculosis H37Rv (ATCC 27294) both with MIC of 250 μg/ml | [227]      |
| Metroeceros excelsa         | Myrtaceae    | Leaf      | Methanol extracts against M. smegmatis with IC$_{50}$ of 0.11 mg/ml | [226]      |
| Millettia stuhlmannii       | Fabaceae     | Leaf      | Acetone extracts against M. smegmatis with MIC of 0.13 mg/ml | [228]      |
| Morinda citrifolia          | Rubiaceae    | Leaf      | Aqueous extract has an inhibition rate of 89% against M. tuberculosis H37Rv | [180]      |
| Mucuna imbricata            | Fabaceae     | Seed      | Methanol extracts have potential antimycobacterial activity and the synergistic group consisting of rifampicin in murine model | [185]      |
| Murraya koenigii            | Rutaceae     | Leaf      | Ethanol extracts against M. smegmatis with IC$_{50}$ of 300 μg/ml | [194]      |
| Musa acuminata              | Musaceae     | Stem      | Methanol extracts against drug-resistant variants of M. tuberculosis with MIC of 200 μg/ml | [204]      |
| Myoporum crassifolium       | Scrophulariaceae | Wood | Hydrodistillation with essential oils against M. bovis BCG (strain 11-73 P2) with MIC of 50 μg/ml | [186]      |
| Plant species            | Plant family  | Part used | Extracts                                                                 | References  |
|-------------------------|---------------|-----------|--------------------------------------------------------------------------|-------------|
| Myrica gale             | Myricaceae    | Root, stem| Ethyl acetate extracts with 96% inhibition at 100 μg/ml against *M.* tuberculosis H37Rv (ATCC 27294) | [198]       |
| Myristica fatua         | Myricaceae    | Almond    | Dichloromethane soluble extracts against *M.* bovis BCG (strain 11-73 P2) with MIC of 50 μg/ml | [186]       |
| Nasturtium officinale   | Cruciferae    | Aerial parts| Chloroform extracts against two drug-resistant strains of *M.* tuberculosis with MIC of 50-100 μM | [204]       |
| Olea europaea           | Oleaceae      | Leaf      | Hexane extracts against the drug-resistant variants of *M.* tuberculosis with MIC of 25-100 μM | [204]       |
| Otostegia integrifolia  | Lamiaceae     | Root      | Chloroform extract of roots was the most active on *M.* tuberculosis H37Rv (MIC 156 μg/ml) and AOZ8W-4 (MDR-TB clinical isolate) (MIC 0.078 mg/ml) | [229]       |
| Pelargonium graveolens  | Geraniaceae   | Seed      | Hydrodistillation for essential oil against tested isolates ranged from 19.5 μg/ml to 78 μg/ml | [230]       |
| Pelargonium sidoides    | Geraniaceae   | Root      | Aqueous extracts inhibiting the growth of *M.* tuberculosis H37Rv (ATCC 27294) by 96% at a sample concentration of 12.5 μg/ml | [231]       |
| Pentanisia prunelloides | Rubiaceae    | Root      | 80% ethanol against *M.* tuberculosis H37Ra (ATCC 25177) with MIC of 0.78 mg/ml | [215]       |
| Persea americana        | Lauraceae     | Leaf, seed| Methanolic extracts against *M.* tuberculosis H37Ra with MIC of 31.2 μg/ml and H37Rv; chloroformic extract of seeds against *M.* tuberculosis H37Rv MIC less than 50 μg/ml | [229, 232] |
| Phymaspermum acerosum   | Asteraceae    | Root, leaf| Ethanol and water extracts had the best MIC value of 20 μg/ml against five *M.* tuberculosis strains | [221]       |
| Piper cernuum           | Piperaceae    | Leaf      | Hydrodistillation with water displayed moderate activity against the *M.* tuberculosis H37Rv with MIC of 125 μg/ml | [233]       |
| Piper diospyrifolium    | Piperaceae    | Leaf      | Hydrodistillation with water displayed moderate activity against the *M.* tuberculosis H37Rv with MIC of 125 μg/ml | [233]       |
| Piper guineense         | Piperaceae    | Seed      | Methanol extracts against *M.* tuberculosis H37Ra and H37Rv with MIC of 256 μg/ml | [210]       |
| Piper imperiale         | Piperaceae    | Flower    | Ethanolic extracts against *M.* tuberculosis H37Rv with MIC of 75 μg/ml | [234]       |
| Piper rivinoides        | Piperaceae    | Leaf      | Hydrodistillation with water displayed moderate activity against the *M.* tuberculosis H37Rv with MIC of 125 μg/ml | [233]       |
| Piper sarmentosum       | Piperaceae    | Leaf      | Extracts with petroleum ether, chloroform, and methanol, against *M.* tuberculosis H37Rv with MIC of 25, 25, and 12.5 μg/ml | [235]       |
| Pisonia borinquena      | Nyctaginaceae| Leaf      | 95% ethanol extracts against *M.* tuberculosis H37Rv (ATCC 27294) with 85% inhibition at 100 μg/ml | [216]       |
| Pittosporum tenuifolium | Pittosporaceae| Leaf      | Ethanol extracts against *M*. smegmatis with IC<sub>50</sub> of 0.78 mg/ml | [225]       |
| Pluchea indica          | Asteraceae    | Flower and leaf | 80% methanol extract against *M.* tuberculosis H37Rv ATCC 25618 with an MIC of 800 μg/ml | [191]       |
| Plumbago zeylanica      | Plumbaginaceae| Root      | Ethanol extract against *M.* tuberculosis H37Rv (ATCC 27294) with MIC of 31.25 μg/ml | [196]       |
| Psychotria zombamontana | Rubiaceae    | Leaf      | Acetone extract decreased 256-fold of MIC in combination with rifampicin against *M.* aurum and reduction of the MICS of the anti-TB drug ranged from 2-fold to 4-fold, 2-fold to 64-fold, and 2-fold to 64-fold for *M*. smegmatis, *M*. aurum, and *M*. tuberculosis, respectively | [207]       |
| Pterocarpus osun        | Fabaceae (Leguminosae) | Stem | Chloroform extract against *M.* tuberculosis H37Rv and *M.* bovis BCG with MIC of 1225 μg/ml and 1100 μg/ml, respectively, by MABA | [67, 236] |
| Pterolobium stellatum   | Fabaceae      | Root      | Chloroform extracts of roots were the most active on *M.* tuberculosis H37Rv (MIC 39 μg/ml) and AOZ8W-4 (MDR-TB clinical isolate) (MIC 0.078 mg/ml) | [229]       |
| Rhynchosia precatoria   | Fabaceae      | Root      | Extracts by n-hexane, dichloromethane, ethyl acetate, and methanol individually against *M.* tuberculosis H37Rv with MIC of 15.6-125 μg/ml | [212]       |
| Ricinus communis        | Euphorbiaceae | Seed      | Hexane extracts against *M.* tuberculosis H37Rv sensitive strain with MIC of 2.5 mg/ml by MABA | [203]       |
extracting solvents, while chloroform, dichloromethane, acetone, and ethyl acetate were used to a lesser extent. Of course, aqueous extract method was also popularly used, which involved the process of soaking, boiling, or/and hydrodistilling. Although the plant part used for study does not determine the extraction method, as a general rule, low molecule organic solvents are recommended when there is no reference.

To date, no specific cut-off value has been established as a reference to analyze the anti-TB activity results of the plant extracts, and many different methods are available to evaluate the activity. As of date, only a few anti-TB plant extracts in Table 2 have been tested in preclinical or clinical trials. It is encouraging that more and more promising crude extracts are now paving a way for the clinical test for their therapeutic applications. This section can provide a new perspective

### Table 2: Continued.

| Plant species                  | Plant family | Part used       | Extracts                                                                 | References |
|-------------------------------|--------------|-----------------|--------------------------------------------------------------------------|------------|
| Rosmarinus officinalis        | Lamiaceae    | Leaf            | Ethanolic extracts against M. tuberculosis H37Rv with MIC of 6.25 μg/ml   | [224]      |
| Satureja aintabensis          | Lamiaceae    | Aerial parts    | Extraction with petroleum ether, ethyl acetate, and methanol killed M. tuberculosis with MIC of 50-800 μg/ml | [237]      |
| Satyrium nepalense            | Orchidaceae  | Flower          | Hexane extracts against M. tuberculosis H37Rv TMC-102 with MIC of 15.7 μg/ml | [238]      |
| Schinus molle                 | Anacardiaceae| Fruit           | Methanol extract against a drug-resistant strain of M. tuberculosis CIBIN/UMF15.99 with MIC of 125 μg/ml | [202]      |
| Securidaca longipedunculata   | Polygalaceae | Root            | Hexane extracts against M. bovis BCG, M. tuberculosis H37Ra, and H37Rv with 62.5 μg/ml | [226]      |
| Solanum torvum                | Solanaceae   | Leaf            | 80% ethanol crude extracts against M. tuberculosis H37Ra (ATCC 25177™) with MIC of 156.3 μg/ml | [184]      |
| Sphaeranthus indicus          | Asteraceae   | Floral head     | Ethanol extract against M. tuberculosis H37Rv (ATCC 27294) with MIC of 31.25 μg/ml | [196]      |
| Sterculia setigera            | Sterculiaceae| Leaf            | Hexane, dichloromethane, and ethyl acetate extracts against M. tuberculosis H37Rv with MICs of 84 μg/ml, 62 μg/ml, and 128 μg/ml, respectively | [239]      |
| Swinglea glutinosa            | Rutaceae     | Fruit peel      | Aqueous extracts for essential oils against M. tuberculosis H37Rv (ATCC 27294) with MIC of 100 μg/ml | [182]      |
| Tabernaemontana elegans       | Apocynaceae  | Root            | Ethyl acetate extracts against M. tuberculosis H37Rv with MIC of 15.6 μg/ml | [226]      |
| Tabernaemontana coronaria     | Apocynaceae  | Leaf            | Hexane partition from methanol extracts of MIC of 100 μg/ml against M. tuberculosis H37Rv | [206]      |
| Terminalia phanerophlebia     | Combretaceae | Leaf, root, twig| 80% ethanol against M. tuberculosis H37Ra (ATCC 25177) with 0.30 and 0.78 mg/ml, respectively | [215]      |
| Terminalia sericea            | Combretaceae | Stem bark       | Acetone extracts against M. tuberculosis H37Ra with MIC of 25 μg/ml         | [197]      |
| Thymus sibthorpii             | Lamiaceae    | Aerial parts    | Extracts with petroleum ether, ethyl acetate, and methanol against M. tuberculosis with MIC of 50–800 μg/ml | [237]      |
| Trachyspermum copticum        | Apiceae      | Aerial parts    | Hydrodistillation extracts against M. kansasi and MDR-TB with MICs of 78 μg/ml | [230]      |
| Urtica dioica                 | Urticaceae   | Leaf            | Hexane extracts against M. smegmatis with MIC of 250 μg/ml                | [201]      |
| Uvaria rufa                   | Annonaceae   | Leaf            | Lead acetate-treated crude chloroform extracts against M. tuberculosis H37Rv with MIC of 8 μg/ml | [136]      |
| Vetiveria zizanoides          | Poaceae      | Root            | Ethanolic extract and hexane fraction 500 μg/ml or 50 μg/ml against M. tuberculosis H37Rv and H37Ra | [240]      |
| Vismia baccifera              | Clusiaceae   | Leaf            | Dichloromethane-methanol extracts (1.1) inhibit the M. tuberculosis H37Rv at 50 μg/ml with 70.3 ± 0.5% | [188]      |
| Xylopia aethiopica            | Annonaceae   | Fruit, bark     | Methanol extracts against M. tuberculosis H37Ra and H37Rv with MIC of 512 μg/ml | [210]      |
| Zanthoxylum capense           | Rutaceae     | Root            | Dichloromethane extracts against M. bovis BCG, M. tuberculosis H37Ra, and H37Rv with MICs of 31.2 μg/ml | [226]      |
| Zingiber officinale           | Zingiberaceae| Rhizome         | Ethanol extract against M. tuberculosis H37Ra with MIC of 2500 μg/ml by MABA | [184]      |

*Minimum inhibitory concentration (MIC); \( ^{\text{a}} \) microplate alamar blue assay (MABA); \( ^{\text{b}} \) half maximal inhibitory concentration (C\text{_{50}}).
Table 3: Important anti-TB traditional medicinal plants in literature by the systemic survey on the prescribed formula.

| Species number | Family number | Main families                                                                 | Country or region                                      | References    |
|----------------|---------------|--------------------------------------------------------------------------------|----------------------------------------------------------|---------------|
| 13             | 10            | Asteraceae (3), Chrysobalanaceae, Araliaceae, Acanthaceae, Chrysobalanaceae, Cucurbitaceae, Fabaceae, Lamiaceae, Melastomataceae, Phyllanthaceae, Polygonaceae | Burundian                                              | [241]         |
| 9              | 8             | Apocynaceae, Verbenaceae, Rubiaceae, Goodeniaceae, Agavaceae, Moraceae, Myrtaceae, Zingiberaceae | Manus Province, Papua New Guinea                          | [242]         |
| 184            | 77            | Fabaceae (21), Asteraceae (12), Malvaceae (11)                                  | Bapedi (South Africa)                                    | [243]         |
| 30             | 21            | Alliaceae (3), Rutaceae (3), Apioaceae (2), Caryophyllaceae (2), Asteraceae (2), Lamiaceae (2), Myrtaceae (2), Solanaceae (2) | Nkonkobe municipality, Eastern Cape Province (South Africa) | [244]         |
| 21             | 12            | Asteraceae, Fabaceae, Geraniaceae                                              | Mananga metro, Thabo Mofutsanyana, and Lejweleputswa in South Africa | [245]         |
| 25             | 14            | Fabaceae (5), Euphorbiaceae (3), Asteraceae (3), Lamiaceae (12%)               | Bas-Congo Province, Democratic Republic of Congo         | [208]         |
| 15             | 13            | Amaryllidaceae (3), Xanthorrhoeaceae (2), Arecaecae (2), Solanaceae (2), Meliaceae, Acanthaceae, Poaceae, Phyllanthaceae, Melastomataceae, Poaceae, Cyperaceae, Zingiberaceae, Amaryllaceae, Asteraceae | Greater Accra and eastern communities in Ghana           | [246]         |
| 95             | 48            | Loranthaceae (6), Caesalpiniaaceae (5), Papilionaceae (5), Poaceae (4), Mimosaceae (4), Sphorhulariae (4), Anacardiaceae (3), Combretaceae (3), Liliaceae (3), and Solanaceae (3) | Niger state, Nigeria                                     | [247]         |
| 66             | 35            | Rutaceae (7), Euphorbiaceae (5), Rubiaceae (4), Anacardiaceae (3), Fabaceae (3), Verbenaceae (3), Arecaecae (2), Annonaceae (2), Solanaceae (2), Moraceae (2), Rhamnaceae (2) | Lao PDR                                                | [248]         |
| 23             | 20            | Arecaecae (2), Aristolochiaceae (2), Rubiaceae (2)                             | Malaysia                                                | [249]         |
| 181            | 67            | Asteraceae (31), Fabaceae (14), Lamiaceae (9), Euphorbiaceae (7), Celastraceae (5) | South Africa                                             | [250]         |
| 62             | 38            | Asteraceae (12), Aristolochiaceae (3), Compositae (3), Rosaceae (3), Juglandaceae (2), Zygophyllaceae (2), Verbenaceae (2), Rutaceae (2), Papaveraceae (2), Fabaceae (2) | Mexico                                                 | [10]          |
| 88             | 36            | Lamiaceae (9), Asteraceae (7), Papilionaceae (4), Acanthaceae (3), Caesalpiniaaceae (3), Capparaceae (3), Euphorbiaceae (3), Mimosaceae (3) | Districts of Kamuli, Kisoro, and Nakapiripiti in Uganda | [251]         |
| 90             | 44            | Fabaceae (13), Asteraceae (7), Moraceae (5), Rutaceae (4)                      | Districts of Mpigi and Butambala, Uganda                | [252]         |
| 35             | 22            | Fabaceae (5), Rutaceae (4), Apocynaceae (3), Menispermaceae (3), Malvaceae (3) | Madhya Pradesh, India                                    | [196]         |
| 132            | 45            | Annonaceae (14), Zingiberaceae (12), Rutaceae (10), Annonaceae (8), Euphorbiaceae (8), Fabaceae (7) | Southeast Asian                                          | [253]         |
| 10             | 8             | Fabaceae (3), Canellaceae (1), Rubiaceae (1), Anacardiaceae (1), Rutaceae (1), Myrtaceae (1), Merlucciidae (1), Guttiferae (1) | Lake Victoria Basin (Uganda, Kenya, and Tanzania)        | [254]         |
| 14             | 8             | Euphorbiaceae (4), Verbenaceae (3), Rutaceae (2)                              | Lake Victoria region and the Samburu community           | [255]         |
| 2              | 2             | Achillea millefolium (1), Dryopteris stewartii (1)                             | Kel village, Neelum Valley, Azad Kashmir, Pakistan       | [256]         |
| 4              | 3             | Amaryllidaceae (1), Lauraceae (1), Amaranthaceae (1), Asteraceae (1)           | Sulaymaniyah Province, Kurdistan, Iraq                   | [257]         |
| 22             | 18            | Liliaceae (3), Euphorbiaceae (2), Verbenaceae (2)                              | India                                                   | [258]         |
| 6              | 6             | Vitaceae (1), Poaceae (1), Pinaceae (1), Musaceae (1), Rosaceae (1), Leguminosae (1) | Arabian Peninsula                                       | [259]         |
| 2              | 2             | Asteraceae (1), Dryopteridaceae (1)                                            | Pakistan                                                | [251]         |
| 70             | 44            | Arecaecae (4), Euphorbiaceae (4), Fabaceae (3), Piperaceae (3), Rutaceae (3) | Malaysia                                                | [191]         |
in expanding the anti-TB plant species for the development of anti-TB medicine in the future.

5. Medicinal Plants Only Found in Formula Prescribed by the Traditional Healers

Traditional healers continually serve the public health in most of the countries. Some ethnomedical information has been published based on many plant species in anti-TB formulas documented by different traditional healing systems, ranging from the poor documented oral African medicine to the well-documented Ayurveda or Chinese medicine. These reports inspired the scientists to find more effective compounds for tuberculosis. The investigations of medicinal plants using frontier technologies are now being reconsidered to be a feasible approach for discovering novel bioactive compounds and crude extracts, in order to solve the wide spreaded TB problems. Table 3 shows the main species or families of the traditional plant medicines and their botanical details in the published papers by the systemic survey of the prescribed formula, but very few studies reveal the working compounds or active crude extracts.

The anti-TB formulas were investigated in many countries or regions, such as China, India, Mexico, South Africa, Pakistan, Iraq, Malaysia, Congo, Lao PDR, Nigeria, Niger, Burundi, Papua New Guinea, Lake Victoria Basin (Uganda, Kenya, and Tanzania), Arabian Peninsula, Southeast Asian, and Manus Province. Most anti-TB formulas were found during the ethnopharmacological investigation of the indigenous plants. To strengthen the anti-TB purpose, the present review summarized the anti-TB plant in the formula from the ethnopharmacological publications, with an emphasis on their classification (Table 3). Although three reports in Table 3 did not show the botanical family of the anti-TB medical plants in detail, it still can be speculated that the family Fabaceae is the most represented species, followed by Asteraceae, Euphorbiaceae, and Liliaceae families.

We need to be aware that the plant medicine used by the traditional healers is based on their according ethnomedical traditional medical theories. In comparison with the western system of medicine, the traditional plant medicines showed certain drawbacks. An important issue of all was that the active components of the herbal drugs prescribed were unknown. The activity of the traditional herbal drugs prescribed by the traditional healers can be greatly affected by the difference in the processing methods, variation in the potency due to difference in plant species and subspecies, varying geographical location of growth, nonuniform quality control standards, etc. Furthermore, for a given plant, a specific place, part, method, and time for collection can significantly affect the therapeutic efficacy [16, 40]. Hence, the plant medicine used by the traditional healers needs a critical evaluation to find the active components.

6. Need for Future Research

Although this review presents a big list of plants with effective anti-TB activities from different traditional medicine systems, there is a need of better therapeutic drug monitoring systems and high throughput in vitro assays for the routine screening to identify potentially serious and clinically significant herb-drug interactions [262]. Furthermore, there is a lack of in vivo information regarding the drug metabolism associated interactions with reference to the traditional medicines and the treatment of TB. This requires health care practitioners to ensure a clear communication with patients regarding the possible negative impacts of simultaneous use of certain TMs and prescribed drugs. It was reported that the widely used Sutherlandia frutescens in the treatment of TB in countries of Southern African Development Community interfered with the isoniazid therapy, but the mechanism of this interaction was not clear [263, 264]. Coadministration also resulted in the reduced bioavailability of ofloxacin [265], while piperine showed the ability to increase the bioavailability of the antituberculosis drug rifampicin [266–268].

Several issues affect the anti-TB activity of the components of the medicinal plants, such as the variation in the potency due to difference in species, absence of an integrated coding for every species used commonly in TMs, varying geographical location of growth and incorrect identification of drugs, and nonuniform quality control standards [269]. No clinic trial was reported on the crude extracts, and even the pure compounds from the medical plants still need to be elucidated for their constituent characterization and the mechanism of action. Till date, not many compounds have been originated from plants for further modification for use in clinic. We hope that this review will help to find a possible way to get better anti-TB results by making a combination of the compounds originated from plants based on the different TB-killing mechanisms.

**Abbreviations**

TB: Tuberculosis  
TM: Traditional medicines
Data Availability

All data included in this article are available from the corresponding author upon request.

Ethical Approval

Ethical approval is not applicable.

Consent

Consent was not necessary.

Conflicts of Interest

The authors declared that there are no conflicts of interest.

Authors’ Contributions

ZS and YX designed and organized the review. CK drafted the manuscript. BL revised the manuscript. All authors read and approved the final manuscript.

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