

Hotspots and trends in Scorpion research: A visualization analysis

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Hotspots and trends in Scorpion research: A visualization analysis

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Abstract: Scorpions, recognized for their evolutionary significance and therapeutic potential including treatment with neurological, cardiovascular, and oncological disorders, were investigated through a systematic bibliometric analysis using ITGInsight software. A total of 2918 English-language publications published between 2014 and 2025 were retrieved from the Web of Science Core Collection to map research trends, collaborative networks, and thematic evolution in scorpion-related studies. The results revealed that the United States, China, and Brazil were the leading contributors to this field, with the National Autonomous University of Mexico and the University of São Paulo emerging as the most productive institutions. High-frequency keywords such as "scorpion" and "venom" highlighted two dominant research themes: scorpion taxonomy and venom studies. By comprehensively characterizing the current research landscape and trend, this study provides a valuable reference for guiding future investigations in scorpion research.

Keywords: Bibliometric, ITGInsight, Scorpion, Research trend

1 Research Background

Scorpions (order *Scorpiones*, class *Arachnida*) originated during the Silurian period approximately 430 million years ago (Howard et al. 2019). They retain substantial ancestral genetic characteristics, and their dual respiratory system, comprising both book lungs and tracheae, provides important evidence for the evolutionary transition from aquatic to terrestrial environments (Binupriya et al. 2008; Abroug et al. 2020; Aria 2022). Widely distributed across diverse ecological niches, scorpions exhibit remarkable adaptability to extreme conditions. This is exemplified in East Asia, highly venomous desert species in India and the Middle East, and xeric-adapted species in the Americas and Africa (Sridhara et al. 2016; Mabunda et al. 2024; Barahoei et al. 2026). Scorpion stings are a public

health concern that cannot be ignored globally, especially in tropical and subtropical regions, causing a large number of envenomation incidents each year, but it is reported that scorpion venom contains a wide array of bioactive components, including neurotoxic peptides, ion channel modulators, and bioactive lipids, many of which show significant therapeutic potential for neurological, cardiovascular, and oncological applications(Mendes et al. 2023; Xia et al. 2023; Mumtaz et al. 2024). In addition, the chitinous exoskeleton of scorpions has inspired the development of bio-derived materials and biosensing technologies(Cody et al. 2011; Kellersztein et al. 2019).

Bibliometrics has emerged as a dynamic and influential subfield within library and information science, distinguished by its ability to transform complex publication data into intuitive visual representations. These visualizations effectively reveal research trends, emerging hotspots, influential scholars, institutional networks, and patterns of scientific collaboration within specific domains(Mazov et al. 2020). Meanwhile, ITGInsight is an advanced bibliometric analysis tool that combines powerful analytical methods with visualization techniques to systematically map and interpret scientific knowledge structures, and it has been extensively deployed in bibliometric studies across diverse research domains(Wang et al. 2022; Wang et al. 2026).

The Web of Science Core Collection (WOSCC) encompasses high-quality journal databases, including the Science Citation Index Expanded (SCI-E), Social Sciences Citation Index (SSCI), and Arts&Humanities Citation Index (A&HCI). Journals indexed in WOSCC are selected through rigorous evaluation criteria, such as impact metrics, editorial standards, and international diversity, making it an optimal data source for bibliometrics study and ensuring both methodological reliability and scholarly representativeness(Singh et al. 2023).

Although a great deal of progress has been achieved in scorpion research, a systematic analysis

remained vague. To address the gap, based on the research background and procedural foundation outlined above, a bibliometric analysis of the scorpion research is conducted according to the WoSCC and ITGInsight while its bioactive components and pharmacological values are reviewed.

2 Data Sources and Research Process

A holistic search strategy was implemented and encompassed publications dated from January 1, 2014, to December 31, 2025 (data accessed on March 1, 2026), with the specific query parameters [TS=(Scorpio) OR (Scorpion)], [Document Type= (Article OR Review Article)], and [Language=(English)] being applied. This process initially identified 3,381 records. Subsequently, automatic filters rigorously excluded irrelevant document types, including Early Access materials, Conference Proceedings, Letters, News Items, and Retracted Publications. Following this, a manual verification process was conducted to eliminate entries unrelated to the scorpion, such as whip spiders (order *Amblypygi*), the scorpionfish (family *Scorpaenidae*), and mud turtles (*Kinosternon scorpioides*), which retained 2,839 high-quality publications. To ensure maximum data integrity, the remaining records underwent a standardized cleansing procedure through ITGInsight. It yielded a refined dataset of 2818 publications suitable for in-depth analysis finally.

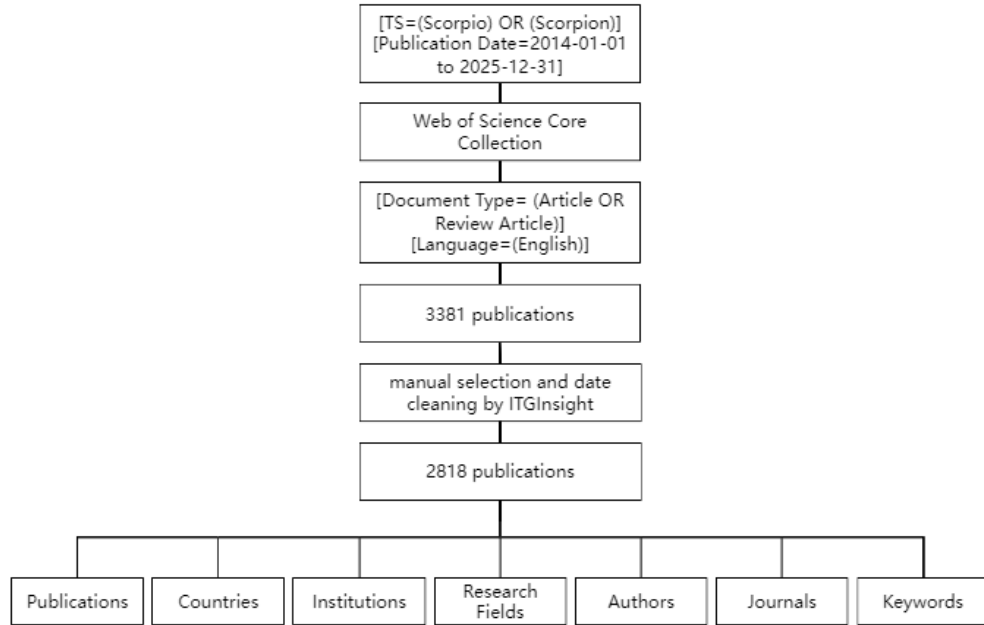


Figure 1. Flow chart of the scorpion data research

3 Annual Publication Output

The study of scorpion research publications between 2014 and 2025 revealed a fluctuating yet noticeable evolution in scholarly activity, as depicted in **Figure 2**. A total of 2,818 publications were registered over this period, with an average of 256 articles published annually, which was roughly 21 articles per month.

From 2014 to 2025, the overall trend showed a stable output in research interest with more than 200 papers every year, although with some annual fluctuations. The year 2021 stood out as the most prolific year with 257 publications, marking the height of research output.

The overall publication output exhibited a steady upward trend from 2014 to 2025, reflecting progressively increasing engagement of the research community in scorpion-related studies. Notably, after 2020, the field entered a phase of accelerated growth, with particularly pronounced increases in 2021 and 2024, during which research activity consistently maintained high output levels. In contrast, the year 2025 showed a small decrease with 216 publications.

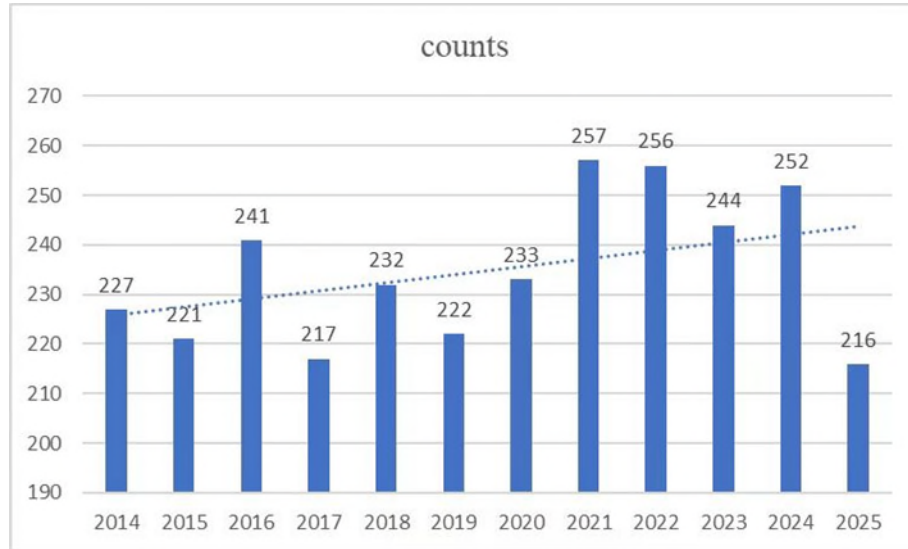


Figure 2. Annual Publication Output (2014-2025)

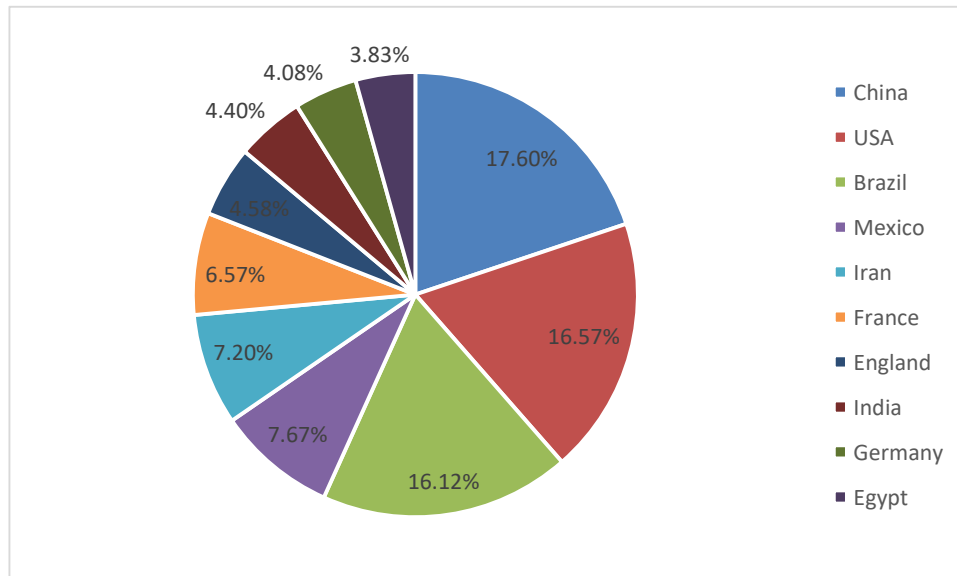
4 Active Publishing Countries

An analysis of the global scorpion research publications reveals significant variations in focus areas and research trends across countries. As **Table 1** and **Figure 3** presented the top ten contributing countries were China (496 publications, 17.60%), the United States (467 publications, 16.57%), Brazil (456 publications, 16.18%), followed by Mexico, Ireland, France, United Kingdom, India, Germany, and Egypt. It indicated that China, the United States, and Brazil dominated the top three positions accounting for about half of the total output.

Figure 4 illustrated the international collaboration network in scorpion research. In this kind of visualization, node size represents the extent of a country's collaborative activity, with larger nodes indicating higher levels of international engagement, while edge thickness reflects the strength of bilateral cooperation. Based on node prominence, China, the United States, and Brazil emerged as central hubs within the network. The notably thick connections among these countries further indicated strong collaborative ties, underscoring their pivotal roles in promoting international cooperation in this field, which was consistent with the analysis above in **Table 1** and **Figure 3**.

Table 1 Top 10 countries

Rank	Country	Publications	Proportion
1	China	496	17.60%
2	USA	467	16.57%
3	Brazil	456	16.12%
4	Mexico	216	7.67%
5	Iran	203	7.20%
6	France	185	6.57%
7	United Kingdom	129	4.58%
8	India	124	4.40%
9	Germany	115	4.08%
10	Egypt	108	3.83%

**Figure 3** Country Share Distribution

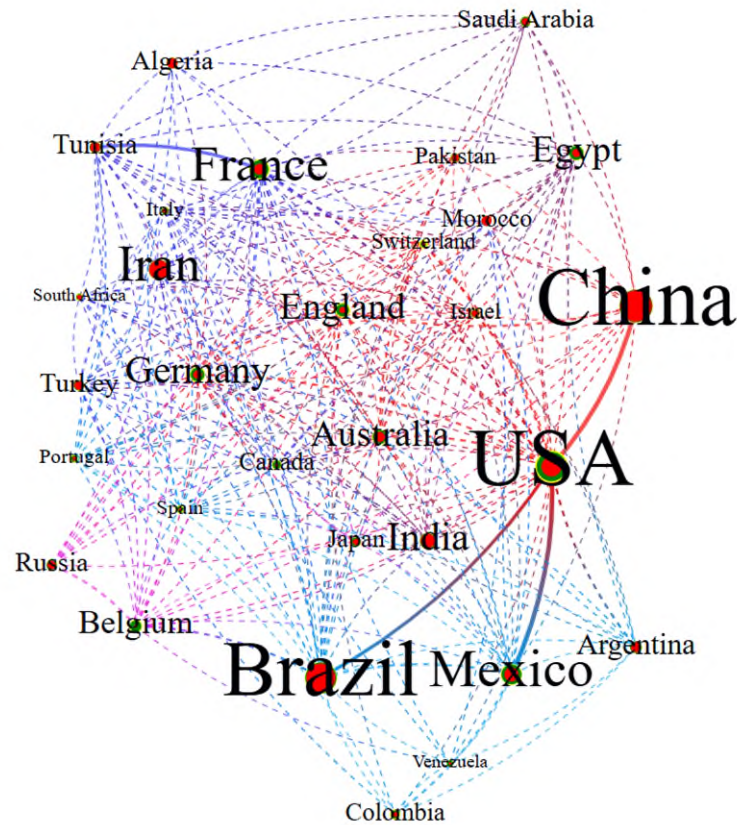


Figure 4 Country Collaboration Network

5 Leading Institutions

As shown in **Table 2**, the ten most productive institutions in scorpion research were geographically distributed across Brazil, Mexico, China, Russia, the United States, Australia, and Iran. Major contributing organizations included the National Autonomous University of Mexico (164 publications) in Mexico, followed by Universidade de São Paulo (108 publications) in Brazil, while the Chinese Academy of Sciences (68 publications) and Wuhan University (67 publications) in China ranked third and the fourth respectively. Overall, this distribution reflected a strong alignment between scorpion research productivity, global centers of scorpion biodiversity—particularly in the Americas and Asia—and the geographic concentration of scientific research resources.

As depicted in **Figure 5**, the institutional collaboration network identifies the National

Autonomous University of Mexico as its core node. Furthermore, transcontinental collaborative relationships are observed among these highly productive institutions: the National Autonomous University of Mexico (Mexico), the University of São Paulo (Brazil), the Chinese Academy of Sciences and Wuhan University (China), and the American Museum of Natural History (United States), which was in lined with the analysis of **Table 2**.

Table 2 top 10 institutions

Rank	Institutions	Which country belong to	Publications	Proportion	Citation
1	National Autonomous University of Mexico	Mexico	164	5.82%	2136
2	Universidade de São Paulo	Brazil	108	3.83%	1819
3	Chinese Academy of Sciences	China	68	2.41%	835
4	Wuhan University	China	67	2.38%	866
5	American Museum of Natural History	USA	61	2.17%	1055
6	Universidade Federal de Minas Gerais	Brazil	50	1.77%	605
7	Russian Academy of Sciences	Russia	49	1.74%	981
8	Instituto Butantan	Brazil	46	1.63%	1076
9	The University of Queensland	Australia	46	1.63%	1475
10	Ahvaz Jundishapur University of Medical Sciences	Iran	42	1.49%	240

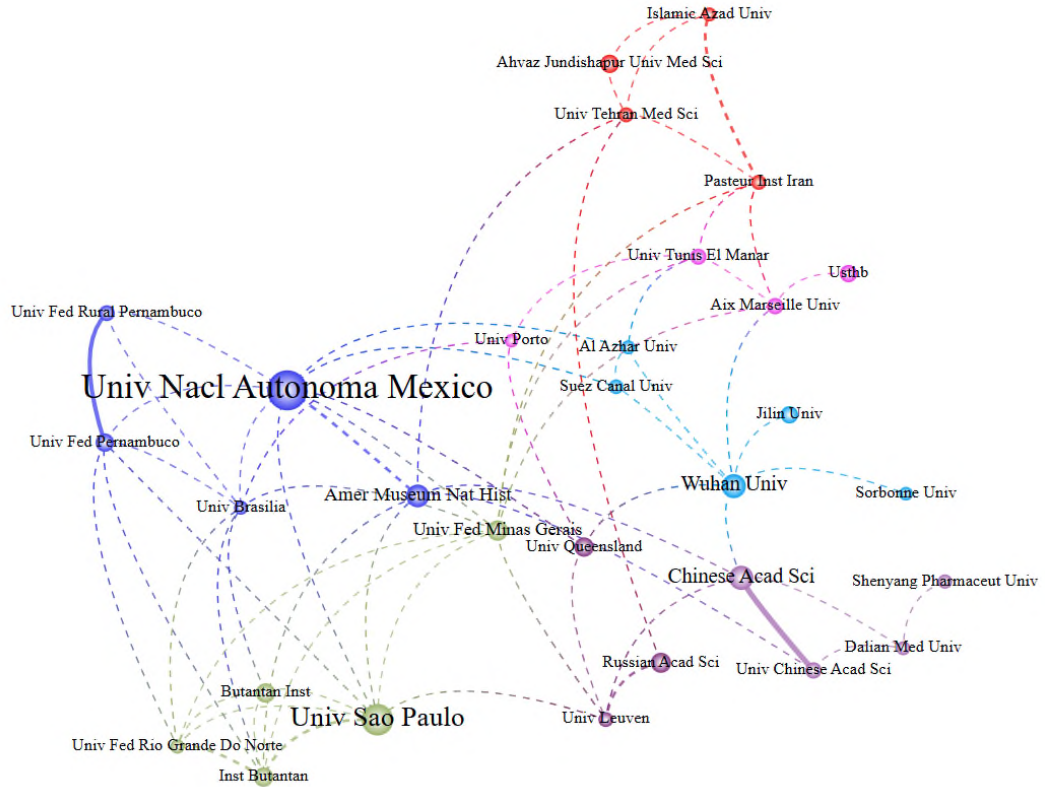


Figure 5 Institutional Collaboration Network

6 Prolific Authors

As shown in **Table 3**, the ten most prolific authors in this field were identified. The analysis revealed three particularly influential scholars: Possani, Lourival D. (70 publications, 1,302 citations), Tytgat, Jan (60 publications, 1,020 citations), and Peigneur, Steve (54 publications, 913 citations). **Figure 6** presented an author clustering diagram, in which the spatial arrangement and node colors differentiated authors into thematic clusters based on their research directions, while node size corresponded to their academic contribution, providing a visual representation of their relative research output.

Figure 7 illustrated the temporal evolution of the author collaboration network and provided a longitudinal perspective on research activity and team dynamics throughout the study period. In this timeline visualization, nodes represented individual authors or affiliated research groups, with distinct colors denoting different collaborative clusters. The horizontal distribution of nodes reflected the

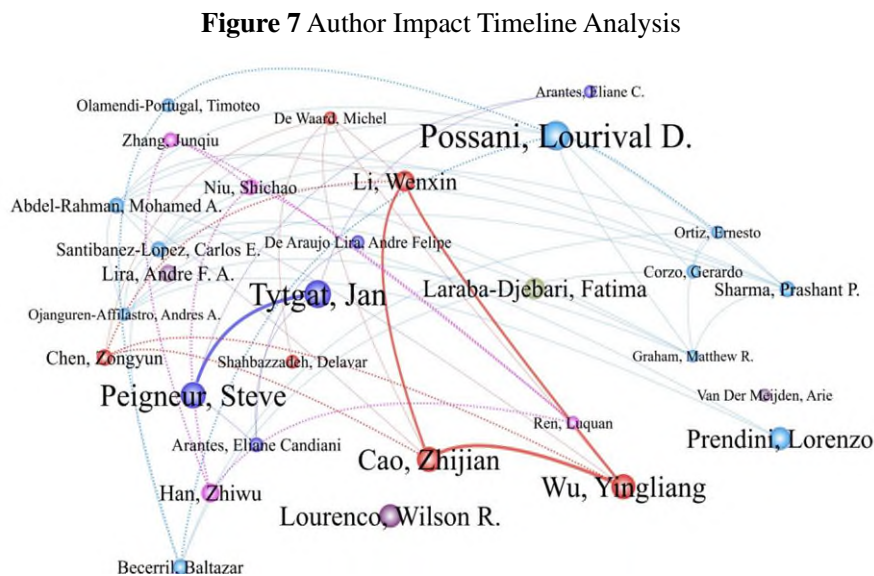
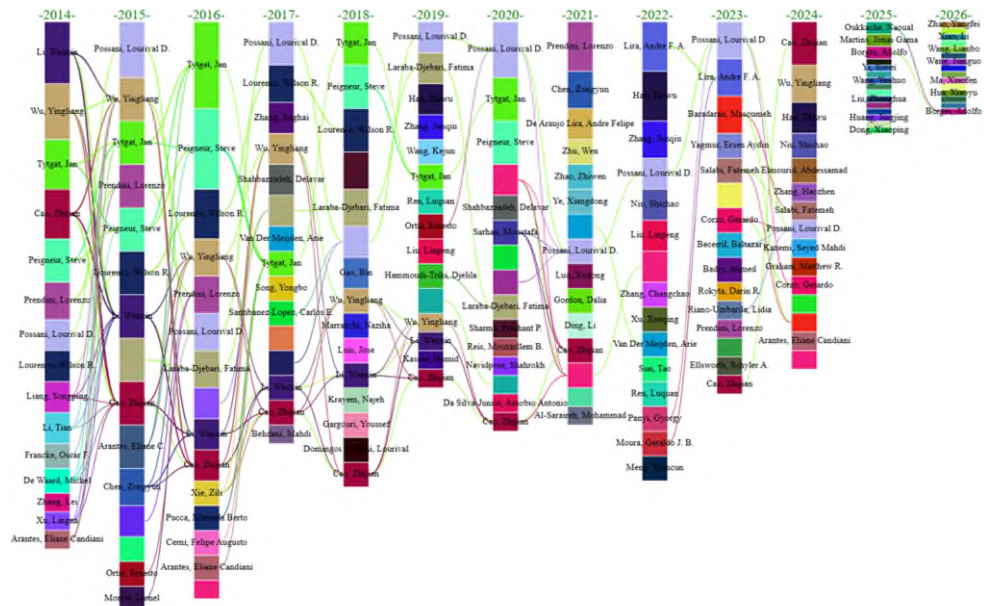
duration of research activity over time, while connecting lines indicated co-authorship relationships, and their thickness represented collaboration strength. Notably, several key authors, including Possani, Lourival D., and Wu, Yingliang, maintained continuous visibility throughout the entire study period. Their extended temporal presence indicated sustained scholarly productivity and long-term engagement in scorpion research.

Figure 8 presented a co-authorship network illustrating the complex structure of research collaborations in this field. In the visualization, the thickness of connecting lines serves as an indicator of collaboration strength, reflecting the intensity of academic partnerships. The analysis, conducted using ITGInsight, identified several particularly strong collaborative relationships, including Tytgat, Jan and Peigneur, Steve (54 co-authored publications), Wu, Yingliang and Cao, Zhijian (46 publications), Li, Wenxin and Wu, Yingliang (36 publications), and Li, Wenxin and Cao, Zhijian (35 publications).

It is noteworthy that Wu, Yingliang, who ranked fourth among the ten most prolific authors, remained consistently active in both the Author Impact Timeline Analysis (**Figure 7**) and the Co-authorship Network Visualization (**Figure 8**). In addition, Possani, Lourival D., who held the top position in **Table 3**, demonstrated sustained prominence in the Author Impact Timeline Analysis (**Figure 7**). Similarly, Tytgat, Jan, ranked second in **Table 3**, also maintained notable activity in **Figure 7**. These findings collectively indicated a high degree of consistency among the results presented in **Table 3**, **Figure 7**, and **Figure 8**.

Table 3 top 10 author

Rank	Author	Which assignee belong to	Publications	Proportion	Citation
1	Possani, Lourival D.	National Autonomous University of Mexico	70	2.48%	1302
2	Tytgat, Jan	University of Leuven	60	2.13%	1020
3	Peigneur, Steve	University of Leuven	54	1.92%	913
4	Cao, Zhijian	Wuhan University	53	1.88%	734
5	Wu, Yingliang	Wuhan University	52	1.85%	742
6	Prendini, Lorenzo	American Museum of Natural History	47	1.67%	559
7	Lourenco, Wilson R.	Sorbonne University University of Science	46	1.63%	298
8	Laraba-Djebari, Fatima	and Technology Houari Boumediene	42	1.49%	339
9	Li, Wenxin	Wuhan University	37	1.31%	711
10	Han, Zhiwu	Jilin University	35	1.24%	665



7 Core Journals

As shown by the journal-level results (**Table 4** and **Figure 9**), *Toxicon* (253 publications; 3,159 citations) was the most productive outlet in scorpion research. Its publications focused primarily on scorpions (49 publications), followed by scorpion venom (43 publications) and venom (41 publications). *Toxins* ranked second (152 publications; 2,152 citations), with a research emphasis on scorpion (24 publications), venom (24 publications), and scorpion venom (20 publications). The third-ranked journal, *Journal of Venomous Animals and Toxins including Tropical Diseases* (69 publications; 1,068 citations), focused mainly on scorpion (17 publications), scorpion venom (17 publications), and venom (8 publications). Overall, scorpion venom emerges as the central research focus across these high-output publications.

Shown in **Figure 10**, the nodes representing the National Autonomous University of Mexico in *Toxicon* (36 publications) and *Toxins* (24 publications) were comparatively large, indicating a high volume of publications by this institution in these two journals. This pattern further suggested a strong alignment between the institution's research focus and the thematic scope of these journals. A similar trend was observed for the Universidade de São Paulo, which contributed the largest number of articles to *Toxicon* (21 publications). What's more, institutions that were highly active in scorpion-related research also tended to publish extensively in the top ten journals, further underscoring a high degree of correspondence between institutional research profiles and journal specialization within this field.

Table 4 top ten journals

Rank	Journals	Publications	Proportion	Citation	Publisher
1	Toxicon	253	8.98%	3159	Elsevier
2	Toxins	152	5.39%	2152	MDPI
3	Journal of Venomous Animals and Toxins Including Tropical Diseases	69	2.45%	1068	CEVAP
4	Plos One	51	1.81%	1013	PLOS
5	Scientific Reports	45	1.60%	690	Springer Nature
6	Journal of Arachnology	38	1.35%	178	American Arachnological Society
7	Peptides	36	1.28%	694	Elsevier
8	International Journal of Peptide Research and Therapeutics	32	1.14%	275	Springer
9	Frontiers in Pharmacology	31	1.10%	487	Frontiers Media
10	Zookeys	30	1.07%	98	Pensoft Publishers

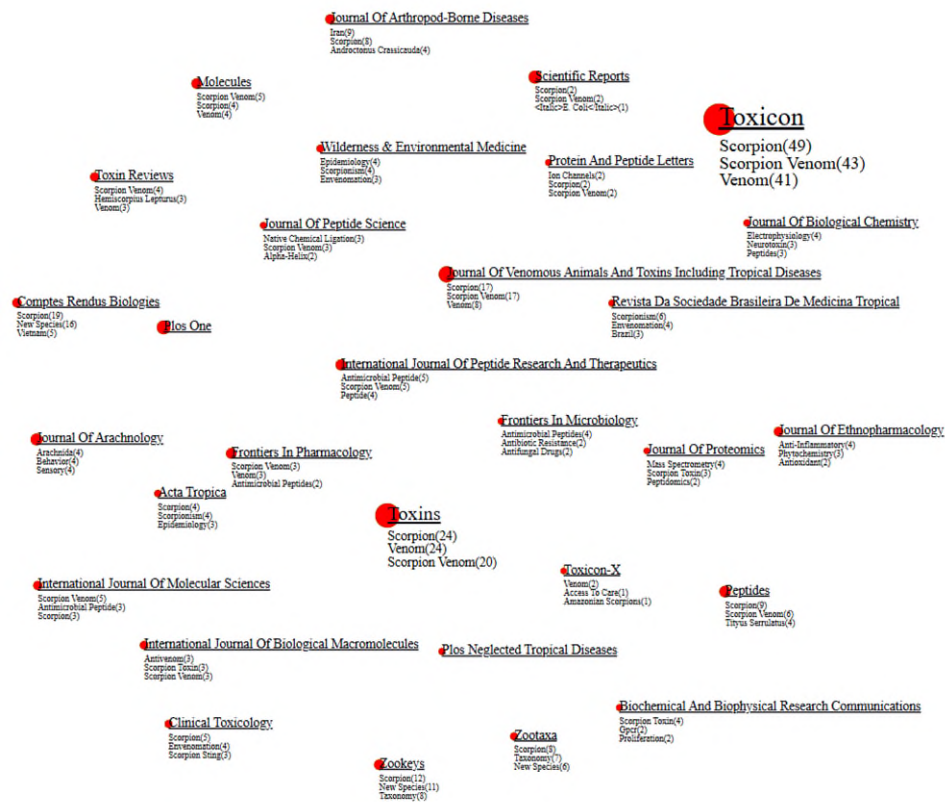


Figure 9 Journal Co-citation Network



Figure 10 Institutional Publication Distribution by Journal

8 The Top 10 Most Cited Publications

As shown in **Table 5**, among the top ten most-cited articles in the field of scorpion research, the relevant topics primarily revolve around "scorpion venom", "pharmacology", and "ion channel mechanisms". Further analysis reveals that three papers (Voltage-Gated Sodium Channels: Structure, Function, Pharmacology, and Clinical Indications; Scorpion Venom Components as Potential Candidates for Drug Development; and From Animal Poisons and Venoms to Medicines: Achievements, Challenges and Perspectives in Drug Discovery) explore the pharmacological potential of scorpion venom. Additionally, two papers (Molecular Biology of Insect Sodium Channels and Pyrethroid Resistance; and Structural Basis for the Modulation of Voltage-Gated Sodium Channels by Animal Toxins) delve into the mechanistic roles of ion channels in pharmacology.

Table 5 top ten articles

Rank	Articles	Citation
1	Voltage-Gated Sodium Channels: Structure, Function, Pharmacology, and Clinical Indications	356
2	Molecular biology of insect sodium channels and pyrethroid resistance	354
3	Scorpion venom components as potential candidates for drug development	243
4	Scorpion Envenomation	171
5	Structural basis for the modulation of voltage-gated sodium channels by animal toxins	170
6	From Animal Poisons and Venoms to Medicines: Achievements, Challenges and Perspectives in Drug Discovery	161
7	Antimicrobial peptides from scorpion venoms	143

8	Scorpion venom peptides with no disulfide bridges: A review	136
9	Structural basis of α -scorpion toxin action on Nav channels	130
10	From Foe to Friend: Using Animal Toxins to Investigate Ion Channel Function	130

9 Keyword Co-occurrence Analysis

As shown in **Table 6** and **Figure 11**, the clustering of high-frequency terms centered on scorpions as the core domain, dominated by "Scorpion" (362 occurrences) or "Scorpions" (131 occurrences). Nodes such as "Scorpion Venom," "Scorpion Toxins," and "Neurotoxin" extended from this core, indicating that the research in this field focused primarily on the toxic components of scorpion venom. Beyond this, the first sub-theme branch revolved around "Scorpion Sting," "Envenomation," "Antivenom," and "Epidemiology," reflecting a clinical medical direction. The second sub-theme concerned bioactive mechanisms, represented by keywords such as "Cytotoxicity," "Apoptosis," and "Antimicrobial Peptides." The third sub-theme was relating to taxonomy and species research, with prominent keywords including "Taxonomy," "New Species," as well as specific familial, generic, or species names of scorpions such as "Buthidae," "Hemiscorpus Lepturus," and "Tityus."

The diachronic keyword mapping shown in **Figure 12** illustrated the temporal evolution of scorpion research. During the initial phase (2014–2017), high-frequency keywords were primarily associated with foundational terms such as "Scorpion," "Scorpion Venom," and "New Species," reflecting an emphasis on taxonomy and basic venom characterization. In the intermediate phase (2018–2021), the keyword spectrum expanded to include "Antimicrobial," "Peptides," indicating increased attention to venom composition and functional properties. In the most recent phase (2022–2025), keywords such as "Apoptosis" and "Morphology" became more prominent, suggesting a trend toward studies addressing biological mechanisms and structural characteristics.

Table 6 top 10 keywords

Rank	Keyword	Count
1	Scorpion	362
3	Scorpion Venom	215
4	Venom	187
5	Scorpions	131
6	Envenomation	74
7	Scorpion Toxin	65
8	Antivenom	61
9	Scorpiones	60
10	Scorpion Sting	57

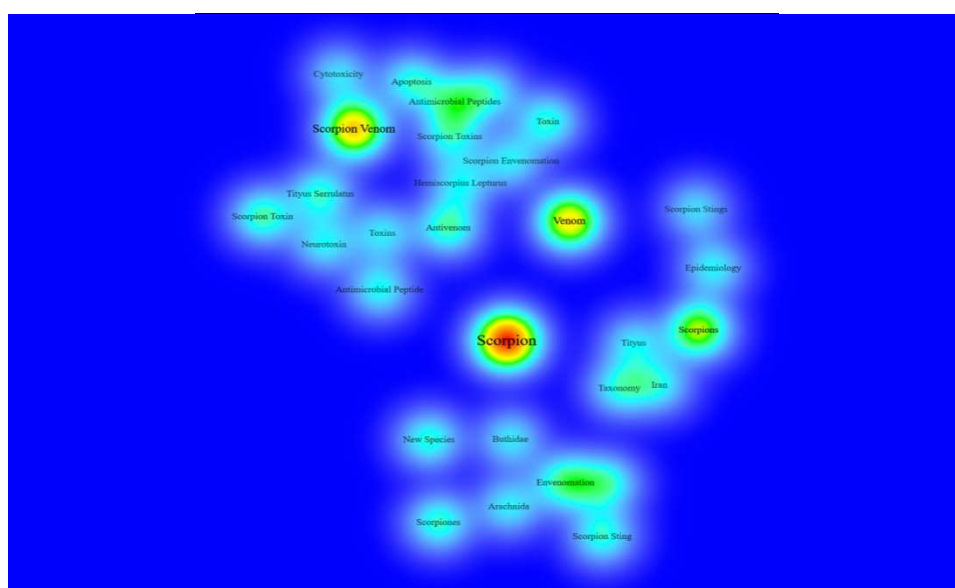


Figure 11 Keyword Co-occurrence Heatmap

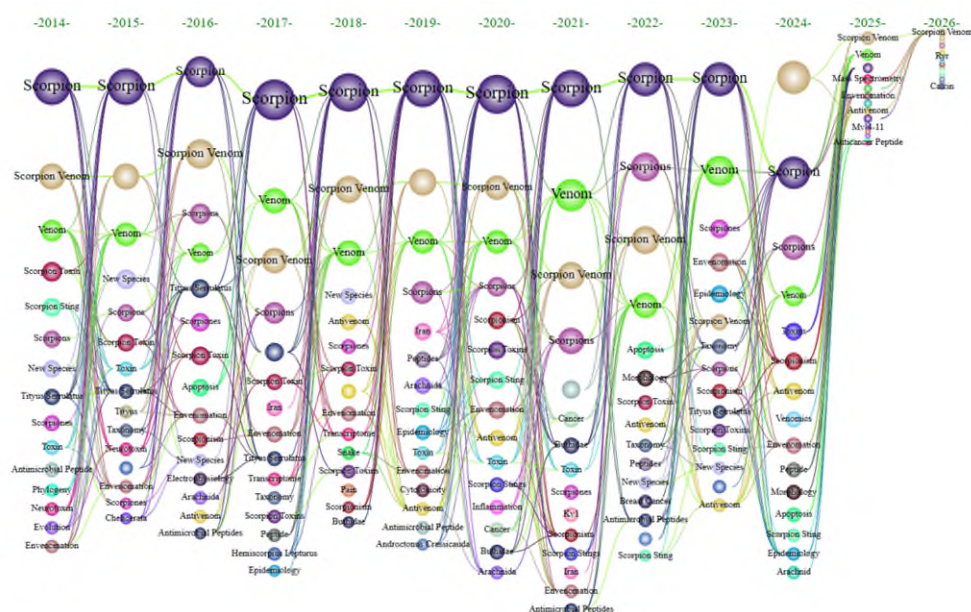


Figure 12 Keyword Evolution Network

10 Cross-Disciplinary Research Landscape

Table 7 summarized the disciplinary distribution of scorpion-related research publications.

Toxicology emerged as the dominant field, accounting for 587 publications, followed by *Pharmacology&Pharmacy* (539 publications) and *Biochemistry&Molecular Biology* (448 publications). *Zooology* ranked fourth with 316 publications, while additional contributing fields included *Food Science&Technology* (169 publications), *Multidisciplinary Sciences* (153 publications), *Entomology* (153 publications), *Tropical Medicine* (130 publications), *Chemistry*, *Multidisciplinary* (104 publications), and *Biology* (103 publications). Overall, the results revealed a clear disciplinary hierarchy, with biomedical fields, particularly toxicology, pharmacology, and biochemistry, dominating the research landscape, while taxonomy was another major research domain, represented by *Zooology and Entomology*. The above pattern was further demonstrated in **Figure 13**, it indicated that scorpion venom research occupied a central position within the field, serving as a focal point toward which all three major domains converged.

Table 7 top 10 landscape

Rank	Landscape	Publications
1	TOXICOLOGY	587
2	PHARMACOLOGY&PHARMACY	539
3	BIOCHEMISTRY&MOLECULAR BIOLOGY	448
4	ZOOLOGY	316
5	FOOD SCIENCE&TECHNOLOGY	169
6	MULTIDISCIPLINARY SCIENCES	153
7	ENTOMOLOGY	153
8	TROPICAL MEDICINE	130
9	CHEMISTRY, MULTIDISCIPLINARY	104
10	BIOLOGY	103

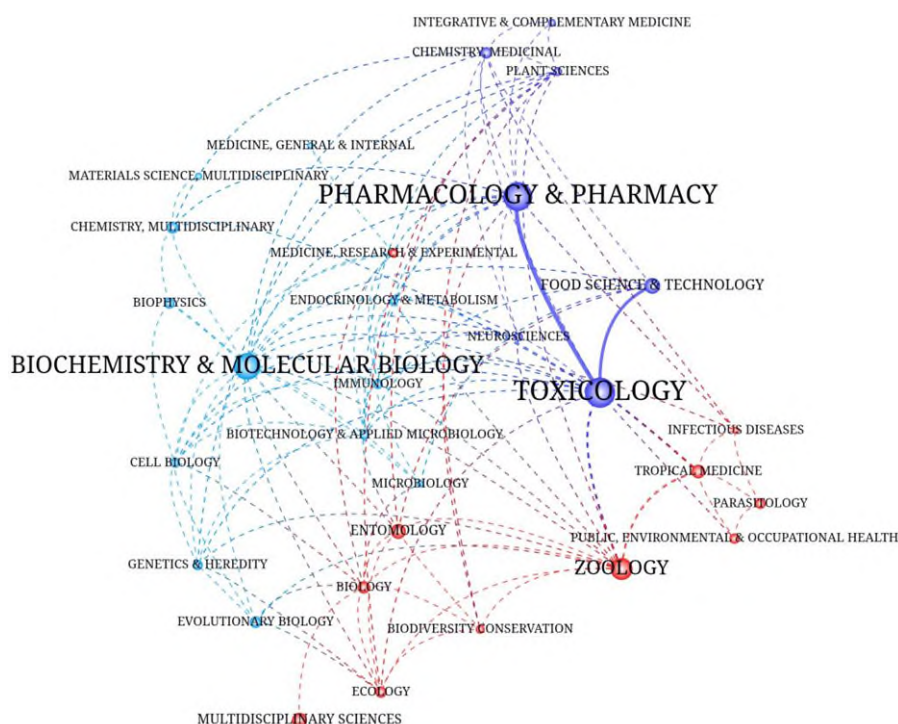


Figure 13 Research Domain Network Map

11 Discussion

By excavating academic publications from the recent decade (2014–2024), this study systematically dissected the evolutionary trajectory, distribution of research hotspots, core contributor networks, and interdisciplinary dynamics of the scorpion research.

11.1 Chemical composition of scorpions

Scorpions are medicinally sourced mainly from *Buthus martensii* Karsch (Lourenço 2018). Their chemical composition is complex, with venom being the key active component (Abdallnasser Amen et al. 2025). Venom consists of proteins (enzymes, peptides) and non-protein substances. Disulfide-bonded peptides act as neurotoxins targeting Na^+ , K^+ , and Ca^{2+} channels. Non-protein components include various lipids (phospholipids, ether phospholipids, triacylglycerols, long-chain sphingomyelins) and amino acids/fatty acids, with unsaturated fatty acids >70% of total fatty acids. They contain 13 protein amino acids (including 7 essentials) and several pharmacologically active amino acids (Liu et al. 2025). The constituents study above provides a strong foundation for pharmacology and other applications of scorpions.

11.2 Pharmacology and Other Applications of scorpions

Modern studies show scorpion extracts exhibit antitumor, analgesic, antiepileptic, and antimicrobial effects (Wang et al. 2018; Liu et al. 2025). Venom peptides inhibit tumors (glioma, colon cancer) via ion channel modulation/apoptosis, block pain through Na^+ channels (Kampo et al. 2024; Dahiya et al. 2026); similarly, it shows antiepileptic potential via circRNA/miRNA axis. Meanwhile, Non-disulfide-bridged peptides disrupt bacterial membranes, effective against resistant strains (Harrison et al. 2014). Furthermore, the lipid fraction, particularly unsaturated fatty acids, exhibits anti-inflammatory, anticancer and immunomodulatory effects (Osman et al. 2026). Additionally, the alkaloid

components in scorpions exhibit broad-spectrum antimicrobial activity, while steroidal compounds can affect the activity of coagulation factors, thereby exerting certain anticoagulant effects. Particularly, unsaturated fatty acids can regulate lipid metabolism and provide cardiovascular protective benefits(Song et al. 2024).

Beyond pharmacological applications, scorpion research has also generated insights of broader interdisciplinary significance. For instance, scorpion-inspired biosensors have attracted increasing attention, while scorpion venom has been investigated as a potential natural insecticide, offering a promising alternative to conventional synthetic pesticides and contributing to more sustainable pest management strategies(Guo et al. 2024; Volkov et al. 2025)

11.3 Research Landscape Analysis

Geographically, the United States, China, and Brazil emerges as the predominant contributors. The United States, leveraging advanced research technologies and abundant resources, has primarily focused on genetic and evolutionary studies. This strategic emphasis stems from the status of scorpions as among the earliest organisms to fully transition to terrestrial life, conferring unique value in evolutionary biology research(Cid-Urbe et al. 2019). Meanwhile, China has adopted a traditional Chinese medicine framework to systematically investigate bioactive compounds derived from scorpions, demonstrating their clinical potential in neurological, cardiovascular, and oncological applications through multiple pharmacological mechanisms(Zheng et al. 2024). At the same time, Brazil has concentrated its research on venom characterization and envenomation management, driven by its rich scorpion biodiversity and associated public health concerns(Guerra-Duarte et al. 2023).

11.4 Research Hotspots and Journal Distribution

The results indicated that scorpion classification remained a major research direction

throughout the study period, while venom-related research emerges as a prominent and increasingly innovative hotspot. Notably, the anti-inflammatory and analgesic effects of scorpion venom, mediated through its action on ion channels, have been extensively studied (Rigo et al. 2019; Richard et al. 2020; Bai et al. 2022). This pattern is consistent with the publication profiles of leading journals in the field, including *Toxicon* and *Toxins*, which served as key outlets for disseminating recent advances in scorpion venom research. Specifically, it is also in line with the analysis of the top 10 most cited publications and keyword Co-occurrence

11.5 Research Focus and Directions

The top ten most-cited papers in the field of scorpion research primarily revolve around three major themes: first, studies related to scorpion venom (including toxin composition and diversity); second, the structure and function of ion channels (particularly voltage-gated sodium and potassium channels); and third, the integration of pharmacology with the aforementioned two themes. These high-impact publications collectively underscore the significant value of scorpion venom-derived peptides: they not only serve as crucial molecular tools for elucidating the mechanisms of ion channels but also represent highly promising candidates for pharmacological research and drug development.

Notably, a substantial proportion of these studies are closely linked to pharmacology, highlighting the broad application prospects of scorpion toxins in areas such as drug discovery, pain management, neurological disorders, and ion channel-targeted therapies. Furthermore, the scope of some highly cited papers extends to broader biological fields, such as arthropod genomics, membrane-active peptides, and biological control, reflecting the trend of interdisciplinary expansion in scorpion-related research.

Overall, these findings indicate that pharmacology-centered research on scorpion venom and

ion channels constitutes the core focus of the field, playing a critical role in advancing both fundamental biological understanding and translational applications. The results of keyword co-occurrence analysis and research hotspot mapping further corroborate this conclusion, demonstrating that high-frequency terms such as "scorpion venom," "toxin," "ion channel," "envenomation," and "pharmacology" consistently dominate the discourse.

11.6 Emerging Frontiers

The integration of multi-omics approaches, including genomics and proteomics, has substantially advanced scorpion research by enabling a more exhaustive elucidation of underlying molecular mechanisms. Genomic sequencing has revealed the diversity and evolutionary relationships of scorpion venom-associated genes, while proteomic analyses have further characterized the structures, compositions, and biological functions of venom proteins. Together, these advances have laid a solid foundation for the discovery and development of scorpion toxin-based therapeutics (Xu et al. 2014; Yamashita et al. 2024; Rabea et al. 2025)..

11.7 Theoretical and practical implications of bibliometric analysis

This bibliometric study with ITGInsight not only delineates the developmental trajectory of the field, but also clarifies its intellectual structure and evolving research hotspots.

First, the findings underscore the value of bibliometric approaches for tracing the evolution of research themes in scorpion studies. By identifying underexplored directions and emerging trends, the analysis refines the conceptual framework of the field and highlights linkages across research domains, for example, the relationship between the therapeutic potential of scorpion venom toxins and their biochemical properties. The study also reveals gaps in current mechanistic research on venom-toxin, based interventions for neurological disorders, motivating key questions such as: How do scorpion

venom toxins selectively modulate ion channels to achieve targeted therapeutic effects? and Do toxins from different scorpion species exhibit synergistic structure–function relationships? Addressing these questions may stimulate theoretical advances and expand the translational scope of venom-toxin–based drug design.

Second, the bibliometric mapping emphasizes the importance of systematic evidence synthesis for strengthening the theoretical foundation of the field. In particular, the limited exploration of integrating scorpion venom toxins with novel drug-delivery systems delineates a clear direction for further investigation. Similarly, the scarcity of studies on the application of scorpion venom toxins in personalized medicine suggests an opportunity to develop hypotheses regarding inter-individual variability in toxin responsiveness, thereby supporting the development of more precise and tailored therapeutic strategies.

From a practical perspective, the use of tools such as ITGInsight enhances both the rigor and interpretability of literature analysis by providing structured visualization of the research landscape. The identified knowledge gaps can inform the prioritization of resources toward high-impact areas, including translational work on scorpion venom toxins for anti-cancer applications and antimicrobial peptide development. Moreover, clarifying the temporal evolution of research themes may assist clinical and industrial stakeholders in tracking frontier developments and optimizing research and development planning.

11.8 Implications of the bibliometric analysis for policy and decision-making

Scorpion research demonstrates substantial potential value across medicine, agriculture, and ecological conservation. Integrating the bibliometric findings presented here can assist policymakers and decision-makers in identifying strategic pathways to advance scorpion research and its translation into

practice. Evidence-informed measures developed on this basis may strengthen the linkage between scientific outputs and societal needs, thereby facilitating the effective deployment of scorpion-related innovations in relevant application domains.

11.9 Strengths and Limitations

This study advances bibliometric analysis in scorpion research through three principal systematic contributions. First, data were sourced exclusively from the Web of Science Core Collection (WoSCC), ensuring the academic authority, reliability, and representativeness of the literature dataset. Second, rigorous screening criteria, including publication time frame, document type, and language, were applied and complemented by manual verification to enhance data quality. This multi-stage screening process accurately captures the current research landscape while minimizing inclusion bias and maintaining taxonomic consistency, thereby strengthening the overall validity of the results. The final dataset satisfies established bibliometric standards for both comprehensiveness and reliability. Third, the study employed an ITGInsight-based analytical framework to systematically examine publication trends and research patterns. Following preliminary data screening, the software was utilized for data refinement and in-depth analysis. Its advanced visualization and network analysis functions provided a robust methodological foundation for subsequent bibliometric exploration.

Despite these strengths, this study has several limitations. First, the analysis was confined to the Web of Science (WoS) database and did not include other major databases such as Scopus or Embase. Second, publications from 2025 were excluded due to the defined search period (January 1, 2014–December 1, 2024) and the incomplete availability of data at the time of retrieval, which may affect the overall completeness of the dataset. Furthermore, the inherent complexity and unique characteristics of bibliometric data may introduce potential biases during data screening and analysis.

12 Conclusion

Based on 2,818 records from the Web of Science Core Collection (2014–2025), this study provides the first systematic bibliometric mapping of scorpion research using ITGInsight, along with a thorough summary of its key bioactive components and pharmacological properties. The United States, China, and Brazil dominate scholarly output, with the National Autonomous University of Mexico leading at 164 publications. Scorpion venom, ion channel modulation, and pharmacological effects remain perennial hotspots. Our work fills the methodological gap in quantitative scorpion research and demonstrates the transferability of ITGInsight for mapping other medicinal arthropods. Looking ahead, the therapeutic potential of scorpion venom—particularly its antitumor, analgesic, and antimicrobial properties—remains a highly promising direction for drug development. Meanwhile, the integration of scorpion-derived bioactive compounds into biosensors and sustainable pest management is emerging as a dynamic new frontier, offering innovative strategies for interdisciplinary applications.

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