

## Herbal Medicines Used for Tuberculosis Worldwide: A Systematic Review of Ethnobotanical, Preclinical, and Clinical Evidence

**Running Title:** Herbal Medicines for Tuberculosis: Global Evidence

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### Abstract

**Introduction:** Tuberculosis (TB) presents an increasing global health threat, driven by mounting drug resistance. This has intensified the search for affordable treatment options, such as herbal medicines, whose safety and effectiveness are assessed in this systematic review.

**Materials and Methods:** To address this objective, this PRISMA-compliant systematic review evaluates herbal medicines for TB treatment globally. We searched Web of Science, Cochrane Library, Scopus, ScienceDirect, PubMed, and Google Scholar (1980–August 2025) using MeSH and free-text terms (e.g., “Tuberculosis AND Herbal Medicines”).

**Results:** From 1,176 articles, 40 studies (in vitro, field, and clinical) were included, identifying 245 plant species (e.g., *Acalypha indica*, *Capparis spinosa*) with anti-TB activity (IC<sub>50</sub> < 0.5 mg/mL). India, South Africa, and Uganda reported the most species. In vitro studies dominate (37/40), with only 2–3 clinical trials, limiting practical use. Safety data are sparse, though *Morella salicifolia* showed no toxicity.

**Conclusion:** Herbal medicines represent promising candidates for future anti-tuberculosis drug discovery; however, their clinical utility in multidrug-resistant tuberculosis (MDR-TB) remains insufficiently validated. Future studies should focus on standardization of extracts, in vivo evaluation, toxicity assessment, and well-designed clinical trials to support evidence-based TB control strategies.

**Keywords:** Ethnomedicinal plants, *Mycobacterium tuberculosis*, Systematic review, Anti-TB Activity

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## Introduction

Tuberculosis (TB) is still a global public health problem, even after years of control efforts. The rise of drug-resistant and multidrug-resistant *Mycobacterium tuberculosis* makes TB harder to control (1). Most resistance happens because TB medicines are misused (2). Many herbal medicines are used worldwide to treat infections, and if proven safe and effective, they could be an affordable and practical option for TB treatment (1).

Herbal medicines could offer additional ways to help control TB worldwide. Because herbal drugs are easy to access and widely available, they can help reduce the heavy financial burden of TB treatment for low-income families (3, 4). To improve the global fight against TB, scientists and healthcare workers should focus on exploring natural, plant-based treatments. Different regions have unique plants that provide important resources for medicine and food, shaped by their geography, climate, and environment. As a result, there are many types of herbal medicines around the world. Traditional healers, who possess deep knowledge and experience, have long used these plants to treat many diseases (5). This systematic review examines herbal medicines used globally to treat TB and evaluates their potential for effective, sustainable TB management using a PRISMA-compliant approach (6). With the growing burden of multidrug-resistant tuberculosis (MDR-TB) and increasing interest in natural therapies, this systematic review aimed to evaluate global evidence on herbal medicines used for TB management, including their antimycobacterial activity, safety, and potential therapeutic value.

## Materials and methods

### Study participants

This systematic review brings together global evidence on herbal medicines used for tuberculosis (TB), including studies from all regions published between January 1980 and August 19, 2025, to ensure a broad and up-to-date overview. The protocol followed PRISMA 2020 guidelines; however, PROSPERO registration was not completed because the review included heterogeneous preclinical and ethnobotanical studies and was initiated before formal protocol submission.

### Search strategy and strategies

A systematic literature search was performed on the Web of Science, Scopus, PubMed, ScienceDirect, Cochrane Library, and Google Scholar for studies published from January 1980 to August 2025. The search strategy incorporated both Medical Subject Headings (MeSH) and free-text terms about tuberculosis and herbal medicine.

**Table 1:** Detailed Search Strategy for Studies on Herbal Medicines Against Tuberculosis

| Search strategy     | Search strategy                                                                                                                                                                 | Search strategy                                                                                                                                                                 |
|---------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Keywords</b>     | "Tuberculosis" OR "Latent Tuberculosis"                                                                                                                                         | "Herbal Plant" OR "Plants Herbal" OR "Herbal Herbs" OR "Pharmaceutical Plants" OR "Healing Plant" OR "Medicine Traditional"                                                     |
| <b>Search terms</b> | [(("Tuberculosis" OR "Latent Tuberculosis") AND ("Herbal Plant" OR "Plants Herbal" OR "Herbal Herbs" OR "Pharmaceutical Plants" OR "Healing Plant" OR "Medicine Traditional"))] | [(("Tuberculosis" OR "Latent Tuberculosis") AND ("Herbal Plant" OR "Plants Herbal" OR "Herbal Herbs" OR "Pharmaceutical Plants" OR "Healing Plant" OR "Medicine Traditional"))] |

**Note:** NTM (non-tuberculous mycobacteria) studies were excluded unless *Mycobacterium tuberculosis* isolates were specifically investigated.

The following search syntax was applied in PubMed: "Tuberculosis" (MeSH) OR tuberculosis

OR "Mycobacterium tuberculosis" AND "Herbal Medicine" OR "Herbal Medicines" OR phytotherapy OR ethnomedicine OR plant extract. Equivalent search strategies were tailored for each database. Boolean operators (AND/OR) were employed to combine search terms. Additionally, reference lists of included studies were manually screened to identify further eligible studies (**Table 1**).

### Inclusion criteria

In this systematic review, all clinical trials, case-control, cross-sectional, cohort, and nested-control studies, as well as field studies, that used herbal medicines or herbal extracts to treat TB patients were included. Entry criteria included no time or place restrictions, English-language studies, and human and *in vitro* studies.

### Exclusion criteria

Lack of access to the full text of articles published after August 2025, books, qualitative studies, and articles that were in the form of letters to the editor (criticism of other articles), proposals, review articles, meta-analysis, or ecological studies, as well as articles that were in the form of letters to the editor (criticism of other articles), proposals, review articles, meta-analysis, or ecological studies, were excluded from the study.

### Data Collection Method

Data from included studies were extracted electronically in Microsoft Excel, recording (1) article details (title, first author, publication year), (2) study location (country), (3) study type (e.g., clinical trial, field study), and (4) intervention details (plant species, plant part, type of extract, anti-TB outcomes). Studies

were organized in EndNote version 8 according to the inclusion criteria and PRISMA guidelines.

### Validity and Reliability of Data Collection

Validity was ensured using specific Medical Subject Headings (MeSH) and free-text terms (e.g., "Tuberculosis OR Mycobacterium" AND "Herbal medicines OR Herbal medicines") to conduct sensitive searches across Web of Science, Cochrane Library, Scopus, ScienceDirect, PubMed, and Google Scholar. This minimized study selection bias. Reliability was maintained through independent data extraction by two investigators (each reviewed and recorded relevant data), with differences resolved by a third researcher to ensure uniformity (consistency across the data). Quality assessment used the Cochrane Risk of Bias tool for clinical and *in vitro* trials to identify methodological flaws and ensure reproducibility.

## Results

Our search yielded 1,176 articles with predetermined keywords (**Table 1**). Following the elimination of 565 duplicates through EndNote version 8 and manual title screening, 611 articles were left. Screening by title eliminated 161 articles not related to the study's objective (assessing herbal medicines for the treatment of tuberculosis), resulting in 450 articles for abstract screening. Of these, 312 were irrelevant (i.e., non-TB focus or non-herbal interventions), yielding 138 articles for full-text screening. After assessment of full texts for scientific quality and inclusion criteria (English-language, human studies, 1980–August 20, 2025), 40 studies were included (**Figure 1**).

**Table 2:** Characteristics of Included Studies on Herbal Medicines Against Mycobacterium tuberculosis

| No | First author     | Year | Country      | Study design                       | Herbal Medicines                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Plant Part Used                                                                                                                                                                                                                                            | Type of extract and Main Funding Limitations                                                                                                                                                                                            |
|----|------------------|------|--------------|------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1  | Mpeirwe (7)      | 2023 | Bazira       | in vitro                           | <i>Zanthoxylum leprieurii</i><br><i>Rubia cordifolia</i>                                                                                                                                                                                                                                                                                                                                                                                                         | stem<br>stem bark<br>bark                                                                                                                                                                                                                                  | The combination of extracts from two drugs demonstrated greater efficacy against Mycobacterium tuberculosis strains in laboratory tests, as indicated by higher inhibition rates compared to those of standard anti-tuberculosis drugs. |
| 2  | Gautam(4)        | 2023 | India        | Ethnobotanical survey              | <i>Nerium oleander</i><br><i>Butea monosperma</i><br><i>Pea nut</i><br><i>Hibiscus cannabinus</i><br><i>Sesbania grandiflora</i><br><i>Salix alba</i><br><i>Eucommia ulmoides</i><br><i>Galaxaura elongate</i><br><i>Ocimum sanctum</i><br><i>Torreya nucifera</i><br><i>Olea europaea</i><br><i>Rosa indica</i><br><i>Pistacia integerrima</i><br><i>Terminalia arjuna</i><br><i>Euphorbia hirta</i><br><i>Morinda citrifolia</i><br><i>Zizyphus mauritiana</i> | Leaf extract<br>Bark<br>Skin and seed<br>Stem extract<br>Leaf extract<br>Leaf extract<br>Bark<br>Powder or extract<br>Leaf extract<br>Leaves and bark<br>Leaf extracts<br>Rose petals<br>Galls extract<br>Fruit<br>Leaf extract<br>Root extract<br>Extract | These findings suggest that herbal medicines and their active components could offer a more effective alternative in the fight against tuberculosis, highlighting their potential for improved patient outcomes.                        |
| 3  | Sharma(2)        | 2023 | India        | in vitro                           | <i>H. coronarium</i>                                                                                                                                                                                                                                                                                                                                                                                                                                             | Stem                                                                                                                                                                                                                                                       | The results showed that <i>H. coronarium</i> has promising intracellular activity against drug-resistant TB <i>in vitro</i> and <i>in vitro</i> .                                                                                       |
| 4  | Priyadarshini(1) | 2021 | India        | Ethnobotanical survey              | <i>Ethnobotanical plants Tithonia diversifolia (Hemsl.) Gray</i><br><i>Couroupita guianensis Aubl</i>                                                                                                                                                                                                                                                                                                                                                            | Leaves                                                                                                                                                                                                                                                     | Extracts derived from these plants can be considered as anti-tuberculosis drugs.                                                                                                                                                        |
| 5  | Oryema(8)        | 2021 | Uganda       | Ethnobotanical survey/<br>in vitro | <i>Ayekyek Olwiro</i><br><i>Olwiro</i><br><i>Yat aona opio</i><br><i>Kicuk</i><br><i>Roki</i><br><i>Oculup</i><br><i>Odwong</i>                                                                                                                                                                                                                                                                                                                                  | Root                                                                                                                                                                                                                                                       | The mentioned plants are facing conservation threats due to root exploitation.                                                                                                                                                          |
| 6  | Tuyiringire(9)   | 2020 | Uganda       | Ethnobotanical survey/<br>in vitro | <i>Zanthoxylum leprieurii</i><br><i>Lantana camara</i><br><i>Cryptolepis Sanguinolenta</i>                                                                                                                                                                                                                                                                                                                                                                       | Leaves ( <i>L. camara</i> ), Roots ( <i>C. sanguinolenta</i> ), Stem barks ( <i>Z. leprieurii</i> )                                                                                                                                                        | The results showed that these plants are potential candidates for providing Herbal effects against multidrug-resistant TB strains.                                                                                                      |
| 7  | Obakiro(10)      | 2020 | Uganda       | Ethnobotanical survey/<br>in vitro | <i>Tetradenia riparia</i><br><i>Warburgia ugandensis</i><br><i>Zanthoxylum leprieurii</i>                                                                                                                                                                                                                                                                                                                                                                        | Leaves<br>Stem<br>bark                                                                                                                                                                                                                                     | More scientific validation on herbal Medicines is needed to standardize the use of herbal medicines and also to promote drug discovery and development against TB.                                                                      |
| 8  | Marealle(6)      | 2020 | Tanzania     | in vitro                           | <i>Morella salicifolia</i>                                                                                                                                                                                                                                                                                                                                                                                                                                       | Root                                                                                                                                                                                                                                                       | The results showed that some compounds isolated from <i>Morella salicifolia</i> can be used to produce anti-TB drugs.                                                                                                                   |
| 9  | Maifo(11)        | 2021 | South Africa | in vitro                           | <i>Croton gratissimus</i><br><i>Leonotis leonorus</i>                                                                                                                                                                                                                                                                                                                                                                                                            | Leaf extracts                                                                                                                                                                                                                                              | The results showed that the extracts have anti-TB properties.                                                                                                                                                                           |

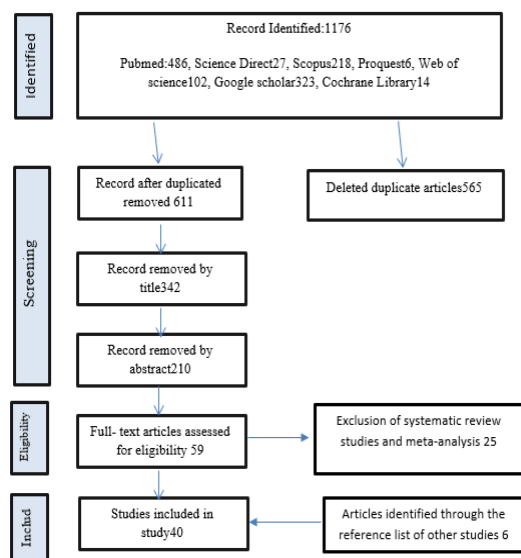
|    |                       |      |           |                       |                                                                                                                                                                                                                                                                                                                    |                                                                                                                                         |                                                                                                                                                                                                      |
|----|-----------------------|------|-----------|-----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 10 | Jethva(12)            | 2020 | India     | in vitro              | Amla<br>Baheda<br>Harde<br>Ashwagandha<br>Nagarmotha<br>Rasna<br>Tulsi<br>Vasaka<br>Long pepper<br>Kharkhodi<br>Vevadi                                                                                                                                                                                             | Fruits<br>Fruits<br>Fruits<br>Roots<br>Rhizomes<br>Rhizomes<br>Leaves<br>Leaves<br>Fruits<br>Roots<br>Whole herb                        | Aqueous extracts of four selected herbal Medicines showed significant anti-tuberculosis activity.                                                                                                    |
| 11 | Monga(13)             | 2020 | India     | in vitro              | Alkaloids<br>Flavonoids<br>Lignans<br>Coumarins<br>Terpenes                                                                                                                                                                                                                                                        | Various                                                                                                                                 | alkaloids, flavonoids, lignans, coumarins, and terpenes as anti-TB agents                                                                                                                            |
| 12 | Cock(14)              | 2020 | Australia | Ethnobotanical survey | One hundred and eighty-seven southern African plant species are recorded as traditional therapies for bacterial respiratory infections.                                                                                                                                                                            | Various (mainly leaves – used in 68 species; roots in 58 species)                                                                       | The inhibitory properties of South African herbal Medicines against bacterial respiratory pathogens are relatively weak, and the antibacterial activity of most plant species needs to be confirmed. |
| 13 | Dehyab(15)            | 2020 | Malaysia  | Ethnobotanicasurvey   | A total of 184 plant species representing 73 families were studied. Among these species, 93 species contained more active compounds with strong anti-MTB activity.                                                                                                                                                 | Various                                                                                                                                 | Herbal plant extracts investigated in this study have anti-TB activity.                                                                                                                              |
| 14 | Ataalpa(16)           | 2020 | Brazil    | descriptive study     | Worm-seed<br>Cockroach berry<br>Mimosa<br>Ironwood<br>Garlic<br>Aloe vera<br>Lemon balm<br>Boldo<br>Common mallow<br>Rosemary<br>Pomegranate                                                                                                                                                                       | Various (commonly aerial parts / leaves for the most cited species)                                                                     | The use of herbal Medicines as a preventive action in the treatment of tuberculosis.                                                                                                                 |
| 15 | Aranaga(17)           | 2020 | France    | in vitro              | Piper sanvicentense<br>Eschweilera parvifolia<br>Protium heptaphyllum<br>Protium heptaphyllum<br>Bromelia goeldiana<br>Byrsonima crassifolia<br>Curatella americana<br>Hyptis dilatata<br>Hyptis dilatata<br>Macoubea guianensis<br>Piper marginatum<br>Polypodium aureum<br>Senna silvestris<br>Xylopia aromatica | Leaf<br>Inner bark<br>Inner bark<br>Branch<br>Fruit<br>Flower<br>Bark<br>Flower<br>Root<br>Leaf<br>Stem<br>Stem<br>Flower<br>Young leaf | Among the herbal Medicines, 5 plants inhibited the growth of TB and inhibited protein kinase activity.                                                                                               |
| 16 | Adnan (5)             | 2019 | Pakistan  | in vitro              | Curcuma longa<br>Punica granatum L.<br>Justicia adhatoda L.<br>Acalypha indica L.                                                                                                                                                                                                                                  | Root<br>Extract<br>Justtod<br>Leaves                                                                                                    | The results showed that <i>Acalypha indica</i> L. is more effective against TB.                                                                                                                      |
| 17 | Pourazar Dizaji ,(18) | 2018 | Iran      | in vitro              | Thymus vulgaris                                                                                                                                                                                                                                                                                                    | Leaves                                                                                                                                  | Thyme has antibacterial activity against TB.                                                                                                                                                         |

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| 18 | Assane Diop(19) | 2018 | Switzerland | cross-sectional-analytical- In vitro | <i>Combretum aculeatum</i><br><i>Guiera senegalensis</i>                                                                                                                                                                                                                                                                                                                 | herbal decoctions<br>herbal decoctions                                                                                                                                                                                                                                                                                                                                          | Both extracts showed significant activity against intracellular and extracellular growth - <i>M. marinum</i> showing an IC50 of less than 0.5 mg/ml compared to the reference drug rifampin (IC50 of 0.4 and 7 µg/ml). No toxicity to amoeba cells was observed at a concentration of 0.8 mg/ml. |
| 19 | Arulmozhi(20)   | 2018 | India       | in vitro                             | <i>Capparis zeylanica</i><br><i>Streblus asper</i><br><i>Tribulus terrestris</i>                                                                                                                                                                                                                                                                                         | Leaves<br>Leaves<br>Fruits                                                                                                                                                                                                                                                                                                                                                      | The results showed that the ethyl acetate extract of <i>C. zeylanica</i> leaves has potential activity against TB, compared to other extracts.                                                                                                                                                   |
| 20 | Aristyani(21)   | 2018 | Indonesia   | in vitro                             | Jahe<br>Jambang<br>Sidaguri<br>Asam Jawa<br>Ki urat; Daun sendok<br>Sirih<br>Singolawang<br>Selasih<br>Rumput gelong; Suruhan<br>Mengkudu<br>Bunga Tahi Ayam<br>Kencur<br>Tukudan<br>Kembang sepatu<br>Adas<br>Patikan kebo<br>Kunyit Putih<br>Kunyit<br>Kopi<br>Jeruk nipis<br>Pegagan<br>Benda/ terap<br>Sambiloto<br>Nanas Putih<br>Lidah buaya<br>Bandotan<br>Dringu | Rhizome<br>Barks; Fruits;<br>Leaves<br>Fruits<br>Leaves<br>Leaves<br>Leaves<br>Seeds; Leaves<br>Not mention<br>Leaves<br>Flowers;<br>Leaves;<br>Rhizome<br>All of the part<br>Flower; Leaves<br>Seeds<br>Herbs<br>Rhizome; Tuber<br>Rhizome<br>Seeds; Leaves<br>Fruit; Flower<br>All of the part<br>All of the part<br>Herbs<br>Fruit<br>Stem; Leaves<br>Herbs<br>Leaf; Rhizome | Twenty-seven species from nineteen families of herbal Medicines are used in Indonesia to control and treat TB.                                                                                                                                                                                   |
| 21 | Onubogu(22)     | 2018 | Nigeria     | invitro                              | <i>A. barteri</i><br><i>C. albidum</i><br><i>C. dependens</i><br><i>E. coccinea</i><br><i>M. benthamianum</i><br><i>P. muellerianus</i><br><i>S. afzelii</i><br><i>S. alata</i><br><i>X. aethiopica</i><br><i>A. fimbriata</i>                                                                                                                                           | Leaves<br>Stem<br>Cotyledon of seeds<br>Leaves<br>Leaves<br>Leaves<br>Leaves<br>Leaves<br>Pods<br>Leaves                                                                                                                                                                                                                                                                        | Four of the plants examined in this study had anti-TB properties.                                                                                                                                                                                                                                |
| 22 | Ademoye(23)     | 2018 | Nigeria     | in vitro                             | <i>C. albidum</i>                                                                                                                                                                                                                                                                                                                                                        | roasted seeds                                                                                                                                                                                                                                                                                                                                                                   | Effectiveness of tuberculosis treatment with roasted seeds of <i>Chrysophyllum albidum</i> due to the existence of hexadecanoic acid and 9,12-octadecadienoic acid that can work together. Synergistically with other antimicrobial agents, it kills macrophages.                                |
| 23 | Gupta(24)       | 2018 | India       | Semi structured                      | <i>Abrus precatorius</i> L.<br><i>Acorus calamus</i> L.<br><i>Alstonia scholaris</i><br><i>Buchanania lanzan</i> Spreng<br><i>Cissampelos pareira</i> L.<br><i>Cocculus hirsutus</i> (L.)<br><i>Curcuma caesia</i> Roxb.                                                                                                                                                 | Seeds<br>Rhizome<br>Bark<br>Bark<br>Roots<br>Leaves<br>Rhizome                                                                                                                                                                                                                                                                                                                  | Plants show an acceptable range of anti-mycobacterial activity against TB.                                                                                                                                                                                                                       |

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|----|------------------|------|--------------|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|    |                  |      |              |          | <i>Cyperus rotundus L.</i><br><i>Desmodium gangeticum</i><br><i>Embelia tsjeriam-cottam</i><br><i>Eulophia nuda Lindl.</i><br><i>Flemingia bracteata</i><br><i>Ficus microcarpa L.f.</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Roots<br>Leaves<br>Leaves<br>Leaves<br>Leaves<br>Tubers                                                                                                                                                                                                                                                        |                                                                                                                                                                                                                                                                 |
| 24 | EHSANIFAR(3)     | 2017 | Iran         | in vitro | <i>Capparis spinosa</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Fruit Extract                                                                                                                                                                                                                                                                                                  | The results showed that <i>Capparis spinosa</i> demonstrated significant antimycobacterial activity against Mycobacterium tuberculosis isolates.                                                                                                                |
| 25 | Madisha(25)      | 2017 | South Africa | in vitro | <i>Aloe marlothii</i><br><i>Maerua angolensis</i><br><i>Drimia elata</i><br><i>Elephantina elephantorrhiza</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Various                                                                                                                                                                                                                                                                                                        | The anti-TB activity of these four plants was observed.                                                                                                                                                                                                         |
| 26 | Hassan(26)       | 2017 | Nigeria      | in vitro | <i>Acacia tortilla</i><br><i>Anogeissus leiocarpus</i><br><i>Bombax costatum</i><br><i>Boswellia dalzielii</i><br><i>Ceiba pentandra</i><br><i>Echinaceae angustifolia</i><br><i>Ficus platyphylla</i><br><i>Ficus sycomorus</i><br><i>Ficus trichopoda</i><br><i>Isobertia doka</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Stem bark                                                                                                                                                                                                                                                                                                      | The results showed a potential for the development of compounds against TB from <i>Anogeissus leiocarpus</i> , <i>Boswellia dalzielii</i> , <i>Acacia tortilis</i> , <i>Bombax konstantum</i> , There are <i>Ceiba pentandra</i> and <i>Ficus platyphylla</i> . |
| 27 | Hozoorbakhsh(27) | 2016 | Iran         | in vitro | <i>Pulicaria gnaphalodes</i><br><i>Perovskia abrotanoides</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Flower                                                                                                                                                                                                                                                                                                         | P. abrotanoides was more effective in treating tuberculosis than others.                                                                                                                                                                                        |
| 28 | Jyoti(28)        | 2016 | Korea        | in vitro | <i>Artemisia capillaris</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Various                                                                                                                                                                                                                                                                                                        | The results show that AC H extracts have promising chemotherapeutic power against drug-resistant TB.                                                                                                                                                            |
| 29 | Chinsemu(29)     | 2016 | Namibia      | in vitro | <i>Combretum molle</i><br><i>Phaseolus vulgaris</i><br><i>Mangifera indica</i><br><i>Rubia cordifolia</i><br><i>Dracaena steudneri</i><br><i>Canarium schweinfurthii</i><br><i>Callistemon citrinus</i><br><i>Erythrina abyssinica</i><br><i>Hibiscus fuscus</i><br><i>Garcinia burchanani</i><br><i>Blighia unijugata</i><br><i>Vernonia amygdalina</i><br><i>Moringa oleifera</i><br><i>Maytenus senegalensis</i><br><i>Aloe vera</i><br><i>Allium sativum</i><br><i>Eucalyptus spp</i><br><i>Warburgia salutaris</i><br><i>Ocimum suave</i><br><i>Zanthoxylum chalybeum</i><br><i>Momordica foetida</i><br><i>Persea Americana</i><br><i>Azadirachta indica</i><br><i>Allium sativum</i><br><i>Bidens pilosa</i><br><i>Acacia hockii</i> | Stem bark<br>Husks<br>Stem bark<br>Leaves<br>Stem bark<br>Stem bark<br>Stem bark<br>Stem bark<br>Leaves<br>Stem bark<br>Stem bark<br>Leaves<br>Fruits, seeds<br>Leaves, fruits<br>Leaves<br>Fruits<br>Stem bark<br>Stem bark<br>Leaves<br>Roots<br>Leaves<br>Leaves<br>Seeds<br>Leaves<br>Flowers<br>Stem bark | This review provides a clear indication of plant species that have anti-TB activity.                                                                                                                                                                            |

|    |                     |      |              |                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                                               |                                                                                                                                                                                                                                     |
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|    |                     |      |              |                      | <i>Carica papaya</i><br><i>Helichrysum odoratissimum</i><br><i>Achyranthes aspera</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Leaves<br>Leaves<br>Flowers                                                                                                                                                                                                   |                                                                                                                                                                                                                                     |
| 30 | Arjomandzadegan(30) | 2016 | Iran         | in vitro             | Aloe vera<br>Mint<br>Hypericum perforatum                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Leaves<br>Leaves                                                                                                                                                                                                              | More evidence is needed to confirm the effectiveness of this herb.                                                                                                                                                                  |
| 31 | Nguta(31)           | 2016 | Ghana        | in vitro             | <i>Solanum torvum</i><br><i>Zingiber officinale</i><br>Aloe vera<br><i>Dissotis rotundifolia</i><br><i>Chenopodium ambrosioides</i>                                                                                                                                                                                                                                                                                                                                                                                                                 | Leaves<br>Rhizomes<br>Leaves<br>Leaves<br>Leaves                                                                                                                                                                              | Evidence suggests that the hydroethanolic leaf extract (80% ethanol) of <i>Solanum torvum</i> leaves can be a potential treatment for TB.                                                                                           |
| 32 | Jahanpour(32)       | 2015 | Iran         | in vitro             | Citrus lemon<br><i>Peganum harmala</i><br>Punica<br><i>Rosa canina</i><br><i>Berberis vulgaris</i><br><i>Digitalis sp.</i>                                                                                                                                                                                                                                                                                                                                                                                                                          | Fruit<br>Seed<br>Peel<br>Fruit<br>Fruit<br>Leaf                                                                                                                                                                               | pulp<br>The results showed that the ethanolic extracts of <i>P. granatum</i> and <i>P. harmala</i> have anti-TB properties.                                                                                                         |
| 33 | Nguta(33)           | 2015 | Ghana        | in vitro             | <i>Azadirachta indica</i> A<br><i>Hygrophila auriculata</i> Heine.<br><i>Chenopodium ambrosioides</i> L.<br><i>Coix lacryma-jobi</i> L<br><i>Solanum torvum</i> Sw.<br><i>Solanum torvum</i> Sw.<br><i>Bidens pilosa</i> L<br><i>Phyllanthus fraternus</i> G.L. Webster<br><i>Dissotis rotundifolia</i> (Sm.) Triana<br><i>Cymbopogon giganteus</i> Chiov<br><i>Cyperus articulatus</i> L<br><i>Allium sativum</i> L<br><i>Zingiber officinale</i> Rosc<br><i>Allium cepa</i> L.<br>Aloe vera var. <i>barbadensi</i><br><i>Cocos nucifera</i> Linn. | Stem bark<br>Whole plant<br>Leaves<br>Glumes<br>Unripe fruits<br>Leaves<br>Whole plant<br>Leaves<br>Leaves<br>Leaves<br>Roots<br>Bulbs<br>Rhizomes<br>Bulbs<br>Leaves<br>Leaves<br>Leaves<br>Leaves<br>Leaves<br>Coconut ater | The results may serve as a basis for further investigation of the effects of this plant in the treatment o                                                                                                                          |
| 34 | Fouotsa(34)         | 2013 | Cameroon     | in vitro             | <i>Garcinia nobilis</i><br><i>Orcia suaveolens</i><br><i>Balsamocitrus camerunensis</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Fruits<br>Root<br>Flowers                                                                                                                                                                                                     | The evidence suggests that the crude extract of <i>G. nobilis</i> , <i>O. suaveolens</i> and <i>B. camerunensis</i> as well as some of their compounds can be considered as a natural antibacterial product in the treatment of TB. |
| 35 | Worku (35)          | 2013 | Ethiopia     | in vitro             | <i>Calpurnia aurea</i><br><i>Ocimum basilicum</i><br><i>Artemisia abyssinica</i><br><i>Croton macrostachyus</i> ,<br><i>Eucalyptus camaldulensis</i>                                                                                                                                                                                                                                                                                                                                                                                                | Root<br>Seed<br>Leave                                                                                                                                                                                                         | 80% crude methanolic extracts of <i>C. aurea</i> root, <i>O. basilicum</i> seeds and <i>A. abyssinica</i> , <i>C. macrostachyus</i> and <i>E. camaldulensis</i> had minimal inhibitory concentration (MIC) anti-TB1 activity.       |
| 36 | Luo(36)             | 2013 | Portugal     | in vitro and ex vivo | <i>Zanthoxylum capense</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Root                                                                                                                                                                                                                          | High antifungal activity, both in vitro and ex vivo against TB, and low cytotoxicity to human macrophages shows that it can be valuable for the development of tuberculosis drugs.                                                  |
| 37 | Lakshmanan(37)      | 2011 | India        | in vitro             | <i>Kaempferia galanga</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Root                                                                                                                                                                                                                          | <i>Kaempferia galanga</i> appears to be a potential drug for TB.                                                                                                                                                                    |
| 38 | Green(38)           | 2010 | South Africa | in vitro             | <i>Ziziphus mucronata</i><br><i>Berchemia discolor</i><br><i>Warbugia salutaris</i><br><i>Cassia petersiana</i>                                                                                                                                                                                                                                                                                                                                                                                                                                     | Bark<br>Bark<br>Leaves<br>Leaves                                                                                                                                                                                              | Acetone extract of <i>Brachemia discolor</i> , <i>Bridelia micranta</i> , <i>Terminalia sericea</i> , and <i>Varbogia salutaris</i> can exhibit antimycobacterial activity against TB.                                              |

|    |           |      |              |          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                 |                                                                                               |
|----|-----------|------|--------------|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|
|    |           |      |              |          | <i>Rhoicissus tridentate</i><br><i>Ximenia caffra</i><br><i>Carisa edulis</i><br><i>Terminalia sericea</i><br><i>Combretum erythrophyllum</i><br><i>Rhus rogersii</i><br><i>Peltophorum africanum</i><br><i>Grewia villosa</i><br><i>Piper capense</i><br><i>Bridelia micrantha</i><br><i>Lippia javanica</i><br><i>Dyospyros mespiliformis</i><br><i>Scotia brakepetale</i><br><i>Scherocarya birrea</i><br><i>Asclepias fruticosa</i><br><i>Allium sativum</i><br><i>Carica papaya</i><br><i>Solanum panduriforme</i><br><i>Securidaca longepedunculata</i> | Bark<br>Leaves<br>Roots<br>Roots<br>Bark<br>Leaves<br>Bark<br>Bark<br>Roots<br>Roots<br>Bark<br>Leaves<br>Leaves<br>Bark<br>Bark<br>Roots<br>Tuber<br>Leaves<br>Leaves<br>Roots |                                                                                               |
| 39 | Kuete(39) | 2010 | South Africa | in vitro | <i>Terminalia superba</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | stem bark                                                                                                                                                                       | The potential use of <i>Terminalia superba</i> plant can be effective in the treatment of TB. |
| 40 | Gupt(40)  | 2010 | India        | in vitro | <i>Acalypha indica</i> <i>Adhatoda vasica</i> ,<br><i>Allium cepa</i> , <i>Allium sativum</i><br><i>Aloe vera</i>                                                                                                                                                                                                                                                                                                                                                                                                                                             | Leaves<br>Leaves<br>Leaves<br>Leaves                                                                                                                                            | The results showed that all five of these plants are active on MDR TB.                        |



**Figure 1:** PRISMA graph of data retrieved from various databases based on inclusion and exclusion criteria

These studies, comprising in vitro, field, and clinical designs, screened 245 plant species for anti-TB activity. Their details, including study design, country, plant species, and primary results, are shown in **Table 2**.

## Discussion

Herbal medicines treat tuberculosis (TB) worldwide, especially where conventional drugs are expensive or unavailable. About 60% of the global population relies on herbal medicines, and 61% of the 877 globally recognized drugs originate from natural-product research (41). This study reports, for the first time, 245 plant species used in different countries, with disproportionate representation from India, South Africa, Uganda, and Iran. High industrial costs, limited access to healthcare, scarcity of medicines, and cultural acceptance of traditional remedies all contribute to the widespread use of herbal medicines for TB in these regions (14, 41, 42).

Although the practice is common, the scientific evidence base for anti TB plant use is fragmented and largely preclinical. Most studies, such as those by Mpeirwe et al. (2023) and Arulmozhi et al. (2018), are in vitro and test plant extracts against *Mycobacterium tuberculosis* under controlled laboratory conditions (7, 20). For example, extracts of *Zanthoxylum leprieurii* (Uganda) have shown growth inhibition comparable to reference drugs ( $p = 0.03$ ), yet no clinical data support their efficacy in humans. To date, only 2–3 studies have included human subjects, and even these involve small cohorts (often <50 participants), which severely limits translatability and generalizability. Clinical trial data, including those evaluating *Thymus vulgaris* extracts, indicate reductions in sputum bacterial load, but these studies remain underpowered and non randomized (18). This underscores the urgent need for adequately sized randomized controlled trials (RCTs) to establish true efficacy and safety in patients.

The anti-tuberculosis activity of herbal Medicines is frequently ascribed to bioactive secondary metabolites such as flavonoids, alkaloids, and terpenoids. The mechanisms of these compounds vary with plant species and extraction solvent (aqueous or ethanolic) (13, 41). Previous studies, including those by Paul Schnitzler and colleagues, have demonstrated that plant-derived bioactive compounds can exert antimicrobial and antiviral effects through mechanisms such as membrane disruption and enzyme inhibition, supporting their potential role in anti-infective therapy (43, 44). For instance, hexadecanoic acid in *Chrysophyllum albidum* has been shown to interfere with the mycobacterial cell wall, suggesting a plausible pharmacological target (23). However, standardization of extracts—including dose, preparation method, and chemical profile—remains a major methodological challenge (13, 41). Safety data are also sparse; although some species, such as *Morella salicifolia*, have shown low toxicity in vitro, comprehensive toxicity and pharmacokinetic profiles are lacking, particularly for long term use or in multidrug resistant (MDR) TB patients (6, 31).

Several limitations affect the current body of literature. Most evidence comes from in vitro studies (12, 24). The clinical relevance of this review is limited because most included studies were preclinical and conducted in laboratory settings. In vitro antimycobacterial effects alone do not confirm effectiveness in humans, as key factors such as pharmacokinetics, tissue penetration, immune response, toxicity, and bioavailability were often not assessed. Therefore, the current evidence should be viewed as preliminary and hypothesis-

generating. There is a notable language bias toward English language publications, likely excluding valuable non English research from regions such as China and Latin America (42). The lack of large scale clinical trials and systematic toxicity assessments hinders the integration of herbal remedies into evidence based TB care (14, 41). To bridge this gap and improve global TB control, we recommend:

1. Conduct large RCTs comparing promising lead plants (e.g., *Acalypha indica*, *Capparis spinosa*) with standard regimens. Use endpoints such as sputum conversion, relapse-free survival, and quality of life (3, 5).

2. Perform in vivo assays to confirm in vitro findings and evaluate effects with anti-TB drugs (24, 31).

3. Systematic toxicity testing to quantify short and long term side effects (6, 31); and

4. Standardize plant extracts to ensure consistent dosing and comparability across studies (13, 41).

Integrating contemporary pharmacology with indigenous knowledge provides a strategic opportunity to develop cost-effective, accessible TB therapies, especially for MDR TB, which affects approximately 410,000 people each year (42). Achieving this requires both robust clinical research and rigorous public education to ensure that herbal medicines are used safely and effectively, rather than on anecdotal evidence (14, 41). Through this dual approach, herbal Medicines can become a scientifically validated element of global TB control strategies, not just an empirical alternative. A quantitative meta-analysis was not conducted due to substantial heterogeneity among the included

studies in plant species, extraction methods, outcome measures, experimental models, and study designs. Therefore, the findings were synthesized using a narrative approach. The clinical relevance of this review is limited because most included studies were preclinical and conducted in laboratory settings. In vitro antimycobacterial effects alone do not confirm effectiveness in humans, as key factors such as pharmacokinetics, tissue penetration, immune response, toxicity, and bioavailability were often not assessed. Therefore, the current evidence should be viewed as preliminary and hypothesis-generating.

### Conclusion

Herbal medicines are a valuable source of compounds with potential activity against *Mycobacterium tuberculosis*, but most of the current evidence remains based on ethnobotanical and preclinical studies. Clinical data remain limited, and variability in study methods, lack of standardization, inadequate safety assessment, and few rigorous clinical trials make firm conclusions difficult. Future research should focus on standardized extracts, detailed safety and pharmacokinetic studies, and well-designed clinical trials to better define their role in tuberculosis treatment.

### Declarations

**Conflict of interest:** None declared.

**Authors' contribution:** Z. A. M and F.H: designed the study; M. D: performed the study; H.A. M and R. M: analyzed the data. A.A wrote the

manuscript and all authors reviewed and approved the final manuscript.

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