Southeast Asian Medicinal Plants as a Potential Source of Antituberculosis Agent

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Despite all of the control strategies, tuberculosis (TB) is still a major cause of death globally and one-third of the world’s population is infected with TB. The drugs used for TB treatment have drawbacks of causing adverse side effects and emergence of resistance strains. Plant-derived medicines have since been used in traditional medical system for the treatment of numerous ailments worldwide. There were nine major review publications on antimycobacteria from plants in the last 17 years. However, none is focused on Southeast Asian medicinal plants. Hence, this review is aimed at highlighting the medicinal plants of Southeast Asian origin evaluated for anti-TB. This review is based on literatures published in various electronic database. A total of 132 plant species representing 45 families and 107 genera were reviewed; 27 species representing 20.5% exhibited most significant in vitro anti-TB activity (crude extracts and/or bioactive compounds 0–<10 μg/ml). The findings may motivate various scientists to undertake the project that may result in the development of crude extract that will be consumed as complementary or alternative TB drug or as potential bioactive compounds for the development of novel anti-TB drug.

1. Introduction

Tuberculosis (TB) is an ancient disease and it is among the world’s most deadly epidemics. Like any other infectious disease, TB can happen to anyone and spares no age, sex, and nationality [1, 2]. Several strains of Mycobacterium tuberculosis (MTB) are the common cause of this deadly infectious disease [3]. This disease is endemic in every country in the world, and death due to TB is more common when compared to other bacterial disease [1, 3, 4]. About two billion individuals are latently infected with TB, but only 10% of these infected persons fall sick with active disease during their lifetime [5–8]. It has been estimated that around nine million persons develop TB and almost 2 million die from it annually [9–12]. About 5.5 million of the cases occur in Asia, 1.5 million in Africa, 745,000 in the Middle East, and 600,000 in Latin America [13]. It is unfortunate that more than 75% of TB cases are found in adults [14]. Unprecedented decision was taken in 1993 by WHO to declare TB as a public health emergency [10, 15], and it is the first disease that has ever been declared as a global emergency by WHO [16].

In order to combat TB, chemotherapy is used, which is the modern TB treatment. The drugs used include rifampicin, isoniazid, ethambutol, pyrazinamide, and streptomycin for TB treatment. However, these drugs have drawbacks of causing adverse side effects and the TB-causing bacterium can gain easy resistance against these drugs. Besides that, there is a chance of “relapse” due to noncompliance with medication within the first year of treatment. Consequently, this results in a more serious condition where the Mycobacterium species develops resistance to the TB drugs [1].

The TB resistance can be categorized into two types: the multi-drug resistant TB (MDR-TB) and extensively drug resistant TB (XDR-TB). Firstly, MDR-TB arises when the strain that is resistant to the first-line standard TB drugs (isoniazid and rifampicin) is involved. More than 4% of TB patients globally are infected with Mycobacterium strains that are resistant to first-line drugs. Secondly, XDR-TB happens...
when the mycobacterial strain is resistant to the first-line drugs, fluoroquinolone, as well as other injectable second-line drugs such as kanamycin, capreomycin, and amikacin. According to the WHO report on surveillance and response to MDR-TB and XDR-TB, approximately 310,000 MDR-TB cases occurred in pulmonary TB patients documented in 2011 while 84 countries were recorded having at least one XDR-TB case [17–20]. In 2012, around 480,000 people have been reported to develop MDR-TB and about 170,000 people died as a result [20, 21]. These forms of TB diseases are often more fatal, costly, and difficult to treat. The second-line drugs used in drug resistant TB have notable side effects, but have about 50% cure rate [22]. Although fluoroquinolones such as ofloxacin and norfloxacin have been used and are considered safer than the aforementioned second-line drugs, however, they also have their own drawback of being more costly.

Due to aforementioned disadvantages, the prospective efficacy of medicinal plants has motivated doctors and scientists to turn to folk medicines for treatment of various chronic diseases, including TB [22]. Hence, the urgent need arises towards the search of a component with a higher anti-TB activity, with easy availability and without side effects [1, 6, 23].

Owing to their chemical diversity and significant role in the drug sighting and development, medicinal plants proffer a great hope to overcome these needs. The medicinal plants have been comprehensively used either as crude extracts or pure materials. However, very few species of medicinal plants have been thoroughly explored for their medicinal properties [24–26]. The plant-derived medicines have been utilized in traditional medical system for the treatment of different illnesses worldwide. Around 75% of the global populace solely depends on medicinal plants for primary health care [27,28]. Consequently, there is so much interest in plant medicine during the last few decades leading to numerous species of medicinal plant being investigated for their pharmacological activities.

In the last 17 years, there were nine major review publications on antimycobacteria from natural products. Newton et al. [29] published a review paper on natural compounds with antimycobacteria derived from plant source, describing their potency in crude extracts as well as pure compounds from 123 plant species [29]. In 2003, Copp [30] published a review article that covered a wide range of natural bioactive products, with reported antitubercular activity within a period of twelve years (i.e., from 1990 to 2002) [30]. In another review, Okunade et al. [31] discussed 88 natural products and their synthetic analogues, mainly from plant source, and fungi as well as some aquatic organisms that displayed substantial activity against M. tuberculosis and other mycobacterial species in in vitro bioassays [31]. In their review, Pauli et al. [32] offered cross-linkage to the literatures of bioactive pure compounds with anti-TB and summarized more current advances in mycobacteriology and natural compounds chemistry tools innovation as well as their prospective to influence the primary steps in TB drug discovery process [32]. A review by Jachak and Jain [33] described recent target-based natural compounds that displayed antimycobacterial action [33]. Gautam et al. [23] reviewed different species of plant from a vast array of families that have exhibited antimycobacterial activity. Gupta et al. [34], in their review article, identified sixty-four medicinal plants used by traditional people in the treatment of leprosy [34].

Some antitubercular plants from Ayurveda as well as foreign origin have been reviewed by Arya [35] to give a scientific account on usage of antitubercular plants. Consequently, various phytochemicals such as alkaloids, flavonoids, tannins, xanthenes, terpenes, and quinones were involved in antitubercular activity [35]. The most recent among all the reviews is by Chinsenbu [20] in 2016. The review focused on antimycobacterial natural products derived from both endophytes as well as medicinal plants of Africa, Asia, Europe, South America, and Canada. Several plant species disclosed in the review demonstrated a putative anti-TB activity. Numerous antimycobacterial bioactive compounds have, as well, been isolated. They include l-epicatechol, allicin, anthocyandin, antraquonine glycosides, arjunic acid, benzophenan-thridine alkaloids, beta-sitosterol, crinine, decarine, ellagic acids, ellagitanin punicalagin, friedelin, galanthimine, gallic acid, glucopyranosides, hydroxybenzoic acids, iridoids, leucopelargonidol, neolignans, phenylpropanoids, taraxerol, and termilignan B. The chemicals may offer leads on new and more effective drugs to minimize the predication TB and lessen the drug resistant strains as well [20].

All the above review articles hardly highlighted any medicinal plant of Southeast Asian source. Even though there is an increasing availability of modern medicine in the Southeast Asia region, the use of traditional medicine remains popular [36]. Due to the enormous diversity of its flora, Southeast Asian region has a great potential for the discovery of novel active compounds. The countries in the region such as Malaysia, Indonesia, Brunei, and Thailand have a long history of using medicinal plant that proffers substantial pharmaceutical prospects [37].

2. Methodology

Related Scientific studies published in journals, books, and reports were reviewed. Relevant literatures were searched in Google Scholar and various electronic databases including Science Direct, IEEE Xplore, Scopus, SciFinder, and MEDLINE using a specific search terms including “TB”, “medicinal plants”, “anti-TB”, “Malaysia OR Philippines OR Indonesia Singapore OR Thailand OR Brunei OR Cambodia OR Laos OR Myanmar (Burma) OR Vietnam”. This review discussed studies from year 2000 to 2016.

3. Bioassay Guidance for Evaluating the Activity of Antituberculosis

Bioassay-guided fractionation is the modern practice presently used in identifying the active compound(s) present in crude extract(s). Due to the fact that the procedure comprises alternating stages of biological screening and active compound fractionation, in the last 20 years, sensitivity of fractionation techniques of pure natural compound
Evidence-Based Complementary and Alternative Medicine

3.1. Target Organism. It is obvious that the ideal organism to be targeted in the effort to discover anti-TB is the actual etiologic agent, Mycobacterium tuberculosis (MTB). The prominent pathogenic strain, MTB H37Rv (ATCC 27294), has fairly represented drug sensitivity profile of most drug sensitive clinical isolated strains. In primary screening, employing MDR strains of MTB is not crucial due to the fact that they are never “superbugs” that have resistant capacity to various drugs by the virtue of a particular mechanisms, such as diffusion pump in some bacteria. However, they are rather the consequence of peculiar step by step mutations to particular drugs. Hence, it is anticipated that they would be susceptible to any novel biologically active product, which does not attack the same site as TB drugs currently in use do [23, 32, 218].

Due to its virulence, the pathogenic strain of MTB must be processed or handled only in a laboratory with biosafety level 3 (BL-3) set-up. In the BL-3 laboratory, individual working is required to don on a protective gear. Most researchers opt to employ avirulent, fast growing, and saprophytic strain of Mycobacterium. Example of such is M. smegmatis (ATCC 607) [218]. Other avirulent substitutes to work with instead of virulent strains of MTB are the slow-growing strains such as M. tuberculosis H37Ra (ATCC 25177) and M. bovis BCG (ATCC 35743). The above species are closely related to pathogenic MTB H37Rv strain in their antimycobacterial susceptibility profile as well as genetic configuration. For this, strains require the employment of a class 2 biosafety cabinet when working with these organisms [23, 218].

3.2. In Vitro Bioassays for Anti-TB Screening

3.2.1. Agar Diffusion. The conventional diffusion assays (well or disk) were applied in various antimicrobial evaluation of compounds from natural sources only to indicate the presence or absence of growth inhibition at unspecified concentrations gradient and hence are never quantifiable when evaluating crude materials or novel products. The sizes of the zones of inhibition can be only interpreted as indicative of either microbial sensitivity or resistance with well characterized antibiotics. This is because the size of inhibition zone depends on both the rate of diffusion of biologically active agent and the growth rate of the targeted organism [32]. Agar diffusion assays need to be avoided with Mycobacteria, since these organisms with high lipid content in their cell wall are usually more sensitive to compounds of less-polarity [218]. Therefore, the diffusion of such compounds will be very slow compared to polar compounds with the same molecular weight on the aqueous agar. This might consequently produce smaller inhibition zones. Furthermore, polar active compounds of low molecular weight could diffuse to equilibrium prior to appearance of colonies in slow-growing mycobacterial strain. And if, at the equilibrium, the concentration is below the MIC, the zone of inhibition will never appear [218].

3.2.2. Micro and Macro Agar Dilution. When screening extracts with known concentrations, fractions in an agar plate enable the MIC value to be determined and its activity to be quantified. Except in some fastidious species, many mycobacterial strains such as MTB tend to produce colonies effectively on Middlebrook 7H10 or 7H11 agar supplemented with Oleic acid, Albumin, Dextrose, and Catalase (OADC). The sample to be tested is added to the semisolid media at final concentration of 1% v/v or subsequently either 100–200 µl medium to 96-well microplates, 1.5 ml to 24-well microplates, 4 ml to 6-well microplates, or 20 ml into usual Petri dishes of 150 mm diameter. Following the hardening of the agar, the inoculum can then be dropped on the surface of the agar using a micro pipette. Some of the volumes of inoculum recommended are as follows: 1–5 µl for 96-well plates, 10 µl for 6- or 24-well plates, and 100 µl for normal Petri dishes. The plates are then incubated at 37°C overnight, after which they should then be inverted for the remaining period of incubation. The major shortcoming with such a bioassay is that it requires a minimum of 18 days to produce a visible colony of Mycobacteria [32, 218].

3.2.3. Microbroth Dilution. Evaluation of susceptibility (bioactivity) of natural products using microplates with 96 wells proffers an edge because it requires little sample, is cheap, and is high-throughput. The mycobacterial species are often cultured in Middlebrook 7H9 broth supplemented with glycerol (0.5%), casitone (0.1%), Tween-80 (0.05%), and ADC (10%). In many strains of Mycobacteria, the growth can be evaluated quantitatively by the broth medium turbidity. However, the proneness of clumps formation makes the assay very challenging [23]. Nevertheless, the utilization of indicator dye like Alamar blue renders this technique more sensitive and rapid. The results of this assay can be read visually, although the reduced form of the dye is quantifiable using calorimeter. This is done by measuring the absorbance at 570 nm and then subtracting absorbance at 600 nm. On the other hand, the second approach has been proven to be more sensitive. Microbroth dilution tests should also be carried out using either resazurin or tetrazolium dyes. Therefore, a high-throughput assay of anti-TB is possible through using a microplate, spectrophotometrically or fluorometrically. These are quantitative assays that could detect even partial inhibition, making it possible to determine the relative activity of fractions from crude extracts using different concentrations [32, 218].

has dramatically improved due to the vast advancements in chromatography. Consequently, this creates new paths for both yet to be investigated materials and previously studied genera. Hence, the new paths were given access to unanticipated chemical varieties and novel biological products [32]. To provide effective direction in discovery program of drug from natural resources, the development of novel phytochemical approaches becomes crucial in a bioassay-directed drug discovery. Another step is bioassay which should be selected wisely in relation to the crucial terminus, that is, the antibiotic screening on virulent mycobacterial strain in vivo. Interestingly, three effective antimycobacterial products have been sequestered from Dracaena angustifolia using this method [23, 32, 218].
4. Electron and Fluorescence Microscopy Studies

Electron and fluorescence microscopy have been used effectively to examine the morphological changes during the growth of microorganisms. In addition, they can also be employed in an attempt to locate the target of action of the test extract-treated mycobacterial samples [219]. The scanning electron microscope (SEM) provides a relatively easy technique of surface morphology study of microorganisms at high magnification with a resolution of around 15 to 20 nm under ideal conditions. One of the largely untapped potentials of this apparatus is the study of the morphological changes after bacterial exposure to antimicrobial agents [220].

The cell-wall-attacking characteristic of the test extracts is revealed in electron microscopy studies. Because the main part of the cell wall of *Mycobacteria* is comprised of lipids, it is assumed that the extracts must possess some effect on them. The target suspected is obviously mycolic acid (predominant lipid). It has been shown that a loss of acid fastness occurs when the cells of *Mycobacteria* are grown in the presence of antibiotics. The staining characteristics of this bacterial cell can be mainly attributed to the mycolic acids presence. Thus, when investigating the staining properties of cultures treated with extract, the culture is grown as for SEM studies. The auramine rhodamine dye is then used to stain the cells and visualized using a fluorescence microscope [219].

5. Genomics Studies and Proteomics Analysis

The systematic study of the whole set of cellular genetic material is called genomics. This will proffer enormous potential in both drug target and antigen discovery. Furthermore, it enhances novel antibacterial agents and vaccine development through DNA sequencing, as well as bioinformatics analysis. In TB study, it was first practiced on MTB H37Rv strain. Its bioinformatic investigation showed the attribution of accurate functions (~40% of the 4,000 genes). Once the functional information is available, it usually enables researchers to pinpoint a possible drug target on the basis of their proposed biological role or their resemblance to known bacterial drug targets [221]. In antibiotic drug discovery, expression of genome-based profiling may represent a useful tool for three applications: (i) target identification, (ii) antibiotics mechanism-of-action (MOA) studies, and (iii) new types of cell assays development for the purpose of drug screening [222].

Although many productive outcomes can be revealed in genomic studies, it is only the proteomic analysis that can obtain the exact cellular information [223]. The term proteomics denotes the proteins expressed by a genome. It addresses the protein, which is the final genomic product. The advantage of proteomics is in the overcoming of a major shortcoming of DNA chip technology. It has been proven to be vital in the novel antimycobacterial drug development [224]. With the aid of a technique called two-dimensional gel electrophoresis coupled with mass spectrometry (2DE-MS), about 263 proteins were identified in *M. bovis* BCG and MTB strains [225]. For protein patterns analysis, it is still the analytical technique available with the best resolution and has appeared as robust and efficient for rapid protein identification. It is assisted by the database of total genome sequence [226].

6. Southeast Asian Medicinal Plants with Anti-TB Activity

Despite the huge medicinal plant research efforts from Southeast Asian region, literature search showed that very little research work has been carried out on anti-TB plants and published by researchers from the region. Considering the abundant biodiversity and traditional ethnomedicinal knowledge in Southeast Asia, there is vast potential to institute a dedicated anti-TB screening programme. This review paper describes the Southeast Asian medicinal plants from a wide array of families that have been evaluated for anti-TB activity in the region so far.

They have been computed in a table form describing the plant species, families, part of plants and solvents used, in vitro activity, and ethnopharmacological uses (see Table 1). Interestingly, these plants species were found mentioned in various traditional medicines. Out of the 132 plants species (from 45 different families and 107 genera) discussed in this review, 114 species (87%) had reported role in the treatment of TB or TB-like symptoms in ethnomedicine (Table 1). More specifically, 24 species (18.2%) were reported for TB, 14 species (10.6%) for leprosy, and 76 species (57.6%) for TB-related diseases such as asthma, bronchitis, coughing, whooping cough, pulmonary infectious, fever, and chest diseases in ethnomedicine. It was found that crude extracts from 32 species representing 24.2% of all (132 species) plants demonstrated significant anti-TB activity in *in vitro* assay (MIC values ranging from 10 to 100 μg/ml). These plant species are *Aegle marmelos* (L.) Correa, *Alpinia galanga* (L.) Sw., *Alpinia purpurata* K. Schum., *Alpinia zerumbet* (Pers.) B. L. Burtt & R. M. Sm., *Amona reticulata* L., *Artocarpus rigidus* Blume, *Boesenbergia pandurata* (Roxb.) Schltr., *Clausena excavata* Burm. f., *Clausena harmandiana* (Pierre) Guillaumin, *Croton kongensis* Gagnep., *Eclipta prostrata* (L.) L., *Eriosema chinense* Vogel, *Feroniell lucida* Swingle, *Glycosmis pentaphylla* (Retz.) DC., *Gynura divaricata* (L.) DC., *Haplophyra adenophyllum* (Wall. ex G. Don) Dop, *Heliotropium indicum* Linn., *Marsypetum modestum* (Pierre) B. Xue, *Micromelum minutum* Wight & Arn., *Morinda citrifolia* Linn, *Orthosiphon stamineus* Benth., *Piper betle* L., *Piper chaba* Hunter, *Piper nigrum* L., *Piper sarmentosum* Roxb., *Rollinia mucosa* (Jacq.) Baill., *Solamum spireale* Roxb., *Tinospora crispa* (L.) Hook. F. & Thomson, *Uvaria microcarpa* Champ. ex Benth., *Uvaria rufa* Blume, *Vitex trifolia* L., and *Zingiber officinale* Roscoe.

Some bioactive compounds that were isolated from the reviewed medicinal plants exhibited good anti-TB activity (MIC values ranged between <1 and 50 μg/ml). Active compound, *Abruquinone B*, from *Abrus precatorius* L. exhibited MIC of 12.5 μg/ml. From *Aglais erythrosperma* Pannell, ethyl eichlerianoate, eichlerialactone, and agalialactone (all showing MIC of 25 μg/ml) and cabraleadiol, cabraleahydroxylactone, cabralea lactone, and flavagline (all
| Scientific name          | Family           | Local name     | Part used: extract/active compound                                                                 | Activity                                                                                                                                                                                                 | Traditional uses (references)                                                                 |
|-------------------------|------------------|----------------|--------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|
| *Abrus precatorius* L.  | Leguminosae      | Akar saga      | Not stated, Aerial part: dichloromethane/Abruquinone B (1) was isolated from the extract          | The extract exhibited at 500 µg/ml concentration of 90.0% and inhibition against both H37Rv and MDR strain in LRP assay [38]. Compound 1 obtained showed anti-TB activity against H37Ra strain with MIC of 12.5 µg/ml [39]. | Bronchitis, cough, TB [18].                                                                                                                   |
| *Abutilon indicum* (L.) Sweet | Malvaceae        | Giling-gilingan | Leaves: dichloromethane and methanol/β-aminin 3-palmitate (1), squaken (2), β-sitosterol (3), and stigmasterol (4) were isolated from the extract | All the isolated compounds (1, 2 and a 1:1 mixture of 3 and 4) showed inhibition at MIC of >128 µg/ml [40].                                                                                              | Cough and leprosy [40].                                                                                                                          |
| *Acanthus ebracteatus* Vahl. | Acanthaceae      | Nguag-plaamoa  | Leaves, stem: chloroform methanol water                                                              | All the chloroform, methanol, water extract of leaves and stem showed activity against H37Ra strain in MABA at MIC of 1000 µg/ml [41].                                                                     | Asthma, cough [42, 43].                                                                                                                          |
| *Aegle marmelos* (L.) Correa | Rutaceae         | Mak toun       | 90% ethanol, Fruits and flowers: 90% ethanol                                                         | The extract was active against H37Rv at MIC 54.88 µg/ml [44]. The activity against H37Rv strain in MABA was observed at the MIC of 47.8 to >100 µg/ml from 90% ethanolic extract [47]. | Cough, respiratory infection, intermittent fever [44–46].                                                                                       |
| *Ageratum conyzoides* L. | Asteraceae       | Babadaton      | Whole plant: 80% methanol                                                                           | Methanolic extract of whole plant exhibited inhibition against H37Rv at the MIC 1600 µg/ml in TEMA [48].                                                                                                     | Asthma, pneumonia, fever [49, 50].                                                               |
| Scientific name                  | Family         | Local name | Part used: extract/active compound                                                                 | Activity                                                                                                           | Traditional uses                      |
|---------------------------------|----------------|------------|---------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|----------------------------------------|
| Aglaia erythrosperma Pannell     | Meliaceae      |            | Fruits and leaves: 95%/cabraleadiol (1), cabraleahydroxylactone (2), ethyl eichlerianoate (3), eichlerialactone (4), aglinin A (5), cabralealactone (6), aglaialactone (7), flavagline (8) were isolated from the extract | Compounds 3, 4, 7 showed anti-TB activity against H37Ra strain with the MIC of 25 µg/ml which is better than compounds 1, 2, 6, 8 with the MIC value of 50 µg/ml, while compound 5 showed weaker activity (MIC, >200 µg/ml) [51]. | Nil.                                   |
| Allium odorum L.                 | Liliaceae      | Kucai      | Leaves: 80% methanol                                                                               | The extract was active against H37Rv strain at MIC 160 µg/ml [48].                                              | Asthma, cough [52].                    |
| Aloe vera L.                     | Aloaceae       | Lidah buaya| Leaves: 80% methanol                                                                               | The extract showed activity against H37Rv strain at the MIC of 1600 µg/ml [48].                                  | Asthma, bronchitis [53].               |
| Alpinia galanga (L.) Sw.         | Zingiberaceae  | Khaa, Lengkuas, | Rhizome: chloroform methanol water Compound 1’acetoxychavicol acetate (1) was isolated from chloroform extract of rhizome Leaves: 80% methanol | The crude chloroform, methanol, water extract of the rhizomes exhibited activity against H37Ra strain at MIC of 0.12, 1000, and 1000 µg/ml, respectively. The MIC value for the isolated compound (1) was 0.024 µg/ml [41]. The extract showed inhibition against H37Rv strain at the MIC 1600 µg/ml [48]. | TB, bronchitis, pain in chest, whooping cough, asthma, sore throat [54–57]. |
| Alpinia purpurata K. Schum.      | Zingiberaceae  | Luyang pula| Leave: methanol/compounds β-sitosteryl-β-D-glucoside (1), β-sitosteryl-3-O-6’-palmityl-β-D-glucoside (2), kumatakenin (3) were isolated from the extract | At 100 µg/ml, the methanolic extract of leaves showed 90% inhibition against H37Rv. All isolated compounds 1, 2, 3 showed MIC > 128 µg/ml [58]. | Cough [59].                            |
| Alpinia zerumbet (Pers.) B. L. Burtt & R. M. Sm. | Zingiberaceae  |            | Rhizomes: methanol                                                                                | At 100 µg/ml, the methanolic extract of rhizomes showed 80% inhibition against H37Rv [58].                          | Common cold [59].                      |
### Table 1: Continued.

| Scientific name                | Family       | Local name | Part used: extract/active compound                                                                 | Activity                                                                 | Traditional uses (references) |
|-------------------------------|--------------|------------|---------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|--------------------------------|
| *Alstonia scholaris* (L.) R. Brown | Apocynaceae  | Dita       | Leaves: methanol/19,20E-vallesamine (1), a mixture of angustilobine B N₄-oxide (2), N₄-methyl angustilobine B (3), 20S-tubotaiwine (4), 6,7-seco-angustilobine B (5), (+)-manilamine (6) were obtained from the extract | Only 4 exhibited activity at MIC of 100 μg/ml, against, while all other compounds like 1, 2, 3, 5, 6 showed activity with >128 μg/ml [60]. | Fever [60].                  |
| *Amaranthus tricolor* L.       | Amaranthaceae| Bayam      | Whole plant: 80% methanol                                                                         | Methanolic extract of whole plant exhibited inhibition against H37Rᵥ strain at the MIC 1600 μg/ml in TEMA [48]. | Cough [61].                  |
| *Andrographis paniculata* Nees | Acanthaceae  | Hempedu Bumi | Herbs: aqueous                                                                                     | At 5 mg/ml the extract exhibited 100.0% inhibition against H37Rᵥ and 93.7% against MDR strain [62]. | Leprosy, sore throat [63].   |
| *Angiopteris evecta* (J. R. Forst.) Hoffm. | Marattiaceae | Paku gajah | Leaves: 80% methanol                                                                               | The extract exhibited activity against H37Rᵥ strain at the MIC of 400 μg/ml [48]. | Cough, fever [64].           |
| *Anisochilus harmandii* Doan ex Suddee & A. J. Paton | Lamiaceae    | Chroomuay  | Aerial part: hexane and EtOAc/pimaric acid (1), 9α,13α-epidioxyabiet-8(14)-en-18-oic acid (2), 15-hydroxydehydroabietic acid (3) were isolated from the extract | 1, 2, 3 all showed anti-TB activity at MIC, 50 μg/ml [65]. | Nil.                         |
| *Amona muricata* L.            | Annonaceae   | Sirsak     | Leaves: aqueous                                                                                   | The extract at concentration of 5 mg/ml showed 82.1% inhibition against H37Rᵥ and 50.0% against MDR strain [62]. | Asthma, cough [66, 67].      |
| Scientific name       | Family  | Local name     | Part used: extract/active compound | Activity                                                                 | Traditional uses (references) |
|-----------------------|---------|----------------|-----------------------------------|---------------------------------------------------------------------------|-------------------------------|
| Annona reticulata L.  | Annonaceae | Kantaloht (peurak) | 90% ethanol                       | The crude extract exhibited activity at the MIC of 49.37 μg/ml against H37Rv [44]. | Cough, high fever [44, 68].  |
| Anomianthus dulcis (Dunal) J. Sinclair | Annonaceae | Num Wua | Stem bark: 80% ethanol, dichloromethane and water/(2S)-5-hydroxy-6,7-dimethoxyflavonone (1), 9-methoxylirodenine (4), Liriodenine (5) were isolated from the extract Compounds (5), (1), (4) demonstrated anti-TB activity against H37Ra using MABA with the MIC values of 100, 200, 200 μg/ml, respectively [69]. | Fever [69]. |
| Artocarpus lakoocha Roxb. | Moraceae | Ma-Haad | Roots: dichloromethane/Lakoochins A (1) and B (2) were isolated from the extract Compound 1 and 2 showed anti-TB activity against H37Ra strain with the MICs of 12.5 and 50 μg/ml, respectively [70]. | Sore throat [71]. |
| Artocarpus rigidus subsp. Rigidus | Moraceae | Tampang | Root bark: flavonoid 7-demethylartonol E (1), chromosome artorigidusin (2), xanthone artonol B (3), flavonoid artonin F (4), flavonoid cycloartobiloxanthone (5), xanthone artoindonesian in C (6), all isolated from n-hexane, chloroform, methanol extracts All the isolated compounds showed activity again H37Ra in MABA with compound 4 being the most active compound (MIC 6.25 μg/ml). This was followed by compounds 2 and 6 (MIC 12.5 μg/ml) and compounds 5, 1,3 with the MIC of 25, 50, 100 μg/ml, respectively [72]. | Asthma, cough [73]. |
| Averrhoa bilimbi L. | Oxalidaceae | Belimbing masam | Fruits, leaves: 80% methanol | The methanol extracts of both fruit and leaves exhibited inhibition against H37Rv at the MIC 1600 μg/ml in TEMA [48]. | Whooping cough and fever [74]. |
| Scientific name       | Family         | Local name     | Part used: extract/active compound | Activity                                                                                         | Traditional uses       |
|-----------------------|----------------|----------------|-------------------------------------|---------------------------------------------------------------------------------------------------|------------------------|
| *Barleria lupulina*   | Acanthaceae    | Sa-let-pangpon | Leaves: chloroform methanol water  | Chloroform, methanol, water extract of leaves all exhibited activity against H37Ra strain at the MIC of 1000 μg/ml. Chloroform extract of stem exhibited inhibition at MIC of 500 μg/ml against H37Ra strain while methanol and water extract showed activities at 1000 μg/ml [41]. | Cough, fever [75, 76]. |
| *Blumea balsamifera*  | Asteraceae     | Sembung utan   | Not stated                          | At 500 μg/ml, the extract exhibited 96.0% and 82.0% inhibition against H37Rv and MDR, respectively, in LRP assay [38]. | Cough [77].            |
| *Boesenbergia pandurata* (Roxb.) | Zingiberaceae | Krachai        | Rhizome: chloroform methanol water | Both methanol and water extracts of rhizome exhibited inhibitory activity in MABA against H37Ra strain at the MIC of 62.5 μg/ml, while chloroform extract showed activity at 1000 μg/ml MIC [41]. | Cough [78].            |
| *Camchaya calcarea*   | Asteraceae     |                | Whole plant: dichloromethane/goyazensolides (1), lychnophorolides A (2), centrtherin or lychnophorolides B (3), isogoyazensolides (4), isocentrtherin (5), 5-epi-isogoyazensolides (7), 5-epi-isocentrtherin (8), 1(10),E₄Z,II(13)-germacratriene-12,6-olide-15-oic acid (9), caffeic acid methyl ester (10) were isolated from the extract | Compound 4 was the most active against H37Ra strain with MIC value of 1.5 μg/ml, followed by compounds 1, 2, 5, 7, 8 with the same MIC value of 3.1 μg/ml. Compounds 3, 9, 10 showed less activities with the MIC values of 6.2, 50, and 25 μg/ml, respectively [79]. | Nil.                   |
| *Capsicum annum*      | Solanaceae     | Cili           | Fruit: 80% methanol                 | The extract showed activity against H37Rv strain at the MIC of 1600 μg/ml [48].                    | Cough, anorexia, asthma, sore throat [80]. |
Table 1: Continued.

| Scientific name                  | Family                  | Local name     | Part used: extract/active compound                                                                 | Activity                                                                 | Traditional uses (references) |
|----------------------------------|-------------------------|----------------|-------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|-----------------------------|
| *Casearia grewiifolia* Vent.     | Flacourtiaceae          | Kruaipa        | Stem bark: hexane and dichloromethane/bioactive compounds, Caseargrewiin A (1), Caseargrewiin B (2), Caseargrewiin C (3), Caseargrewiin D (4), rel-(2S,5R,6R,8S,9S,10R,18S,19R)-18,19-diacetoxy-18,19-epoxy-6-methoxy-2-(2-methylbutanoyloxy)cleroda-3,13(16),14-triene (5) and rel-(2S,5R,6R,8S,9S,10R,18S,19R)-18,19-diacetoxy-18,19-epoxy-6-hydroxy-2-(2-methylbutanoyloxy)cleroda-3,13(16),14-triene (6) were isolated from the extract | 1, 2, 4, 5, 6 all exhibited good anti-TB activity against H37Ra strain with MICs of 12.5 μg/ml while 3 showed moderate activity with MIC of 25 μg/ml [81]. | Fever [81].                  |
| *Catharanthus roseus* (L.) G. Don | Apocynaceae             | Kemunting cina | Leaves: 80% methanol                                                                             | The extract was active against H37Rv at MIC 1600 μg/ml [48].             | Asthma, TB [82].            |
| *Ceiba pentandra* (L.) Gaertn.   | Bombacaceae             | Kabu           | Fruit: 80% methanol                                                                              | The extract exhibited anti-TB activity against H37Rv strain at the MIC of 1600 μg/ml [48]. | Bronchitis, fever [83].     |
| *Centella asiatica* (L.) Urb.    | Apiaceae                | Pegaga         | Whole plant: 80% methanol                                                                         | The extract showed activity against H37Rv strain at the MIC of 1600 μg/ml [48]. 78.5 and 50.0% inhibition were observed at 5 mg/ml concentration against H37Rv and MDR, respectively [62]. | TB, leprosy, asthma [84].   |
| *Chioscheton penduliflorus* Planch. ex Hiern | Meliaceae               |                | Wood and leaves: 95% methanol/cabralediol (1), allo-aromadendrane-10β, 14-diol (2), allo-aromadendrane-10α, 14-diol (3) eichlerialactone (4), cabralealactone (5), cabralealactone (6), allo-aromadendrane-10β,13,14-triol (7) were isolated from the extract | Compound 4 showed good anti-TB activity against H37Ra with the MIC value of 25 μg/ml, better than 1, 2, 5, 6, 7 with the MICs of 50 μg/ml, while compound 3 showed weaker activity (MIC, 100 μg/ml) [85]. | Nil.                        |
| *Chromolaena odorata* (L.) R. M. King & H. Rob. | Asteraceae              | Agonoi         | Flowers: isosaikuranetin (1), 4'-hydroxy-5,6,7-trimethoxyflavanone (2), acacetin (3), luteolin (4), all isolated from chloroform extract | The compounds isolated exhibited activities against H37Ra at different MIC values (μg/ml) 174.8 (1), 606.0 (2), 704.2 (3), 699.3 (4) [86]. | Cough [87].                 |
| Scientific name | Family       | Local name         | Part used: extract/active compound | Activity                                                                                                                                                                                                 | Traditional uses (references) |
|-----------------|--------------|--------------------|-----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------|
| *Citrus aurantiifolia* (Christm.) Swingle | Rutaceae      | Limaun nipis       | Not stated                        | In LRP assay, extract at 500 μg/ml showed 98.0% inhibition against *H37Rv* strain and 36.0% against MDR strain [38].                                                                                       | Sore throats, bronchitis, asthma [88, 89]. |
| *Citrus microcarpa* Bunge              | Rutaceae      | Limai kasturi      | Leaves: 80% methanol              | The extract exhibited anti-TB activity against *H37Rv* strain at the MIC of 1600 μg/ml in TEMA [48].                                                                                                          | Cough [90].                  |
| *Clausena excavate* Burm. f.           | Rutaceae      | Sun Soak           | Dentin (1), nordentatin (2), clausenidin (3), O-methylated clausenidin (4), 3-formylcarbazole (5), mukonal (6), 3-methoxycarbonylcarbazole (7), 2-hydroxy-formyl-7-methoxycarbazole (8), clauszoline (9); compounds 1, 2, 6, 7, 8, 9 where isolated from the chloroform extract of rhizomes; compound 3 was isolated from crude hexane extract of rhizome. Methylation of compound 3 gave rise to compound 4; compound 10 was isolated from crude chloroform extract of the root. | Compounds 1, 4, 7, isolated, were more active against *H37Ra* with MIC of 50 μg/ml; this is followed by 2, 5, 8, 9 with MIC of 100 μg/ml, while compounds 3 and 6 are with MIC of 200 μg/ml [91]. | TB [92].                     |
| *Clausena guillauminii* Tanaka          | Rutaceae      |                   | Roots: acetone/fluroclausine A (1) and heptazoline (2) were obtained from the extract                                                                                                                     | Using the green fluorescent protein microplate assay (GFPMA), both 1 and 2 exhibited anti-TB activity against *H37Ra* strain with the same IC₅₀ value of 25 μg/ml [93]. | Cough [94].                  |
| *Clausena harmandiana* (Pierre) Guillaumin | Rutaceae      | Song Fa            | Fruits and flowers: 90% ethanol   | MICs of 83.1 to >100 μg/ml were observed when 90% ethanolic extract of fruits and flowers was tested against *H37Rv* in MABA [47].                                                                             | Cough [94].                  |
| Scientific name                      | Family         | Local name        | Part used: extract/active compound | Activity                                                                 | Traditional uses (references) |
|--------------------------------------|----------------|-------------------|-----------------------------------|--------------------------------------------------------------------------|-------------------------------|
| Clerodendrum indicum (L.) Kuntze     | Verbenaceae    | Bunga pagoda      | Flowers: 80% methanol             | The extract exhibited anti-TB activity against H37Rv strain at the MIC of | Cough, asthma [95].           |
|                                      |                |                   |                                   | 1600 μg/ml [48].                                                         |                               |
| Clitoria ternatea L.                 | Leguminosae    | Bunga kelentik    | Whole plant: 80% methanol         | At MIC = 1600 μg/ml, the extract showed anti-TB activity against H37Rv  | Asthma, leprosy, TB [96].     |
|                                      |                |                   |                                   | strain [48].                                                             |                               |
| Coccinia grandis (L.) Voigt          | Cucurbitaceae  | Phak tamlueng     | Leaves: chloroform methanol water  | In MABA, chloroform, methanol, water extract of leaves all exhibited     | Asthma, cough, bronchitis      |
|                                      |                |                   |                                   | activity against H37Ra strain at the MIC of 1000 μg/ml [41].             | [97, 98].                     |
| Coleus atropurpureus L. Benth        | Lamiaceae      | Piladang          | Compound 2, 5-dimethyl benzopelargonolactone was isolated from the      | The isolate was active against H37Rv strain at the MIC of 200 μg/ml     | Bronchitis, TB [99].          |
|                                      |                |                   | chloroform fraction of leaf      | [99].                                                                    |                               |
| Colocasia esculenta (L.) Schott      | Colocasiaceae  | Keladi cina       | Leaf: 80% methanol                | The methanol extract of leaves showed activity against H37Rv strain with | Asthma, coughing with sputum  |
|                                      |                |                   |                                   | the MIC value 1600 μg/ml [48].                                          | [100].                        |
| Combretum griffithii Van Heurck & Müll. Arg. | Combretaceae | Khamin khruea     | Stem: methanol/1-(2-hydroxy-4- methoxyphenyl)-3-(4-hydroxy-3- methoxyphenyl)propane (1) were isolated from the extract | I exhibited anti-TB activity against H37Ra strain with the MIC of 3.13 μg/ml [101]. | Coughing, leprosy [102]. |
|                                      |                |                   |                                   |                                                                           |                               |
| Cordia globifera W. W. Smith         | Boraginaceae   | Sak Hin           | Root: dichloromethane/Globiferin (I), cordiachrome B (2), cordiachrome C (3), cordiaquin C (4), alliodorin (5), elaeagin (6), cordiachromene (7) were isolated from the extract | Compounds 1, 2, 3 displayed good activity (MIC, 6.2, 12.5, 1.5 μg/ml resp.) using MABA against H37Ra, followed by 5, 6, 7 (MIC, 12.5 μg/ml) and then 4 with MIC of 25 μg/ml [103]. | Cough [104].                 |
|                                      |                |                   |                                   |                                                                           |                               |
| Costus speciosus (J. Koenig) Sm.     | Costaceae      | Setawar halia     | Stem and flowers: 80% methanol   | The methanol extract of Stem and flowers exhibited anti-TB activity      | Asthma, bronchitis [105].     |
|                                      |                |                   |                                   | against H37Rv strain with the MIC value 800 μg/ml [48].                 |                               |
| Scientific name          | Family         | Local name                        | Part used: extract/active compound                                                                 | Activity                                                                                       | Traditional uses (references)                                                                 |
|-------------------------|----------------|-----------------------------------|---------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|
| *Croton kongensis* Gagnep. | Euphorbiaceae | Plao Ngeon, Khô sâm bắc bô     | Leaves: crude dichloromethane extract.                                                            | Dichloromethane crude extract exhibited activity against H37Ra strain with the MIC value 12.5 μg/ml in MABA. The isolated compounds 2 and 3 showed better activity with the MIC value 6.25 μg/ml than compound 1 with 25.0 μg/ml MIC [106]. |
|                         |                |                                   | *ent*-8,9-seco-7α,11β-diacetoxykaur-8(14),16-dien-9,15-dione (1), *ent*-8,9-seco-8,14-epoxy-7α-hydroxy-11β-acetoxy-16-kauren-9,15-dione (2), *ent*-8,9-seco-7α-hydroxy-11β-acetoxykaur-8(14),16-dien-9,15-dione (3), all were isolated from dichloromethane extract of leaves       |
|                          |                |                                   | Whole plants, leaves: ethanol, ethyl acetate, methylene chloride, n-Hexane/ent-1β,7α,14β-triacetoxykaur-16-en-15-one (1), ent-7α,18-dihydroxykaur-16-en-15-one (2), ent-16(5)-18-acetoxy-7α-hydroxykaur-15-one (3), ent-18-acetoxy-7α-hydroxykaur-16-en-15-one (4), *ent*-1,14β,16β-triacetoxy-7α-hydroxykaur-16-en-15-one (5), *ent*-12β-acetoxy-7α,14β-dihydroxykaur-16-en-15-one (6), ent-7α,14β-dihydroxykaur-16-en-15-one (7) were all isolated from ethanol, ethyl acetate, methylene extract of whole plants and leaves |
| *Curcuma aeruginosa* Roxb. | Zingiberaceae | Waan mahaamek                    | Rhizomes: water/essential oil                                                                    | The activities against H37Ra strain were observed at the MIC of 25–50, >50, 6.25–12.5, 12.5–25 μg/ml from ethanol, ethyl acetate, methylene chloride, n-Hexane crude extracts of whole plants and leaf using microtiter resazurin assay. Isolated compound 1 exhibited the highest activity with MIC values of 0.78, 1.56, 3.12–12.5 μg/ml against H37Ra, H37Rv; other resistant strains of *M. tb* screened. Both compounds 2 and 3 exhibited MIC at 1.56 μg/ml. Compounds 4, 5, 6, 7 on the other hand showed MIC value 3.12–6.25 against H37Ra and H37Rv and other resistant strains of *M. tb* [108]. |
|                         |                |                                   | Using GFPMA, essential oil showed weaker anti-TB activity against H37Ra strain with 2500 μg/ml MIC value [109]. |
|                         |                |                                   |                                                                                                   | Leprosy, weight loss [107].                                                                 |

**Table 1**: Continued.
### Table 1: Continued.

| Scientific name                          | Family        | Local name   | Part used: extract/active compound                                                                 | Activity                                                                                                                                                                                                 | Traditional uses (references) |
|------------------------------------------|---------------|--------------|--------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|
| *Dalbergia parviflora* Roxb.             | Leguminosae   | Sak Kee      | Stem: hexane, ethyl acetate, methanol/Flavanone (1), dalparvone (2), dalparvinene (6) were isolated from the extract | Using GFPMA, compound 1 exhibited good anti-TB activity against H37Ra strain with the MIC of 12.5 μg/ml, while compounds 2 and 6 showed activity with the MICs of 50 μg/ml [110]. | Expectorant [110].            |
| *Dasymaschalon dasymaschalum* (Blume) I. M. Turner | Annonaceae    | Buu ngong    | Leaves: ethyl acetate/3β-hydroxy-21-O-acetyl-24-methylene cycloartenone (1) was obtained from the extract | Compound 1 displayed activity against H37Ra strain with the MIC value of 50 μg/ml [111]. Nil.                                                                                                           | Nil.                          |
| *Dendrolobium lanceolatum* (Dunn) Schindl. | Leguminosae   | Kraduk-Khat  | Root: hexane and dichloromethane extract/3-methoxy-(3"5",4"5"-dihydro-3",4"-dihydroxy-2"2"-dimethylpyran-(7,8:5",6")-flavone (1), 2"-methoxy-4",5"-methylenedi oxyfu ran (7,8:4",5")-flavone (2), 8,4"-dimethoxy-7-O-γ γ-dimethylallylisoflavone (3), 3,4-methylenedioxy-7′-methoxy-7′oxo[2]benzopyran(4,3-b)benzopyran (4), desmethoxy kanugin (5), karanjin (6), lacheolatin B (7), pongachromene (8), 3,7-dimethoxyflavone (9), pachycarin D (10), maackiain (11), medicarpin (12) karanjachromene (13), pinnatin (14) isolated from this extract | Compound 1 exhibited highest activity against H37Ra strain with MIC of 6.3 μg/ml, followed by 2 (MIC, 12.5 μg/ml) and then 3 and 5 with MICs of 25 μg/ml [112]. | Nil.                          |
| *Derris indica* L.                       | Leguminosae   |              | Root and stem: dichloromethane extract/3-methoxy-(3"5",4"5"-dihydro-3",4"-dihydroxy-2"2"-dimethylpyran-(7,8:5",6")-flavone (1), 2"-methoxy-4",5"-methylenedioxyfu ran (7,8:4",5")-flavone (2), 8,4"-dimethoxy-7-O-γ γ-dimethylallylisoflavone (3), 3,4-methylenedioxy-7′-methoxy-7′oxo[2]benzopyran(4,3-b)benzopyran (4), desmethoxy kanugin (5), karanjin (6), lacheolatin B (7), pongachromene (8), 3,7-dimethoxyflavone (9), pachycarin D (10) showed stronger activity compared to 1, 5, 7, 9, 10 (25, 50, 50, 50 μg/ml resp.) that showed moderate activity with 3, 8, 10,12 (100, 100, 200, 100 μg/ml resp.) showing weaker activity against H37Ra strain using MABA [113]. | Bronchitis and whooping cough [23].                                                                                                           |
| Scientific name                  | Family      | Local name | Part used: extract/active compound | Activity                                                                 | Traditional uses (references) |
|---------------------------------|-------------|------------|-----------------------------------|--------------------------------------------------------------------------|-------------------------------|
| **Diospyros decandra** Lour.    | Ebenaceae   | Chan       | Betulinic acid (1) and 2-oxo-\(\beta\)-dihydroxy-24-nor-urs-12-en-28-oic acid (2) | 1 and 2 exhibited moderate to weak anti-TB activity against H37Ra strain with MIC of 25 and 200 µg/mL, respectively [114]. | Fever [114].                   |
| **Diospyros ehretioides** Wall. ex G. Don | Ebenaceae   | Nom ngua   | Fruits: dichloromethane/palmarumycins JC1 (1), palmarumycins JC2 (2), isodiospyrin (3), isodiospyrol A (4) | Compound 2 exhibited good (MIC = 6.25 µg/mL) anti-TB activity against H37Ra, followed by compound 4 (MIC = 50 µg/mL). Compounds 1 and 3 showed weak activity (MICs ≥ 200 µg/mL) [115]. | Nil.                          |
| **Diospyros glandulosa** Lace    | Ebenaceae   | Klua ruesi | Diospyrin, isolated from dichloromethane extract of wood | Diospyrin isolated showed activity against H37Ra in MABA with the MIC of 6.25 µg/mL [116]. | Nil.                          |
| **Diospyros rhodocalyx** Kurz    | Ebenaceae   | Tako Na    | Betulinaldehyde, obtained from dichloromethane extract of wood | Betulinaldehyde exhibited inhibitory activity in microbroth dilution assay against H37Ra with the MIC of 25 µg/mL [116]. | Nil.                          |
| **Eclipta prostrata** (L.) L.    | Asteraceae  | Kra-meng   | Whole plant: chloroform methanol water | Water, chloroform, methanol extracts of whole plant exhibited inhibition in MABA against H37Ra strain at the MICs of 62.5, 125, 1000 µg/mL respectively [41]. | Asthma and TB [117].          |
Table 1: Continued.

| Scientific name               | Family       | Local name | Part used: extract/active compound                                                                 | Activity                                                                                                                                                                                                 | Traditional uses (references) |
|-------------------------------|--------------|------------|--------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|
| *Eriosema chinense* Vogel     | Leguminosae  | Toon Khonklong | Roots: hexane, dichloromethane, methanol/Khonklonginol A (1), B (2), F (6), H (8), lupinifolinol (9), dehydro-lupinifolinol (10), flemichin D (11), eriosemaone A (12), lupinifolin (13) were obtained from the extract | Crude hexane extract showed anti-TB activity against H37Ra strain with the MIC value of 50 μg/ml using MABA. Compounds 10, 11, 12, 13 demonstrated good anti-TB activity against H37Ra strain with the same MIC value of 12.5 μg/ml. Compounds 1, 8, 9 exhibited moderate activity with the same MIC value of 25 μg/ml. Compounds 2 and 6 showed activity at MIC values of 50 and 100 μg/ml, respectively [118]. | Nil.                          |
| *Erythrina fusca* Lour.       | Fabaceae     | Thong long  | Stem bark: hexane and ethyl acetate/sandwicensin (1), erythrisenegalone (2), lonchocarpol A (3), lupinifolin (4) were isolated from the extract | Compounds 1, 2, 3, 4 demonstrated anti-TB activity against H37Ra with MICs of 100, 50, 50, 25 μg/ml, respectively [119].                                                                                   | Antibacterial [120].          |
| *Erythrina subumbrans* Merr.  | Leguminosae  |            | Bark: n-hexane, dichloromethane and methanol/1-methoxyerthyrobysin II (1) was isolated from the extract Stem: n-hexane and dichloromethane/erycristagallin A (1), erycristagallin (2), 5-hydroxysophoranone (3), erysubin F (4) were isolated from the extract | Compound 1 showed activity against H37Ra strain with 50 μg/ml MIC value [121]. All compounds 1, 2, 3, 4 exhibited anti-TB activity against H37Ra with the MICs of 12.5 μg/ml [122]. | Cough [122].                  |
| *Etlingera elatior* (Jack) R. M. Sm. | Zingiberaceae | Bunga kantan | Rhizomes: methanol/Stigmasterol (1) and β-sitosterol (2) were isolated from the extract | At 100 μg/ml, the methanolic extract of rhizomes showed 86% inhibition against H37Rv. The isolated compounds 1 and 2 exhibited MIC > 128 μg/ml [58].                                                          | Nil.                          |
| Scientific name | Family | Local name | Part used: extract/active compound | Activity | Traditional uses (references) |
|-----------------|--------|------------|-----------------------------------|----------|-----------------------------|
| *Etlingera pavieana* (Pierre ex Gagnep.) R. M. Sm. | Zingiberaceae | | Rhizomes: dichloromethane/(E)-((E)-3-(4-methoxyphenyl)allyl)3-(4-hydroxyphenyl)acrylate (I) was isolated from the crude extract | Compound I demonstrated anti-TB activity with the MIC value of 50.00 µg/ml [123]. | Fever and cough [123]. |
| *Fernandoa adenophylla* (Wall. Ex G. Don) Steenis | (Bignoniaceae) | Khae Pa | Fruits and flowers: 90% ethanol | In microbroth dilution assay, the extract exhibited inhibition at MIC of 79.7 to >100 µg/ml [47]. | Skin diseases [124]. |
| *Feronia lucida* Swingle | Rutaceae | Sung (mak)/kohk sung | 90% ethanol | The extract showed inhibition against H37Rv at MIC value 91.54 µg/ml in MABA [44]. In MABA, 90% ethanolic extract of fruits and flowers exhibited activity against H37Rv strain with MIC ranging from 90.4 to >100 µg/ml [44]. | Cough, TB [44, 125]. |
| *Ficus carica* L. | Moraceae | Ara | Leaves: 80% methanol | There was anti-TB activity against H37Rv strain at 1600 µg/ml [48]. | Asthma, cough [126]. |
| *Flemingia strobilifera* (L.) W. T. Aiton | Fabaceae | Serengan | Leaves: 80% methanol | At MIC = 1600 µg/ml, the extract showed anti-TB activity against H37Rv strain [48]. | TB [127]. |
| *Friesodielsia discolor* (Craib) D. Das | Annonaceae | | Leave: dichloromethane and ethyl acetate/3'-formyl-2',4',6'-methoxychalcone (I) was isolated from the extract | Compound I exhibited anti-TB activity against H37Ra strain with 6.25 µg/ml MIC value [128]. | Nil. |
| *Garcinia mangostana* L. | Clusiaceae | Mangkhud | Fruits: α-mangostin (1), β-mangostin (2), γ-mangostin (3), gacrinone D (4), mangostenol (5), garcinone B (6), mangostatin (7), mangostanol (8), mangostenone A (9), tovophyllin B (10), demethylobalabaxanthone (11), trapezifolixanthone (12), mangostinone (13) all isolated from chloroform, methanol extract | Compounds isolated showed activities against H37Ra in microbroth dilution at different MIC values (µg/ml) 6.25 (1), 6.25 (2), 25 (3), 25 (4), 100 (5), 6.25 (6), 25 (7), 200 (8), 25 (9), 25 (10), 12.5 (11), 12.5 (12), 200 (13) [129]. | Fever [130]. |
| Scientific name                        | Family      | Local name       | Part used: extract/active compound                                                                 | Activity                                                                                                                                                                                                 | Traditional uses (references) |
|----------------------------------------|-------------|------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|
| Glycosmis pentaphylla (Retz.) DC.      | Rutaceae    | Xom Xeuan        | Fruits and flowers: 90% ethanol                                                                                                                       | The 90% ethanol extracts of fruits and flowers exhibited activities against H37Rv strain with the MIC of 93.5 to >100 μg/ml in MABA [47].                                                                 | Cough [31].                   |
| Goniothalamus gitingensis Elmer       | Annonaceae  |                  | Leaves/Liriodenine (1) was isolated from the extract                                                                                                     | 1 showed anti-TB with the MIC of 16 μg/ml [132].                                                                                                                                                      | Nil.                          |
| Goniothalamus laoticus (Finet & Gagnep.) Bàn | Annonaceae  | Khao-Lam-dong    | Flowers: goniotriol (1), (+)-alholactone (2), howitinA (3) and an aporphine alkaloid; (-)-nordicentrine (4), all isolated from n-hexane, ethyl acetate, methanol extracts | In microbroth dilution, the isolated compound 4 showed the best activity against H37Ra with MIC of 12.5 μg/ml, followed by compounds 2 and 3 both with the MIC of 6.25 μg/ml, and then compound 1 with 100 μg/ml [133]. | Cold [134].                   |
| Gynura divaricata (L.) DC.             | Asteraceae  |                  | Leaves: hexane, dichloromethane, methanol/essential oil                                                                                                  | The essential oil showed inhibitory effect against H37Ra strain with the MIC value of 50 μg/ml [135].                                                                                            | Bronchitis and pulmonary TB [135]. |
| Gynura pseudochina (L.) D.C. var. hispida Thv. | Asteraceae  | Waan Mahaakaan   | Whole plant: chloroform methanol water                                                                                                                  | At the MIC of 200 μg/ml, chloroform extract of whole plant exhibited activity against H37Ra strain while both methanol and water extracts exhibited activity at 1000 μg/ml MIC, respectively [41]. | Asthma, fever, AIDS [136, 137]. |
| Haplophragma adenophyllum (Wall. ex G. Don) Dop | Bignoniaceae | Kay pa           | 90% ethanol                                                                                                                                             | In MABA, the MIC of 83.25 μg/ml was observed against H37Rv [44].                                                                                                                                   | Cough [44].                   |
| Scientific name             | Family         | Local name     | Part used: extract/active compound                                      | Activity                                                                 | Traditional uses (references) |
|-----------------------------|----------------|----------------|------------------------------------------------------------------------|--------------------------------------------------------------------------|--------------------------------|
| *Hedychium ellipticum*      | Zingiberaceae  |                | Rhizomes: n-hexane and dichloromethane/Coronarin E (1) and 16-Hydroxyabda-8(17),11,13-trien-15,16-olide (7) were isolated from the extract | Compounds 1 and 7 exhibited good anti-TB activity against H37Ra strain using GFPMA with the MIC value of 12.5 and 6.25 μg/ml, respectively [138]. | Bronchitis [139]. |
| *Heliotropium indicum*      | Boraginaceae   | Yaa Nguang Chaang | Leaves: water                                                           | The crude extract showed activity against H37Ra strain using MABA with the MIC of 20.8 μg/ml [140]. | Asthma [140]. |
| *Hibiscus rosa-sinensis*    | Malvaceae      | Bunga raya      | Leaves: 80% methanol                                                   | The extract exhibited anti-TB activity against H37Rv strain at the MIC of 1600 μg/ml [48]. | Cough, leprosy, bronchial catarrh [141]. |
| *Hymenocardia wallichii*    | Euphorbiaceae  |                | Stem: dichloromethane, methanol, hexane/Squalene were isolated from the extract | Squalene displayed anti-TB activity against H37Ra strain with the MIC value of 300 μg/ml [142]. | Nil. |
| *Hyptis suaveolens*         | Lamiaceae      | Maeng luk kha   | Whole plant: hexane, chloroform and methanol/8α,9α-epoxysuaveolic acid (2), suaveolic acid (4), suaveolol (5) were isolated from the extract | Compounds 2, 4, 5 displayed weak anti-TB activities (MIC 100–200 μg/ml) against H37Ra strain using MABA [143]. | Fever and respiratory tract infections [143]. |
| *Jasminum sambac*           | Oleaceae       | Melor           | Leaves: 80% methanol                                                  | At MIC = 1600 μg/ml, the crude extract showed inhibition against H37Rv strain [48]. | Cough, Leprosy [144]. |
| Scientific name          | Family       | Local name | Part used: extract/active compound                                                                 | Activity                                                                 | Traditional uses (references) |
|--------------------------|--------------|------------|----------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|-------------------------------|
| *Jatropha curcas* L.     | Euphorbiaceae| Jarak      | Leaves: 80% methanol                                                                                           | The extract showed *in vitro* activity against H37Rv strain at the MIC of 1600 μg/ml [48]. | Leprosy [145].                |
| *Jatropha integerrima* Jacq. | Euphorbiaceae|            | Roots: dichloromethane and ethanol/caniojane were isolated from the extract | Caniojane exhibited anti-TB activity against H37Ra strain using MABA with 25 μg/ml MIC value [146]. | Styptic [147].                |
| *Justicia gendarussa* Burm. f. | Acanthaceae| Urat sugi   | Leaves: 80% methanol                                                                                           | The extract exhibited anti-TB activity against H37Rv strain at the MIC of 1600 μg/ml [48]. | Respiratory disorders [148].  |
| *Kaempferia galangal* L. | Zingiberaceae| Kencur      | Not stated                                                                                                       | In LRP assay, the extract at 500 μg/ml exhibited 69.0% inhibition against both H37Rv and MDR strain [38]. | Asthma, cough [149].          |
| *Kaempferia marginata* Carey | Zingiberaceae| Tup mup     | Whole plant: dichloromethane and ((1R,2S,5S,9S,10S,11R,13R)-1,2,11-trihydroxy-pimara-8(14),15-diene (2), (1S,5S,7R,9R,10S,11R,13R)-1,7,11-trihydroxy-pimara-8(14),15-diene (3), (1R,2S,5S,7S,9R,10S,13R)-1,2-dihydroxy-pimara-8(14),15-diene-7-one (6), sandaracopimaradien-1α-ol,2α-acetoxy-sandaracopimaradien-1α-ol, sandaracopimaradien-1α,2α-diol were isolated from the extract | Compounds sandaracopimaradien-1α-ol and 2α-acetoxy-sandaracopimaradien-1α-ol exhibited ant-TB activity against H37Ra strain with the MIC values of 25 and 50 μg/ml, respectively. Compounds 2, 3, 6, sandaracopimaradien-1α-ol,2α-acetoxy-sandaracopimaradien-1α-ol, sandaracopimaradien-1α,2α-diol were less active (MICS of > 100 μg/ml) [150]. | Fever [150].                  |
| *Lantana camara* L.     | Verbenaceae   | Kembang telek | Not stated                                                                                                       | At 500 μg/ml, the extract exhibited 94.0 and 79.0% inhibition against H37Rv and MDR, respectively, in LRP assay [38]. | TB, leprosy, asthma [151, 152]. |
| *Lepisanthes rubiginosa* (Roxb.) Leenh.  | Sapindaceae   | Mertajam    | Leaves: 80% methanol                                                                                           | In broth microdilution assay, the extract showed inhibition against H37Rv strain at 1600 μg/ml [48]. | TB [153].                    |
| Scientific name          | Family       | Local name | Part used: extract/active compound | Activity                                                                 | Traditional uses (references) |
|-------------------------|--------------|------------|-----------------------------------|--------------------------------------------------------------------------|-------------------------------|
| *Licuala spinosa* Thunb. | Arecaceae    | Palas tikus | Leaves: 80% methanol              | In TEMA, the extract showed inhibition against H37Rv strain at 600 µg/ml [48]. | TB [48].                     |
| *Limnophila geoffrayi* Bonati | Scrophulariaceae | Prod Ka yaeng | Flavones nevadensin (I) and isothymusin (2), all were isolated from chloroform extract of aerial part | Both compounds 1 and 2 showed activities against H37Ra in MABA at the MIC = 200 µg/ml [154]. | Expectorant [155]. |
| *Marsypopetalum modestum* (Pierre) B. Xue | Annonaceae | Tin Tang Tia | Fruits and flowers: 90% ethanol | The extract of fruits and flowers exhibited activities at MIC ranging between 0.05 and 11.9 µg/ml in MABA against H37Rv [47]. | Nil. |
| *Micromelum minutum* Wight & Arn. | Rutaceae | Sa Mat Khao | Fruits and flowers: 90% ethanol | The activity against H37Rv strain in MABA was observed at the MIC of 45.7 to >100 µg/ml from 90% ethanolic extract [47]. | Cough, fever [156]. |
| *Momordica charantia* L. | Cucurbitaceae | Ampalaya | Leaves: ethanol/2,4-bis(2-phenylpropan-2-yl)phenol (1) isolated from the extract | Compound 1 exhibited anti-TB activity against H37Rv strain MIC value of 14 µg/ml using MABA [157]. | Leprosy [158]. |
| *Morinda citrifolia* Linn. | Rubiaceae | Noni | Leaves: ethanol and hexane/(E)-phytol (1), cycloartenol (2), stigmasta-4-en-3-one (3), stigmasta-4-22-dien-3-one (4), β-sitosterol (5), stigmasterol (6), campesta-6,22-dien-5,8α-epidioxy-3β-ol (7) were isolated from the extract | At 100 µg/ml, the crude extract of ethanol and hexane fractions displayed 89 and 95% inhibition, respectively, against H37Rv strain. 2:1 mixture of compounds 3 and 4 exhibited good activity (MIC = 2 µg/ml) against H37Rv strain followed by 7 (MIC = 2.5 µg/ml) and then 1 and 6 (MICs = 32 µg/ml). Compound 2 and 5 were less active with MIC values of 64 and 128 µg/ml, respectively [159]. | Respiratory infection [159]. |
| Scientific name                           | Family        | Local name | Part used: extract/active compound                     | Activity                                                                 | Traditional uses (references) |
|------------------------------------------|---------------|------------|-------------------------------------------------------|--------------------------------------------------------------------------|--------------------------------|
| Morus alba L.                            | Moraceae      | Merbatu    | Leaves and fruit: 80% methanol                        | In broth microdilution assay, the extract showed inhibition against H37Rv strain at 1600 μg/ml [48]. | Cough [160].                      |
| Murraya paniculata (L.) Jack             | Rutaceae      | Kaeo       | Leaves: chloroform methanol water                     | Chloroform extract of leaves at the MIC of 250 μg/ml showed activity against H37Ra strain while both methanol and water extracts exhibited activity at 100 μg/ml MIC, respectively [41]. | Cough, asthma, expectorant [161–163]. |
| Orthosiphon staminaeus Benth.            | Lamiaceae     | Misai Kuching | Leaves: hexane, chloroform, ethyl acetate             | The hexane, chloroform, ethyl acetate extracts of leaves exhibited activity with the MICs of 25.00, 3.12, 6.25 μg/ml [164]. | Loss of weigh [165].                |
| Passiflora foetida L.                    | Passifloraceae | Letup-letup | Whole plant: 80% methanol                             | There was inhibition against H37Rv at MIC = 1600 μg/ml [48].              | Cough [166].                      |
| Pedilanthus tithymaloides (L.) Poit.     | Euphorbiaceae | Sa yack    | Leaves: methanol, water, hexane/α,β,γ,δ,ε-trihydroxy-3β,7β-dibenzoyloxy-9β,15β-diacetoxyjatropha-5,11E-diene (1), 1α,7β,13β,14α,15β-tetrahydryoxy-3β-benzoyloxy-9β,15β-diacetoxyjatropha-5,11E-diene (2), 1α,8β,9β,9α,15β-pentaacetoxy-3β-benzoyloxy-7-oxojatropha-5,12-diene (3), 7,8β,9β,14α,15β-pentaacetoxy-3β-benzoyloxy-1α,5β-dihydroxyjatropha-6(7),12-diene (4), 1α,7,8β,9β,14α,15β-hexaacetoxy-3β-benzoyloxy-5β-hydroxyjatropha-6(7),12-diene (5) were obtained from the extract | Compound 1 showed stronger (12.5 μg/ml) activity compared to 2, 3, 4, and 5 (100, 50, 100, and 50 μg/ml resp.) against H37Ra in MABA [167]. | Nil.                            |
| Scientific name   | Family             | Local name | Part used: extract/active compound | Activity                                                                                                                                  | Traditional uses (references) |
|-------------------|--------------------|------------|-----------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|------------------------------|
| *Petiveria alliacea* L. | Phytolaccaceae    | Singwalang | 96% ethanol: leaves                | The ethanolic extract of leaves exhibited activity against drug sensitive and resistant strains of H37Rv at the MIC of 1280 \( \mu \)g/ml [168]. At 500 \( \mu \)g/ml, the extract exhibited 98.0 and 76.0% inhibition against H37Rv and MDR, respectively, in LRP assay [38]. | Antibacterial [169].          |
| *Phyllanthus acidus* (L.) Skeels | Euphorbiaceae     | Cermai     | Leaves: 80% methanol               | The extract exhibited anti-TB activity against H37Rv strain at the MIC = 1600 \( \mu \)g/ml [48].                                                                 | Cough [170].                 |
| *Piper betle* L.    | Piperaceae         | Plu, Daun sirih | Leaves: chloroform methanol water   | Chloroform extract of leaves was more active against H37Ra strain with MIC value 62.5 \( \mu \)g/ml than the methanol and water extract both with activity at MIC of 1000 \( \mu \)g/ml [41]. | Asthma, leprosy cough, dyspnea, bronchitis [171–173]. |
### Table 1: Continued.

| Scientific name | Family | Local name | Part used: extract/active compound | Activity | Traditional uses (references) |
|-----------------|--------|------------|-----------------------------------|----------|-------------------------------|
| *Piper chaba* Hunter | Piperaceae | Dee plee | Fruit: chloroform, methanol, water; compound Piperine (1) was isolated from chloroform crude extract of fruit. Stem: n-hexane/chabamide (1) was isolated from the extract | Inhibition against H37Ra strain was observed at MIC (\(\mu g/ml\)) of 16, 25, 1000 with respect to the chloroform, methanol, water extract of fruit in MABA. Compound 1 isolated exhibited activity at MIC of 50 \(\mu g/ml\) [41]. Compound 1 exhibited anti-TB activity with the MIC value of 12.5 \(\mu g/ml\) against H37Ra strain [175]. | Asthma [174]. |
| *Piper nigrum* L. | Piperaceae | Lada hitam | Fruit: 80% methanol | The extract exhibited anti-TB activity against H37Rv strain at the MIC of 1600 \(\mu g/ml\) [48]. Ethyl acetate, n-hexane, water extract fraction of leaves exhibited inhibition against H37Rv strain using TEMA at the MIC values of 25, 50, 100 \(\mu g/ml\), respectively [176]. | Asthma, bronchitis, TB, sore throat [176, 177]. |
| *Piper sarmentosum* Roxb. | Piperaceae | Kadok, Cha-plu | Whole plant: 80% methanol | At the MIC = 800 \(\mu g/ml\), the extract showed inhibition against H37Rv strain [48]. The methanol extract of leaves showed more activity against MTB (MIC 12.5 \(\mu g/ml\)) in TEMA than both petroleum ether and Chloroform extracts (MIC 25 \(\mu g/ml\)). The ethyl acetate and chloroform fractions of methanol extract exhibited MICs at 3.12 \(\mu g/ml\) [179]. The aqueous and ethanol extracts of leaves exhibited anti-TB activity MIC/MBC 12.5 \(\mu g/ml\). Methanolic extract was fractionated with ethyl acetate; the fraction of ethyl acetate exhibited anti-TB activity with MIC/MBC 312 \(\mu g/ml\) [180]. | Cough [178]. |
| *Pistia stratiotes* L. | Araceae | Water lettuce | Whole plant: 80% methanol | The inhibition against H37Rv was observed at the MIC of 1600 \(\mu g/ml\) [48]. | Leprosy, TB [182]. |
| Scientific name                  | Family       | Local name | Part used: extract/active compound | Activity                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Traditional uses (references) |
|---------------------------------|--------------|------------|------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------|
| *Pluchea indica* (L.) Less.     | Asteraceae   | Beluntas   | Flower: 80% methanol Leaves: aqueous | In TEMA, the extracts of flowers and leaves showed inhibitory activities against H37Rv strain at the MIC of 800 μg/ml each [48]. The extract showed 100% inhibition against H37Rv and MDR at 5 mg/ml [62].                                                                                                                                                                                                                                                                                                                                 | TB [183].                    |
| *Polyalthia cerasoides* (Roxb.) | Annonaceae   | Sai den    | Root: hexane, EtOAc, MeOH/Bideline E (1), octadeca-9,11,13-triynoic acid (2), α-humulene (3) were isolated from the extract | Isolated compounds 1, 2, 3 showed anti-TB activity against H37Ra strain with MICs of 6.25 μg/ml [184].                                                                                                                                                                                                                                                                                                                                                                           | Fever [184].                 |
| *Polyalthia debilis* (Piere) Finet & ganep | Annonaceae | Kon Krok   | Root: methanol/Debilisone B (1), Debilisone C (2), Debilisone E (3) | Compounds 1, 2, 3 showed moderate anti-TB activity against H37Ra strain with MIC values of 25.0, 12.5, 25.0 μg/ml, respectively [185].                                                                                                                                                                                                                                                                                                                                                                                                           | TB [186].                     |
| *Premna odorata* Blanco         | Lamiaceae    | Alagaw     | Leaves: methanol and dichloromethane/1-heneicosyl formate (1) was isolated from the extract | Crude methanolic extract showed inhibition against H37Rv strain with >128 μg/ml MIC. Compound 1 showed good anti-TB activity (8 μg/ml) [187].                                                                                                                                                                                                                                                                                                                                                                                               | TB [187].                     |
| *Rhoeo spathacea* (Sw.) Stearn | Commelinaceae | Nil        | Leaves: 80% methanol | At 5 mg/ml, the extract exhibited 100% inhibition against H37Rv and MDR [62].                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | TB, asthma [188].           |
| *Rollinia mucosa* (Jacq.) Baill.| Annonaceae   | Khanthahtoht | Fruits and flowers: 90% ethanol | Fruits and flowers extract were active at MIC ranging between 43.9 and 75.2 μg/ml in MABA [47].                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Nil.                         |
Table 1: Continued.

| Scientific name               | Family           | Local name | Part used: extract/active compound                                                                 | Activity                                                                 | Traditional uses (references) |
|-------------------------------|------------------|------------|---------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|-----------------------------|
| *Rothmannia wittii* (Craib) Bremek. Rubiaceae | Muk Mo           | Bark and fruits: n-Hexane and ethyl acetate/A compound 6β-hydroxy-10-O-acetylgenipin (1) was isolated from the extract | Compound 1 displayed activity against H$_37$Ra using MABA with MIC value of 12.50 $\mu$g/ml [189]. | Fever [189]. |
| *Sapium indicum* L. Euphorbiaceae |                   | Fruit: hexane/compounds 12-(2-N-methylaminobenzoyl)-4β,5,20-trideoxyphorbol-13-acetate (1), 12-(2-N-methylaminobenzoyl)-4α,5,20-trideoxyphorbol-13-acetate (2), sapintoxin A (3), α-saponine (4), sapintoxin C (5), 12-(2'-N-methylaminobenzoyl)-4α,20-dideoxy-5-hydroxyphorbol-13-acetate (6) sapintoxin B (7), 12-(2'-N-methylaminobenzoyl)-4α-dideoxy-5,20-dihydroxyphorbol-13-acetate (8), 12-(2-methylaminobenzoyl)-4α-deoxyphorbalddehyde-13-acetate (9) were isolated from extract | Compound 3 (MIC, 3.12 $\mu$g/ml) was the most active compound against H$_37$Ra using MABA, followed by 7 (MIC, 12.5 $\mu$g/ml) and then followed by 5, 8, 9 (MIC, 25 $\mu$g/ml). Compound 1 showed moderate activity (MIC, 50 $\mu$g/ml) while 2, 4, 6 showed weak activity (200, >200, >200 MIC, $\mu$g/ml, respectively) [190]. | Fever [191]. |
| *Selaginella plana* (Desv. ex Poir.) Hieron. Selaginellaceae | Paka merak       | Whole plant: 80% methanol                                                                          | In *in vitro* assay, the extract showed activity against H$_37$Rv at 1600 $\mu$g/ml MIC [48]. | Coughing and asthma [48]. |
| *Sesbania grandiflora* (L.) Poir. Leguminosae | Geti             | Fruit: 80% methanol                                                                               | The extract exhibited inhibition against H$_37$Rv strain at the MIC of 1600 $\mu$g/ml [48]. The methanol crude extract exhibited anti-TB activity against H$_37$Rv with MIC value of 625 $\mu$g/ml. Isolated compounds 1-3 exhibited MIC of 50 $\mu$g/ml while compound 4 showed activity at MIC of 100 $\mu$g/ml [193]. | Sore throat [192]. |
| *Solanum spirale* Roxb. Solanaceae | Pak dit          | Fruit: water                                                                                      | Essential oil extracted showed anti-TB activity against H$_37$Ra strain with MIC value of 50 $\mu$g/ml [194]. | Fevers and colds [194]. |
| Scientific name | Family | Local name          | Part used: extract/active compound | Activity                                                                 | Traditional uses (references) |
|-----------------|--------|---------------------|------------------------------------|--------------------------------------------------------------------------|-------------------------------|
| **Solanum torvum** Sw. | Solanaceae | Terung pipit      | Fruit: 80% methanol               | There was inhibition at the MIC of 1600 μg/mL against H37Ra strain [48]. | Cough [95].                   |
| **Spilanthes acmella** (L.) Murray | Asteraceae | Raan               | Whole plant: chloroform methanol water | The chloroform, methanol, water extract of whole plant exhibited inhibition in MABA, against H37Ra strain at the MIC of 500, 1000, 1800 μg/ml, respectively [41]. | TB, cough, sore throats [196, 197]. |
| **Spondias pinnata** (L.f.) Kurz | Anacardiaceae | Lolohcemcem | Chloroform, 80% ethanol.           | The extracts were active against MDR strain of Lowenstein-Jensen medium with 100% inhibition at concentration of 100 mg/ml [198]. | Chronic cough [198].          |
| **Tabernaemontana coronaria** (L.) Willd. | Apocynaceae | Jasmine            | Leaves: 80% methanol              | At the MIC of 800 μg/ml, the extract showed inhibition against H37Rv strain [48]. | TB [48].                      |
| **Tiliacora triandra** (Colebr.) Diels | Menispermaceae | Ya-nang           | Roots: tiliacorine (1), 2’-nortiliacorine (2), tiliacorine (3), 13’-bromo-tiliacorine (4) were isolated from the extract | Compounds 1, 2, 3, 4 demonstrated anti-TB activity against MDR-MTB strains with the MIC values ranging from 0.7 to 6.2 μg/ml [199]. | Fever [200].                 |
| **Tinospora crispa** (L.) Hook. F. & Thomson | Menispermaceae | Kheuah Khao Ho    | Fruits and flowers: 90% ethanol    | In microbroth dilution assay, the extract exhibited inhibition at MIC of 2.43 to 96.2 μg/ml [47]. | Coughs, asthma leprosy [201, 202]. |
| **Trigonostemon reidioides** (Kurz) Craib | Euphorbiaceae | Lot Thanong       | Root: n-hexane, EtOAc, MeOH/Compounds trigonoreidon A (1), trigonoreidon B (2), trigonoreidon C (3), trigonostemon C (7), spruceanol (8), trigonostemone (9), rediocide A (10), rediocide B (11), rediocide C (12), rediocide F (13), rediocide G (14) were isolated from the extract | Among the tested compounds, 12 and 14 were the two most active compounds against H37Ra strain with the MICs of 3.84 μM, followed by 13, with the MIC of 3.91 μM. Compounds 11 and 10 were active and moderately active with the MICs of 7.86 and 15.72 μM, respectively. Compounds 1, 2, 3, 7, 8, 9 exhibited weak activity with MICs of 183.57, 168.71, 88.35, 83.79, 72.58, 38.30 μM, respectively [203]. | Asthma [203].                |
| Scientific name                  | Family       | Local name         | Part used: extract/active compound | Activity                                                                                           | Traditional uses (references) |
|----------------------------------|--------------|--------------------|------------------------------------|----------------------------------------------------------------------------------------------------|-----------------------------|
| *Uvaria microcarpa* Champ. ex Benth. | Annonaceae  | Phi Phouan        | Fruits and flowers: 90% ethanol    | The extract showed inhibition at MIC ranging from 43.2 to >100 µg/ml against H37Rv [47].            | Nil.                        |
| *Uvaria rufa* Blume              | Annonaceae   | Mak Phii Phouan, Susung kalabaw | Fruits and flowers: 90% ethanol Methanol, ethyl acetate, n-butanol Kaempferol (1), quercitrin (2) isolated from methanolic extract of leave | The activity against H37Rv strain was observed at the MIC ranging from 33.1 to >100 µg/ml in MABA [47]. All three extracts showed inhibition in MIC value >128 µg/ml in MABA. Mixture of 1 and 2 exhibited activities against H37Rv with MIC of 64 µg/ml using microplate Alamar Blue assay [205]. | TB [204].                  |
| *Uvaria valderramensis* Cabuang, Exconde & Alejandro | Annonaceae  | Usog               | Leaves: dichloromethane and methanol/valderramenols A (1), grandiuvarone (2), andreticuline (3) isolated from the extract | Compound 1 showed better activity (10 µg/ml) while 2 and 3 exhibited lesser activity (32 µg/ml) against H37Rv using MABA [206]. |                             |
| *Vitex trifolia* L.              | Verbenaceae  | Phisua            | 90% ethanol                        | The extract showed inhibition at MIC value of 8.02 µg/ml against H37Rv [44]. In *in vitro* assays, 90% ethanolic fruit and flower extract exhibited activity against H37Rv strain at the MIC ranging from 77.6 to >100 µg/ml [47]. | Asthma, cough [44, 207].    |
| *Voacanga globosa* Merr.         | Apocynaceae  | Bayag-usa         | Leaves: dichloromethane and methanol/Globospiramine (I) was isolated from the extract | Demonstrated potent anti-TB activity against H37Rv strain as demonstrated in MABA (MIC = 4 µg/ml) and low-oxygen recovery assay (MIC = 5.2 µg/ml) [208]. | TB [209].                  |
Table 1: Continued.

| Scientific name              | Family       | Local name   | Part used: extract/active compound                                                                 | Activity                                                                 | Traditional uses (references)                                      |
|------------------------------|--------------|--------------|---------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|---------------------------------------------------------------------|
| **Zingiber officinale**      | Zingiberaceae| Halia, Luya  | Rhizome: 80% methanol/6-shogaol (1) and 6-gingerol (2) were isolated from the extract              | In TEMA, the extract of methanol showed inhibition against H37Rv strain at the MIC of 1600 μg/ml [48]. At 100 μg/ml, the methanolic extract of rhizomes showed 61% inhibition against H37Rv. The isolated compound 2 (MIC 33 μg/ml) showed more activity than 1 (MIC 64 μg/ml) [58]. | Cough, asthma [210].                                               |
| **Zingiber zerumbet**        | Zingiberaceae| Haeo dam     | Rhizome: chloroform methanol water                                                                | In MABA, the chloroform, methanol, water extract of rhizome exhibited inhibition against H37Ra strain at the MIC of 125, 1000, 1000 μg/ml, respectively [41]. | Leprosy, cough, asthma, chest pain, loss of appetite [211, 212].   |
| **Ziziphus mauritiana**      | Rhamnaceae   | Phut-sa      | Root: mauritine M (1) and nummularines H (2), all isolated from ethanol extracts                   | Isolated compounds exhibited activities against H37Ra at the MIC 72.8 μg/ml (1) and 4.5 μg/ml (2) [213]. | Asthma, bronchitis [214, 215].                                     |
| **Ziziphus oenoplia**        | Rhamnaceae   |              | Root: hexane, ethyl acetate and methanol/Ziziphine N and Q were isolated from the extract          | Ziziphine N and Q showed weak anti-TB activity against H37Ra strain with the same MIC value of 200 μg/ml [216]. | Asthma, fever [217].                                               |
showing MIC values of 50 μg/ml) were obtained. 1’Acetoxy-
chavicol acetate isolated from Alpinia galanga (L.) Sw.
showed MIC value of 0.024 μg/ml. Pimarinic acid, 9α-
13α-epidioxyabiet-8 (14)-en-18-oic acid, and 15-hydroxy-
deroabietic acid obtained from Anisochilus harmandii
Doan ex Suddee & A. J. Paton all showed MIC value of
50 μg/ml. Lakoochins A and B were isolated from
Artocarpus lakoahoa Roxb. showed MICs of 12.5 and 50 μg/ml,
respectively. Flavonoid artonin F, chromone artorigidusin, xan-
phone artindonesianin C, flavonoid crotoxaloxybionthan, and
flavonoid 7-demethyartelon E isolated from Artocarpus
rigidus Wall. showed MIC values of 6.25, 12.5, 12.5, 25, and
50 μg/ml, respectively. Active compounds obtained from
Camchaya calcaria Kitamura are isogoyazesolides (MIC,
1.5 μg/ml), goyazesolides, lycnhorpholides A, isocentra-
therin, isogoyazesolides and 5-epi-isocenttherin (with
the same MIC value of 3.1 μg/ml), lycnhorpholides B, 1(10),E,4Z,11(13)-germacatriene-12,6-olide-15-oic acid, and
caffic acid methyl ester (MICS, 6.2, 50, and 25 μg/ml resp.
). Caseargrewini A, Caseargrewini B, Caseargrewini D, rel-
(25,S,5R,6R,8S,9S,10R,18S,19R) -rel-18-19-diacetoxy-19-epoxy-6-
metoxy-2-(2-methylbutanoyloxy)cleroda-3,13(16),14-triene,
and rel-(25,S,5R,6R,8S,9S,10R,18S,19R)-18-19-diacetoxy-19-
epoxy-6-hydroxy-2-(2-methylbutanoyloxy)cleroda-3,13(16),
14-triene (all showing MIC value of 12.5 μg/ml) and
Caseargrewini C (showing MIC of 25 μg/ml) were isolated
from Casearia grewiifolia Vent. Cabaaleadiol, allo-aro-
madendrane-10β, 14-diol, cabraalehydroxyacolate, cabraale-
acone, allo-aramadendrane-10β, 13, 14-triol (all displaying
MICS of 50 μg/ml), and eichleriaclea (MIC, 25 μg/ml) were
obtained from Chisocheton penduliflorus Planch. ex Hiern. Flurocasuline A and heptazoline isolated from
Clausena guillauminii Tanaka all showed MIC of 25 μg/ml.
Dentatin, O-methylated clausenidin, and 3-methoxycarbon-
ylcarbazole isolated from Clausena excavata Burm. f.
also showed MIC value of 50 μg/ml. 1-(2-Hydroxy-4-methoxy-
phenyl)-3-(4-hydroxy-3-methoxyphenyl)propane isolated
from Combretum griffithii Vent. Cabraleahydroxylactone, cabra-
aealactone, allo-aramadendrane-10β, 14-diol, cabraalehydroxyacolate, cabraaleactone, allo-aramadendrane-10β, 13, 14-triol (all displaying
MICS of 50 μg/ml), and eichleriaclea (MIC, 25 μg/ml) were
obtained from Cordia globifera W. W. Smith. The bioactive
compounds of Croton kongensis Gagnep. s ent-
1β,7α,14β-triacetoxykaur-16-en-15-one (MICS, 0.78, 1.56,
and 3.12–12.5 μg/ml), ent-7α,18-dihydroxykaur-16-en-15-one
(MIC, 1.56 μg/ml), and ent-16(S)-18-acetoxy-7α-hydroxy-
kaur-15-one exhibited MIC of 1.56 μg/ml. Furthermore,
ent-18-acetoxy-7α-hydroxykaur-16-en-15-one, ent-1β,14β-diace-
toxy-7α-hydroxykaur-16-en-15-one, ent-1β-18-acetoxy-7α,14β-
dihydroxykaur-16-en-15-one, and ent-17α,14β-dihydroxy-
kaur-16-en-15-one showed MIC values ranging from 3.12
to 6.25 μg/ml. Other active compounds isolated from Croton
kongensis are ent-8,9-seco-8,14-epoxy-7α-hydroxy-11β-acet-
toxy-16-kaurens-9,15-diene (MIC, 6.25 μg/ml), ent-8,9-seco-
7α-hydroxy-11β-acetoxykaur-8(14),16-diien-9,15-diene (MIC,
6.25 μg/ml), and ent-8,9-seco-7α,11β-diacetoxykaur-8(14),
16-diien-9,15-diene (MIC, 25.0 μg/ml). Flavanone, delp-
arrowine, and delparvinine isolated from Dalbergia parviflora
Roxb. showed MIC values of 12.5, 50, and 50 μg/ml respecti-
vly. 3β-hydroxy-21-O-acetyl-24-methylencyclooctane from
Dasymaschalon dasymaschaulum (Blume) I. M. Turner
exhibited MIC of 50 μg/ml. Bioactive compounds isolated
from Dendrobolium lancelatum (Dunn) Schindl., Flavana-
one 1, flavanones, flavan, and 4’-hydroxy-7,8-(2”,3”)-di-
metilpyrany)flavan, exhibited MICs of 6.3, 12.5, 25, and
25 μg/ml, respectively. Compounds 3,4-methylenedioxy-10-
metoxy-7-oxo[2]benzopyrano[4,3-b]benzopyran, karan-
jarchromene, pinnatin, 3-methoxy-(3”4”,6”)-di-hydro-3”A’-
diacetoxy)-2”2”-dimethylpyranyo-[7:8:5’”6’”]-flavone, des-
methoxy kanugin, lachneol B, 3,7-dimethoxyflavone, and
pachycurin D (showing MIC values of 6.25, 12.5, 12.5,
25, 50, 50, and 50 μg/ml, resp.) were isolated from
Derris indica L. Betulinic acid from Diospyros decandra Lour., showing MIC of 25 μg/ml. From Diospyros
ehretioides Wall. ex G. Don, palmarumycin J C2 (MIC,
6.25 μg/ml) and isodorisopyron A (MIC, 50 μg/ml) were
isolated. Diospyrin, isolated from Diospyros glandulosace Lace.,
showed MIC value of 6.25 μg/ml. Betulinaldehyde isolated
from Diospyros rhodocalyx Kurz exhibited MIC value of
25 μg/ml. Dehydrolupinifolinol (MIC, 12.5 μg/ml), flemi-
chin D (MIC, 12.5 μg/ml), eriosemaene A (MIC, 12.5 μg/ml),
lupinifolin (MIC, 12.5 μg/ml), Khonkonlignon A (MIC,
25 μg/ml), Khonkonlignon H (MIC, 25 μg/ml), lupinifolin
(MIC, 25 μg/ml), and Khonkonlignon B (MIC, 50 μg/ml)
were isolated from Eriosema chinense Vogel. From Erythrina
fusca Lour., erhythrisengalone (50 μg/ml MIC), lonicarpol A
(50 μg/ml MIC), and lupinifolin (25 μg/ml MIC) were isolated. Bioactive compounds erystagallin A, erycrista-
alin, 5-hydroxysohpanorone, ersubin F (all showing MICS
of 12.5 μg/ml), and 1-methoxyerythryabysin II (showing
MICS of 50 μg/ml) were obtained from Erythrina subum-
brans Merr. (E)-3-(4-methoxyphenyl)allyl-3-(4-hydroxy-
phenylen)acrylate from Etingeria paviesana (Pierre ex Gagnep.)
R. M. Sm., exhibited MICS of 50 μg/ml 3’-formyl-2’,4’-
dihydroxy-6’-methoxyxchalcone, a bioactive compound
from Frisiodisida discolar (Craib) D. Das, showed MICS
of 6.25 μg/ml. From Garcinia mangostana L. α-mangostin
(MIC, 6.25 μg/ml), β-mangostin (MIC, 6.25 μg/ml), γ-
mangostin (MIC, 25 μg/ml), garcinone D (MIC, 25 μg/ml),
garcinone B (MIC, 6.25 μg/ml), mangostatin (MIC, 25 μg/ml),
mangosteneone A (MIC, 25 μg/ml), tovophyllin B (MIC,
25 μg/ml), demethylcalabaxanthone (MIC, 12.5 μg/ml),
and trapezifolixanthone (MIC, 12.5 μg/ml) were identified
as active compounds. Active compound Liriodenine isolated
from Goniathalum gitigensis Elmer exhibited MIC of
16 μg/ml. Active compounds (+)-altholactone (MIC, 6.25 μg/ml),
howiinA (MIC, 6.25 μg/ml), and (+)-nordicentrine
(12.5 μg/ml) were isolated from Goniathalum laoticus
(Finet & Gagnep.) Bän. Coronarin E and 16-Hydroxyab-
1(7)ll,13-trien-15,16-oide isolated from Hedychium ellip-
ticum Buch.-Ham. ex Sm. showed MICS of 12.5 and
6.25 μg/ml, respectively. Caniojane isolated from Jatropha
integerrima Jacq. demonstrated MIC of 25 μg/ml. Bioactive
compounds, sandaracopimaradien-1α-ol and 2α-acetoxy-
sandaracopimaradien-1α-ol isolated from Kaempferia margi-
nata Carey, showed MICS of 25 and 50 μg/ml, respectively.
From *Morinda citrifolia* Linn., campesta-6,22-dien-5α,8α-epidioxy-3β-ol (2.5 μg/ml), (E)-phytol (32 μg/ml), and stigmasterol (32 μg/ml) were obtained. Active compounds 2,4-bis(2-phenylpropan-2-yl)phenol isolated from *Momordica charantia* L. showed 14 μg/ml MIC. 1α,13β,14α-trihydroxy-3β,7β-dibenzoxyloxy-9β,15β-diacetoxyjatropa-5,11E-diene and 1α,8β,9β,14α,15β-pentacetoxy-3β-benzoxyloxy-7-oxojatropa-5,12-diene isolated from *Pedilanthus tithymaloides* (L.) Poit. demonstrated 12.5 and 50 μg/ml MIC. From *Piper sarmentosum* Roxb., pellitorine, 1-(3,4-methlenedioxy-phenyl)-1E-tetradecene, guineensine, sarmentine, and brachymide B showed MICs of 25, 25, 50, and 50 μg/ml, respectively. Bidebiline E (6.25 μg/ml), octadeca-9,11,13-triynoic acid (6.25 μg/ml), and α-humulene (6.25 μg/ml) were isolated from *Polyalthia cherasoides* (Roxb.) Benth. ex Bedd. Debilison B, Debilison C, and Debilison E isolated from *Polyalthia debilis* (Pierre) Finet & Rothmannia wittii (Crab) Bremek. showed 8 and 12.5 μg/ml MIC values, respectively. The compounds chambade and piperine isolated from *Piper chaba* Hunter exhibited MIC values of 12.5 and 50 μg/ml, respectively. Bioactive compounds saptoxin A (3.12 μg/ml), saptoxin B (12.5 μg/ml), saptoxin C (25 μg/ml), 12-(2′-N-methylaminobenzoyl)-4α-deoxy-5,20-dihydroxyporphorol-13-acetate (25 μg/ml), 12-(2-methylaminobenzoyl)-4-deoxyphoraldehyde-13-acetate (25 μg/ml), and 12-(2-N-methylaminobenzoyl)-4β,5,20-trideoxyphorphorol-13-acetate (50 μg/ml) were isolated from *Sapium indicum* L. From *Sebbania grandiflora* (L.) Poir., isovestitol (50 μg/ml), medicarpin (50 μg/ml), and sativan (50 μg/ml) were isolated as active compounds. Tiliacorine, 2′-nortiliacorine, tiliacorine, and 13′-bromo-tiliacorine from *Tiliacora triandra* (Colebr.) Diels exhibited MIC ranging between 0.7 and 6.2 μg/ml. From *Uvaria valderramensis* Cabuang, Exconde & Alejandro, valderramenols A, grandiuvarone, and reticuline were iso-

#### 7. Conclusion

There has been an increase in demand for the phytopharmaceuticals worldwide due to the fact that allopathic drugs have more side effects. This review makes an attempt to compile some of the anti-TB plants of Southeast Asian origin from wide range of families and genera that have exhibited significant in vitro anti-TB activities and a number of bioactive compounds from different groups of chemicals have been isolated. As stated earlier, about 2 million individuals worldwide die from TB yearly. Therefore, the findings may encourage numerous researchers to embark on the project that potentially leads to the development of standardized crude extracts that will be consumed as either complementary or alternative TB drug. The findings might as well motivate various researchers to undertake the project that may further identify and characterize the active components from these plant species in order to search for the novel natural product leads useful for new anti-TB drug discovery and development.

### Conflicts of Interest

The authors declare that they have no conflicts of interest.

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