

## Fighting drug-resistant tuberculosis with traditional medicine, a global bibliometric review (1980–2025)

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Multidrug-resistant (MDR-TB) and extensively drug-resistant tuberculosis (XDR-TB) pose a significant threat to global TB control efforts, which have made considerable gains over the past few decades. Although standard chemotherapy remains the primary mode of therapy, the long duration, toxicities and growing resistance to the drugs have led to the search for adjunct therapies. Ancient traditional medicine (TM) systems such as *Ayurveda*, Traditional Chinese Medicine, Unani, African ethnomedicine and others have previously reported treatments for respiratory ailments that are being explored for their potential benefit in treating resistant TB. This is the first worldwide bibliometric analysis of documents from the last 45 years (1980-2025) on traditional medicine for drug-resistant tuberculosis via PubMed and Scopus databases. 495 documents were bibliometrically analysed using VOSviewer software to identify publication trends, co-authorship, institutional collaboration and co-occurring keywords. The study shows a remarkable increase in publications since 2010, with India, the US and China as the frontrunners. Key journals like the Journal of Ethnopharmacology were found to be pivotal in disseminating research, although cross-country and institutional collaborations are scarce. The study reveals leads in medicinal plants and phytoconstituents showing antimycobacterial and immunomodulatory activities. But there is a need for research into mechanisms of action, standardisation and particularly rigorous clinical trials to establish the safety and efficacy. Traditional medicine holds promise as a supplement in TB control but its adoption into policy and practice needs to be careful and rigorous with evidence-based approaches and global collaboration and rigorous research methods.

**Keywords:** Bibliometric analysis, Drug-resistant tuberculosis, Ethnopharmacology, Multidrug resistance, Phytotherapy, Traditional medicine

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Tuberculosis (TB) remains one of the deadliest infectious diseases worldwide, with an estimated 10.6 million new cases and 1.3 million deaths reported in 2022 alone<sup>1</sup>. Despite global advances in diagnostics and chemotherapy, the emergence of multidrug-resistant (MDR-TB) and extensively drug-resistant tuberculosis (XDR-TB) poses a serious public health crisis<sup>2</sup>. These resistant forms threaten to undermine decades of progress, requiring longer treatment regimens, higher costs, and often leading to poorer outcomes<sup>3</sup>. The World Health Organization (WHO) has declared drug-resistant TB as a major global health emergency, urging the exploration of innovative therapeutic strategies that go beyond conventional antibiotics<sup>4</sup>.

In this context, traditional medicine (TM) has drawn growing scientific and policy attention. Systems such as

*Ayurveda*, Traditional Chinese Medicine (TCM), *Unani*, and African ethnomedicine describe numerous plants, minerals, and formulations historically employed in the treatment of respiratory disorders including *Rajayakshma* (an ancient *Ayurveda* term for TB-like conditions)<sup>5</sup>. Many medicinal plants including *Ashwagandha* (*Withania somnifera*), *Yashtimadhuka* (*Glycyrrhiza glabra*), *Rasona* (*Allium sativum*), and *Haridra* (*Curcuma longa*) have demonstrated immunomodulatory, anti-inflammatory, and antimicrobial effects in experimental or clinical studies relevant to TB pathogenesis<sup>6,7</sup>. Moreover, several phytoconstituents such as alkaloids, flavonoids, and terpenoids exhibit activity against *Mycobacterium tuberculosis*, offering leads for drug discovery<sup>8</sup>.

Over the past four decades, there has been a noticeable rise in global scientific output on the intersection of traditional medicine and drug-resistant

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TB, reflecting both the unmet therapeutic need and the increasing legitimacy of integrative approaches in public health<sup>9</sup>. However, research in this area remains fragmented, spanning ethnopharmacology, phytochemistry, microbiology, immunology, and clinical studies, with limited cross-disciplinary collaboration. Consequently, a comprehensive bibliometric analysis is essential to map the research landscape, identify key players, visualise global trends and identify gaps. Bibliometric analysis, a quantitative study of books and other literature, allows for the assessment of research productivity, citation patterns, collaboration, and research trends in a particular field<sup>10</sup>. Software such as VOSviewer helps to visualise co-authorship, institutional, co-occurrence, citation, and global collaboration networks<sup>11</sup>. While both drug-resistant tuberculosis and traditional medicine have seen an increasing amount of literature in recent years, there has not been a bibliometric integration of these two strands of research.

This research seeks to offer the first global bibliometric and visual assessment of traditional medicine research on drug-resistant tuberculosis (1980-2025) sourced from PubMed and Scopus. Using VOSviewer mapping, it examines trends in publications, key contributors, institutional and international collaborations, and research themes<sup>12</sup>. The results aim to offer insights for researchers, clinicians and policymakers, while also identifying gaps to inform strategies for future research in integrative care for drug-resistant tuberculosis. This research does not assess the clinical effectiveness or therapeutic value of traditional and complementary medicine. Rather, it uses a quantitative (bibliometric and scientometric) approach to map global research output, collaboration and theme evolution of traditional medicine in drug-resistant tuberculosis over time, offering a structural knowledge mapping overview rather than a clinical perspective. As far as we know, this is the first study to offer a broad review of traditional medicine and drug-resistant tuberculosis from a bibliometric and scientometric perspective over a long time frame. Current research mostly comprises experimental, clinical, or narrative reviews that do not provide quantitative mapping of global research patterns, collaborations and thematic shifts. Thus, the current study presents a new knowledge-mapping perspective by examining the publication trends, research hotspots, and gaps in the field.

## Materials and Methods

### Literature search

This is a bibliometric and scientometric study for quantitative mapping of research output, collaboration, citation and thematic trends, and not a clinical study for evaluating treatment efficacy. To understand the global body of literature on traditional medicine in relation to drug resistant tuberculosis, we searched for bibliographic data in two primary databases: PubMed and Scopus, from 1980 to 2025. The two data sets were searched separately to capture all relevant material from biomedical (PubMed) and multidisciplinary (Scopus) indexed scientific literature on traditional and complementary medicine for cancer supportive care. Using PubMed and Scopus offers multiple benefits. PubMed provides excellent biomedical indexing using MeSH terms and extensive coverage of health-related and clinical literature, while Scopus provides multidisciplinary indexing and comprehensive citation and collaboration information. Combining results from the two databases improves thematic mapping, addresses biases from single-database studies, and enriches interpretation and analysis of bibliometric networks. While there was expected overlap between the two databases, we used different search strategies to ensure high recall and to avoid publication bias. For PubMed, the Boolean query string was applied as, (((((((antimicrobial resistance) OR (drug resistance)) OR (multidrug resistant)) AND (tuberculosis)) OR (Mycobacterium tuberculosis)) OR (MDR-TB)) AND (traditional medicine)) OR (herbal medicine)) OR (complementary medicine)) OR (alternative medicine)). For Scopus, a refined search strategy was used with title and abstract fields as, TITLE-ABS ( tuberculosis OR "Mycobacterium tuberculosis" OR "MDR-TB" ) AND TITLE-ABS ("drug resistance" OR "multidrug resistant" OR "XDR-TB") AND TITLE-ABS ("traditional medicine" OR "herbal medicine" OR phytotherapy OR ethnomedicine) AND ("1980/01/01"[Date - Publication]: "2025/08/15"[Date - Publication]).

The aim of the search strategy was to retrieve both traditional knowledge-based and experimental studies pertinent to herbal or complementary medicines in drug-resistant tuberculosis. Bibliographic data were downloaded in CSV format and analysed using VOSviewer software (version 1.6.20) to create bibliometric maps<sup>13</sup>. This involved mapping of publication trends, co-authorship, institutional, country and keyword co-occurrence, and citation

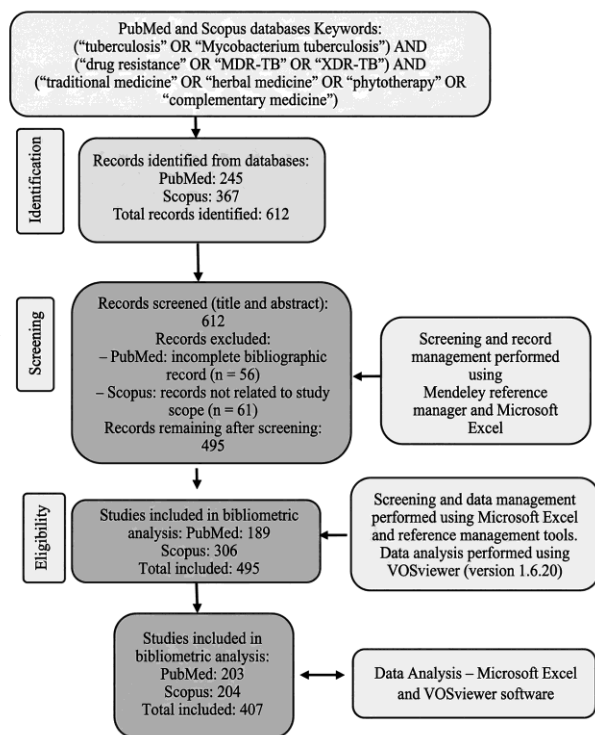


Fig. 1 —PRISMA-style flow diagram showing study selection process for bibliometric analysis of traditional medicine in drug-resistant tuberculosis (1980–2025)

clusters. The database search initially retrieved 612 publications (PubMed: 245; Scopus: 367). Following exclusion of duplicate and non-relevant articles based on title/abstract review, 495 articles (PubMed: 189; Scopus: 306) were used for the final bibliometric analysis. Publications were excluded if they did not fit the inclusion criteria, such as not being focused on drug-resistant tuberculosis, not having an association with traditional or complementary medicine, not being peer-reviewed or not having adequate bibliometric data. A PRISMA-style diagram shows the selection process for the study (Fig. 1).

#### Data cleaning and normalization

Data were extracted on 21 August 2025. Author and institutional names were standardised, and keywords were standardised via a VOSviewer thesaurus file. For the network, full counting was used with per keyword count thresholds of  $\geq 10$ , and per author or institution count thresholds of  $\geq 10$  documents. VOSviewer version 1.6.20 was used for all analyses. Data from PubMed and Scopus were processed separately, and duplicates across datasets were not removed, as they may have created artificial network connections.

#### Inclusion criteria

The criteria for inclusion were publications from 1980 to 2025 in PubMed or Scopus that explicitly mentioned tuberculosis or *Mycobacterium tuberculosis* in the context of drug resistance including multidrug-resistant tuberculosis (MDR-TB) and extensively drug-resistant tuberculosis (XDR-TB). Research that featured traditional, herbal, complementary and alternative medicine (THCAM) such as ethnopharmacology, phytotherapy and plant compounds were included. We focused solely on peer-reviewed original research articles, reviews and conference proceedings. We limited our search to English language publications, or those with English abstracts, and ensured adequate bibliometric information was available (title, author, keywords, date, and citations).

#### Exclusion criteria

We excluded records published before 1980 and after 2025, non-peer-reviewed material (magazines, blogs, newsletters or editorial notes), and articles that mentioned traditional medicine or tuberculosis only in passing without substantial discussion. Redundant records and those with missing metadata (such as authors or keywords) were excluded. Non-English language articles without English abstracts or missing bibliometric information were also removed. Research exclusively on synthetic anti-TB drugs with no mention of traditional or herbal medicine was also excluded.

#### Results

##### PubMed database

PubMed is a free, publicly accessible database maintained by the U.S. National Library of Medicine. It provides access to a vast collection of biomedical literature, including research articles, reviews, and clinical studies from trusted scientific journals worldwide<sup>14</sup>. In the present study, a total of 189 documents related to traditional medicine in the context of drug-resistant tuberculosis were retrieved from the PubMed database for the period 1980-2025 and analyzed using VOSviewer for bibliometric and visual mapping.

##### Co-authorship analysis

Figure 2, the visualization of co-authorship of PubMed-indexed publications on traditional medicine and drug-resistant tuberculosis, shows a sparse network of collaboration. Only small groups of



Fig. 2 — Author clustering in PubMed-indexed publications on traditional medicine in drug-resistant tuberculosis (PubMed, 1980–2025)

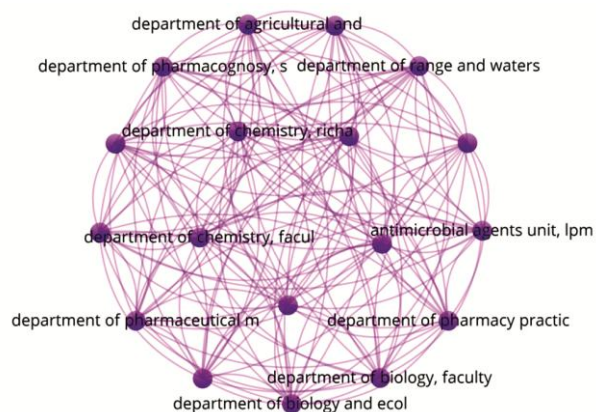


Fig. 3 — Institutional co-authorship network of PubMed-indexed publications on traditional medicine in drug-resistant tuberculosis (PubMed, 1980–2025)

connected authors were seen, the majority of the researchers being isolated nodes. One of the most successful collaborations was found between Jennifer Herrmann and Rolf Muller, which was a dyadic one. Other key contributors like Xueting Liu, Shasank S. Swain, Peter Masoko and Elvira Garza-Gonzalez were seen as individual agents without a strong connection to broader collaborative teams. This discontinuity points to the fact that, although individual scholars are working on the field, more comprehensive and interconnected patterns of collaboration have not yet emerged in PubMed-indexed literature on this topic.

#### ***Institutional collaboration based on co-authorship data***

The institutional collaboration network based on the PubMed data illustrates a comparatively well-connected network than the author-level analysis in Fig. 3. Several institutions in the form of

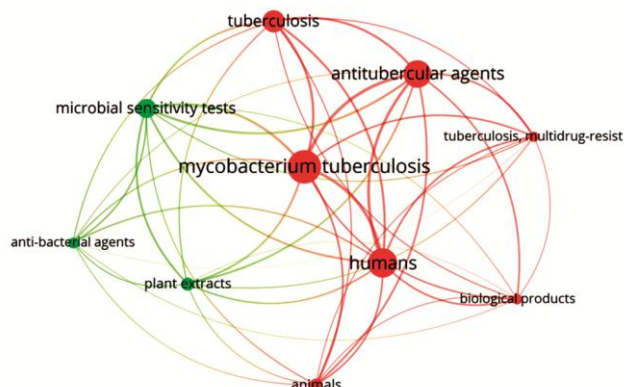


Fig. 4 — Keyword co-occurrence network of PubMed-indexed publications on traditional medicine in drug-resistant tuberculosis (PubMed, 1980–2025)

departments of pharmacognosy, chemistry, biology, pharmacy practice, agricultural sciences and antimicrobial research units emerge as the central nodes, which mean that they are actively involved in the field. The thick interconnections among these departments imply interdisciplinary cooperation in the field of chemistry, biology, pharmaceutical sciences, and applied agricultural sciences. Nonetheless, the network exhibits high intra-cluster connections, but is predominantly limited to single departments, as opposed to a wider inter-university or cross-national networks. This shows that despite the emergence of departmental level cooperation, there is still much room to enhance multi-institutional and international cooperation in order to deepen research base on traditional medicine intervention to treat drug resistant tuberculosis.

#### ***Keyword co-occurrence network***

Figure 4 is emphasized by the keyword co-occurrence analysis of PubMed data that showcases the thematic organization of the studies on the topic of traditional medicine and drug-resistant tuberculosis. Key words like *Mycobacterium tuberculosis*, *tuberculosis*, *antitubercular agents* and *humans* take centre stage in the network, which is indicative of the clinical and microbiological orientation of the literature. The close connection with such keywords as *multidrug-resistant tuberculosis* and *biological products* highlights the fact that the problem of drug resistance and therapeutic interventions continues to be topical. There was a clear group of interest around *plant extracts*, *anti-bacterial agents*, and *microbial sensitivity tests* indicating an increasing interest in natural products and their comparison with

resistant strains. The availability of both clinical descriptors (*humans, animals*) and experimental terms (*microbialsensitivity tests, biological products*) suggest that the field covers both translational research involving laboratory testing to studies with patients in the center. Broadly, what can be seen about this network is that drug-resistance is still the core theme although there is some beginning to emerge that ethnopharmacology and plant-based treatment are interacting.

#### **MeSH keyword co-occurrence network**

The co-occurrence analysis of the MeSH keywords illustrates the conceptual arrangement of the literature in PubMed indexed on traditional medicine and drug-resistant tuberculosis as depicted. The core of the network is made up of major terms like *Mycobacterium tuberculosis, humans* and *tuberculosis* that are the main clinical and microbiological interest of indexed studies. Intimately related terms such as *multidrug-resistant tuberculosis, biological products*, and *animals* highlight the clinical issues of resistance, as well as the models used in research. On the opposite side, terms such as *plantextracts, microbial sensitivity tests* and *anti-bacterial agents* create a separate cluster, indicating the input of ethnopharmacological methods and research into natural products. The dual clustering pattern identifies the overlap of mainstream biomedical research with traditional or plant-based interventions, and it is possibly a gradual adoption of alternative therapeutic strategies into the discussion on resistant tuberculosis.

#### **Scopus database**

Scopus is a comprehensive abstract and citation database maintained by Elsevier. It covers a wide range of peer-reviewed literature across science, technology, medicine, social sciences, and the arts and humanities, making it a valuable tool for academic research and literature analysis<sup>15</sup>. For the present study, a total of 306 documents related to traditional medicine in the context of drug-resistant tuberculosis were retrieved from the Scopus database for the period 1980-2025 and analyzed using VOSviewer for bibliometric and visual mapping.

#### **Co-authorship analysis**

The co-authorship analysis of Scopus-indexed literature revealed a small but clearly defined collaborative cluster. Authors including Hui-Yong Zhang, Shao-Yan Zhang, Zhen-Hui Lu, and Lei Qiu

appeared as interconnected nodes, representing a cohesive research group contributing jointly to publications in this domain. Unlike the PubMed network, where most researchers appeared as isolated entities, the Scopus dataset displayed a more concentrated collaboration pattern within a single cluster. However, the limited number of visible connections suggests that, despite the presence of active partnerships, broader multi-author and cross-institutional collaborations remain underdeveloped. This indicates that while select groups are driving contributions, there is considerable scope for expanding collaborative engagement across the wider research community.

#### **Institutional collaboration network**

The network of institutional collaboration based on the Scopus data presents a discontinuous and loosely knit network. Another organization like the Shanghai University of Traditional Chinese Medicine, Department of Physiology (Faculty level), the Epidemic Intelligence Service, and the Center of Policy Research seem to be disconnected dots without any apparent interconnections. In contrast to the PubMed database, which revealed more tightly knit departmental-level interactions, the Scopus findings indicate that the study of traditional medicine and drug-resistant tuberculosis continues to be carried out in institutional solipses of its own. This lack of serious inter-institutional or cross-regional cooperation emphasizes a significant knowledge exchange gap and the lack of coordination, which underlines the necessity of strengthening partnerships in universities, research centers, and international institutions of health.

#### **Country-wise collaboration network**

The United States and India are the top contributors to traditional medicine and drug-resistant tuberculosis research as the country collaboration network based on Scopus data indicates. India holds the leading position in the network which shows its central location in scholarly output and the United States also seems to be a chief hub with wide international connections as indicated in (Fig. 5). Smaller nodes represent moderate contributions by other countries like South Africa, China, Saudi Arabia, Brazil, Italy, Belgium, Canada and Mexico. The inter-relationship between South Africa and the United States and European countries hints at future cross-regional relationships. Nonetheless, the network also shows

that the activity of research in the world is extremely concentrated in a small number of countries, and other TB-infested areas are not actively involved as shown in (Table 1). This highlights the necessity to make international collaboration, especially with low- and middle-income nations, more vigorous to promote a more balanced and inclusive research environment. The Scopus dataset was used to conduct country-level collaboration analysis because it has more complete and standardized affiliation metadata. The same analysis with PubMed data would be able to give more comparative information and can be taken into account in the future.

#### Keyword co-occurrence network

The co-occurrence analysis of the Scopus dataset (Fig. 6) shows the conceptual terrain of the research on drug-resistant tuberculosis and traditional medicine in the world. It is highly networked around the keyword terms *tuberculosis* and *Mycobacterium tuberculosis*, which seem to be the biggest and most connected ones, meaning the overwhelmingly

microbiological and disease specifically oriented literature. Another tightly connected cluster in relation to the terms of *multidrug resistance* and *antibiotic resistance* indicates the central area of research focus on *drug resistant TB* and *antimicrobial resistance* mechanisms. Thematic cluster A specific thematic cluster is the association of *medicinal plant*, *plant extract*, and *antimicrobial activity*, and has shown a significant and increasing number of studies investigating the use of plant based and traditional treatment against resistant strains of *M. tuberculosis*. The connection of these terms with the resistance related nodes implies a growing scientific interest in the natural products as the adjuncts or the alternative anti-tubercular drug. Moreover, the inclusion of drug-associated terms like *pyrazinamide* indicates the further inclusion of the traditional pharmacological drug anti-tuberculosis in the study of resistance. On the whole, the network is characterized by a high level of thematic clustering and interconnections between the microbiological, pharmacological and



Fig. 5 — Country-wise co-authorship network of Scopus-indexed publications on traditional medicine in drug-resistant tuberculosis (Scopus, 1980–2025)

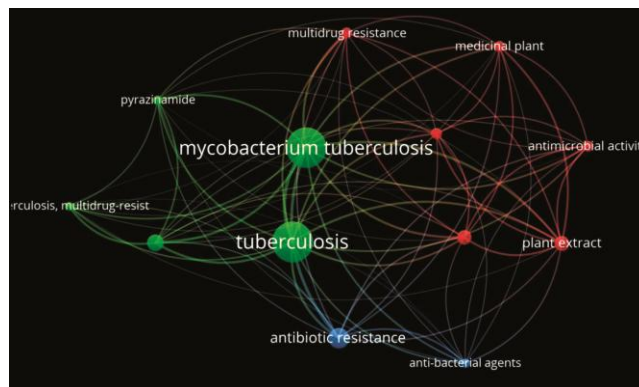


Fig. 6 — Keyword co-occurrence network of Scopus-indexed publications on traditional medicine in drug-resistant tuberculosis (SCOPUS, 1980–2025)

Table 1 — Country-wise distribution of documents, citations, and collaboration strength of traditional medicine in drug-resistant tuberculosis research (Scopus, 1980–2025)

Sr. No.	Name of Country	Number of documents	Number of citations	Total link strength
1	India	73	1767	21
2	United States	52	2517	37
3	China	35	857	9
4	United Kingdom	27	1931	23
5	South Africa	23	856	11
6	Italy	13	1628	9
7	Mexico	13	504	2
8	Saudi Arabia	12	154	11
9	Canada	11	509	12
10	Belgium	10	867	8
11	Brazil	10	81	3

plant-based areas, which evidences an increasingly interdisciplinary approach where traditional medicine and natural products are being investigated with conventional therapies to tackle drug-resistant tuberculosis.

**Top-cited articles, co-citation anchors influencing the field**

Citation analysis revealed the most frequently cited articles and authors, highlighting influential contributions to the research on fighting drug-resistant tuberculosis with traditional medicine. It also helped identify core journals and emerging focus areas within this field, reflecting growing global interest in integrating traditional remedies into tuberculosis management strategies.

The citation analysis of Scopus-indexed literature identified a set of influential publications that have shaped research on traditional medicine and drug-resistant tuberculosis. Prominent works include Travis (2006)<sup>16</sup>, Fox (2013)<sup>17</sup>, Savoia (2012)<sup>18</sup> and Cantas (2013)<sup>19</sup>, which appear as larger nodes, reflecting their high citation frequency and central role in guiding subsequent studies. Other notable contributions include Udwadia (2010)<sup>20</sup>, Das (2015)<sup>21</sup>, Imperial (2018)<sup>22</sup>, Fletcher (2015)<sup>23</sup>, Zhang (2014)<sup>24</sup> and Baker (2018)<sup>25</sup>, each of which forms part of distinct thematic clusters. The dispersed arrangement of nodes suggests that while these studies are individually influential, they belong to relatively independent research streams rather than being part of a strongly interconnected citation network. Overall, this pattern indicates that the field is built upon several landmark contributions, but lacks cohesive integration, highlighting the need for future research to bridge existing thematic gaps.

**Journal-wise publication trends**

A journal co-citation network was generated using VOSviewer on the topics of traditional medicine and drug-resistant tuberculosis research in the Scopus database between 1980 and 2025. The Journal of Ethnopharmacology seems to have been the most used and most cited journal, demonstrating its critical importance in this area of research. Ethnopharmacology, general science, and microbiology have been collaborating interdisciplinarily with other high-caliber journals like PLOS ONE and Future Microbiology. The node sizes indicate citation frequency and the connecting lines indicate the strength of the co-citation relationships. This figure of speech highlights that traditional medicine-based journals have a great

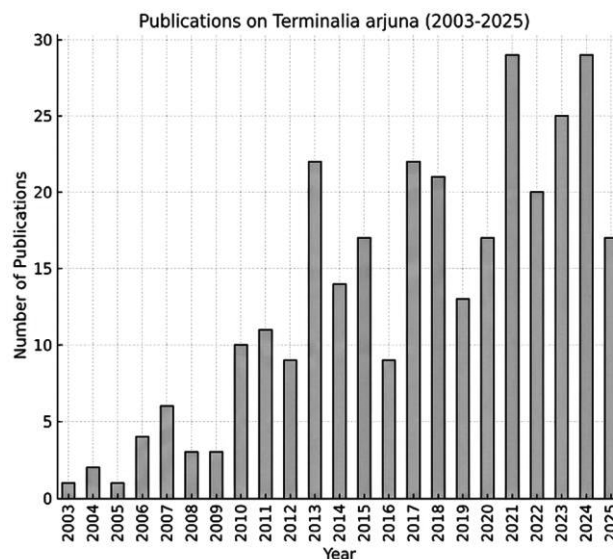


Fig. 7 — Bibliometric trends in publications in the field of traditional medicine in drug-resistant tuberculosis (Scopus, 1980–2025)

influence on the overall research environment in solving drug-resistant tuberculosis globally. Scopus data were used to perform this analysis because it has a larger coverage of citations and is appropriate in co-citation network analysis.

**Temporal trend in publications**

Scopus database gave the temporal trend in the publications on traditional medicine in the case of drug-resistant tuberculosis (1980-2025). The choice of Scopus in analysis is because it has a complex coverage and the reliable indexation of the metadata of publications that can be used in a temporal bibliometric analysis. Publications in the period between 1980 and 2002 were infrequent and few, as the world had just awakened to the issue of drug-resistant TB and the importance of traditional remedies. Since 2003, the level of research activity has started to pick up, and it has increased consistently over the 2000s. A steep increase can be observed since 2010, which is associated with an increase in global awareness about the problem of antimicrobial resistance and the emergence of the necessity to find alternative therapeutic options. The most drastic increase was observed after 2017 and the frequency of publications rose to its highest point between 2021 and 2024, which underlines the growing interest towards the traditional medicine as a possible adjunct in the management of TB as depicted in (Fig. 7).

Table 2 — Proposed research questions for advancing the integration of traditional medicine in drug-resistant tuberculosis

Sr. No.	Research focus area	Recommended research questions
1	Pharmacological Evaluation	-What bioactive compounds in traditional medicinal plants show antimycobacterial activity against drug-resistant <i>Mycobacterium tuberculosis</i> strains? -How can synergistic interactions between TM-derived compounds and existing anti-TB drugs be characterized?
2	Clinical Efficacy and Safety	-What is the clinical effectiveness of TM-based interventions when integrated with standard TB regimens? -What safety concerns, herb–drug interactions, or adverse events may arise during long-term use of TM in TB patients?
3	Mechanistic Insights	-Through which molecular pathways do TM interventions exert immunomodulatory, anti-inflammatory, or antimicrobial effects in TB management? -Can systems biology approaches elucidate multi-target mechanisms of TM formulations in TB treatment?
4	Standardization and Quality Control	-How can traditional herbal formulations be standardized for consistent potency, dosage, and purity? -What innovative analytical methods can ensure the reproducibility and safety of TM preparations used in TB?
5	Socio-cultural and Behavioral Studies	-What are patients' perceptions, acceptance, and adherence patterns toward TM-based adjunct therapies in different cultural settings? -How can community-level ethnomedical practices inform integrative TB control strategies?
6	Health Policy and Integration Models	-What policy frameworks can effectively incorporate TM into national TB programs without compromising evidence-based standards? -How can cost-effectiveness analyses support the integration of TM into resource-limited healthcare systems?
7	Global Collaborative Research	-What international collaborative models can accelerate research on TM for DR-TB? -How can traditional knowledge holders, researchers, and clinicians co-create integrative TB management protocols?

## Discussion

The overall patterns of publications in the bibliometric analysis of the 1980s to 2025 indicate a consistent and steady increase in the world research on the topic of traditional medicine in the treatment of drug-resistant tuberculosis, and a significant rise in the past decade. This is a wave of both the desperate necessity of alternative to long and more and more ineffective chemotherapy regimes, and a more general revival of interest in the systems of ethnopharmacological knowledge. The three countries, India, the United States, and China became leading contributors, highlighting their high academic and institutional investment in this field, and the fact that other high-burden regions were largely underrepresented indicates imbalanced global research involvement. Thematic clustering suggests that the bulk of literature is still dedicated to phytoconstituents, plant extracts, and immune-modulatory effects, but the translation to rigorous clinical appraisal is still in its infancy. These results imply that although the traditional medicine is starting to receive the acknowledgment of the possible use as an auxiliary method in managing tuberculosis, the areas of collaboration, mechanistic investigation, and clinical

confirmation still lack. These trends are discussed in the following discussion as they relate to the research gaps, collaboration patterns and implications to integration of traditional medicine into evidence-based TB control strategies. In (Table 2), the suggested research questions were developed based on the qualitative synthesis of the bibliometric results, such as the co-occurrence of the keywords, thematic grouping, and publication trends analysis. Priority research directions were developed based on areas with low research density, new themes and gaps found within the literature.

### Recommended research questions for scholarly study

To advance the field of publications on traditional medicine in drug-resistant tuberculosis, the research questions listed in (Table 2) shall be considered.

The research gaps summarized in (Table 3) were identified based on interpretation of bibliometric results, including thematic analysis of keywords, co-authorship patterns, and limitations observed in the existing body of literature, particularly the lack of clinical validation, standardization, and interdisciplinary collaboration.

Table 3 — Identified research gaps in the integration of traditional medicine in drug-resistant tuberculosis

Sr. No.	Category	Research gap
1	Clinical Evidence	A small number of randomized controlled trials (RCTs) to support the safety and effectiveness of traditional medicine interventions on DR-TB.
2	Pharmacological Insights	Lack of mechanistic research on bioactive plants with antimycobacterial property.
3	Integration into Health Systems	Absence of uniform guidelines and procedures to be followed in the integration of traditional medicine into national TB control strategies.
4	Drug–Herb Interactions	Limited information regarding the pharmacokinetic and pharmacodynamic interactions between conventional TB medicines and conventional remedies.
5	Quality Control & Standardization	Lack of standardization of quality assurance, dosage, and preparation of herbal preparations.
6	Socio-Cultural Acceptance	Minimal discussion of patient perceptions, cultural acceptability and adherence issues in the use of TM to treat DR-TB.
7	Global Collaboration	Minimal cross-cultural studies and research frameworks on the topic of cross-cultural knowledge exchange and cross-cultural collaborative research.
9	Policy & Regulation	Loopholes in regulatory policies, intellectual property rights and ethical systems regulating the use of TM in TB management.

### Investigation of research gap

#### *Balance & caution*

Even though bibliometric tendencies suggest an increased interest in using traditional medicine in the case of drug-resistant TB, it does not prove any therapeutic value. The majority of the studies are limited to in vitro or animal ones, and there are limited randomized controlled trials that can confirm the clinical safety and efficacy. In the absence of such validation, medical applicability should not be confused with research visibility. There are still concerns over drug-herb interactions, lack of consistency in quality control of herbal preparations and of limited mechanistic research on bioactive compounds. Subsequent developments should be subject to strict pharmacological assessments, properly structured clinical trials, and uniform methodologies to be reproducible. Such evidence-based methods are the only way to make traditional medicine findings significant as far as strategies in combating drug-resistant tuberculosis are concerned.

Collectively, the bibliometric data highlights the potential and the shortcomings of the existing research on TM in drug-resistant tuberculosis. Although the gradual rise in the number of research articles proves the increasing awareness of alternative therapeutic options, the insufficiency of high-quality clinical validation, scarcity of cross-disciplinary integration, and the not-so-good representation of the TB-endemic areas are significant obstacles. The ability to fill these gaps by engaging in global initiatives, identifying standardized approaches and strict evaluation will be essential in the translation of

traditional knowledge into effective and evidence-based interventions. Notably, this paper transcends the traditional narrative review by offering a quantitative and visual synthesis of the global research arena and thus a systematic insight of how traditional medicine research in drug-resistant tuberculosis has changed over time.

### Conclusion

This bibliometric review shows a gradual increase in the number of publications relating traditional medicine and drug resistant tuberculosis throughout the world in the last 40 years. The analysis indicates active roles of countries like India, the United States and China with the collaboration among countries increasing but disparate. The field has been influenced by core journals such as the Journal of Ethnopharmacology, interdisciplinary sources, as natural products and ethnopharmacological methods have been increasingly recognized as important in TB research. In spite of these developments, the area is still disjointed with little cross disciplinary integration and the number of high quality clinical trials being limited. Traditional medicine has given good prospects, including phytoconstituents with antimycobacterial activity, immunomodulatory formulations, but the effort to translate into evidence-based clinical practice is still in infancy. Enhancing international partnership, mechanistic investigations, and focus on rigorous clinical validation will be crucial in establishing the traditional remedies as legitimate complements in combating drug-resistant TB.

### Limitations

There are limitations to this review. First, PubMed and Scopus were limited to the bibliometric analysis, which, though comprehensive, might not be representative of research published in non-indexed or regional journals. Second, the results were limited to English-language publications that have bibliometric metadata, which may not have captured useful publications in other languages. Third, the use of bibliometric measures implied that quality, rigor, and reproducibility of the studies included could not be determined; citation frequency and co-authorship networks are measures of influence, not measures of efficacy. The analysis of country-level collaboration was restricted to the Scopus database since the metadata was structured differently; the use of PubMed-based country networks may create more comparative data in the future. The paper lacks time-based evolution and overlay analysis of keywords, which would further inform about certain trends and the change in study focus over the years. Lastly, as the research environment is rapidly changing, new or current research might not be represented in the databases yet, creating a time-lag effect.

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The authors declare that generative AI tools (e.g., ChatGPT, OpenAI) were used solely for language editing and improving readability of the manuscript. The AI tool was not used for data generation, analysis, interpretation, or development of scientific content. All outputs generated with AI assistance were carefully reviewed, verified, and edited by the authors to ensure accuracy, originality, and compliance with ethical standards. The authors take full responsibility for the integrity and content of the manuscript.

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### Author Contributions

RP: Conceptualization, methodology/study design, validation, formal analysis, data curation, writing – review and editing, visualization, AG: Writing – original draft, visualization, methodology/study design, software, DK: Writing – review and editing, visualization.

### Conflict of Interest

The author declares that there is no conflict of interest.

### Ethics Statement

This study is based on analysis of publicly available bibliographic data and does not involve human participants, animal subjects, or clinical data; therefore, ethical approval was not required.

### Data Availability

The data used in this study were obtained from publicly accessible databases (PubMed and Scopus). Processed data and analysis files are available from the corresponding author upon reasonable request.

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