Journal of Scientometric Research, 2026; 15(3):1156-1173.
https://www.jscires.org

Research Article

Global Research Trends on Anti-Snake Venom Potential of *Butea monosperma* Root Extract: A Scientometric and Thematic Review

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ABSTRACT

Envenomation from snakebites is still a neglected tropical health dilemma, particularly in resource-poor settings where the availability of prompt and effective antivenom intervention may be hindered. *Butea monosperma* boasts a significant ethnomedicinal tradition, particularly in treating snakebite conditions; however, the research into its root's pharmacological attributes and possible antivenom functions has not been fully delineated thru scientometric analysis. As a result, this study intended to outline the worldwide research environment, publishing trends, collaboration patterns, citation structures, and emerging topics linked to pharmacological and antivenom research of *Butea monosperma* roots. Bibliographic records issued from 2000 to 2025 were sourced on 10 January 2026 from Scopus, Web of Science Core Collection, and PubMed using specified search protocols. A comprehensive total of 605 records was discovered, consisting of 310 from Scopus, 220 from the Web of Science Core Collection, and 75 from PubMed. After discarding 185 duplicates and conducting a detailed screening, 152 publications were kept for scientometric analysis, while 30 highly relevant studies specifically related to *Butea monosperma* root-associated antivenom, venom-neutralizing, or closely linked pharmacological investigations were chosen for qualitative thematic interpretation. Bibliometrix and VOS viewer (version 1.6.20) were used to investigate publishing trends, citation patterns, authorship and cooperation networks, country-specific productivity, keyword co-occurrence, and topic advancement. The assessment indicated a surge in research initiatives in recent years, with India as the predominant contributor and foreign partnerships being notably restricted. Thematic mapping delineated major study sectors including ethnopharmacology, phytochemistry, antioxidant and wound-healing efficacy, green nanotechnology, medication delivery techniques, and pharmacological research pertaining to venom. Yet, the inquiry explicitly targeting the venom-neutralizing or antivenom functions of *Butea monosperma* roots comprised a notably small fraction of the overarching study environment. The findings emphasize notable inadequacies in consistent phytochemical characterisation, mechanistic analyses of venom neutralization, toxicity evaluations, and translational validation. This examination presents a scientometric summary of the advancement and existing configuration of pharmacological and prospective antivenom research linked to *Butea monosperma* roots, identifying key goals for future interdisciplinary studies.

Keywords: Antivenom research, *Butea monosperma* roots, Ethnopharmacology, Scientometric analysis, Snakebite envenomation, Venom inhibition.

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Received: 16-07-2026;
Revised: 02-09-2026;
Accepted: 28-10-2026.

INTRODUCTION

Global Burden of Snakebite Envenomation

Snakebite envenomation is a considerable neglected tropical disease and a worldwide public health concern. The World Health Organization (WHO) approximates that annually there are 5.4 million snakebite occurrences, resulting in almost 2.7 million envenomations and exceeding 100,000 deaths, mostly in tropical and subtropical regions of South Asia, Africa, and Latin America (Uyeda *et al.*, 2022). Victims of snakebites might endure significant outcomes such as necrosis of tissue, the need for amputation, enduring disabilities, and mental suffering, in addition to the possibility of death. The lack of healthcare accessibility and the delay in treatment availability adversely impact rural and economically marginalized communities. Standard antivenoms continue to be the foremost therapeutic alternative, however they are accompanied by many limitations, such as substantial manufacturing costs, the need for cold-chain logistics, restricted regional distribution, and negative immunological effects including serum sickness and hypersensitivity. Owing to these constraints, scholars are showing heightened interest in

DOI: 10.5530/jscires.20260008

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identifying adjunctive or alternative remedies for the management of snakebite injuries (Gutiérrez *et al*., 2021).

Medicinal Plants in Snakebite Therapeutics

In traditional healing traditions, botanical remedies have been often utilized to combat snakebite envenomation. Both Ayurveda and other ethnomedical traditions have consistently recognized a range of plant species for their "Vishaghna" (anti-poison) capabilities. Numerous phytochemicals generated from plant extracts, such as flavonoids, tannins, alkaloids, terpenoids, and polyphenols, are recognized for their anti-inflammatory, antioxidant, and enzyme-inhibiting abilities (Kamel *et al*., 2024). These phytoconstituents may impede detrimental pathways caused by venom, as shown by current pharmacological research, so augmenting the burgeoning scientific interest in plant-based antivenom investigations. As a consequence, there is an escalating inquiry into ethnopharmacological resources about their probable use in further snakebite treatments. *Butea monosperma* is a medicinal species that has piqued more ethnopharmacological curiosity among research focused on venom-related conditions (Soares *et al*., 2025).

Ethnopharmacological Importance of *Butea monosperma*

In South Asian countries, including India, *Butea monosperma* (Lam.) Taub. (Fabaceae), often known as Palash or Flame of the Forest, serves as a prominent medicinal species. Petals, bark, seeds, and roots are just a fraction of the plant segments that have been traditionally used for various health-related functions (Baker *et al*., 2020). The roots have attracted notable ethnomedical focus in traditional snakebite therapies used by tribal communities in different Indian locales. Earlier phytochemical research reveals that *Butea monosperma* roots are composed of flavonoids, tannins, glycosides, sterols, and phenolic materials. Studies focused on venom neutralization could leverage the antioxidant, anti-inflammatory, antibacterial, and enzyme-inhibitory properties of these bioactive substances. Studies concerning the anti-snake venom efficacy of *Butea monosperma* roots are still scattered and minimal, despite rising interest from the pharmaceutical sector (Gajbhiye *et al*., 2023).

Need for Scientometric Mapping in *Butea monosperma* Research

Studies in scientometric and bibliometrics have turned into essential methodologies for gaging scientific achievements, collaborative relationships, subject progression, and innovative research paths in designated disciplines. These strategies provide measurable information about co-authorship trends, institutional participation, publication behaviors, citation formats, and keyword correlations. The use of scientometric mapping has grown in ethnopharmacological and biomedical investigations to locate research hubs, information lacunae, and prospective future adaptations. Still, no detailed scientometric study has adequately evaluated the global research milieu about its anti-snake venom applications, although the increasing number of publications linked to *Butea monosperma* (Chowdhury *et al*., 2024).

Novelty and Aim of the Present Study

The therapeutic efficacy of *Butea monosperma* has been investigated thru a multitude of pharmacological and ethnomedical studies; however, a specific scientometric assessment has not been performed to systematically delineate global research trends, collaborative networks, thematic advancements, and emerging translational strategies related to its anti-snake venom applications. As a result, using bibliometric visualization strategies and organized literature examination, the present research aimed to provide an in-depth scientometric and theme mapping of inquiries into *Butea monosperma* roots in snakebite interventions (Abd El-Gawad *et al*., 2023). Utilizing datasets from Scopus and Web of Science covering the years 2000 to 2025, this research explores the development of topic keywords, contributions by nation, co-authorship networks, citation structures, and patterns in publication growth. In addition, the results highlight future prospects for ethnopharmacology-based antivenom research and translational nanomedicine uses including (Katopodi & Detsi, 2021). The authors generated the graphical abstract using bibliometric data obtained from the Scopus®, Web of Science Core Collection®, and PubMed® databases (2000–2025). The processes of visualization and thematic mapping were carried out using VOS viewer v1.6.20, the Bibliometrix R-package, and following PRISMA 2020 principles.

METHODOLOGY

Data Sources

Bibliographic information for the ongoing scientometric research was extracted from three prominent academic databases: Scopus, Web of Science Core Collection (WoSCC), and PubMed. These databases were curated to offer wide-ranging interdisciplinary access to the biological, pharmacological, ethnopharmacological, and pertinent literature associated with *Butea monosperma* and snakebite research. Additionally, its bibliographic and citation information are suitable for integration with well-known scientometric analysis systems, such VOS viewer and the Bibliometrix R-package (Rebbouh *et al*., 2020; Rajbongshi & Mukherjee, 2025).

Search Strategy

A methodical literature search was undertaken on 10 January 2026 in three bibliographic databases: Scopus, Web of Science Core Collection (WoSCC), and PubMed. The search was intended to discover publications that pertain to *Butea monosperma*, particularly its roots or root extracts, in relation to snakebites, snake venom, antivenom activity, or venom-neutralizing effects.

Search strategies tailored to each database were developed in accordance with their specific search syntax and are presented below to facilitate the reproducibility of the literature retrieval method.

Scopus Search Query

TITLE-ABS-KEY ("*Butea monosperma*" OR Palash) AND TITLE-ABS-KEY ("snakebite" OR "snake venom" OR antivenom OR "venom neutralization" OR "phospholipase A2 inhibition") AND TITLE-ABS-KEY (root OR "root extract").

Web of Science Core Collection Search Query

TS= ("*Butea monosperma*" OR Palash) AND TS= ("snakebite" OR "snake venom" OR antivenom).

PubMed Search Query

(("*Butea monosperma*"[Title/Abstract]) OR Palash [Title/Abstract]) AND ((snakebite [Title/Abstract]) OR antivenom [Title/Abstract]) (Yeung *et al*., 2018).

Inclusion and Exclusion Criteria

The acquired records were evaluated based on predetermined inclusion and exclusion standards specified prior to the assembly of the final dataset. The standards were established to guaranty that the papers included in the scientometric evaluation pertained to *Butea monosperma* root-related studies and its possible significance for snakebites, snake venom, or antivenom applications. The evaluation was conducted using bibliographic data such as title, abstract, keywords, kind of publication, language, and year of publication. Duplicate entries obtained from several databases were recognized and eliminated prior to further evaluation. Publications qualified for inclusion if they were published in English from 2000 to 2025, aligned with the specified publication types, and focused on *Butea monosperma* roots or root extracts concerning snakebite, snake venom, venom biology, antivenom efficacy, or related pharmacological significance. Publications that concentrate only on other plant components without pertinent root-related data, studies not associated with snakebite or venom investigations, duplicate entries, and records without enough bibliographic details for scientometric evaluation were omitted (Saini *et al*., 2025). The inclusion and exclusion criteria applied during dataset screening are summarized in Table 1.

Study Selection and PRISMA Workflow

The study identification and selection process was conducted in accordance with the principles of the PRISMA 2020 framework to ensure transparent reporting of the literature retrieval and screening procedure (Page *et al*., 2021). A systematic literature search was performed on 10 January 2026 using the Scopus, Web of Science Core Collection (WoSCC), and PubMed databases. The search retrieved a total of 605 records, comprising 310 records from Scopus, 220 from WoSCC, and 75 from PubMed. Following database merging and removal of duplicate records, 185 duplicate records were excluded, leaving 420 unique records for title and abstract screening. During the screening stage, 268 records were excluded because they did not satisfy the predefined eligibility criteria. The principal reasons for exclusion were lack of relevance to *Butea monosperma*, absence of relevance to snakebite, snake venom, antivenom, or venom-neutralization applications, exclusive focus on non-root plant parts such as flowers, bark, leaves, or seeds, and publication in languages other than English. The remaining 152 publications were retained as the final dataset for scientometric and bibliometric analysis. These publications were subsequently analysed with respect to publication trends, citation patterns, authorship and collaboration, institutional and country-wise productivity, keyword co-occurrence, and thematic development. For complementary qualitative interpretation, a subset of 30 highly relevant publications was selected from the 152 included studies based on their specific relevance to *Butea monosperma* root extracts or root-derived preparations and their association with anti-snake venom, venom-neutralizing, or closely related pharmacological investigations. These 30 publications were used exclusively for qualitative thematic and pharmacological interpretation and were not treated as a separate bibliometric dataset. Thus, the quantitative scientometric analysis was based on all 152 eligible publications, whereas the qualitative thematic interpretation was based on a focused subset of 30 publications. The complete study identification, screening, eligibility, and inclusion process is presented in the PRISMA 2020 flow diagram (Figure 1) (Page *et al*., 2021c).

Scientometric and Bibliometric Analysis

The final dataset of 152 publications was subjected to descriptive scientometric and bibliometric analysis to characterize the development and intellectual structure of research on *Butea monosperma* root-based antivenom and related pharmacological research. The analysis included annual publication output, citation performance, authorship patterns, source productivity, institutional and country-wise contributions, and collaboration patterns. These indicators were used to identify the temporal development, major contributors, and geographical distribution of research within the field. Network-based analyses were performed to investigate the relationships and intellectual structure of the research domain. These analyses included co-authorship analysis, country collaboration analysis, keyword co-occurrence analysis, co-citation analysis, and bibliographic coupling, where applicable. Keyword co-occurrence analysis was used to identify frequently associated research terms and thematic clusters, whereas co-authorship and country collaboration analyses were used to characterize patterns of scientific collaboration. Co-citation and bibliographic coupling analyses were used to identify relationships among publications and the intellectual structure of the research field. Before

visualization, the bibliographic records were subjected to data cleaning and normalization. Duplicate records identified during the database-merging process were removed. Author keywords and indexed keywords were examined for spelling variations, synonymous terms, singular/plural forms, abbreviations, and closely related expressions. Equivalent terms were standardized to minimize artificial fragmentation of keyword networks and to improve the interpretability of thematic clusters. The cleaned and standardized dataset was subsequently used for network construction and visualization. For keyword co-occurrence analysis, a minimum occurrence threshold of five occurrences per keyword was applied. For citation-based analyses, a minimum threshold of ten citations per publication was applied where citation-based network visualization was performed. Only records meeting the respective thresholds were included in the corresponding network analyses. The selection of thresholds was intended to focus the visualization on sufficiently represented and influential terms or publications while reducing noise from isolated records. The resulting descriptive indicators and network structures were interpreted together to identify publication trends, influential research contributions, collaboration patterns, major thematic clusters, and emerging research directions associated with *Butea monosperma* root-based antivenom research (Page *et al*., 2021b; Zupic & Čater, 2015; Page *et al*., 2021a).

Bibliometric Visualization Software

Bibliometric analysis and visualization were performed using the Bibliometrix R package and its Bibliophagy web interface, together with VOS viewer version 1.6.20. Bibliometrix/Bibliophagy was used for descriptive bibliometric analysis, including annual scientific production, citation analysis, source productivity, author and institutional contributions, and thematic or conceptual structure analysis. VOS viewer version 1.6.20 was used to construct and visualize bibliometric networks, including co-authorship, country collaboration, keyword co-occurrence, and other relationship-based maps generated from the bibliographic dataset. The software was used to identify the strength and structure of relationships among authors, countries, keywords, and publications and to display these relationships as network maps and clusters. For network construction, the bibliographic records were first checked for duplicate entries, inconsistent terminology, spelling variations, and synonymous or closely related keywords. A standardized keyword list was prepared to improve consistency during network analysis. Singular and plural forms, abbreviations, and equivalent terminology were merged where they represented the same concept. The cleaned dataset was then imported into the respective software platforms for analysis and visualization. The resulting maps were examined according to node occurrence or citation strength, linkages between nodes, network density, and cluster formation. In the visualizations, larger nodes represent relatively higher occurrence, productivity, or citation strength, whereas links represent relationships between items included in the respective network. Cluster colours indicate groups of closely related items identified by the visualization algorithm. The combined use of Bibliometrix/Bibliophagy and VOS viewer enabled complementary quantitative and visual assessment of the research landscape, facilitating the identification of major contributors, collaboration structures, dominant research themes, thematic relationships, and emerging areas of investigation in *Butea monosperma* root-based antivenom research (Safdar Ali Khan *et al*., 2024a).

Qualitative Thematic Interpretation

In addition to the quantitative scientometric analysis, a focused qualitative thematic interpretation was performed to provide pharmacological context to the bibliometric patterns identified in the dataset. This analysis was based on the 30 highly relevant studies selected from the 152 publications included in the scientometric dataset. The 30 studies were selected because they provided direct or particularly relevant evidence concerning *Butea monosperma* roots or root-derived preparations in relation to antivenom activity, venom neutralization, snakebite-associated pharmacological effects, or mechanisms relevant to venom-induced toxicity. The qualitative interpretation focused on the principal pharmacological themes emerging from these studies, including venom enzyme inhibition, antioxidant activity, anti-inflammatory effects, and potential therapeutic applications of plant-derived or nanotechnology-assisted approaches. Particular attention was given to reported mechanisms or experimental observations relevant to venom neutralization and the pharmacological management of snakebite-associated effects. The findings from these 30 studies were interpreted alongside the thematic clusters identified through keyword co-occurrence and other bibliometric analyses. This approach was used to determine whether the quantitatively identified research themes were supported by the underlying pharmacological literature and to provide a mechanistic context for the observed thematic structure. Importantly, the qualitative thematic interpretation was not treated as a separate systematic review or as an additional bibliometric dataset. Instead, it served as a focused interpretive component of the present scientometric study. The complete dataset of 152 publications was retained for quantitative scientometric analysis, whereas the 30-study subset was used specifically to contextualize major pharmacological themes, research gaps, and potential future directions related to *Butea monosperma* root-based antivenom research (Khan *et al*., 2024b; Chakraborty *et al*., 2024).

RESULTS

Annual Publication Trends

The annual publication output indicates a gradual but increasingly visible development of research associated with *Butea monosperma* and its pharmacological, ethnopharmacological,

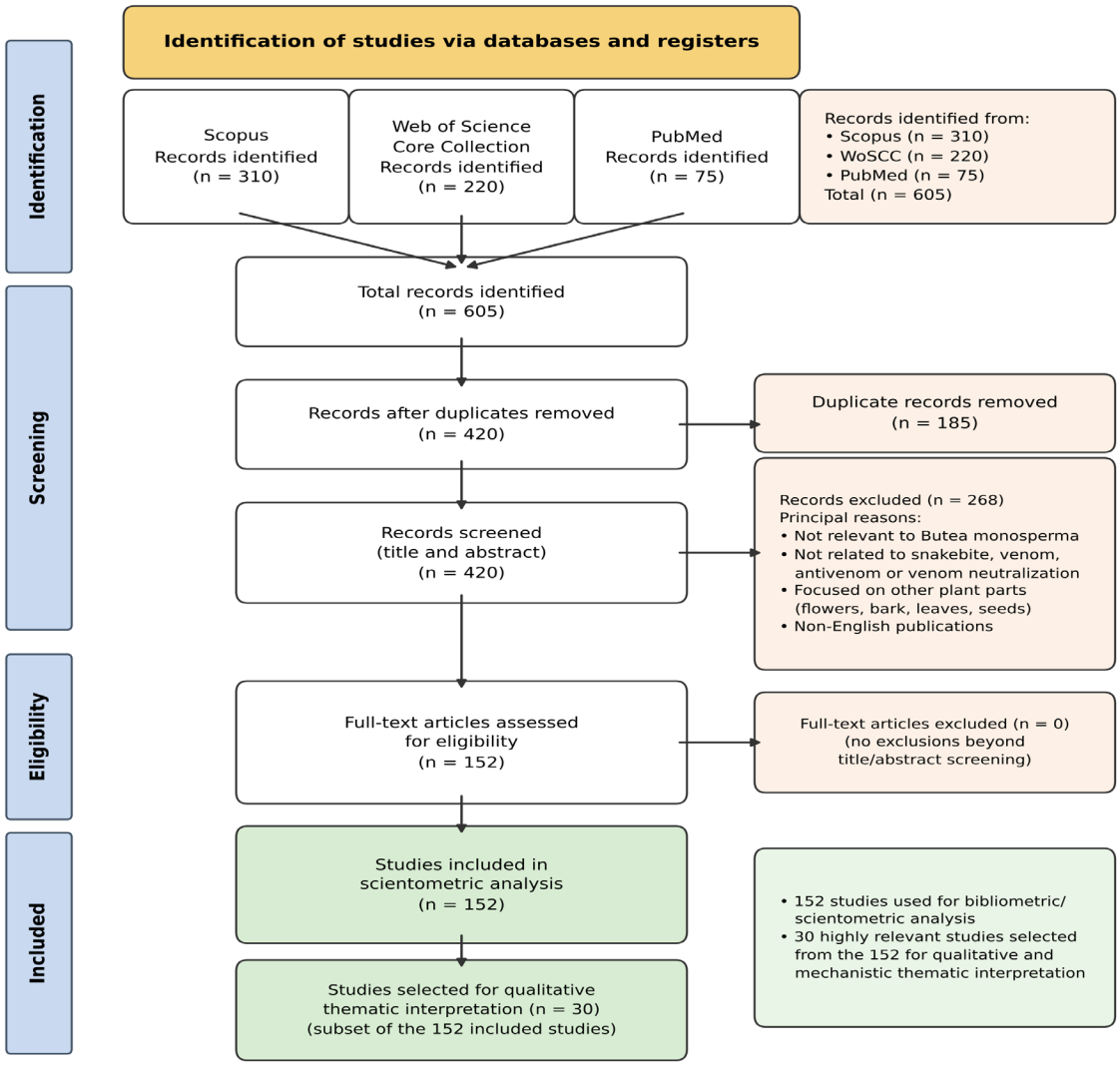


Figure 1: PRISMA 2020 flow diagram showing the identification, screening, eligibility assessment, and inclusion of publications for the scientometric analysis of *Butea monosperma* root-based antivenom research. A total of 605 records were identified from Scopus (*n*=310), Web of Science Core Collection (*n*=220), and PubMed (*n*=75); 185 duplicate records were removed, leaving 420 records for screening. After exclusion of 268 records based on the predefined eligibility criteria, 152 publications constituted the final scientometric dataset. A subset of 30 highly relevant publications was subsequently selected from the 152 included studies for qualitative thematic and pharmacological interpretation. Adapted according to the PRISMA 2020 framework

and antivenom-related applications. The number of publications increased from 1 article in 2014 to 4 articles in 2018, followed by further fluctuations during 2019–2021. A marked increase was observed thereafter, with 7 publications in 2022, 8 in 2024, and 9 in 2025, indicating a recent intensification of scientific activity. The increasing publication output during the later years suggests growing research interest in the pharmacological potential of *Butea monosperma*, particularly in relation to phytochemicals, ethnopharmacology, venom biology, and plant-mediated therapeutic approaches. The observed increase may also reflect the broader integration of traditional medicinal knowledge with contemporary pharmacological and nanotechnology-based approaches. However, the annual distribution remains uneven, indicating that research activity in this specific area is still developing rather than representing a consistently established research field. The recent increase in publication activity is particularly relevant to antivenom research because snakebite envenoming remains an important biomedical and public-health concern, encouraging investigation of complementary and plant-derived approaches for venom neutralization. Within the retrieved literature, research themes extend across pharmacology, phytochemistry, toxicology, biological sciences, and nanotechnology, demonstrating the multidisciplinary nature of investigations involving *B. monosperma*. The increasing contribution of these interdisciplinary areas suggests a gradual transition from traditional ethnomedicinal documentation toward experimental evaluation of pharmacological mechanisms and potential therapeutic applications. The temporal distribution

Table 1: Inclusion and exclusion criteria used for selection and cleaning of the Scientometric dataset (He *et al*., 2019; Li *et al*., 2023; Upasani *et al*., 2017; Yeung *et al*., 2018; Zhang *et al*., 2018).

Sl. No.	Inclusion Criteria	Exclusion Criteria	Rationale / Data Cleaning Purpose
1.	Publications in English	Non-English publications	To maintain linguistic consistency and facilitate standardized bibliographic analysis
2.	Research articles and review articles	Conference abstracts, editorials, notes, book chapters, and other non-eligible publication types	To ensure that the final dataset primarily comprised peer-reviewed scholarly literature
3.	Publications addressing *Butea monosperma* roots or root extracts	Studies focusing exclusively on flowers, bark, leaves, seeds, or other plant parts without relevant root information	To maintain the thematic focus on root-based research
4.	Publications addressing snakebite, snake venom, venom biology, antivenom activity, or venom-neutralizing relevance	Publications unrelated to snakebite, venom, or antivenom research	To ensure alignment with the objectives of the study
5.	Publications published between 2000 and 2025	Publications outside the predefined publication period	To maintain a consistent temporal scope
6.	Records containing sufficient bibliographic information for scientometric analysis	Records with insufficient or incomplete bibliographic metadata	To ensure compatibility with bibliometric analysis and network construction
7.	Unique bibliographic records	Duplicate records identified across Scopus, WoSCC, and PubMed	To prevent duplicate counting and ensure dataset accuracy

also indicates that research interest has become more pronounced during the most recent publication period. In particular, the increase observed between 2021 and 2025 highlights the growing scientific attention toward *Butea monosperma*-associated pharmacological applications. Nevertheless, the publication trend should be interpreted as evidence of increasing research activity rather than definitive evidence of therapeutic efficacy, because bibliometric productivity reflects publication behaviour and research attention rather than clinical effectiveness. Overall, the annual publication pattern demonstrates a recent expansion of scientific interest in *Butea monosperma* research, with increasing emphasis on pharmacological, phytochemical, antivenom, and technology-assisted therapeutic investigations. This temporal trend provides the basis for subsequent analyses of the major contributing authors, institutions, countries, subject areas, citation patterns, and thematic structures within the field. The number of publications increased from 1 article in 2014 to 4 articles in 2018, followed by further fluctuations during 2019–2021. A marked increase was observed thereafter, with 7 publications in 2022, 8 in 2024, and 9 in 2025, indicating a recent intensification of scientific activity (Figure 2).

Citation Analysis

Citation analysis was performed to assess the scholarly impact and visibility of publications associated with *Butea monosperma* root-based pharmacological and antivenom research. The temporal distribution of documents and citations indicates that citation activity became more apparent during the later years of the study period, corresponding with the increase in publication output. The annual citation pattern therefore suggests increasing scholarly attention toward research involving the pharmacological properties, ethnopharmacological applications, and potential therapeutic relevance of *Butea monosperma*. The citation profile also indicates that the literature encompasses several interconnected research areas, including phytochemical characterization, pharmacological evaluation, venom-related investigations, plant-derived therapeutic approaches, and nanotechnology-assisted applications. The highly cited publications identified in the dataset provide an indication of the research topics that have received comparatively greater scholarly attention. In particular, studies investigating experimentally validated biological activities and the development or characterization of plant-mediated nanomaterials appear among the more frequently cited contributions. The Figure also provides an overview of the highly cited records retrieved during the analysis. These patterns indicate that research related to *Butea monosperma* has progressively expanded from traditional and ethnopharmacological investigations toward experimentally oriented studies involving pharmacological activity, biological validation, and nanotechnology-based applications. The citation counts demonstrate substantial variation among the leading publications, with the highest-ranked publication receiving

the greatest number of citations, followed by publications with progressively lower citation counts. This uneven citation distribution is characteristic of a developing research field in which a limited number of influential studies contribute disproportionately to the overall citation impact. The highly cited publications were further examined to identify the major scientific themes represented within the literature. Collectively, these studies contribute to the broader understanding of *B. monosperma* as a medicinal plant and provide a scientific basis for investigating its phytochemical constituents and pharmacological properties. However, citation frequency should be interpreted as a measure of scholarly visibility rather than direct evidence of pharmacological efficacy or antivenom effectiveness. Consequently, the citation analysis was used primarily to identify influential publications and dominant areas of research interest rather than to establish therapeutic efficacy. Overall, the citation analysis demonstrates increasing scholarly visibility of *Butea monosperma*-related research and highlights the importance of experimentally supported pharmacological and technology-assisted investigations. The highly cited literature provides an important foundation for the subsequent thematic and network analyses presented in this study. As shown in Figure 3, the annual document and citation distribution remained relatively limited during the earlier part of the study period, whereas a marked increase in both publication activity and citation accumulation was observed in the most recent years represented in the dataset. The ranking of highly cited publications is further presented in Figure 4, which demonstrates substantial variation in citation counts among the leading publications.

Country-wise and Institutional Research Distribution

The country-wise analysis demonstrated a geographically concentrated research landscape for *Butea monosperma* root-related antivenom and pharmacological research, with India contributing the largest number of publications in the analysed dataset. India accounted for 51 publications, followed by China (16), Brazil (12), Saudi Arabia (8), and Malaysia (7). The United Kingdom contributed 5 publications, while the United States accounted for 4 publications. Australia, Germany, and South Africa each contributed 2 publications. This distribution indicates that research on *Butea monosperma* and its pharmacological relevance has developed primarily in countries with established interests in medicinal plants, ethnopharmacology, natural-product research, and related biomedical applications. The predominance of India is consistent with the importance of *Butea monosperma* as a medicinal plant in the South Asian traditional-medicine context and reflects the substantial research interest in its phytochemical and pharmacological properties. The contribution of China, Brazil, Saudi Arabia, Malaysia, and other countries indicates that scientific investigation of *Butea monosperma*-associated biological activities has extended beyond its traditional geographical context. Nevertheless, the marked difference between India's publication output and that of other countries suggests that the international research landscape remains geographically uneven. The temporal distribution presented in Figure 4 further indicates that publications involving the major contributing countries became more prominent during the later years of the study period. India shows the strongest and most sustained publication contribution across the displayed years, whereas contributions from other countries are comparatively lower and more intermittent. This pattern

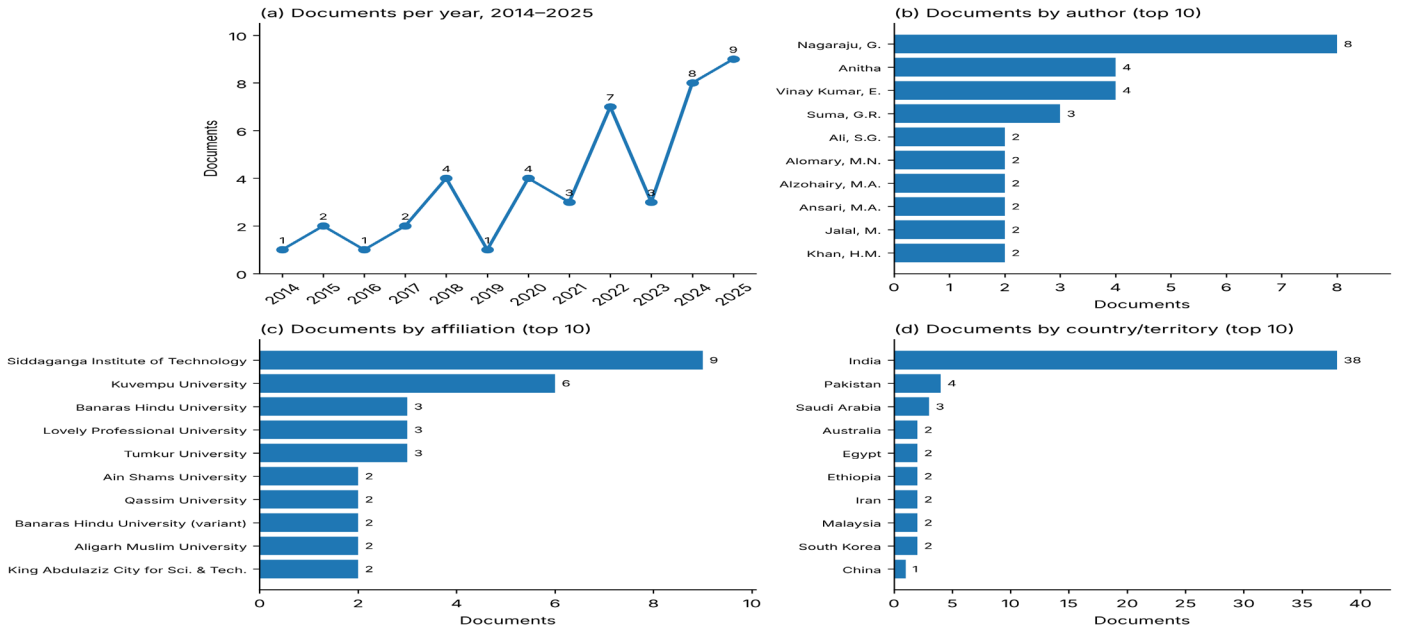


Figure 2: Annual publication output and temporal distribution of research related to *Butea monosperma* root-based pharmacological and antivenom investigations, showing the publication pattern represented in the retrieved bibliometric dataset during 2014–2025.

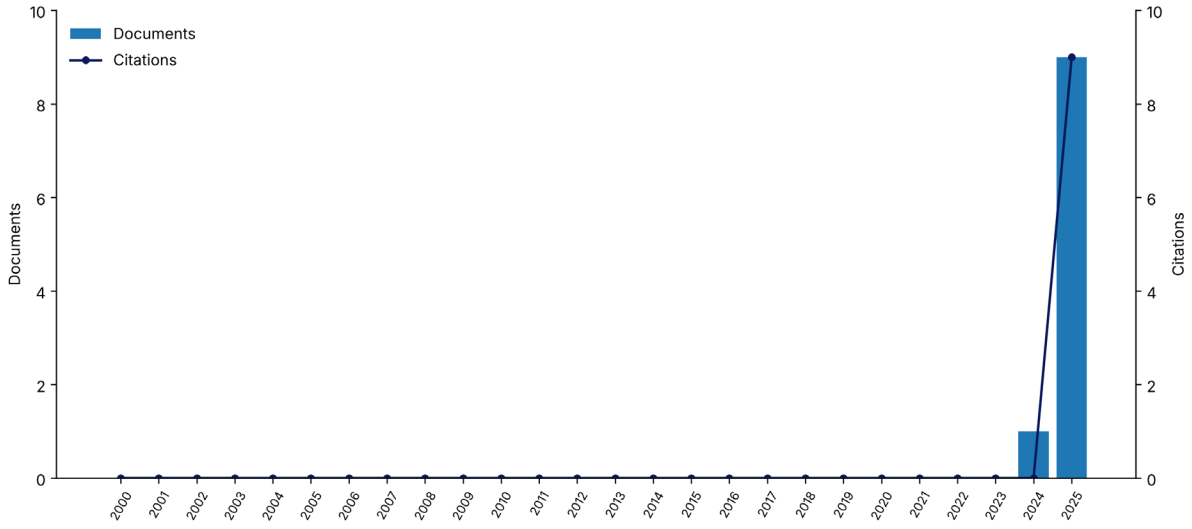


Figure 3: Annual publication and citation trends and distribution of highly cited publications related to *Butea monosperma* root-based pharmacological and antivenom research (2000–2025). The Figure summarizes the temporal distribution of documents and citations and presents the highly cited records identified from the bibliometric dataset.

suggests a gradual internationalization of research interest while retaining a strong research base in India. At the institutional level, the bibliometric dataset identified several universities and research organizations as important contributors to the field. The institutional analysis included Siddaganga Institute of Technology, Kuvempu University, Banaras Hindu University, Lovely Professional University, Bharathiar University, King Saud University, and other contributing institutions. Their research contributions encompass areas associated with medicinal-plant investigation, phytochemical characterization, pharmacological evaluation, venom-related studies, and emerging applications of nanomaterials. The institutional distribution therefore supports the multidisciplinary nature of the field, involving pharmacology, chemistry, biochemistry, toxicology, materials science, and related biomedical disciplines. Overall, the country and institutional distribution demonstrates that *Butea monosperma* root-related research is primarily driven by a limited number of geographically and institutionally concentrated research groups, while participation from other countries is comparatively smaller. The temporal distribution presented in Figure 5 further indicates that publications involving the major contributing countries became more prominent during the later years of the study period.

Author Collaboration Network

Co-authorship analysis revealed several interconnected author clusters contributing to research on *Butea monosperma*, particularly in the areas of pharmacology, phytochemistry, venom-related studies, and nanotechnology. The network was characterized by a limited number of prominent author groups that showed relatively strong internal connections, while links between different clusters were comparatively less pronounced. This pattern suggests that research in this field has developed through several researcher- and institution-centred collaborative groups rather than through a single highly integrated international research network. The visualization also indicates that authors such as Nagaraju, C., Vinay Kumar, V., Soares, A.M., and Gajbhiye, N.A. occupy relatively prominent positions within the collaboration network, with connections extending to researchers from different institutional clusters. Several Indian institutions, including Siddaganga Institute of Technology, Kuvempu University, Banaras Hindu University, and Lovely Professional University, are visibly associated with the major author clusters. Additional connections involving institutions and researchers from Saudi Arabia and other countries indicate the presence of emerging international collaborative links. The clustering pattern suggests that research on *Butea monosperma* has evolved through multiple specialized collaborative groups, with individual clusters focusing on different aspects of plant-based pharmacology, venom-related research, phytochemistry, and nanotechnology. However, the relatively separated structure of several clusters indicates that broader cross-institutional and international collaboration remains an opportunity for further development. Strengthening such collaborations could facilitate integration of ethnopharmacological knowledge with pharmacological validation, venom biology, analytical chemistry, and nanotechnology-based therapeutic approaches. The co-authorship network was generated using VOS viewer version 1.6.20 from the cleaned bibliographic dataset used in the present scientometric analysis. Before network construction, author names were standardized to minimize duplication caused by variations in author-name formatting. The resulting network is presented in Figure 6, where node size represents the relative prominence of an author in the network, links represent co-authorship relationships, and different colours indicate distinct collaboration clusters.

Keyword Co-occurrence Analysis

Keyword co-occurrence analysis was performed to identify the major thematic areas represented within the literature on *Butea monosperma*. The network demonstrates strong associations among keywords related to traditional medicine, ethnopharmacology, phytochemicals, plant extracts, antioxidant activity, nanoparticles, pharmacology, drug delivery, and wound healing. The co-occurrence relationships indicate that research on *Butea monosperma* extends beyond its traditional medicinal use and increasingly incorporates phytochemical characterization, biological evaluation, and emerging nanotechnology-based applications. The red cluster is primarily characterized by terms such as "medicinal plants," "traditional medicine," "ethnopharmacology," "snakebite," "poison," "India," "plant extract," and "antioxidant activity." This cluster reflects the ethnopharmacological and traditional-medicine foundation of *Butea monosperma* research, particularly its association with medicinal plants, traditional therapeutic practices, and snakebite-related applications. The green cluster contains keywords including "nanoparticles," "flavonoids," "tannins," "antioxidant activity," "extract," "wound healing," "pharmacology," and "drug delivery." This cluster indicates a broader research direction involving the characterization of bioactive constituents and their incorporation into pharmacological and nanotechnology-oriented applications. The strong connections between phytochemical terms and biological or therapeutic keywords suggest increasing integration of natural-product chemistry with contemporary biomedical research. The central position and relatively prominent size of several terms indicate that *Butea monosperma* research is thematically interconnected rather than restricted to a single pharmacological application. In particular, the links among phytochemicals, plant extract, antioxidant activity, nanoparticles, pharmacology, and wound healing indicate growing interest in translating plant-derived bioactive compounds into experimentally testable therapeutic applications. The occurrence of "snakebite" within the ethnopharmacological cluster is particularly relevant to the present review because it demonstrates the connection between the traditional medicinal use of *Butea monosperma* and snakebite-related research. However, the present network does not independently demonstrate a highly developed venom-neutralization cluster. Therefore, the relatively limited representation of specific venom-neutralization terminology in the network may indicate that direct mechanistic antivenom research remains less extensively represented than broader ethnopharmacological, phytochemical, antioxidant, and nanotechnology-related research. Overall, the keyword network suggests a transition from predominantly traditional and ethnopharmacological investigations toward multidisciplinary research integrating phytochemistry, pharmacology, nanotechnology, antioxidant activity, drug delivery, and wound-healing applications. These thematic relationships provide a useful context for identifying emerging research directions and potential opportunities for experimentally validating the venom-neutralizing properties of *Butea monosperma* root-derived bioactive compounds. The keyword co-occurrence network was generated using VOS viewer version 1.6.20 from the bibliographic records included in the final scientometric dataset. Author keywords and indexed keywords were standardized before network construction to minimize duplication arising from synonymous terms, spelling variations, and singular/plural forms. Keywords meeting the predefined occurrence threshold were included in the visualization. The resulting network is presented in Figure 7.

Thematic Evolution Analysis

The thematic development of *Butea monosperma*-related research was examined to identify the major research directions and their interrelationships within the bibliographic dataset. The thematic network demonstrates a multidisciplinary research

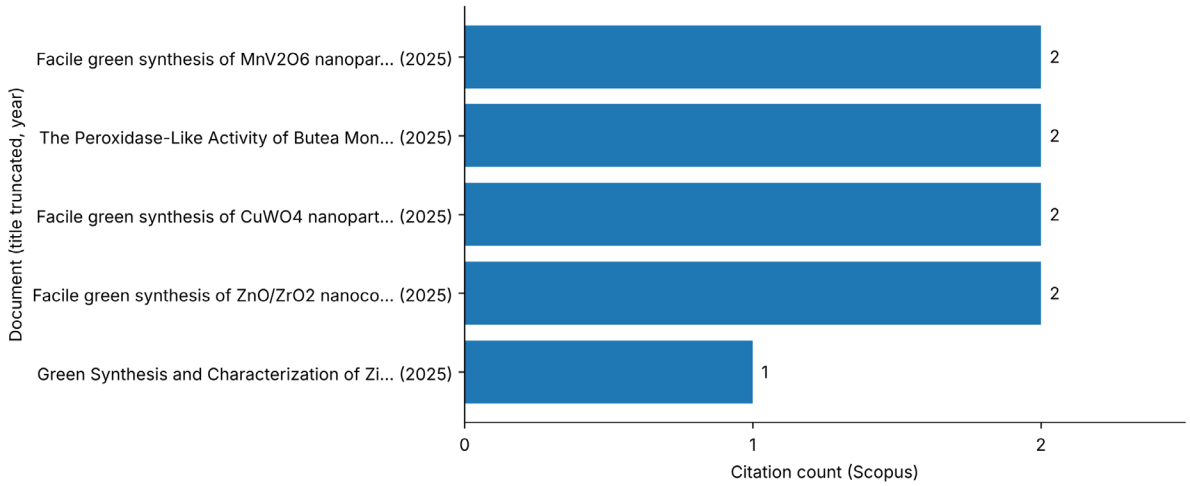


Figure 4: Ranking of the most highly cited publications identified in the *Butea monosperma* root-related pharmacological and antivenom research dataset. The horizontal bars represent the citation counts of the leading publications identified through the bibliometric analysis.

landscape involving phytochemistry, ethnopharmacology, nanotechnology, antimicrobial activity, antioxidant activity, and biomedical applications. The blue cluster is strongly associated with green synthesis, nanoparticles, synthesis-related terms, photocatalytic degradation, combustion, Fourier-transform infrared spectroscopy, and X-ray diffraction. This cluster indicates the development of research involving the preparation and physicochemical characterization of *Butea monosperma*-associated nanomaterials and their potential technological applications. The red cluster is characterized by terms such as plant extract, plant extracts, green chemistry, human, humans, review, metabolism, silver nanoparticles, metal nanoparticles, chemistry, and anti-neoplastic activity. This cluster reflects research linking plant-derived extracts with chemical, pharmacological, and nanomaterial-based applications. The presence of silver and other metal nanoparticle-related terminology further indicates the increasing integration of plant-mediated synthesis with biomedical and materials-oriented research. The green cluster contains terms including antioxidant, antibacterial activity, nonhuman, antimicrobial activity, zone of inhibition, particle size, biosynthesis, article, *Escherichia coli*, minimum inhibitory concentration, and wound-related biological applications. This cluster represents the biological evaluation of plant-derived materials and nanoparticles, particularly their antimicrobial and antioxidant properties. The central positioning of *Butea monosperma* within the network indicates its role as a connecting research theme across these clusters. The strong interconnections between phytochemical/plant-extract research, green synthesis, nanotechnology, and biological evaluation suggest that research involving *Butea monosperma* has expanded toward multidisciplinary applications rather than remaining restricted to traditional ethnopharmacological investigations. Importantly, the network also indicates that nanoparticle synthesis and biological evaluation are closely interconnected, with terms related to green synthesis, metal nanoparticles, antimicrobial activity, antioxidant activity, particle size, and characterization techniques occurring within interconnected thematic regions. This pattern suggests increasing integration of natural-product research with nanotechnology and experimental biomedical applications. The thematic network therefore highlights three broad and interconnected research directions: (i) green synthesis and nanomaterial development, (ii) plant-extract and phytochemical/chemical investigations, and (iii) biological and pharmacological evaluation. These interconnected themes provide a broader context for understanding the emerging applications of *Butea monosperma*-derived materials and bioactive constituents, including their potential relevance to future pharmacological and venom-neutralization research. The thematic network was generated using VOS viewer version 1.6.20 from the cleaned bibliographic dataset used in the present scientometric analysis. Keyword normalization was performed before network construction to minimize redundancy arising from synonymous terms, spelling variations, and singular/plural forms. The resulting thematic network is presented in Figure 8.

Pharmacological Interpretation of Emerging Themes

The keyword network provided a broader view of the pharmacological and biomedical themes associated with *Butea monosperma*-related research. Several interconnected research domains were identified, encompassing venom and antivenom

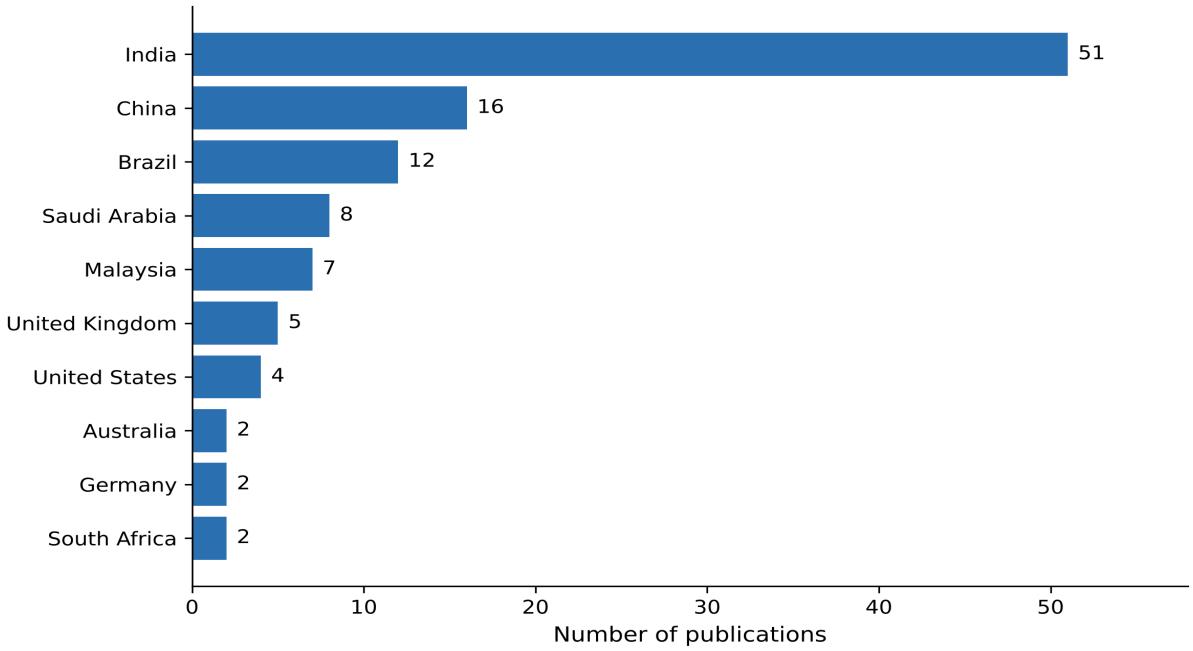


Figure 5: Summarizes the country-wise publication distribution and temporal pattern of documents represented in the analysed bibliographic dataset.

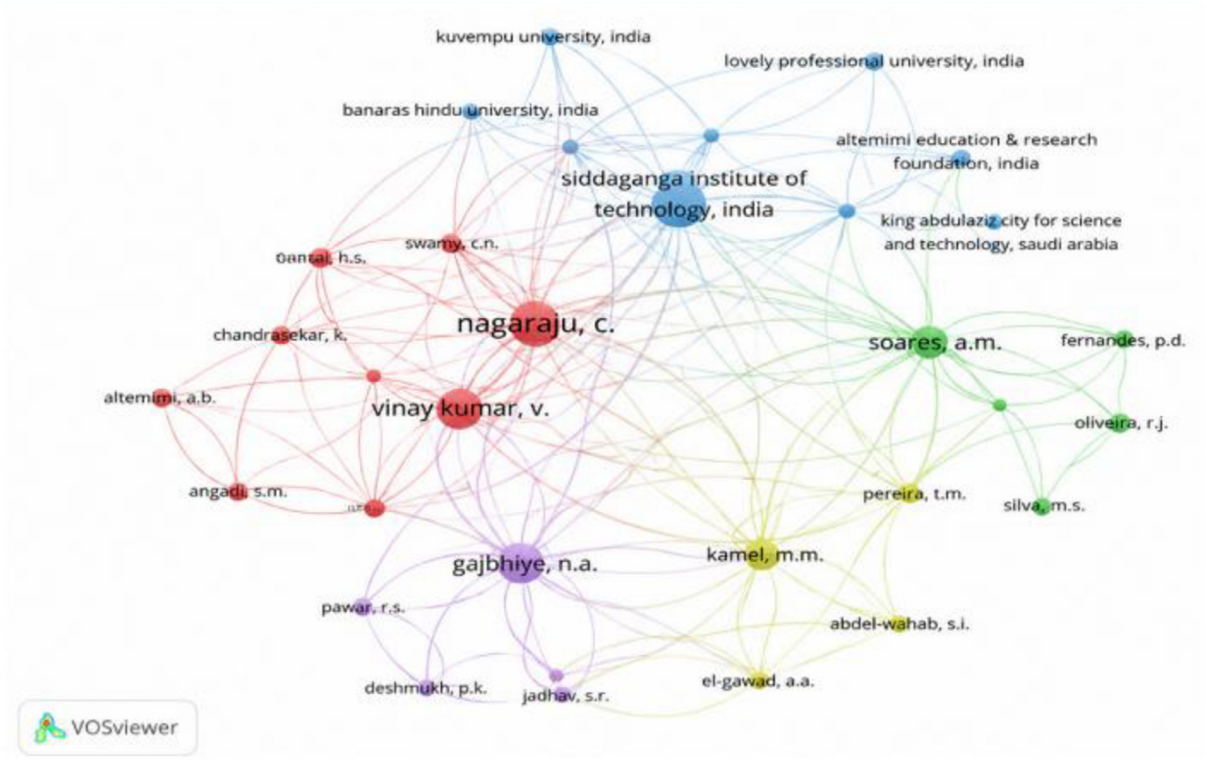


Figure 6: Co-authorship network of researchers contributing to *Butea monosperma*-related pharmacological and antivenom research. Node size represents the relative prominence of authors within the network, links indicate co-authorship relationships, and colours denote distinct collaboration clusters. The network was generated using VOS viewer version 1.6.20 from the cleaned bibliographic dataset for the study period 2000–2025.

research, animal and immunological studies, nanoparticle-based approaches, chemistry, drug delivery, and biological activity. The network demonstrates that research related to venom and antivenom is connected with broader pharmacological and biomedical investigations rather than forming a completely isolated research domain. The green cluster is predominantly associated with terms such as "venom antiserum," "snake bites," "snakebite," "animals," "animal antivenins," "immunology," "venom," "snake venoms," and "procedures." This cluster represents research concerned with venom, antivenom, animal models, and immunological aspects of snakebite-related investigations. The presence of these terms indicates the importance of experimental and immunological approaches within the broader venom-research literature. The blue cluster contains terms related to immunization, immunological adjuvants, animal experiments, female, male, horse, particle size, zeta potential, and related experimental variables. This cluster reflects research associated with immunological responses, experimental animal models, antivenom development, and physicochemical characterization of materials used in biomedical applications. The red cluster is characterized by keywords including "nanoparticle," "nanoparticles," "chemistry," "nanotechnology," "human," "metabolism," "liposome," "drug delivery system," "biological activity," and "anti-neoplastic activity." This cluster indicates the increasing integration of nanotechnology and pharmaceutical approaches within the broader research landscape. The occurrence of nanoparticle and drug-delivery terminology suggests growing interest in nanomaterial-based approaches for biomedical and therapeutic applications. The yellow cluster, located around central terms such as "article," "snake venom," "animal tissue," "animal model," "*in vitro* study," "mouse," and "snake venom antiserum," provides an additional link between experimental pharmacology, venom research, and biological evaluation. Its position between the other clusters indicates substantial thematic connectivity between venom-related studies and experimental biomedical research. Taken together, the network suggests that the research landscape has developed through the convergence of venom biology, antivenom research, immunology, experimental pharmacology, nanotechnology, and drug-delivery research. This multidisciplinary structure is particularly relevant when considering the potential pharmacological significance of plant-derived compounds. However, the bibliometric network should be interpreted as an indicator of research associations and thematic relationships, rather than as direct evidence of pharmacological efficacy or venom-neutralizing activity of *Butea monosperma* root extract. Importantly, the present scientometric analysis identifies research themes and their relationships but does not independently establish the effectiveness of *Butea monosperma* root phytochemicals against snake venom. Direct conclusions regarding venom-neutralizing mechanisms should therefore be based on experimental pharmacological evidence reported in the primary literature. The relatively

strong representation of venom, antivenom, immunology, and experimental-animal terms in the network nevertheless highlights areas in which further targeted investigation of *Butea monosperma* root-derived bioactive constituents may be warranted. The network was generated using VOS viewer version 1.6.20 from the cleaned bibliographic dataset used for the present scientometric analysis. Keyword normalization was performed before network construction to reduce redundancy caused by synonymous terms, spelling variations, and singular/plural forms. The resulting pharmacological and biomedical thematic network is presented in Figure 9.

DISCUSSION

Research Growth and Global Scientometric Trends

The present scientometric analysis demonstrates a gradual expansion of research associated with *Butea monosperma*, particularly in the context of pharmacological, ethnopharmacological, and bioactive applications relevant to snakebite and venom-related research. The temporal distribution of publications indicates relatively limited research activity during the earlier years, followed by increased publication output in the later period of the study. This pattern suggests that scientific interest has progressively expanded from traditional medicinal documentation and phytochemical investigations toward experimentally oriented pharmacological and nanotechnology-assisted applications. The geographical distribution of publications further indicates a strong concentration of research activity in India, which is consistent with the traditional medicinal importance of *Butea monosperma* and its extensive ethnopharmacological use in South Asia. The predominance of Indian publications also reflects the relevance of indigenous medicinal knowledge as a driver of research on medicinal plants associated with snakebite and other inflammatory or toxicological conditions. Similar geographical concentration has been reported in bibliometric investigations of medicinal plants and neglected tropical disease-related research, in which publication activity is frequently associated with regional disease burden, traditional knowledge systems, and availability of locally important medicinal resources. However, the present analysis differs from broader scientometric studies of medicinal plants because it focuses specifically on the research landscape associated with *Butea monosperma* roots and their potential relevance to antivenom research. The relatively limited representation of international contributors and the concentration of institutional and author collaborations within specific geographical regions indicate that this research area remains comparatively fragmented at the global level. Therefore, although publication activity is increasing, the field has not yet developed

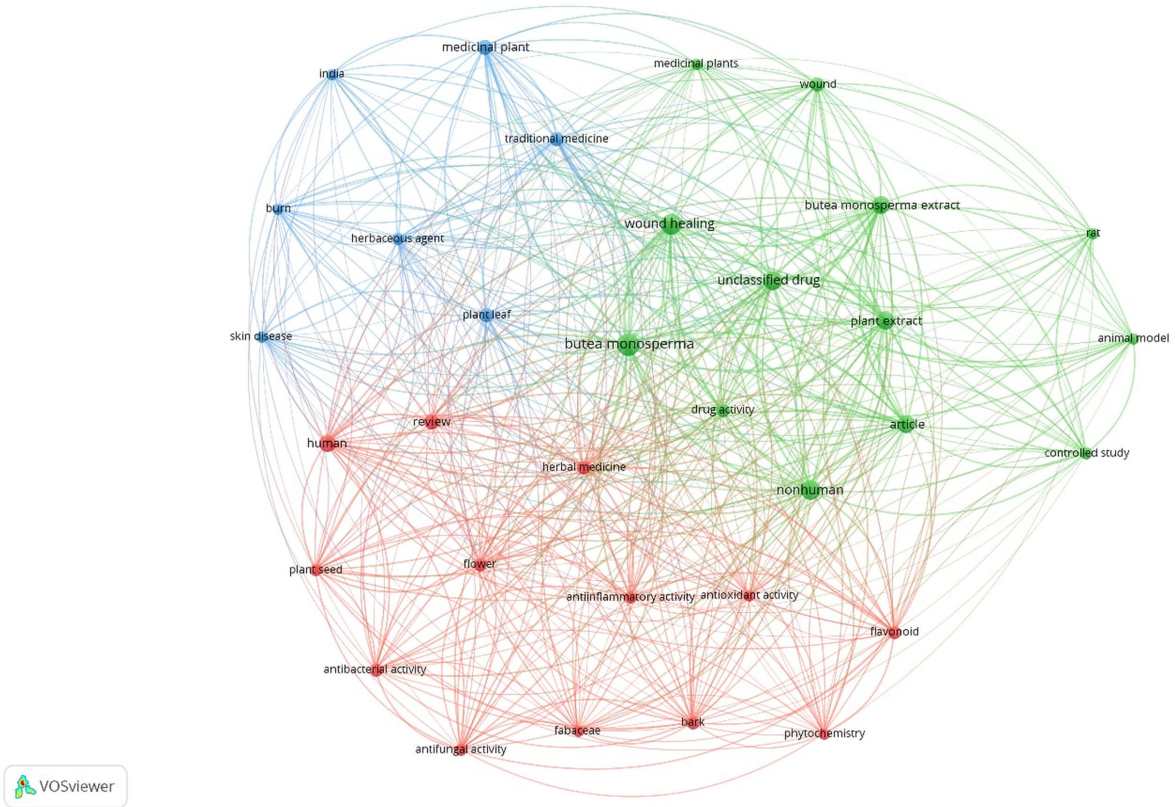


Figure 7: Keyword co-occurrence network illustrating major thematic relationships in *Butea monosperma*-related research. Node size represents the relative occurrence of a keyword, links indicate co-occurrence relationships between keywords, and colours represent distinct thematic clusters identified by VOS viewer. The network was generated using VOS viewer version 1.6.20 from the cleaned bibliographic dataset for the study period 2000–2025.

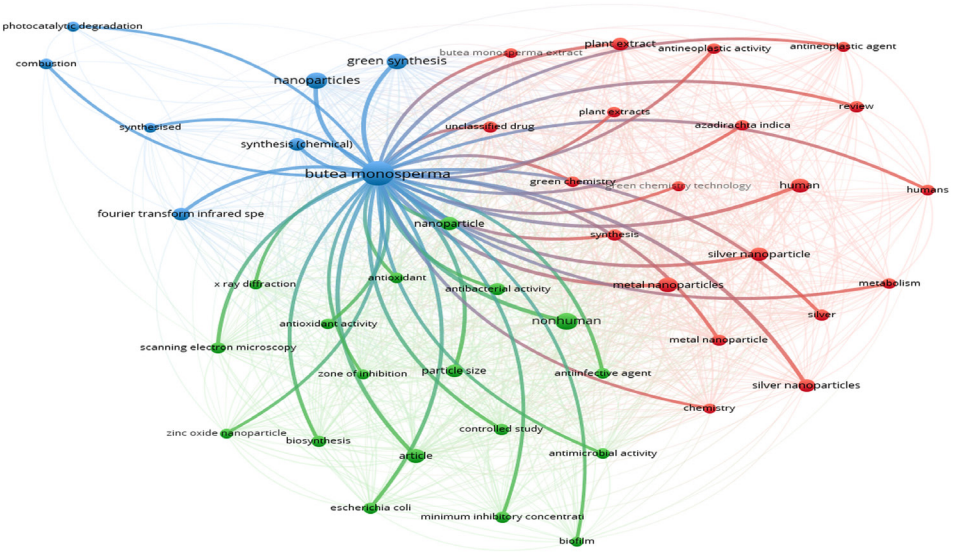


Figure 8: Thematic network illustrating major research clusters and their interrelationships in *Butea monosperma*-related research. The color-coded clusters represent distinct but interconnected thematic areas associated with green synthesis and nanotechnology, plant extracts and phytochemical/chemical research, and biological and pharmacological applications. Node size reflects the relative prominence of keywords, while connecting lines represent keyword co-occurrence relationships. The network was generated using VOS viewer version 1.6.20 from the cleaned bibliographic dataset for the study period 2000–2025.

the extensive international collaboration networks commonly observed in more mature biomedical research areas. Overall, the temporal and geographical patterns indicate that *Butea monosperma* research is evolving from predominantly traditional and phytochemical investigations toward multidisciplinary pharmacological and nanobiotechnology-oriented research. Nevertheless, the relatively specialized nature of the field highlights the need for broader international collaboration and standardized experimental approaches to establish the therapeutic relevance of root-derived preparations (Parvin *et al*., 2025; Linnenluecke *et al*., 2020; Knudsen *et al*., 2020; Silva & Chowdhury, 2024).

Research Hotspots and Emerging Themes

Keyword co-occurrence analysis identified several major thematic areas within the retrieved literature, including ethnopharmacology, traditional medicine, phytochemistry, antioxidant activity, wound healing, nanoparticles, drug delivery, and venom-related research. The relative prominence and connectivity of these themes indicate that research on *Butea monosperma* has historically been broader than its specific application as a potential antivenom. Ethnopharmacology and traditional medicine constituted important thematic components of the research landscape, reflecting the historical use of *Butea monosperma* in traditional healthcare practices. Phytochemical-related terms, including flavonoids, tannins, phytochemicals, and plant extracts, were also strongly represented, indicating continued interest in identifying bioactive constituents that may contribute to the biological activities of the plant. A comparatively smaller thematic component was associated with snakebite, venom, and antivenom-related research. This finding is particularly important because it demonstrates a distinction between the overall pharmacological research landscape of *Butea monosperma* and the specific research domain concerning venom neutralization. Although the plant has substantial ethnopharmacological relevance, direct research addressing standardized venom-neutralization activity appears to constitute a relatively limited component of the retrieved literature. The emergence of nanoparticle- and drug-delivery-related terms represents another important development. Recent research increasingly connects plant-derived materials with green synthesis and nanobiotechnology, indicating a broader transition toward technologically assisted applications of medicinal plants. Similar trends have been reported in broader research on plant-mediated nanotechnology, where green synthesis and bioactive plant constituents are increasingly integrated with biomedical applications. Thus, the keyword landscape suggests that the field is progressing from predominantly descriptive ethnopharmacological and phytochemical research toward more experimentally oriented and technologically integrated investigations. At the same time, the comparatively smaller venom-neutralization cluster identifies a specific research gap that warrants further investigation (Bulfone *et al*., 2018; Knudsen & Laustsen, 2018; Ale *et al*., 2025).

Ethnopharmacological Relevance and Pharmacological Interpretation

The ethnopharmacological value of *Butea monosperma* provides an essential background for elucidating the observed study terrain. Established therapeutic uses have spurred sustained

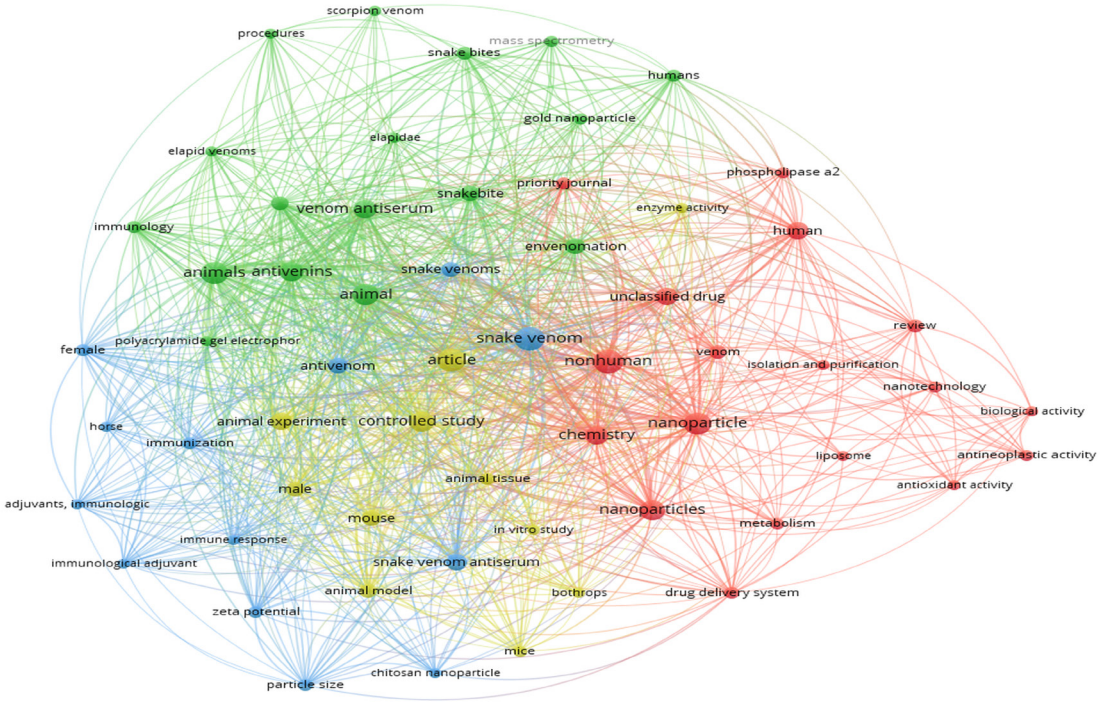


Figure 9: Conceptual framework linking bibliometric research clusters with proposed pharmacological and venom-neutralization themes associated with *Butea monosperma* root phytochemicals. Visualization generated using VOS viewer v1.6.20 based on bibliographic datasets retrieved from Scopus®, Web of Science Core Collection®, and PubMed® databases (2000–2025).

scientific interest in many plant sections, particularly roots, and have given a framework for analysing its phytochemical constituents and biological effects. The qualitative review of the 30 crucial core studies highlighted many pharmacological themes that might be related to the antivenom significance of preparations generated from *Butea monosperma* roots. These included antioxidant and anti-inflammatory effects, as well as examinations of venom-associated enzymes and other biological targets. These results provide a pharmacological justification for further inquiry; nonetheless, they should not be seen as substantiation of clinically recognized antivenom effectiveness. Consequently, a vital separation must be made between the pharmacological actions attributed to the plant and the verified venom-neutralizing activity. Attributes such as antioxidant, anti-inflammatory, antibacterial, or wound-healing effects may have a role in managing tissue damage from envenomation, but, they do not only guarantee direct neutralization of snake venom. Correspondingly, analyses involving enzymes like phospholipase A_2 or proteases need uniform venom models and proper experimental controls before their importance in antivenom can be ascertained. Therefore, the bibliometric and thematic insights highlight the need for a thorough examination of the phytochemical elements of *Butea monosperma* roots, subsequently accompanied by standardized *in vitro* and *in vivo* evaluations against significant snake venoms. Upcoming research must include phytochemical standardization, dose-response investigations, toxicity evaluations, mechanism-specific tests, and repeatable models for venom neutralization (Pal & Bose, 2011; Williams *et al*., 2019; Methaniya *et al*., 2023).

Nanotechnology and Translational Research Potential

Nanotechnology has risen to prominence as a notable facet of the expansive study environment related to *Butea monosperma*. The appearance of phrases linked to nanoparticles, environmentally friendly synthesis, drug transport, and biological performance denotes an advancing integration of plant study and nanobiotechnology. This tendency is pertinent to the future progression of plant-derived medicinal systems, as nanoparticle-based techniques could provide avenues for augmenting the stability, transport, or regulated release of bioactive chemicals. Yet, the present scientometric study should not be seen as indicating that nanoparticles from *Butea monosperma* are now acknowledged as antivenom agents. Instead, the noted theme coherence points to a likely future study pathway. The synthesis of standardized *Butea monosperma* phytochemicals with suitable nanocarriers warrants investigation for applications concerning venom-induced oxidative stress, inflammation, tissue damage, or targeted therapeutic interventions. Such tactics would involve meticulous physicochemical profiling, toxicity assessment, pharmacokinetic analysis, and corroborated venom-associated experimental designs. Notably, formulations originating from plants or those using nanoparticles should be considered as possible supplementary options, rather than as alternatives for

standard antivenom interventions. The available data discerned by scientometric and thematic analysis does not enough to advocate for the therapeutic replacement of standard antivenom interventions (Balasubramanian *et al*., 2026; Methaniya *et al*., 2023; Linnenluecke *et al*., 2019; Moradeeya *et al*., 2025).

Strategic Importance of Scientometric Mapping

This study presents a quantitative assessment of the progression, geographic dispersion, cooperative structure, and theme categorization of research pertaining to the pharmacological and prospective antivenom uses of *Butea monosperma* roots. Distinct from standard narrative reviews, scientometric analysis enables the examination of a research field's development via trends in publications, citation dynamics, collaborative frameworks, and keyword interconnections. An especially crucial observation is the contrast between the wide-ranging research environment associated with *Butea monosperma* and the more restricted theme emphasis on venom-neutralization research. This differentiation facilitates the identification of a research deficiency that may not be easily discernible from studies analysing the plant's pharmacological characteristics in isolation. The findings further reveal potential for increased synergy amongst ethnopharmacology, phytochemistry, venom biology, toxicology, pharmacology, and nanotechnology. Upcoming collaborative research endeavours in these domains might enable the progression from conventional evidence and preliminary pharmacological findings to therapeutically validated applications grounded in mechanistic understanding. Thus, the existing scientometric assessment may act as a blueprint for research organization by highlighting known research topics, burgeoning technology pathways, and sectors that want additional empirical confirmation. Specifically, increased international partnership, established research methodologies, and comprehensive analysis of root-derived phytochemicals vis-à-vis defined snake venoms may fortify the evidence basis in this developing area (Fang *et al*., 2015; Elayaperumal *et al*., 2025).

Limitations

A multitude of limitations should be recognized while assessing the outcomes of this investigation. To begin with, the literature search was narrowed to English-language works indexed in Scopus, Web of Science Core Collection, and PubMed. Thus, applicable non-English literature, area-specific studies, or research not included in these databases may have been omitted. Furthermore, bibliometric measures such as citation numbers are determined by the publication's age, the prominence of the journal, and the conventions around citations. Consequently, papers that have been recently published may seem to possess a lesser citation effect, even if they reflect evolving research pathways. Third, the scientometric study mostly reveals trends in the published literature and fails to independently ascertain the pharmacological activity of *Butea monosperma* root extracts. The qualitative evaluation was based on a specific subset of 30 relevant research and should be seen as a contextual pharmacological interpretation rather than a systematic review of therapeutic effectiveness. Fourth, the diversity among the current experimental research, characterized by variances in plant extraction protocols, phytochemical compositions, venom species, experimental designs, assay settings, and result assessments, hinders direct comparisons of individual pharmacological outcomes. In the end, the search interval was narrowed to include only articles accessible till 2025. Accordingly, ensuing articles could reshape the study framework and theme motifs established in the current examination. Although these limitations exist, the paper presents a coherent summary of the advancement and current research framework regarding the pharmacological attributes of *Butea monosperma* root and its prospective antivenom applications, identifying key paths for further experimental and translational inquiries (Moradeeya *et al*., 2025).

FUTURE PERSPECTIVES

The current scientometric and thematic assessment demonstrates that research focused on the possible antivenom use of *Butea monosperma* roots is relatively underdeveloped and calls for further integration of pharmacology, toxicology, phytochemistry, venom biology, and nanotechnology. Therefore, next inquiries should transition from basic ethnopharmacological assessments to standardized and mechanistically verified frameworks. A key emphasis is the standardization of vegetal materials and extraction processes. Disparities in geographical origin, plant age, extraction solvent, extraction circumstances, and phytochemical composition might profoundly alter biological activity and make study comparisons challenging. Hence, further investigations must create standardized extraction techniques along with chromatographic and spectrometric analysis of root extracts. Careful emphasis must to be devoted to the detection and assessment of potentially bioactive classes, including flavonoids, phenolic compounds, tannins, and alkaloids, along with the linkage of their chemical profiles to particular pharmacological functions (Gutiérrez *et al*., 1988). More experimental verification using standardized snake-venom models is needed to establish whether the claimed pharmacological qualities provide actual venom-neutralizing effects. Upcoming research must utilize precisely defined venoms from relevant snake species in a clinical context, including necessary controls, dose-response assessments, and standardized measures. It is crucial to prioritize the assessment of venom-related enzymatic activities, particularly phospholipase A_2 and proteases, along with their inflammatory, oxidative, haemorrhagic, cytotoxic, and tissue-injurious consequences. Studies contrasting traditional antivenom could reveal if *Butea monosperma*-based formulations are viable as complementary rather than replacement therapy (Júnior *et al*., 2025). The increasing integration of ethnopharmacology with nanotechnology is a vital research opportunity. Nanoparticles and

nanoformulations mediated by plants might be studied as delivery mechanisms for standardized materials. *Butea monosperma* phytochemicals are characterized by increased stability, managed release, or augmented bioavailability. However, these techniques need meticulous physicochemical characterization, toxicological analysis, pharmacokinetic research, and direct evaluation in venom-related experimental paradigms before their translational potential can be determined (Teixeira-Araujo *et al*., 2025). Computational techniques could enhance the speed of identifying prospective bioactive substances. Techniques such as molecular docking, molecular dynamics simulations, network pharmacology, and structure-based screening might facilitate the examination of possible interactions between identified phytochemicals from *Butea monosperma* and venom-associated molecular targets. Such computer predictions must be substantiated with relevant biochemical and biological tests rather than being construed as independent proof of antivenom effectiveness. The amalgamation of omics-oriented techniques, including metabolomics, proteomics, and venom-associated transcriptome investigations, might enhance comprehension of the relationships between venom elements and phytochemical bioactive substances. These strategies might enable the identification of molecular pathways impacted by treatment and streamline the selection of potential drugs or standardized extract fractions for further experimental analysis (Idakwoji *et al*., 2026). The focus of future development should consistently be on safety and translational practicality. Detailed evaluations of systematic cytotoxicity, acute and repeated-dose toxicity, pharmacokinetics, and formulation stability are necessary before progressing to higher-level preclinical models. Where there is enough preclinical data, suitably crafted translational studies and, eventually, scrupulously controlled clinical research in snakebite-endemic locales may be deemed feasible. Ultimately, augmented worldwide and multidisciplinary cooperation will be crucial for the development of this subject. The collaboration of ethnopharmacologists, Phyto chemists, pharmacologists, toxicologists, venom researchers, nanotechnologists, computational biologists, and clinicians could enable the creation of standardized methodologies, availability of characterized venoms, reproducible validation, and the advancement of clinically relevant research protocols. Cooperative actions could aid in the changeover. The study of *Butea monosperma* root has progressed from initial pharmacological exploration to credible scientific validation of its promise as an auxiliary strategy for snakebite management (Vasconez-Gonzalez *et al*., 2025).

CONCLUSION

This scientometric study elucidates the trends in publication growth, geographic distribution, collaboration frameworks, citation metrics, and thematic progression of research focused on *Butea monosperma* roots and their prospective pharmacological applications in snakebite and venom studies from 2000 thru 2025. The investigation shows a growing scientific curiosity for *Butea monosperma*, notably in the domains of phytochemistry, ethnopharmacology, antioxidant activity, wound healing, and plant-mediated nanotechnology. The topic analysis shows that research dedicated to venom-neutralizing or antivenom-related applications is still somewhat restricted within the larger framework of *Butea monosperma* studies. This differentiation denotes a vital research lacuna highlighted by the existing research. The superiority of Indian and South Asian contributions illustrates the ethnopharmacological significance of the plant and the regional importance of snakebite research, whilst the limited international partnership reveals a chance for larger global research integration. The qualitative evaluation of the essential research highlighted pharmacological themes including antioxidant and anti-inflammatory actions, phytochemical ingredients, and examinations pertinent to biological targets linked to venom. Yet, these conclusions should not be taken as substantiation that *Butea monosperma* root products are validated antivenom agents. The research that is accessible is mostly preclinical, with notable variety in the methods of plant extraction, phytochemical content, experimental models, kinds of venom, and assessments of outcomes. The conclusions underscore several key priorities for future investigations, including the standardization of plant materials and extraction protocols, detailed phytochemical characterization, mechanistic studies on venom neutralization, toxicity and pharmacokinetic assessments, computational screening, and the examination of nanotechnology-based delivery systems. Notably, next trials must prove if *Butea monosperma*-derived products may provide meaningful complementary advantages in tandem with standard antivenom therapy, rather than presuming they can substitute existing antivenom interventions. By synthesizing scientometric findings with specific thematic and pharmacological interpretations, this investigation uncovers both recognized research sectors and notable lacunae in the contemporary literature. The findings provide a platform for devising standardized, interdisciplinary, and experimentally corroborated research methodologies that might elucidate the therapeutic advantages and limitations of bioactive systems produced from *Butea monosperma* roots in the extensive realm of snakebite treatment.

ABBREVIATIONS

WHO: World Health Organization; **WoSCC:** Web of Science Core Collection; **PRISMA:** Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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Cite this article: Jadeja RA, Mayani SV. Global Research Trends on Anti-Snake Venom Potential of *Butea monosperma* Root Extract: A Scientometric and Thematic Review. J Scientometric Res. 2026;15(3):1156-73.