

Herbal and tuberculosis in Indonesia: bibliometric analysis

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Abstract. This study explores the herbal status, grounded in Indonesia's extensive tradition of herbal medicine, to address tuberculosis. The primary aim is to elucidate the extent of herbal research in tuberculosis through a bibliometric analysis of relevant research published in Scopus databases between 1996 and 2023. The study used RStudio, complemented by the Bibliometrix package, to assess publication patterns, contributing institutions, influential authors, and keyword trends. Two hundred-one documents have been published across 138 different sources, with an annual growth rate of 13.83%, suggesting possibilities of growing interest in herbal tuberculosis research. The average number of co-authors per document is 5.65, and 21.89% of the publications involve international co-authorship, highlighting a significant level of global collaboration. Universitas Padjajaran and Airlanga are at the forefront of research in this domain, contributing significantly to the scholarly output. Noteworthy contributions by prolific authors such as Massi MN and Mertaniasih underscore the critical nodes of academic influence. Keyword co-occurrence analysis identified "mycobacterium tuberculosis," "animal experiment," and "plant extract" as central themes, highlighting a predominant focus on preclinical research and the chemical analysis of plant-based treatments.

1 Introduction

Tuberculosis (TB) remains a significant public health challenge in Indonesia, where the country ranks among the highest in the world for TB burden. According to the World Health Organization (WHO), Indonesia is one of the top four countries with the highest incidence of TB, alongside India, Bangladesh, and Nigeria, with an estimated 845,000 cases and a mortality rate of approximately 98,000 deaths annually due to the disease [1, 2]. The prevalence of TB in Indonesia is exacerbated by various socio-economic factors, including poverty, malnutrition, and inadequate healthcare access, which contribute to the persistence and spread of the disease [3, 4].

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Herbal medicine, particularly in the form of "jamu," plays a vital role in Indonesia's healthcare practices, reflecting the country's rich cultural heritage and biodiversity. Jamu, a traditional herbal remedy, has been utilized for centuries and is deeply integrated into the daily lives of many Indonesians. It is often employed for various health issues, ranging from common ailments to chronic conditions, and is recognized for its potential therapeutic benefits [5-9]. The popularity of herbal medicine is supported by the vast array of Indigenous medicinal plants available in Indonesia, which includes over 5,000 species, contributing to the country's status as a leading producer of medicinal plants globally [10, 11].

Herbal medicine has become an increasingly significant component in the management of tuberculosis (TB) in Indonesia, where traditional practices often complement modern medical treatments. The use of herbal remedies, particularly those derived from indigenous plants, reflects a long-standing cultural heritage emphasizing natural healing. In Indonesia, various plants are utilized for their purported antitubercular properties, with traditional healers often incorporating these remedies into their treatment regimens for TB patients [5, 12]. Research indicates that many herbal formulations contain bioactive compounds that may enhance immune responses and exhibit antimicrobial activity against *Mycobacterium tuberculosis*, the bacterium responsible for TB [13, 14].

Bibliometric analysis has emerged as a powerful tool in medical research, enabling scholars to quantitatively assess and visualize the landscape of scientific literature across various domains. This method employs statistical and mathematical techniques to analyze published works, providing insights into research trends, collaborations, and the impact of specific studies or journals [15]. By systematically evaluating large volumes of literature, bibliometric analysis can identify key authors, institutions, and countries contributing to a particular field, thus highlighting the global research dynamics and areas of focus [16].

In herbal medicine, bibliometric analysis has been instrumental in mapping the evolution of research trends, revealing how traditional practices are being integrated into modern medical frameworks. For instance, studies have shown that bibliometric methods can effectively track the growth of literature related to herbal treatments for various conditions, including chronic diseases and infectious diseases like tuberculosis [17]. This quantitative approach not only facilitates the identification of research hotspots but also uncovers gaps in knowledge that warrant further exploration [18].

Moreover, bibliometric analysis aids in evaluating the quality and impact of research outputs, which is crucial for funding decisions and policy-making in healthcare [19]. By providing a comprehensive overview of publication metrics, such as citation counts and journal impact factors, researchers can better understand the significance of their work within the broader scientific community [20]. As the field of herbal medicine continues to grow, leveraging bibliometric analysis will be essential for guiding future research directions and fostering collaborations that enhance the integration of traditional knowledge into contemporary medical practices [21]. Thus, this study aims to comprehend herbal research and tuberculosis in Indonesia. The study addresses the following review questions: I) How is the trend of herbal research for tuberculosis in Indonesia? II) Which authors and institutions contribute more to this topic? III) What are the key trends of this research?

2 Materials and methods

2.1 Study technique and search strategy

Fig.1. outlines a structured bibliometric workflow based on the PRISMA protocol, showcasing the systematic approach used for identifying and screening relevant literature on herbal treatments for tuberculosis. The process begins with the identification stage, where a

search query is conducted in the Scopus database using a combination of terms related to tuberculosis and herbal remedies. The initial results are filtered by language and geographic region, focusing specifically on English-language documents about Indonesia. Next, in the screening phase, the extracted documents are reviewed for relevance, with certain types of publications (e.g., reviews, conferences, book chapters) being excluded to narrow down the selection to articles that meet the study's criteria. Finally, after removing irrelevant documents, a refined set of articles remains for the bibliometric analysis. This workflow ensures a focused and comprehensive review, filtering out non-pertinent documents and maintaining only those that align with the research objectives.

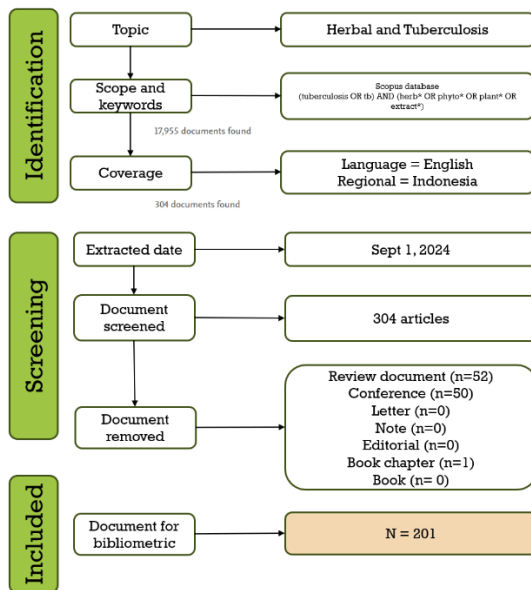


Fig. 1. Bibliometric workflow (adapted from PRISMA protocol).

2.2 Data analysis

Data analysis was executed utilizing Rstudio [22], augmented by applying Bibliometrix, a software solution devised by the Department of Economics and Statistics at the University of Naples Federico II, Italy [23]. This study comprehensively examined publication patterns, including assessing contributing countries, authors, and collaboration networks among researchers across Indonesia.

3 Results and discussions

3.1 General information

Fig.2. provides an overview of the bibliometric analysis, presenting key metrics related to publications on a specific research topic over a defined timespan. It showcases various aspects, such as the number of sources, documents, and authors contributing to the field. The analysis highlights the extent of international collaboration, showing a significant level of co-authorship across borders. It also reveals that the field experiences a healthy growth rate in new publications, with a robust average of co-authors per document, indicating a

collaborative research environment. The figure also emphasizes the diversity of author keywords used, which helps identify research trends and topics of interest. The average age of documents indicates that the field is relatively dynamic, with a moderate number of recent publications contributing to the ongoing discourse.

The high rate of international co-authorship and a substantial average number of co-authors per document suggest that research on this topic is being conducted collaboratively, often crossing geographical boundaries. This points to the global relevance of the research area. Additionally, the steady growth in publications indicates increasing interest and recognition of the importance of this field. The relatively high average citations per document highlight the impact and visibility of the research, further demonstrating its significance in the academic community. These factors collectively reflect a thriving research environment that actively contributes to advancing knowledge in the domain.

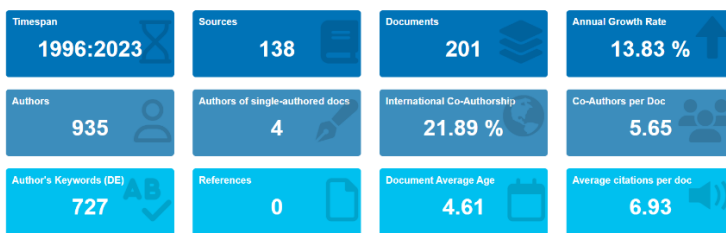


Fig. 2. General information of bibliometric results.

3.2 Trend analysis

Fig.3. illustrates the annual scientific production in the given field, showcasing the trend in the number of publications over time. The data highlights a noticeable increase in scientific output starting from the mid-2000s, with a sharp rise in the years following 2015, indicating growing interest and research activity in this domain. The line graph shows the fluctuations in the number of publications per year, with a general upward trend. The graph reflects a significant upward trend in scientific production, particularly in the last decade, suggesting that the research topic has gained substantial momentum. The growth rate, combined with the results of the Mann-Kendall and Pettitt's tests, points to the field's increasing relevance and emerging importance within the scientific community. The noticeable spike in publications after 2015 could be attributed to heightened global awareness or advancements in the studied area. The increasing trend suggests that this topic will likely continue attracting academic attention, which can result in more collaborative research efforts, funding, and innovations shortly.

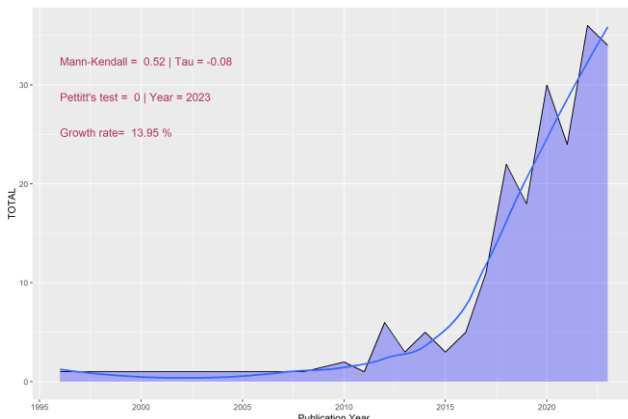


Fig. 3. Annual scientific production.

3.3 Author productivity analysis

Fig.4 illustrates the top 10 most productive authors based on their total and fractionalized publication outputs in the field. The authors are ranked according to the number of documents they have contributed, with fractionalized values indicating the proportion of their contributions to collaborative works. The top three most productive authors are highlighted in blue, signifying their prominence in the research area, while the remaining authors are marked in gray. This provides a clear visual representation of individual research contributions within the domain. The presence of highly productive authors suggests that a small group of researchers is driving much of the progress in this field. The fractionalized scores further indicate the level of collaboration among these researchers, with the top contributors participating extensively in joint projects. This trend toward collaboration, particularly among the top-ranked authors, highlights the importance of teamwork in advancing knowledge in this domain. Additionally, the dominance of a few key individuals suggests the possibility of leadership or expertise concentration in certain areas of the research, which could have implications for research direction and policy-making within the field.

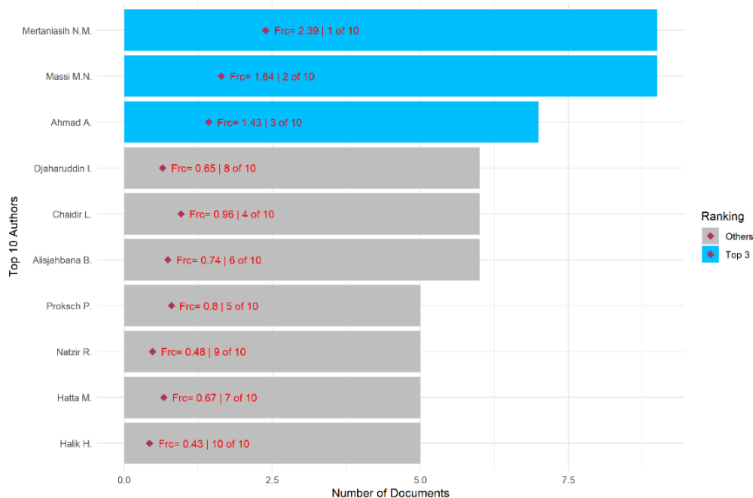


Fig. 4. The most productive authors (total and fractionalized publication).

Fig.5 displays the publication trends of the most productive authors over time, visualizing the number of published articles and the citations they received annually. The size of the circles corresponds to the number of articles published, while the color intensity indicates the number of citations per year. Authors with consistent contributions and higher citation rates are visually distinguishable, showcasing their productivity and impact over time. The figure highlights the variability in research activity among the top authors, with some showing sustained contributions over many years while others have emerged more recently. Notably, certain authors have a higher citation rate, suggesting that their work has garnered significant attention within the research community. This pattern of consistent contributions, coupled with high citation counts, reflects these authors' lasting impact and influence in the field. The data also indicates periods of increased research output, possibly aligning with advancements in the field or shifts in research priorities, which can provide insight into the evolution of research trends over time.

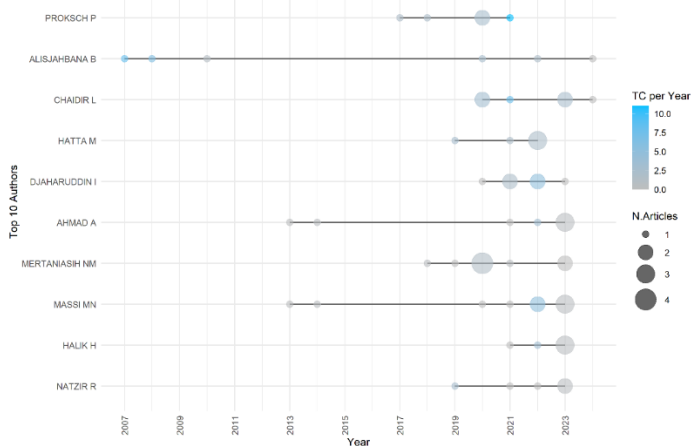


Fig. 5. The most productive authors over time.

3.4 Affiliation analysis

Fig.6 illustrates the most productive universities based on their total number of publications and citations. The top three universities are highlighted, showing their prominence in research output. Red diamonds indicate each university's total number of citations, offering a comparative view of their academic impact relative to their document count. The figure reveals that certain universities, particularly the top-ranked ones, have produced many documents and received high citation counts, indicating a strong influence in the field. This suggests that these institutions are leaders in generating impactful research. Universities such as Universitas Airlangga, Universitas Padjadjaran, and Universitas Gadjah Mada play a central role in advancing knowledge in the area through volume and influence. On the other hand, some universities with fewer publications still achieve notable citation counts, reflecting the high quality or importance of their research. This highlights the importance of quantity and quality in academic output and the role of institutional reputation and research focus in driving citations and influence.

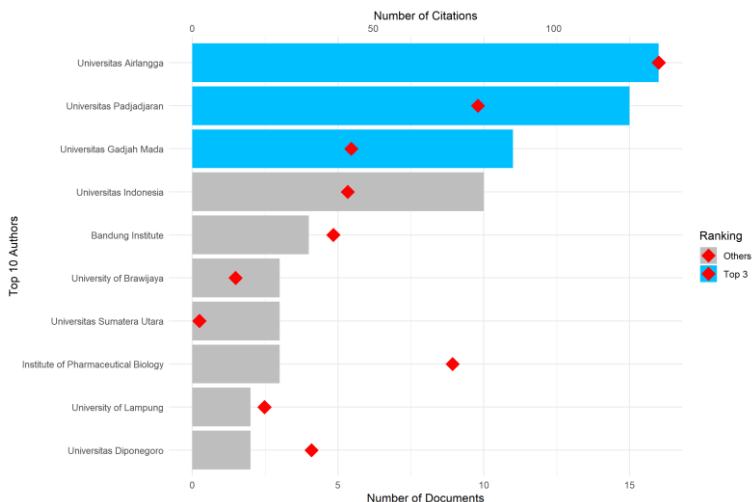


Fig. 6. The most productive university (Total document and Citation); red diamond represents total citations.

3.5 Structure analysis

Fig.7 presents a co-occurrence network of key terms related to herbal treatments and tuberculosis in the bibliometric analysis. Nodes represent keywords; the lines connecting them indicate co-occurrences in the same documents. The size of the nodes reflects the frequency of occurrence, while the colors group related terms into clusters, showing the relationships between topics and concepts within the field. The co-occurrence network highlights the centrality of key terms such as "mycobacterium tuberculosis" and "controlled study," indicating that much of this area focuses on clinical trials or controlled studies of herbal remedies against tuberculosis. The network also suggests that topics related to human subjects, such as "male" and "female," are prominent, reflecting the focus on demographic studies in tuberculosis research. The connections between "plant extract" and "antimicrobial activity" suggest significant interest in the efficacy of herbal compounds in combating tuberculosis. Moreover, the distinct clustering of related terms implies specialized research niches within the broader field, such as specific herbal treatments or clinical methodologies. This network analysis demonstrates how different research areas are interconnected and may guide future studies toward underexplored or emerging areas within the field.

3.6 Limitations and future research directions

Despite the comprehensive nature of this bibliometric analysis, several limitations should be acknowledged. First, the study's reliance on a single database (Scopus) may have excluded relevant publications indexed in other databases, such as Web of Science, PubMed, or Google Scholar. This could lead to a limited view of the overall research landscape, as publications exclusive to those databases may present different trends or essential contributions not captured here. Additionally, the analysis focused on documents published in English and within a specific regional context (Indonesia), which may have inadvertently excluded valuable research from other languages or regions. This could skew the interpretation of international collaboration or global trends. Lastly, while helpful in identifying key terms and research clusters, the co-occurrence network analysis needs to capture the depth of the relationships between the terms. The connections identified are based on mere co-occurrence in documents, which may not fully reflect the intricacies or nuances of the research topics.

Future research could benefit from several approaches to build on the current findings. First, expanding the scope of the analysis to include other databases, such as PubMed or Web of Science, would provide a more holistic understanding of the global research landscape on herbal treatments for tuberculosis. Additionally, incorporating studies published in languages other than English could offer valuable insights into region-specific research and traditional medicinal practices that may need to be more widely disseminated in the international community. Future bibliometric analyses could also focus on tracking the evolution of clinical outcomes associated with herbal treatments, mainly through more granular metrics such as clinical trial success rates, patient outcomes, or specific herbal formulations. Furthermore, longitudinal studies examining shifts in research priorities or emerging topics within the field—perhaps through trend analysis of funding or patent data—would provide deeper insights into the trajectory of this research area. Lastly, exploring the policy implications of this research, especially about healthcare systems and the integration of herbal medicine into standard tuberculosis treatment protocols, could be a valuable direction for future work.

4 Conclusion

This bibliometric analysis provides a comprehensive overview of research trends, productivity, and collaboration patterns in herbal treatments for tuberculosis. The results highlight this research domain's dynamic and rapidly growing nature, with significant contributions from various countries and institutions, mainly from Indonesia and a few key universities. Over time, the increase in publications and citations reflects the growing academic and clinical interest in exploring alternative treatments for tuberculosis using herbal compounds. The analysis also underscores the importance of international collaboration, as evidenced by the high rate of co-authorship across borders. This suggests that research in this field is global and that collaborative efforts may be crucial in advancing the development and validation of herbal treatments for tuberculosis. Key research areas, such as "mycobacterium tuberculosis" and "controlled studies," form the core focus of many studies, with significant attention also given to plant extracts' efficacy and antimicrobial activity. While the findings are promising, they also reveal the need for more diverse regional contributions and a broader scope of research methodologies. The study's limitations, such as the reliance on a single database and language bias, indicate that there may be untapped research and insights in other regions and languages. Nonetheless, this analysis serves as a solid foundation for understanding the current landscape and future research potential in herbal treatments for tuberculosis. The future of this field holds considerable promise, especially with a continued focus on international collaboration and a multidisciplinary approach that includes clinical,

pharmacological, and ethnobotanical perspectives. As this area continues to evolve, it is essential to consider the scientific developments and the policy implications for integrating herbal medicine into tuberculosis treatment regimens globally.

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