

Herbal medicine and leptospirosis in Southeast Asia: a comprehensive bibliometric analysis (1973-2023)

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Abstract. This study provides a bibliometric analysis of research on herbal medicine and leptospirosis in Southeast Asia from 1973 to 2023. The investigation identified 3,043 documents through a systematic search in the Scopus database using keywords. One hundred forty-seven papers were published across 100 different sources, revealing an annual growth rate of 6.07%, indicating a growing interest in the intersection of herbal medicine and leptospirosis. The study shows significant collaboration, with 935 authors contributing to the body of research and an average of 7.55 co-authors per document. Notably, 40.14% of the publications involve international co-authorship, reflecting the global relevance and collaborative efforts in addressing leptospirosis through herbal remedies. Keyword analysis highlights "leptospirosis," "leptospira," and "DNA extraction" as central themes, demonstrating a focus on the genetic and diagnostic aspects of the disease alongside the exploration of plant-based treatments. The research also emphasizes the role of preclinical studies and the chemical analysis of herbal remedies for leptospirosis. The study identifies key contributors to the field, with prolific authors such as Chee HY, Sekawi Z, and Patarakul K leading the research efforts. Malaysia, Thailand, and Japan are highlighted as the most productive countries, significantly contributing to this domain's research output and citation impact.

1 Introduction

Leptospirosis represents a significant public health burden in Southeast Asia, characterized by high morbidity and mortality rates. The disease is endemic in several countries, including Malaysia, Thailand, and Indonesia, with reported incidence rates exceeding 39 cases per 100,000 population in Indonesia alone [1]. The Global Burden of Disease Study estimates that leptospirosis accounts for approximately 1.03 million yearly cases. Southeast Asia is particularly affected due to its tropical climate and socio-economic conditions [2]. The prevalence of the disease is exacerbated by environmental factors such as heavy rainfall and

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flooding, which facilitate the transmission of the pathogen *Leptospira* through contaminated water sources [3].

Current treatment for leptospirosis primarily relies on antibiotics such as doxycycline and penicillin. However, the limitations of doxycycline arise in severe cases of leptospirosis, where the need for more aggressive treatment regimens, including intravenous antibiotics like penicillin or ceftriaxone, becomes critical [4]. Furthermore, doxycycline's effectiveness may be compromised in cases of co-infection with other pathogens, necessitating a more comprehensive treatment approach [5, 6]. Furthermore, the rise of antimicrobial resistance (AMR) poses a growing threat to the efficacy of these antibiotics, particularly in resource-limited settings where diagnostic facilities are inadequate. The lack of affordable, widely accessible alternative therapies highlights an urgent need for innovative treatment strategies. In this context, herbal medicine has emerged as a complementary approach, offering potential solutions grounded in traditional knowledge and natural bioactive compounds. Southeast Asia's rich biodiversity and cultural heritage in traditional medicine provide a fertile ground for exploring herbal remedies. Often cost-effective and culturally accepted, these therapies hold promise for addressing the limitations of current treatment modalities for leptospirosis. However, further research is needed to validate their efficacy and safety, mainly through clinical trials and interdisciplinary studies.

Herbal medicine practices in Southeast Asia are deeply rooted in the region's rich cultural and biological diversity, reflecting a long-standing tradition of utilizing local flora for therapeutic purposes. These practices encompass a wide range of herbal remedies derived from various plants, which are employed to treat numerous ailments, from common colds to chronic diseases [7-9]. For instance, plants such as *Nelumbo nucifera* (lotus) are recognized for their astringent properties and are commonly used in traditional medicine systems across Southeast Asia [10]. Similarly, *Cosmos caudatus* and *Averrhoa bilimbi* have been identified as significant sources of bioactive compounds, contributing to their use in functional drinks aimed at managing diabetes and hypertension [11].

Herbal medicine has emerged as a complementary approach to managing leptospirosis, particularly in Southeast Asia, where traditional practices are deeply ingrained in the culture. The antibacterial properties of various herbal extracts have been investigated for their potential efficacy against *Leptospira interrogans*, the causative agent of leptospirosis. For example, a study demonstrated that the methanolic extracts of *Momordica charantia*, *Cassia alata*, and *Allium sativum* exhibit significant antibacterial activity against *Leptospira interrogans* serovar Manilae, with minimum inhibitory concentrations (MICs) that suggest their potential use in treatment [12]. Additionally, *Boesenbergia rotunda*, a herb traditionally used in Indian medicine for treating fevers, has also demonstrated promising antibacterial effects, with MICs ranging from 62.5 to 125 µg/mL, indicating its potential as an adjunct therapy for leptospirosis [12].

The bibliometric analysis of herbal medicine reveals a growing body of literature that underscores its significance in traditional and modern healthcare systems. A notable study by Delima et al. highlights the patterns of herbal medicine prescriptions by medical doctors in Indonesia, indicating that herbal remedies are frequently used with conventional treatments for various health problems [13]. This trend is echoed in research conducted by Utomo et al., which emphasizes the widespread use of herbal medicines among patients with type-2 diabetes mellitus in Indonesia, citing benefits such as lower side effects and greater cultural acceptance [14]. Furthermore, bibliometric analysis provides valuable insights into the quality and impact of research outputs, which are critical for making funding and policy decisions in healthcare [15]. By analyzing publication metrics like citation counts and journal impact factors, researchers gain a clearer understanding of the relevance of their work within the broader scientific community [16]. As the field of herbal medicine expands, leveraging bibliometric analysis will be vital in shaping future research directions and fostering

collaborations that enhance the integration of traditional knowledge into contemporary medical practice [17]. Therefore, this study aims to conduct a comprehensive bibliometric analysis of research on herbal medicine and leptospirosis in Southeast Asia, focusing on identifying publication trends, leading contributors, collaboration networks, and research themes. The primary hypothesis is that the growing interest in herbal remedies reflects an increasing recognition of their potential to address the limitations of conventional treatments for leptospirosis, particularly in regions with high disease burdens and limited healthcare access. This analysis is necessary to map the evolution of research in this field, highlight key knowledge gaps, and guide future investigations toward more targeted and impactful studies. By identifying influential authors, institutions, and trends, the study is expected to provide valuable insights into how herbal medicine can be better integrated into modern medical practices, particularly for managing infectious diseases like leptospirosis. Ultimately, these findings aim to foster interdisciplinary collaboration and inform policymakers on the potential role of herbal remedies in complementing existing treatment strategies.

2 Materials and methods

2.1 Study technique and search strategy

Fig.1 denotes a bibliometric workflow adapted from the PRISMA protocol to analyze publications related to herbal treatments for leptospirosis. A search was conducted in the Scopus database using relevant keywords and filters, resulting in 3,043 documents. After applying language (English) and regional (Southeast Asia) restrictions, 170 papers were selected. Following a screening process that removed non-relevant document types such as reviews, conferences, letters, notes, and book chapters, a total of 155 documents were included for bibliometric analysis. The final dataset provides a focused collection of research relevant to the intersection of herbal treatments and leptospirosis.

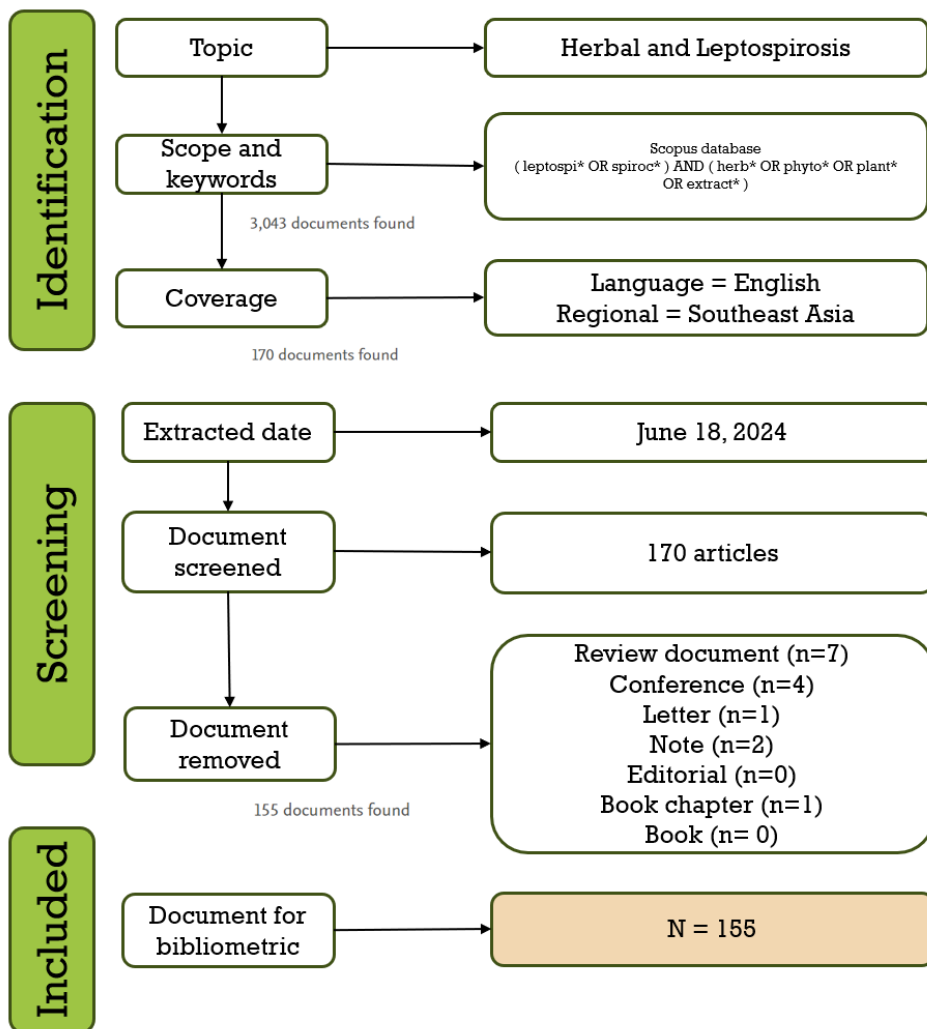


Fig. 1. Bibliometric workflow (adapted from PRISMA protocol).

2.2 Data analysis

The data analysis was conducted using RStudio [18], enhanced by the application of Bibliometrics, a software tool developed by the Department of Economics and Statistics at the University of Naples Federico II, Italy [19]. This study thoroughly analyzed publication trends, focusing on key aspects such as contributing countries, authors, and collaboration networks among Southeast Asian researchers.

Collaboration metrics were assessed by analyzing the co-authorship patterns within the dataset. The number of authors per document and the ratio of single-country publications (SCP) to multi-country publications (MCP) were used to measure the extent of domestic and international collaboration. A high co-authorship rate and MCP percentage indicate the involvement of multidisciplinary teams and global cooperation, which are critical for addressing complex research topics like herbal treatments for leptospirosis. These metrics were visualized through network maps, where nodes represent authors or countries, and edges

represent collaborative links, providing insights into the strength and frequency of partnerships [19].

Citation analysis evaluated the academic impact and influence of research outputs. Citation counts were aggregated for individual authors, institutions, and countries to identify the most impactful contributors. Metrics such as total citations (TC) and citations per document (CPD) were used to determine the influence of specific studies or regions. High citation counts signify the relevance and recognition of research, while the average CPD provides a normalized measure of impact across publications. Fractionalized publication scores, which distribute credit among co-authors based on their contributions, were also calculated to give a nuanced view of individual authors' contributions [1].

Keyword co-occurrence analysis was performed to identify the thematic structure and emerging trends within the field. Keywords from article titles and abstracts were extracted and analyzed for frequency and co-occurrence patterns. Co-occurrence networks were created to visualize clusters of related terms, where the proximity and thickness of connections represent the strength of their association [12]. For instance, frequent connections between terms such as "leptospirosis," "antibacterial activity," and "herbal medicine" highlight central research themes, while isolated clusters may reveal niche or underexplored areas. These clusters were interpreted to understand the field's multidisciplinary nature and identify potential directions for future research [19].

3 Result and discussion

3.1 General information

Fig.2. The bibliometric analysis from 1973 to 2023 revealed a steady increase in research on herbal treatments for leptospirosis, with a 6.07% annual growth rate. The high co-authorship rate (7.55 authors per document) and significant international collaboration (40.14%) suggest that this topic requires diverse expertise and global cooperation. The relatively young average document age of 6.5 years, combined with 16.07 citations per document, indicates that this field is actively developing and drawing attention. The presence of only one single-authored document suggests that this area of research is complex, often necessitating team efforts for comprehensive studies.

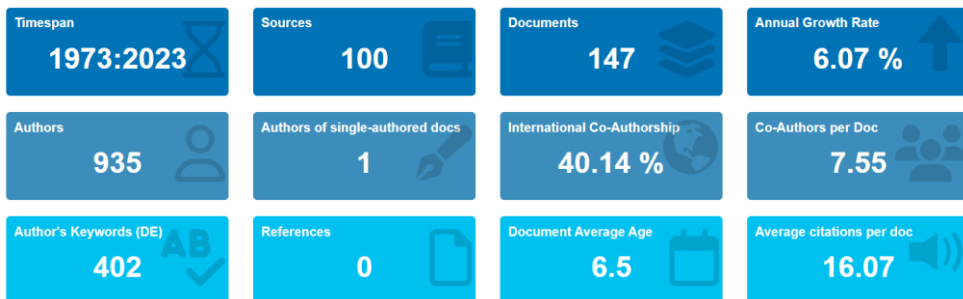


Fig. 2. General information of bibliometric results.

3.2 Trend analysis

Fig.3. illustrates that the annual scientific production of herbal treatments for leptospirosis shows a significant increase, particularly after 2010, with a notable spike in recent years. The growth rate of 6.07% indicates accelerating research activity in this area. The Mann-Kendall test value of 0.47, with a slight negative Tau (-0.08), suggests that while there is an upward trend, some fluctuations occur over time. Pettitt's test places a breakpoint in 2023, marking it a pivotal year for heightened research focus. The sharp rise in publications could be attributed to increased awareness of the health impacts of leptospirosis, advancements in herbal medicine, or a growing interest in alternative treatments, reflecting global efforts to explore natural remedies for infectious diseases.

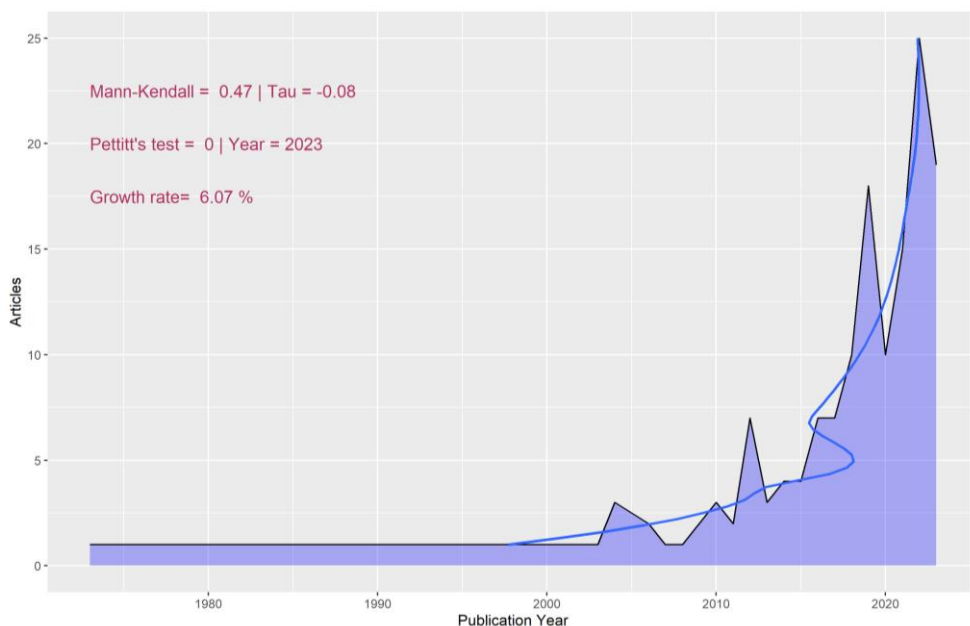


Fig. 3. Annual scientific production.

From a practical perspective, this upward trend has several implications. First, it demonstrates a growing body of evidence supporting herbal medicine's potential to complement conventional leptospirosis treatments. This surge in research may help address the urgent need for cost-effective and accessible therapies, particularly for resource-limited settings where leptospirosis poses a significant public health burden. Second, the increasing scientific output reflects a collaborative global effort to explore natural remedies, aligning with broader trends in sustainable healthcare and integrating traditional knowledge into contemporary medical systems [20]. The peak in 2023 also signals a call to action for researchers, policymakers, and funding agencies. With the rising volume of research, it becomes imperative to prioritize translational studies that move beyond laboratory investigations and preclinical models to clinical trials and real-world applications [21]. Additionally, fostering interdisciplinary collaborations that integrate ethnobotanical studies, pharmacology, and epidemiology will be essential for developing effective and safe herbal treatments. This can help bridge the gap between experimental findings and practical implementations, benefiting populations at risk of leptospirosis.

3.3 Author productivity analysis

Fig.4 displays the analysis of the top 10 most productive authors in research on herbal treatments for leptospirosis, reveals significant contributions from individuals, and highlights the collaborative nature of this field. Chee HY emerges as the leading contributor, with the highest fractionalized publication (Frc) score of 1.262, signifying a substantial role in advancing the research landscape. Authors such as Phulsuksombati D and Sekawi Z demonstrate notable influence with Frc scores of 1.01 and 0.841, respectively, underscoring their active engagement in collaborative studies. The fractionalized publication (Frc) score provides a more nuanced perspective by accounting for shared authorship, reflecting the importance of individual expertise and teamwork in this domain. The varied Frc scores combined with the number of total documents highlight a balance between authors with prolific individual contributions and those deeply involved in collaborative research efforts. This pattern suggests that addressing complex challenges like leptospirosis treatment requires both key researchers' leadership and multidisciplinary teams' input. Authors with high Frc scores, such as Chee HY and Sekawi Z, likely play pivotal roles in shaping research direction, fostering collaborations, and driving impactful studies.

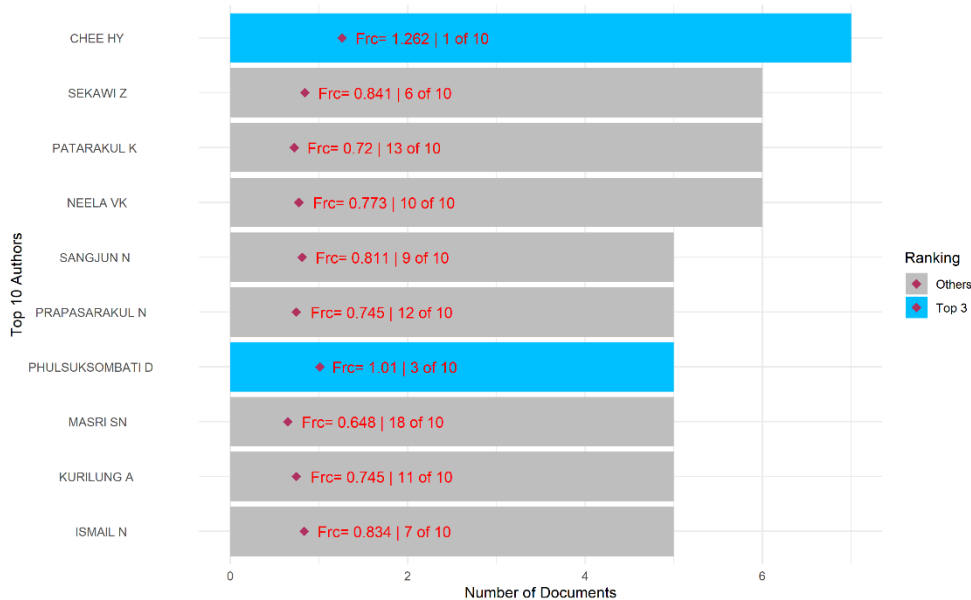


Fig. 4. The most productive authors (total and fractionalized publication).

From a practical standpoint, this analysis provides insights into potential leaders and institutions that could serve as hubs for future collaborations in this field. By identifying these influential contributors, researchers and funding agencies can strategically engage with key players to accelerate advancements in herbal medicine for leptospirosis [22]. Furthermore, the prominence of certain authors indicates areas of established expertise, which could guide new researchers in identifying mentors or institutions aligned with their interests [23, 24].

Fig. 5 presents the analysis of the top 10 authors over time, demonstrating fluctuating productivity and impact in research on herbal treatments for leptospirosis. Authors Sekawi Z and Philip N stand out for their significant contributions, with the highest total citations (TC) per year, particularly during 2019 and 2020. This prominence is visually represented by the more prominent and darker blue circles, indicating a higher volume of publications and a more significant impact during this period. These peaks suggest focused research activity that may have been driven by specific projects or increased attention to herbal medicine as a complementary treatment for leptospirosis during these years. Conversely, authors like Kurilung A and Masri SN contributed multiple articles but achieved a lower citation impact, as indicated by smaller and lighter bubbles. This variation underscores the diverse roles authors play in the research ecosystem, with some focusing on foundational studies or niche areas that may still need to garner widespread attention.

The temporal variation in citation impact and publication volume reflects shifts in research activity and influence across the years. It may also highlight emerging trends or collaborative efforts that align with broader global or regional priorities in healthcare and infectious disease management. For example, periods of heightened productivity could correspond to increased funding, interdisciplinary collaborations, or new findings that drive interest in the field. These insights have practical implications for guiding future research. Identifying the authors with consistent contributions and high impact can help establish potential leaders for collaborative efforts and provide direction for researchers entering this domain [20]. Additionally, analyzing these temporal trends allows stakeholders to pinpoint periods of significant advancement, which can inform strategic planning for future studies, particularly those focusing on underexplored herbal remedies or regions.

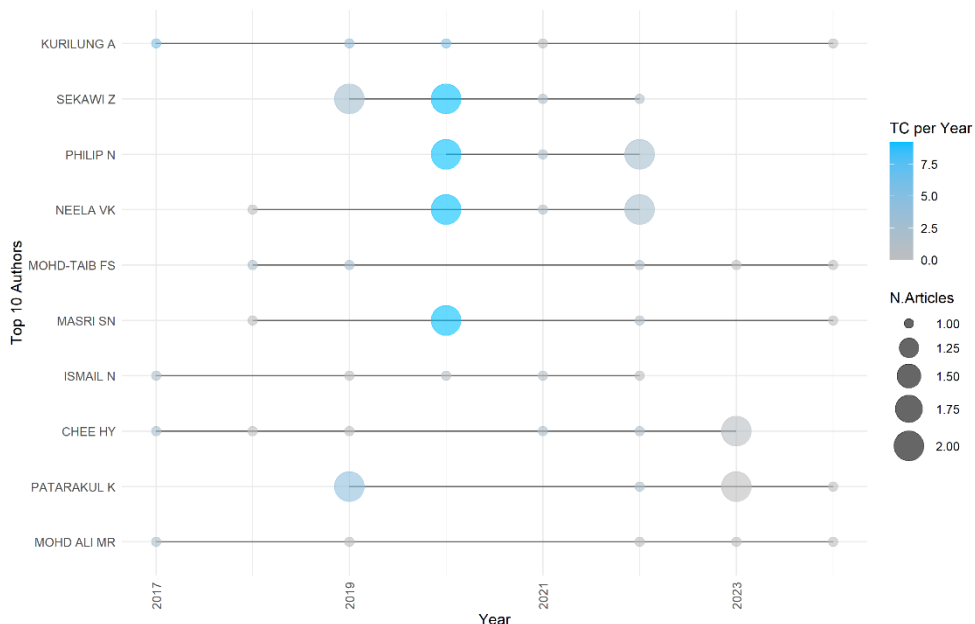


Fig. 5. The most productive authors over time.

3.4 Country analysis

Fig. 6 illustrates that the country analysis highlights Malaysia and Thailand as the most productive contributors to research on herbal treatments for leptospirosis, with Malaysia leading in both the number of documents and citations (over 600) and Thailand following

closely with over 500 citations. This significant output underscores the pivotal role of these countries in advancing the field, likely driven by their local endemic conditions, which necessitate focused research, and their rich traditions in herbal medicine. Combining single-country publications (SCP) and multi-country publications (MCP) in these countries reflects strong domestic research capacity alongside active international collaboration.

Japan, Australia, and the USA also make notable contributions, though their output and citation counts are comparatively lower. These countries' involvement suggests an international recognition of the relevance of herbal treatments for leptospirosis and indicates a willingness to collaborate on addressing this global health challenge. MCPs in these regions further emphasize the importance of interdisciplinary and cross-border cooperation in tackling complex diseases like leptospirosis. The high citation counts for Malaysia and Thailand highlight their research leadership and signal their studies' practical relevance and quality. This focus may stem from these countries' geographic and socio-economic context, which includes frequent leptospirosis outbreaks and a reliance on traditional medicine as a complementary healthcare approach. By leveraging their natural biodiversity and cultural knowledge, researchers in these regions have likely explored innovative herbal remedies that resonate with local and global scientific communities.

From a strategic perspective, these findings suggest opportunities for other countries, particularly Southeast Asian countries with similar endemic conditions, to build on the frameworks established by Malaysia and Thailand. Enhancing regional collaborations and knowledge sharing could amplify research outputs and contribute to developing accessible and culturally relevant treatment options. Additionally, increased involvement from countries with advanced research infrastructure, such as the USA and Australia, could support capacity building and drive translational research to bring herbal treatments into practical applications.

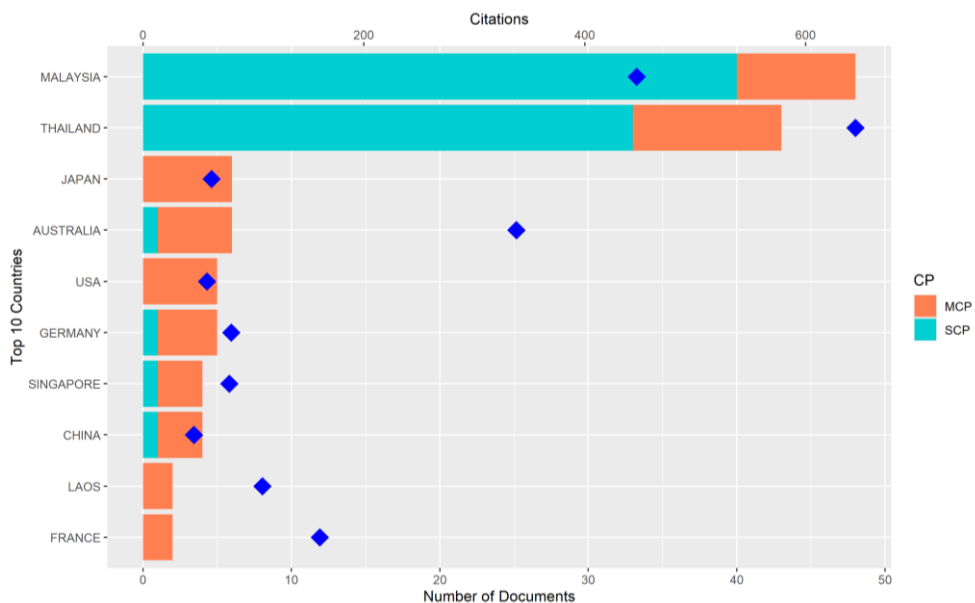


Fig. 6. The most productive country (total document and citation); blue diamond represents total citations.

3.5 Structure analysis

Fig.7 reveals that the co-occurrence network of keywords in herbal treatments and leptospirosis research reveals a complex structure, with several distinct clusters reflecting diverse focus areas within the field. Central and frequently occurring terms such as "leptospirosis," "article," and "uncontrolled study" dominate the network, highlighting their foundational importance in the research landscape. These central nodes are highly interconnected with other keywords, signifying their relevance across various subfields, including clinical studies, experimental research, and epidemiological assessments.

The clusters within the network provide deeper insights into the thematic organization of research in this domain. For example, one cluster emphasizes human studies and uncontrolled trials, suggesting ongoing exploration of clinical applications and challenges in designing controlled studies for herbal treatments. Another cluster focuses on animal models, which serve as a critical step in preclinical research for evaluating the efficacy and safety of herbal remedies against *Leptospira*. Additional clusters explore specific interventions and epidemiological perspectives, highlighting efforts to understand disease dynamics and integrate herbal medicine into broader public health strategies.

The dense connections between terms in the network underscore the multidisciplinary nature of research on herbal treatments for leptospirosis. These interconnections suggest active collaboration among fields such as microbiology, ethnobotany, pharmacology, and public health. This multidisciplinary approach is essential for addressing leptospirosis treatment's complexities, which requires scientific validation of herbal remedies and practical integration into healthcare systems. The structural insights gained from this analysis have practical implications. Identifying underexplored clusters or isolated nodes could guide future research to address knowledge gaps and foster innovation [25, 26]. For instance, terms with sparse connections may indicate areas where more studies are needed, such as specific herbal compounds or regional epidemiological patterns. Additionally, the interconnectedness of keywords highlights opportunities for

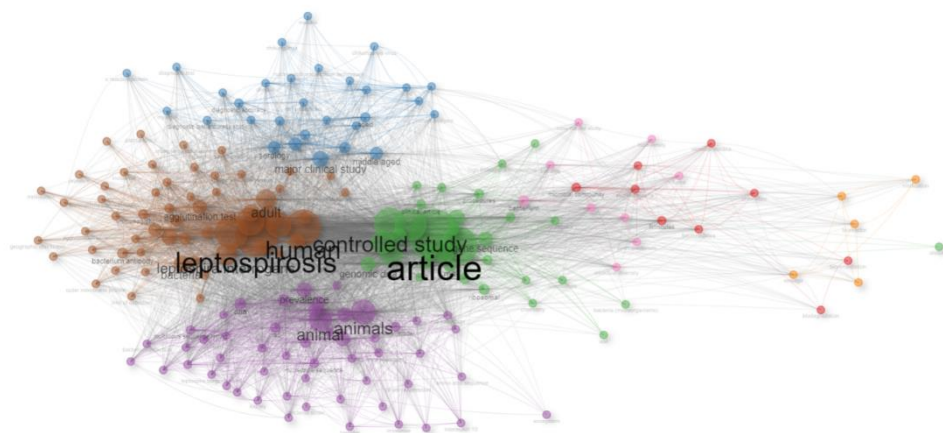


Fig. 7. Co-occurrence network of herbal and leptospirosis bibliometric.

The results of this bibliometric analysis highlight the growing attention to herbal treatments for leptospirosis, particularly in Southeast Asia, where the disease burden and the use of traditional herbal medicine are prevalent [1-3]. The increase in scientific output, especially after 2010, underscores a rising global interest in exploring alternative treatments for infectious diseases, likely driven by the limitations of conventional therapies and the

increasing incidence of antimicrobial resistance. The rapid publication growth may also reflect enhanced research infrastructure in Southeast Asia, where countries like Malaysia and Thailand have emerged as leaders in scientific contributions and citation impact. These countries likely benefit from their unique position as regions where leptospirosis is endemic, coupled with a strong tradition of herbal medicine, providing both the need and the resources to investigate natural remedies. The author and country analyses further underscore the collaborative nature of research in this field. The high co-authorship rates and significant international collaborations suggest that tackling leptospirosis with herbal treatments requires multidisciplinary expertise, combining microbiology, ethnobotany, and clinical medicine. Authors like Chee HY and institutions in Malaysia have contributed significantly to advancing this area of research, as indicated by their high fractionalized publication scores and citation counts. This pattern may reflect concentrated efforts within certain academic or research institutions that are well-positioned to lead in discovering and disseminating herbal treatments.

The co-occurrence network analysis reveals the complexity and breadth of research on herbal treatments for leptospirosis. The interconnectedness of keywords such as "leptospirosis," "article," and "uncontrolled study" highlights the multidisciplinary nature of the research, drawing on clinical trials, animal studies, and epidemiological assessments. The diversity in research focus—from laboratory-based studies on the antibacterial properties of herbs to field studies addressing disease transmission—illustrates how research on herbal medicine spans multiple domains. This network also suggests the potential for future collaboration and integration of diverse research methodologies, which could help overcome current limitations in leptospirosis treatment. Overall, the increasing scientific production, collaboration across borders, and the rich cultural backdrop of herbal medicine in Southeast Asia all contribute to the promising future of research in this field. Bibliometric analyses such as this will be essential in identifying gaps, directing future research efforts, and fostering the integration of traditional knowledge into modern medical practices [19].

This bibliometric analysis provides a fresh perspective on the intersection of herbal medicine and leptospirosis, a niche area with limited prior exploration in bibliometric studies [23, 27]. While previous bibliometric analyses have often focused on broader topics, such as herbal medicine's application in various diseases or general trends in infectious disease research, this study uniquely addresses the integration of traditional herbal remedies specifically for leptospirosis, a neglected tropical disease with significant public health implications. By narrowing its focus to this intersection, the study contributes novel insights into a field that remains underrepresented in the scientific literature.

Unlike general bibliometric studies that emphasize overarching trends in herbal medicine or antimicrobial resistance, this analysis identifies specific thematic clusters, such as human studies, animal models, and the chemical analysis of herbal remedies for *Leptospira*. These findings highlight a critical gap in translational research, as many studies remain preclinical. Comparatively, previous bibliometric studies in herbal medicine have often concentrated on conditions like diabetes, cancer, or hypertension, where herbal treatments have gained more widespread recognition [13]. This study, by contrast, brings attention to leptospirosis—a disease disproportionately affecting tropical regions—thereby emphasizing its unique relevance to Southeast Asia and similar endemic areas.

Moreover, the network visualization of keyword co-occurrences and collaboration metrics presented in this study adds a multidimensional understanding of the research landscape, often lacking in broader bibliometric analyses. For example, the dense co-occurrence of terms like "leptospirosis," "herbal medicine," and "antibacterial activity" in this study underscores the multidisciplinary nature of research in this domain. This contrasts with findings from previous studies where thematic clusters are often limited to single disciplines [28, 29]. The emphasis on international collaboration, with 40.14% of the

publications involving multi-country efforts, further distinguishes this study by highlighting the global relevance and the need for coordinated efforts to address a regional health challenge [30].

This study's focus on regional leaders such as Malaysia and Thailand also offers a new angle compared to earlier bibliometric analyses, which typically highlight contributions from globally dominant research hubs like the United States or Europe. By identifying regional strengths, this analysis provides a pathway for capacity building and underscores the potential of leveraging local knowledge and biodiversity to develop novel treatments.

3.6 Limitations and future research directions

Despite this bibliometric analysis's valuable insights, several limitations must be acknowledged. First, the study was restricted to publications indexed in the Scopus database, which may have excluded relevant research from other databases such as PubMed, Web of Science, or regional journals not covered by Scopus. This limitation could result in an incomplete representation of the global research landscape on herbal treatments for leptospirosis. Additionally, the analysis focused solely on English-language publications, potentially omitting essential studies published in local languages, particularly in Southeast Asia, where herbal medicine has deep cultural and historical roots. This language bias may underrepresent the contributions of non-English-speaking researchers and institutions, which could provide valuable context and insights into the use of herbal remedies in leptospirosis treatment. Another significant limitation is the reliance on citation metrics to gauge the impact of research. While citation counts serve as a useful measure of academic influence, they may only sometimes reflect the practical relevance of studies, especially in fields like herbal medicine, where traditional knowledge is often shared through non-academic channels. Moreover, the inherent time lag between publication and citation could result in newer, potentially groundbreaking studies being undervalued in the analysis. The absence of references in some studies further restricted the ability to track connections and influence within the literature.

A critical limitation of the findings is the preclinical focus of most research in this field. At the same time, this analysis highlights a growing body of evidence on the antibacterial properties of herbal remedies against *Leptospira*; most studies still need to be expanded to laboratory and animal models. This preclinical emphasis underscores a pressing need for translational research to validate the efficacy and safety of herbal treatments in real-world clinical settings. Without clinical trials and comprehensive safety evaluations, the practical applicability of these findings remains uncertain. To address these limitations, future research should expand the scope of bibliometric studies to include a broader range of databases and languages, ensuring a more comprehensive understanding of global research efforts on herbal treatments for leptospirosis. Additionally, qualitative assessments—such as case studies on how herbal remedies are integrated into public health strategies—could complement bibliometric analyses and offer deeper insights into their practical applications. More focused studies are also needed to evaluate the efficacy and safety of specific herbal treatments in treating leptospirosis, mainly through well-designed clinical trials. Interdisciplinary approaches combining ethnobotanical knowledge with modern scientific techniques, such as pharmacological studies and molecular analysis, hold promise for developing novel and effective herbal therapies. By addressing these gaps, future research can enhance the translational potential of herbal medicine and contribute to combating leptospirosis in endemic regions.

4 Conclusion

This bibliometric analysis underscores the growing interest in herbal treatments for leptospirosis, driven by increasing research output, particularly in Southeast Asia, with Malaysia and Thailand leading contributions. Key findings reveal a robust preclinical focus, emphasizing antibacterial efficacy and animal studies, but highlight a critical gap in clinical research necessary to validate herbal remedies for practical use. The study's implications stress the need for translational research to address limitations of current antibiotic treatments, such as resistance and accessibility, positioning herbal medicine as a culturally relevant and sustainable option. Researchers should prioritize clinical trials and interdisciplinary collaborations to bridge traditional knowledge and modern medicine. Policymakers must invest in infrastructure, funding, and policies to support clinical advancements and integrate herbal remedies into healthcare frameworks. Healthcare practitioners should consider herbal treatments as adjunct therapies backed by evidence-based protocols and patient monitoring. By addressing these gaps, stakeholders can advance sustainable treatment strategies for leptospirosis, improving public health outcomes globally.

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References

1. R. Kira, L. M. Bilung, R. Ngui, K. Apun, L. Su'Ut, Spatial and temporal disparities of leptospirosis transmission in Sarawak (Malaysia), 2011-2018. *Borneo Journal of Resource Science and Technology*. **12**, 1-10 (2022). <https://doi.org/10.33736/bjrst.4456.2022>.
2. B. Garba, A.R. Bahaman, S. Khairani-Bejo, Z. Zakaria, A. Mutalib, Retrospective study of leptospirosis in Malaysia. *Ecohealth*. **14**, 389-398 (2017). <https://doi.org/10.1007/s10393-017-1234-0>.
3. M. Cunha, F. Costa, G.S. Ribeiro et al., Rainfall and other meteorological factors as drivers of urban transmission of leptospirosis. *Plos Neglected Tropical Diseases*. **16**, e0007507 (2022). <https://doi.org/10.1371/journal.pntd.0007507>.
4. J. Dai, C. Yao, H.A. Ling et al., A rare case of severe leptospirosis infection presenting as septic shock in a non-endemic area: a case report and literature review. *BMC Infectious Diseases*. **23** (2023). <https://doi.org/10.1186/s12879-023-08367-w>.
5. E.D.F. Daher *et al.*, Leptospirosis-Associated Acute Kidney Injury: Penicillin at the Late Stage Is Still Controversial, *Journal of Clinical Pharmacy and Therapeutics*, vol. 37, no. 4, pp. 420-425, 2011. <https://doi.org/10.1111/j.1365-2710.2011.01312.x>
6. J.B. Gunasena, S.D. Silva, Double-Trouble: a rare case of co-infection with melioidosis and leptospirosis from Sri Lanka. *Tropical Doctor*. **53**, 332-337 (2023). <https://doi.org/10.1177/00494755231156490>.
7. K.R. Paudel, N. Panth, Phytochemical profile and biological activity of *Nelumbo nucifera*. *Evidence-Based Complementary and Alternative Medicine*. **2015**, 1-16 (2015). <https://doi.org/10.1155/2015/789124>.
8. S.C. Batubara, N. Mayulu, A.A. Putri, The effect of the formulation of kenikir leaf extract (*Cosmos caudatus*) and blimbing wuluh extract (*Averrhoa bilimbi*) on the functional drink quality. *Proceedings of the Nutrition Society*. **80**, OCE3 (2021). <https://doi.org/10.1017/s0029665121002755>.
9. F.E.S. Vista, B.P.D.D. Galicia, Antibacterial activity of crude *Momordica charantia*, *Cassia alata*, and *Allium sativum* methanolic extracts on *Leptospira interrogans*

- Serovar Manilae. *Acta Medica Philippina*. 1-6 (2024). <https://doi.org/10.47895/amp.vi0.8362>.
10. D. Delima, L. Widowati, H. Siswoyo, Nurhayati, O.D. Sampurno, F.S. Halim, The pattern of herbal medicine prescribed by medical doctor for 10 health problems in several cities of Indonesia (Analysis of Jamu Registry 2016 and 2018 Database), Proceedings of the 4th International Symposium on Health Research (ISHR 2019). **22** (2020). <https://doi.org/10.2991/ahsr.k.200215.122>.
 11. A.W. Utomo, E. Annisaa, A.L. Antari, D. Armalina, The use of herbal medicines in patients with type-2 diabetes mellitus in Indonesia. *Sains Medika Jurnal Kedokteran Dan Kesehatan*. **13** (2022). <https://doi.org/10.30659/sainsmed.v13i1.13487>.
 12. D. Li, M. Zuo, X. Hu, Global trends in research of treatment on bladder cancer with Chinese medicine monomer from 2000 to 2021: a bibliometric analysis. *J Oncol*. **2022**, 3382360 (2022). <https://doi.org/10.1155/2022/3382360>.
 13. Y. Song, F. Zhao, Bibliometric analysis of metabolic surgery for type 2 diabetes: current status and future prospects. *Updates Surg*. **74**, 697-707 (2022). <https://doi.org/10.1007/s13304-021-01201-5>.
 14. R.N. Ridzuan, N. Fauzi, R.A. Amat, N.Z.M. Ghazali, A bibliometric study towards the application of herbs in an academic environment. *Khizanah Al-Hikmah Jurnal Ilmu Perpustakaan Informasi dan Kearsipan*. **7** (2019). <https://doi.org/10.24252/kah.v7i1a3>.
 15. RCoreTeam, R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria, (2022). <https://doi.org/https://www.R-project.org/>.
 16. M. Aria, C. Cuccurullo, M. M. Aria, Package ‘bibliometrix’, ed: CRAN, (2022).
 17. H.H. Musa et al., Traditional herbal medicine: overview of research indexed in the Scopus database. *Advances in Traditional Medicine*. **23**, 1173-1183 (2022). <https://doi.org/10.1007/s13596-022-00670-2>.
 18. C. Asare, L. Aziato, D. Boamah, Facilitators and Barriers to the clinical administration of herbal medicine in Ghana: a qualitative study. *BMC Complementary Medicine and Therapies*. **21**, (2021). <https://doi.org/10.1186/s12906-021-03334-x>.
 19. C. Wang, Q. Meng, Global research trends of herbal medicine for pain in three decades (1990–2019): a bibliometric analysis. *Journal of Pain Research*. **14**, 1611-1626 (2021). <https://doi.org/10.2147/jpr.s311311>.
 20. Y. Seo *et al.*, A bibliometric analysis of research on herbal medicine for obesity over the past 20 years. *Medicine*, **101**, e29240 (2022). <https://doi.org/10.1097/md.00000000000029240>.
 21. Y. Xu, J. Chen, H. Wang, Y. Lu, Research and application of herbal medicine in the treatment of chronic kidney disease since the 21st century: a visualized bibliometric analysis. *Frontiers in Pharmacology*. **13**, (2022). <https://doi.org/10.3389/fphar.2022.971113>.
 22. J. M. Bowen *et al.*, Describing the State of a research network: a mixed methods approach to network evaluation. *Research Evaluation*. **32**, 188-199 (2022). <https://doi.org/10.1093/reseval/rvac034>.
 23. R. Ohta, Enhancing the comprehensive integration of general medicine education in rural Japan: a thematic analysis. *Cureus*. **15**, e50874 (2023). <https://doi.org/10.7759/cureus.50874>.
 24. A. Dixit, B. Gulati, G. Sharma, G. Bhatia, R. Priya, S. Bhattacharya, Evaluation of phytochemical and antimicrobial activity of *Ocimum* spp. *Integrative Food Nutrition and Metabolism*. **8** (2021). <https://doi.org/10.15761/ifnm.1000299>.

25. L. Fu, Mapping the landscape: a bibliometric analysis of resting-state fMRI research on schizophrenia over the past 25 years. *Schizophrenia*. **10** (2024). <https://doi.org/10.1038/s41537-024-00456-2>.
26. D. Garg, P. Tiwari, Impact of social media sentiments in stock market predictions: a bibliometric analysis. *Business Information Review*. **38**, 170-182 (2021). <https://doi.org/10.1177/02663821211058666>.
27. J.T. Ellis, B. Ellis, A. Velez-Estevez, M.P. Reichel, M.J. Cobo, 30 years of parasitology research analysed by text mining. *Parasitology*. **147**, 1643-1657 (2020). <https://doi.org/10.1017/s0031182020001596>.
28. R. Nur, Analysis of the literature on the role of physical activity in improving wellbeing and quality of life. *West Science Interdisciplinary Studies*. **1**, 1157-1166 (2023). <https://doi.org/10.58812/wsis.v1i11.340>.
29. S. Jo, C. Park, J. Lee, et al., Revealing role of Korean Physics society with keyword co-occurrence network. *J. Korean Phys. Soc.* **81**, 368–376 (2022). <https://doi.org/10.48550/arxiv.2205.09969>
30. D. K. Kirtania, Network visualization of ChatGPT research: a study based on term and keyword co-occurrence network analysis. *Preprints*. 2023040069 (2023). <https://doi.org/10.20944/preprints202304.0069.v1>.