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PLANT-DERIVED BIOACTIVE COMPOUNDS FOR NEURODEGENERATIVE DISEASES: A BIBLIOMETRIC ANALYSIS

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Abstract:

The global rise in neurodegenerative diseases (NDs), such as Alzheimer's, Parkinson's, and dementia, has intensified research efforts to discover new therapeutic strategies, particularly those involving natural compounds. Medicinal plants have long been used in traditional medicine for treating cognitive and memory-related disorders. This study presents a bibliometric mapping analysis of research publications focused on neuroprotective bioactive compounds derived from plants. Relevant literature was retrieved from the Web of Science (WoS) database using predefined selection criteria. The analysis revealed a consistent upward trend in publication output since

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2015, with a notable surge over the past five years, reflecting growing interest in plant-based neuroprotection. A total of 1,144 documents were identified, spanning 50 research areas and published in four languages. These publications originated from 106 countries, involving 1,936 organisations and 6,342 authors, and collectively received 27,681 citations. Moreover, 202 funding agencies were identified as contributors to this research domain. Network visualization uncovered a globally interconnected research landscape, with China, the USA, and European countries playing central roles. Meanwhile, collaborative efforts from Asia, Africa, and Latin America are increasingly visible, indicating emerging regional participation. The presence of these regional clusters suggests that research development may be influenced by linguistic, cultural, or funding-related factors. This bibliometric analysis provides a comprehensive overview of the current state and global dynamics of research on plant-based neuroprotective compounds.

Keywords:

Bioactive Compounds; Bibliometric Analysis; Medicinal Plants; Neuroprotective; Science Mapping

Introduction

Neuroprotection is the preservation of the structure and function of neurons from insults arising from cellular injuries induced by a variety of agents or neurodegenerative diseases (NDs). Neuroprotection refers to the mechanisms and strategies employed to defend the central nervous system (CNS) against injury due to both acute (e.g. trauma or stroke) and chronic neurodegenerative disorders (e.g. Dementia, Parkinson's, Alzheimer's, Epilepsy etc.). Millions of people worldwide are afflicted by the many NDs, including as Alzheimer's, Parkinson's, and Huntington's illnesses as well as amyotrophic lateral sclerosis, with ageing serving as the primary risk factor. The most pervasive and dangerous of the NDs is the Alzheimer's disease (AD). It is an incurable disorder of cognition and conduct that impairs social and professional activities and is also the main reason for older people being institutionalised. The risk of AD for those who live into their 80s has been estimated to increase to 20–40%, depending on a number of variables like demographic dynamics and geography (Cole et al., 2007; Lamptey et al., 2022). The number of people with NDs and the related dementia also continues to rise as the global population ages and the economy develops (Brown et al., 2005). The hunt for new therapeutic agents for the primary, auxiliary, or tertiary prevention of these diseases has consequently received a tremendous rise in scientific interest (Patnaik, 2015). Numerous natural products, but primarily plants extracts, have been reported to be used in traditional medicine for neuroprotective, memory enhancing, and anti-aging purposes. Examples of such plants include *Ginkgo biloba, Panax ginseng, Curcuma longa, Bacopa monnieri,* and *Salvia officinalis*. These plants have been studied to confirm the traditional claim with special attention given in understanding the mechanism by which they elicit the neuroprotective effects (Elufioye et al., 2017; Ghosh et al., 2023; Iriti et al., 2010; Kumar & Khanum, 2012). The prevention of neurodegeneration is another promising area for pharmaceutical investment. Using phytochemicals as anti-inflammatory, antioxidant, and immunomodulators against neurodegeneration in various predisposing conditions is paramount (de Lima et al., 2025; Elufioye et al., 2017; Fan et al., 2018; Ghosh et al., 2023; Kelsey et al., 2010). It became essential to providing the landscape of research output in the field of pharmacological studies on neuroprotective properties of bioactive components from plant origin.

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Thus, the primary objective of this bibliometric study is to assess the research publication performance in this field of studies across the world apart from a broad overview of existing research publications by utilizing the Web of Science (WoS) database. Web of Science is highly suited for a bibliometric analysis since it has more than 21,000 peer-reviewed high quality publications (Bilge & Yaman, 2021; Juza & Hahn, 2004; Liu, 2019; Tijjani et al., 2020). This provides insights into the trends and directions of research activities to discover potential therapeutic strategy in preventing the progression of cognitive deterioration in vascular dementia and Alzheimer's disease patients. This effort corresponds to the essential goal of this article, which is to contribute to the discovery of new therapeutic agents for prevention of these diseases through the application of bibliometric analysis. Furthermore, the study aligns with the broader goals of the United Nations Sustainable Development Goal (SDG-3), which aspires to ensure health and well-being for all (Hales & Birdthistle, 2023; Shevelkova et al., 2023). In pursuit of this objective, the article intentionally abstains from conducting an extensive content analysis of the plant-derived bioactive compounds with neuroprotection properties but is limited to bibliometric analysis. The analysis provides a quantitative evaluation of the publication trends in the research area, identifying key authors, influential journals, and research collaborations. This study helps in mapping the evolution of the field and guiding future research in decision-making process related to research based on neuroprotective properties associated with plant-based compounds.

Literature Review

Research on plant-derived bioactive compounds for all types of neurodegenerative diseases has emerged as a critical area of inquiry due to the increasing global prevalence of neurodegenerative disorders and the limitations of current therapeutic options (Rahaman et al., 2024). Over recent decades, the field has evolved from focusing primarily on synthetic drugs to exploring natural products with neuroprotective properties, reflecting a shift towards safer and multi-targeted treatment strategies (Cui et al., 2023). Neurodegenerative diseases such as Alzheimer's disease (AD), Parkinson's disease (PD), Huntington's disease (HD), and amyotrophic lateral sclerosis (ALS) impose significant social and economic burdens, with millions affected worldwide and projections indicating a sharp rise in incidence with aging populations (Shoaib et al., 2023). This NDs represent a group of progressive and debilitating disorders of the central nervous system characterized by the gradual loss of neuronal structure and function. The current pharmacological interventions for NDs are predominantly symptomatic and offer limited efficacy in halting or reversing disease progression. Moreover, many synthetic drugs are associated with side effects and are often ineffective in targeting the multifactorial nature of these disorders. These limitations have intensified the search for novel, safer, and more effective therapeutic strategies, leading to growing interest in plant-derived bioactive compounds.

Over the past few decades, the field of natural product research has expanded significantly, with plant-derived bioactive compounds emerging as promising neuroprotective agents. These compounds, which include flavonoids, alkaloids, terpenoids, saponins, and phenolic acids, are known to exert multiple biological effects such as antioxidant, anti-inflammatory, anti-apoptotic, and anti-amyloidogenic activities (Grosso et al., 2023; Shoaib et al., 2023). Unlike synthetic single-target drugs, plant-derived bioactive compounds have emerged as promising alternatives in the management of NDs, offering multifaceted therapeutic properties and diverse molecular targets owing to their varied structures and biological activities. These compounds, derived from various plants, exhibit significant neuroprotective effects, addressing

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the underlying mechanisms of NDs such as oxidative stress, neuroinflammation, and protein aggregation. For instance, blueberries, belonging to the *Vaccinium* genus, are rich in polyphenols known for their potent antioxidant properties. Extracts from blueberries have been shown to protect microglial cells, reduce neuroinflammation, and help slow the progression of dementia (Debnath-Canning et al., 2020). Eighteen compounds were identified in the leaf extracts of *Sophora secundiflora* and *Sophora tomentosa* through LC-ESI-MS/MS analysis. In vivo studies demonstrated notable neuroprotective effects, including the reduction of acetylcholinesterase (AChE), noradrenaline, and dopamine levels, along with an increase in glutathione and acetylcholine levels (Aly et al., 2021). These findings suggest that plant-based compounds not only offer potential symptomatic relief but may also target disease-modifying mechanisms.

While the preclinical evidence supporting the efficacy of this bioactive compound is strong, the clinical translation has been comparatively modest. Challenges include difficulties in optimizing dosage, low bioavailability, rapid renal elimination and variability in extract composition (Shoaib et al., 2023).Advances in drug delivery systems, such as nanoparticle formulations and chemical modifications, are being explored to enhance the therapeutic potential of these compounds. Additionally, synergistic effects of compound mixtures and plant extracts are being investigated for their enhanced neuroprotective efficacy.

Research Question

To begin, a complete bibliometric study was conducted from 2015 to 2025 (as of 9th April) to address key inquiries relevant to studies on neuroprotective bioactive compounds from medicinal plants. The research aims to shed light on the following aspects:

1. Which country exhibits the highest volume of WoS publications in the studies of neuroprotective agents from plants?
2. Identifying the organization with the most influential and prolific research in the studies of neurological therapy through publication output and highest total citations.
3. Which author with the most significant WoS total citations and total publication
4. Exploring the collaborative landscape among researchers concerning the field of studies in neurological therapy.
5. Uncovering the keywords and co-occurrence patterns prevalent in articles centered on neuroprotective bioactive compounds from plants
6. A brief assessment of research funding for the research in finding new therapy for neurological disorders.

These inquiries provide the framework for bibliometric analysis, offering insights into the scholarly and scope of the studies on neuroprotective bioactive compounds from plants origin.

Methodology

The techniques applied in this study are categorised into two different types which are performance analysis and science mapping. The main function of performance analysis is essentially to evaluate the contributions of research constituents, predominantly authors' citations, total publication, and affiliation. Other information such as country of origin, year of publication, source title and funding information can be obtained and examined.

Science mapping explores the interconnections among co-authorship, citation, and co-occurrence relationships. To generate a visual representation of these connections, the VOSviewer (1.6.19 version) software is used. All the stated data types can be obtained through

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the WoS Core Collection database by selecting export and choosing the type of data format to be exported. To make the analysis smooth, some functions of VOSviewer were used such as the type of analysis set to “citation” with the unit of analysis to “authors”, “source” and “organization” respectively. The output of the analysis will show the list of authors, sources, and organizations based on the metric of documents and citations. From these, the influential and prolific category can be determined. The term 'prolific' refers to the number of publications produced, while 'influential' pertains to the number of citations received. These metrics are analyzed further at the levels of authorship, organizational affiliation, and source titles to assess research productivity and impact. Next, the data produced from the VOSviewer is transferred to MS Excel for further analysis and added relevant information to make the data presentation more conceivable. Figure 1 is a brief simplification of the methodology represented through the flowchart

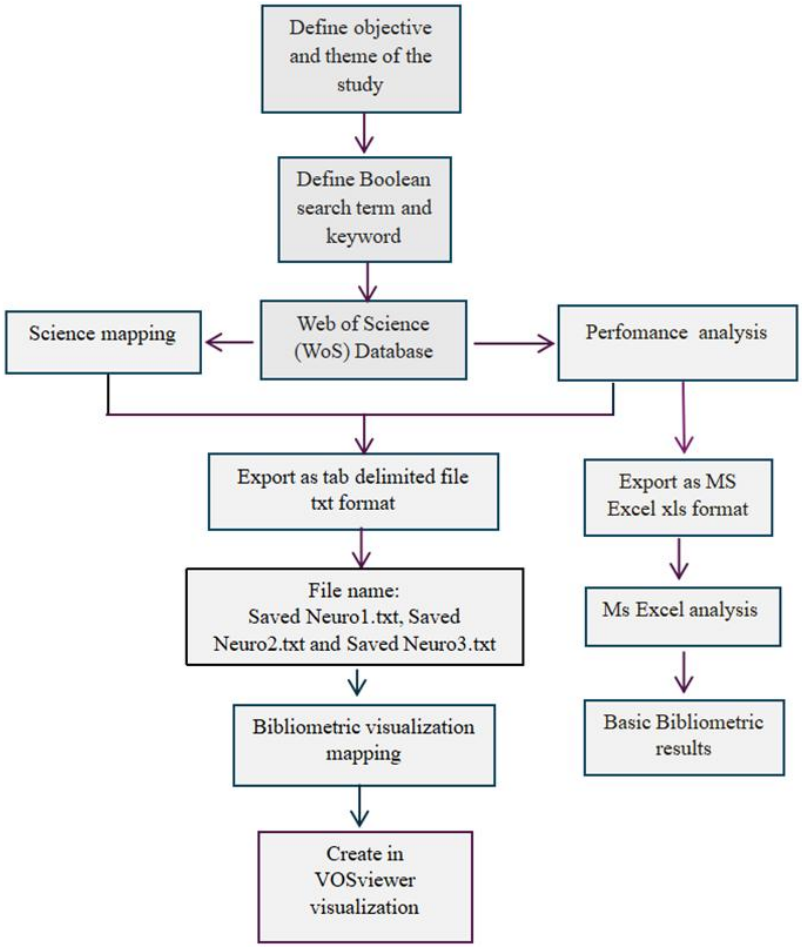

Figure 1: Flowchart of Methodology

Upon selecting the search button, a substantial dataset was generated and presented on the database page. Following the compilation of data from the WoS database, a thorough examination of each title was conducted to ensure its relevancy to the study’s objectives. Titles and associated content that met the study’s criteria were identified and accordingly marked in the checkbox. Subsequently, this marked data was transferred to a dedicated "Marked List" within the WoS database for organized storage.

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The bibliometric data was extracted from the Web of Science databases on April 9, 2025. The Web of Science Core Collection database is used as the primary source of data due to its well-known academic database collection and can greatly help in bibliometric analysis (Ang et al., 2022). The focus of this study revolves around the topic of neuroprotective properties of bioactive compounds. The selected Index topic was [Topic Search (TS) = "Neuroprotective" AND "properties" OR "effects" OR "activities" AND "bioactive" and "compounds" OR "plant-based" OR "natural products". As illustrated in Figure 2, a total of 1301 results were generated spanning the extensive timeframe from 2015 to 2025, covering more than 10 years. The search was not constrained by country, language, source type, or document selection criteria. Filters were applied to include only articles related to SDG-3 which focus on good health and well-being. Consequently, a total of 157 data points were afterward excluded from the initial dataset with 1144 data remaining.

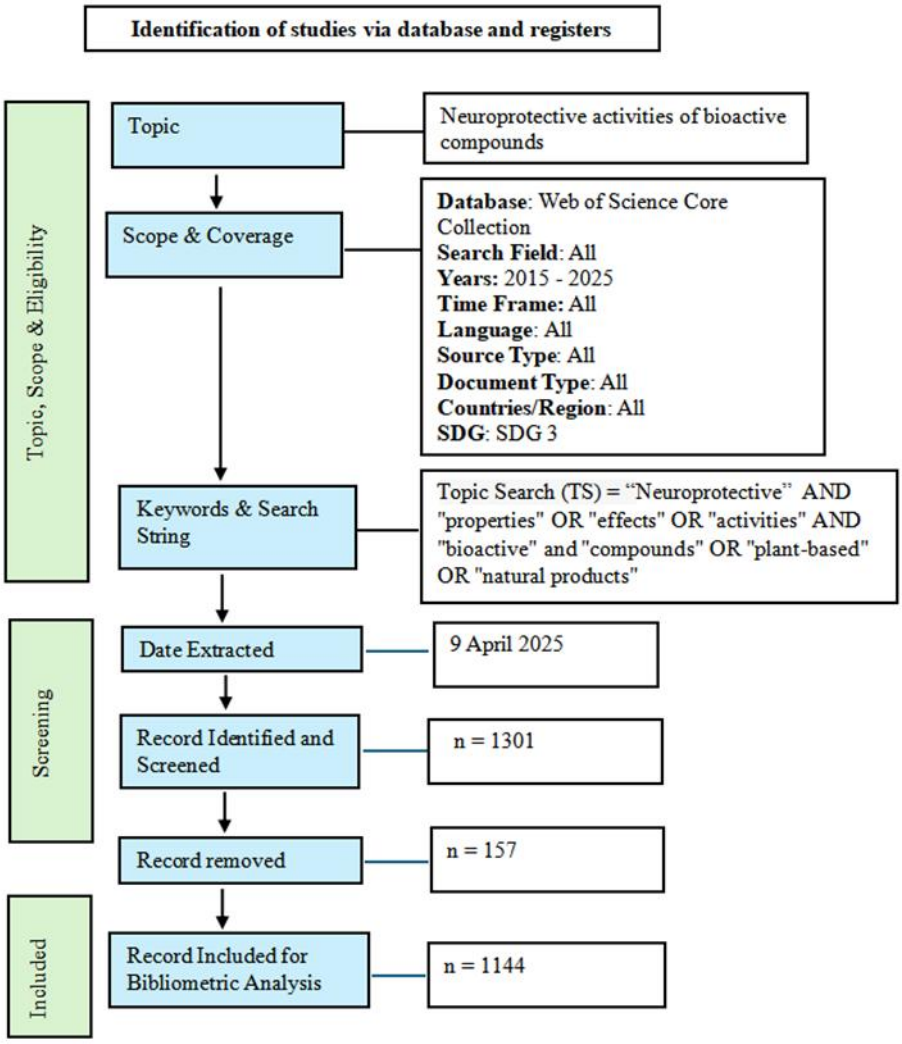

Figure 2: PRISMA Flow Diagram

Next, the extracted 1144 data then undergo a screening process to determine its relevancy to the topic of the study. A structured screening protocol was followed to ensure consistency in identifying the relevance to the scope of the study. The search approach for finding the database followed a guideline contained in the Preferred Reporting Items of Systematic Reviews and

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Meta-Analysis (PRISMA) as simplified in the flow diagram in Figure 2. Finally, the data was analyzed quantitatively trough performance analysis and science mapping.

Result and Discussion

The study provides an insightful overview of the current landscape concerning publications in the study for neuroprotective bioactive compounds. As illustrated in Table 1, the data retrieved from the WoS is summarized based on various parameters, including the total number of documents, document types, languages, research areas, prolific and influential authors, prolific and influential organizations, funding agencies, and citation with all these parameters will be assessed against countries whenever applicable.

The ensuing sections will investigate a comprehensive discussion of each of these summary items, providing a more detailed analysis of the research landscape. The total document gathered from the WoS database consists of 1144 documents with only three documents existing in different languages other than English. Research areas that were related to the topic cover a total of 50 different areas although some publications may relate to more than one area. The study identified a total of 6342 individuals, including lead authors and co-authors, contributing to publications in the selected topic.

Table 1: Main Information from the Search in WoS

Items	Frequency/count
Total documents	1144
Languages	4
Research areas	50
Countries	106
Organisations	1936
Authors	6342
Overall Citations	27681
Funding agencies	202

Analysing Trend of Publication with Year

The findings indicated that research focused on the neuroprotective effects of bioactive compounds first recorded in WOS database in 2003. The article which was publish in the European Journal of Neuroscience presented unique evidence that antioxidant therapy derived from marine invertebrate egg protectants could effectively protect both adult and developing mammalian brains, and the recycling properties of an oxidized antioxidant compound are as crucial as its reduced form in specific neuroprotective properties (Vamecq et al., 2003).

From 2015 to April 9th, 2025, the dataset for publications on "neuroprotective bioactive compounds" in WoS totalled 1301, with 1204 documents related to SDG-3. The publication performance and citations on the topic from 2015 to April 9th, 2025, is illustrated in Figure 3. The publication trends on this subject initiated relatively late, with only one or two publications per year during the early period from 2003 to 2011 but shows a significant rise from 2015 onwards. The research output on plant-derived neuroprotective compounds is expected to reach its peak in 2025 with nearly 200 articles, suggesting an unprecedented level of scientific interest in this field. One of the factors that contribute to the upward trend is the increasing global interest in neuroprotective agent from plant-based compounds. This is largely driven by the

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rising prevalence of neurodegenerative disease such as Alzheimer's and Parkinson's (Jiang et al., 2025; Pal et al., 2024).

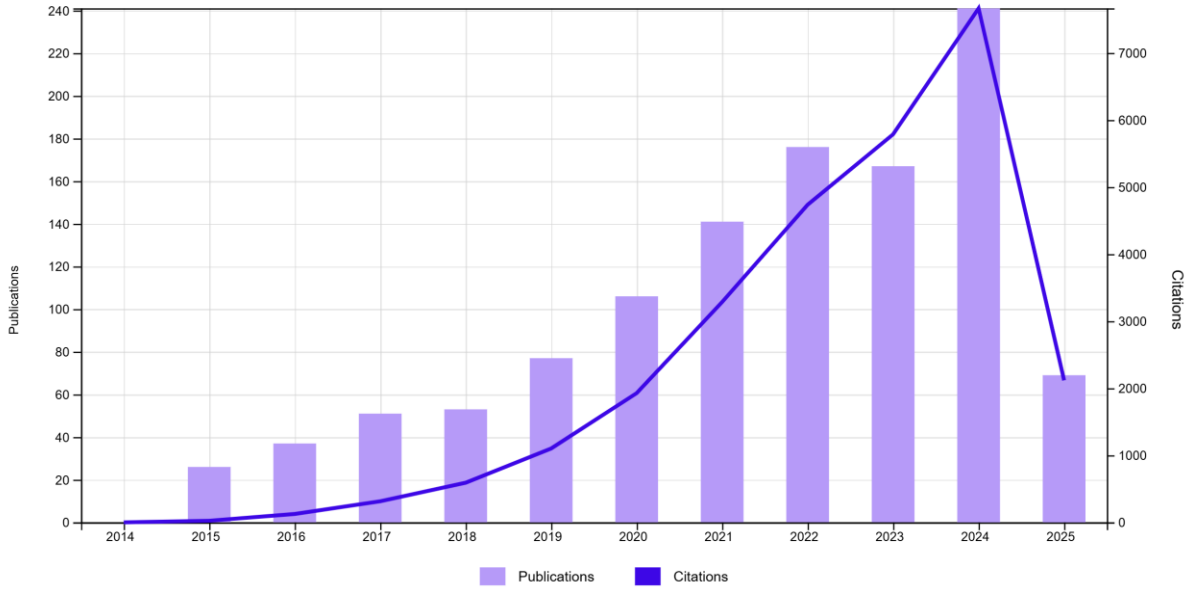

Figure 3: Publication Performance Over the Period of 2015 – April 2025

The advancements in biotechnology, computational drug discovery, and research methodologies could be another contributing factor which have made the neuroprotective mechanisms studies easier (Atanasov et al., 2021). The expansion of international collaboration and availability of research funding also boost the number of publications. Moreover, the current demand for alternative treatment for neurological disease has led to surge in the research output. These trends indicate the increasing focus on natural compounds as potential therapeutic agents for neurodegenerative diseases and emphasize the importance of continued interdisciplinary efforts in this area (de Zambotti, 2016).

Analysing Trend of Publication by Countries

Figure 4 illustrates the number of publications related to bioactive compounds with neuroprotective effects contributed by top 15 countries, as indexed in the Web of Science (WoS). The results indicates that China exhibited the most substantial contribution, constituting 26.5 % of the total publications, followed by India at 17.6 %. Italy with 8 % of the total publications within the study occupying the third positions in terms of publication count. South Korea, USA and Spain, contributed 7.8 %, 7.2 % and 6.8 % respectively, from the total of 1144 publications.

China and India are leading in this field due to several factors. Both countries have large populations, which contribute to a higher number of researchers and scientists. Additionally, significant investments in education and research infrastructure have bolstered their scientific output. Government policies in both nations have been supportive of research and development, providing funding and resources necessary for advanced studies. Furthermore, the rich biodiversity in these regions offers a vast array of plant species for research, enhancing the potential for discovering bioactive compounds. International collaborations and technological advancements also play a crucial role in their dominance in this research area (Direito et al., 2024; Moise et al., 2024)

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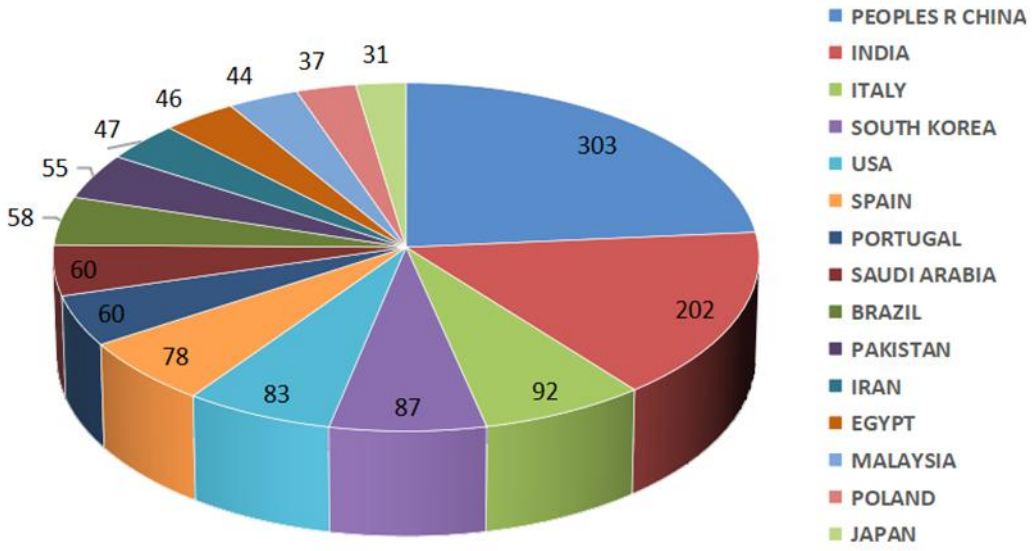

Figure 4: Top Publication by Country

Analysing Type of Document

Table 2 provides a comprehensive breakdown of the various document types, and their respective publication counts that facilitate the publication percentage contribution on the topics from 2015 to 2025. It is clearly showed that review articles are the most prevalent, comprising 51.84 % of the total publications, followed by regular articles at 47.99 %. Both review and regular articles make up more than 99 % of the total publications. Early access documents contributed 2.01 %, indicating a low number of pre-publication release. Proceeding papers is less common, making up 0.79 % of total publications. Book chapters and retracted publications are the least represented, both contributing 0.26 % and 0.09 % respectively. This distribution highlights the dominance of review articles and regular articles in WoS database, with other document types being significantly less frequent.

Table 2: Document Type and Publication Count

Document Types	Record Counts	**Percentage (n=1144)**
Review Article	593	51.84
Article	549	47.99
Early Access	23	2.01
Proceeding Paper	9	0.79
Rectracted Publication	4	0.35
Book Chapter	3	0.26
Meeting Abstract	1	0.09

Analysing Co-Authorship

Co-Authorship Between Countries

The co-authorship analysis using VOSviewer examines the structured partnerships forged between countries, leading to a heightened comprehension of the intricate network of relationships within the research domain (Ishak et al., 2023). The bibliometric analysis using VOSviewer provides a visual representation of the publication landscape within the study of

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bioactive compounds for neuroprotection. Each node or bubble within the diagram represents a specific country, with the size of the bubble indicating the volume of research documents produced. Additionally, the colour of the nodes reflects the activity or recency of the documents, offering insights into the temporal progression of research activities (Donthu et al., 2021). The color gradient indicates the average year of publications - ranging from dark blue/purple (older publication) to yellow (more recent publications).

A co-author analysis with a minimum threshold of 5 documents per country identified a total of 49 countries. A closer examination of the colour-coded nodes in the overlay visualization illustrated in Figure 5 reveals intriguing patterns. From the map, China and India emerge as the most prominent contributors, with large node sizes, indicating a high volume of research publications. China's node appears in a teal-green shade, suggesting that its research activity has been consistent but slightly older compared to countries like Poland, Saudi Arabia, or Egypt, which appear in brighter yellow tones, reflecting more recent research output.

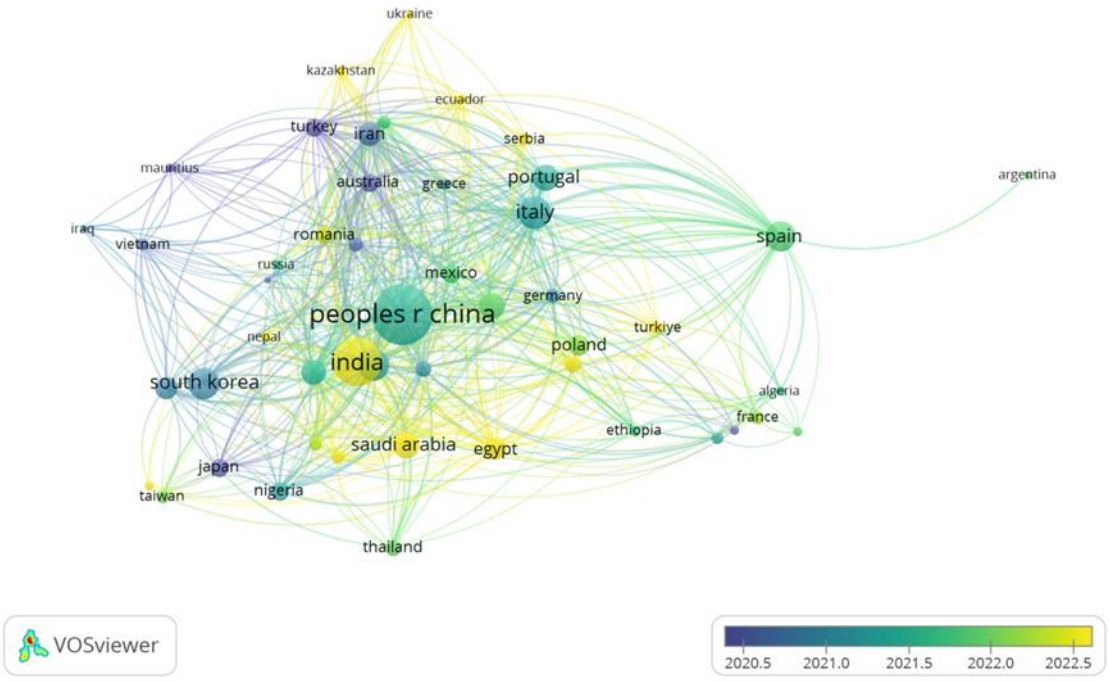

Figure 5: Overlay Visualization of The Co-Authorship by Countries

Spain, although somewhat isolated visually, has significant collaborations extending outward, especially toward Argentina which suggesting a focused but impactful research partnership. Countries like Portugal, Italy, Iran, South Korea, and Turkey also display strong connectivity, indicating active international collaborations. Clusters of countries such as South Korea, Japan, Taiwan, and Vietnam in the left section, shaded mostly in blue and purple, imply earlier engagement in the field, possibly pioneers or earlier adopters of research topics being analyzed. Meanwhile, countries like Kazakhstan, Ukraine, and Ecuador show more recent engagement (yellow-green), possibly indicating emerging participation in the field. The tight web of connections in the central area of the map reflects a high degree of co-authorship and collaboration among a diverse set of countries. This suggests a globally interconnected research community, with certain countries like China, India, Portugal, and Iran playing central roles in facilitating cross-border academic collaboration. The network visualization map illustrated in

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Figure 6 presents international research collaboration patterns based on author-country affiliations. China and India once again stand out as the most prominent contributors, indicating their central role and high publication volume. They are closely linked to many other countries, suggesting extensive international collaboration. China is positioned at the centre of the network, acting as a hub connecting various countries from different clusters.

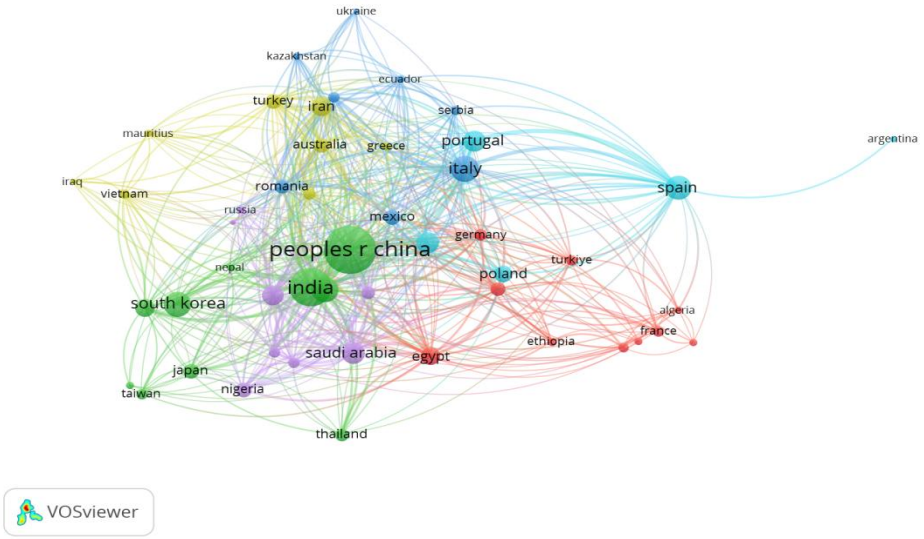

Figure 6. Network Visualization of The Co-Authorship Between Countries

Countries are grouped into color-coded clusters that represent distinct collaboration groups. Portugal, Italy, and Spain form a blue cluster, indicating a strong collaborative network within southern Europe and extending toward Latin America. The red cluster includes countries such as France, Poland, Algeria, and Ethiopia, highlighting another strong regional network, possibly reflecting historical or linguistic ties. The green cluster, centered around China, South Korea, and Japan, reflects strong intra-Asian collaborations. Similarly, India, Saudi Arabia, and Egypt fall into the purple cluster, which could suggest a Middle East-South Asia collaboration group. The visualization demonstrates a highly interconnected global research landscape, with a few key countries acting as bridges between multiple regional networks. This map emphasizes the collaborative nature of the field, highlighting how scientific output is increasingly the product of multinational teamwork.

Co-Authorship Between Organizations

The network visualization map in Figure 7 illustrates the collaborative relationships between authors and their affiliated organizations, forming distinct clusters based on co-authorship and institutional linkages. Each node represents an institution, and links between nodes indicate co-authorship or research collaboration. The colors identify clusters of closely collaborating institutions, while the size of the node reflects the number of publications or co-authorship frequency

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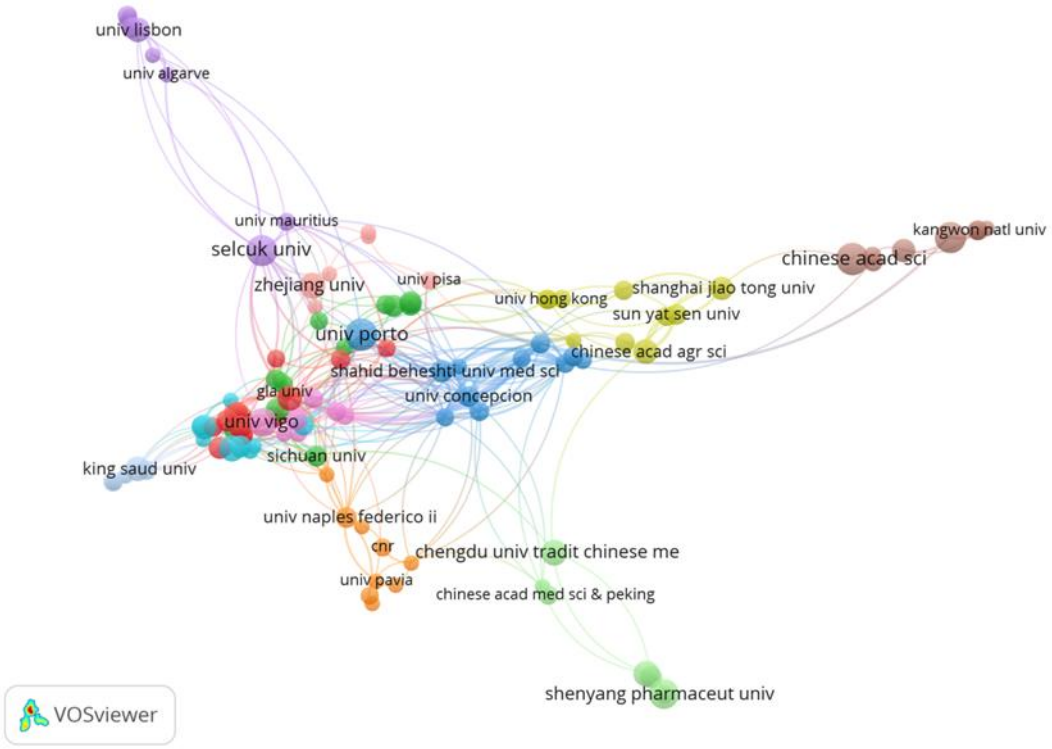

Figure 7. Network Visualization of The Co-Authorship Between Organization

The author–organization network visualization reveals 12 distinct clusters, each representing close collaborations among institutions. Chinese universities are particularly prominent, forming dense and active collaboration networks, with key institutions like Shanghai Jiao Tong University, Sun Yat-sen University, and the Chinese Academy of Sciences appearing as major hubs. Similarly, strong connections exist within European institutions such as the University of Porto, University of Vigo, and Shahid Beheshti University of Medical Sciences, suggesting regional or project-based collaboration, possibly under international funding. Other notable clusters include Korean institutions (e.g., Kangwon National University), Italian universities (e.g., University of Naples Federico II), and Portuguese networks involving universities in Lisbon and Algarve, sometimes extending to African institutions. Overall, the map shows that institutional collaborations are often shaped by geographic proximity, language, or existing academic partnerships, with Chinese and European institutions emerging as the most central and productive nodes in this network.

Figure 8 shows the overlay visualisation for the collaboration network between universities and research institution in this field. This overlay visualization map shows the temporal evolution of institutional collaboration in the field of study. Nodes (representing institutions) are colored based on the average publication year, as indicated by the color scale (from purple/blue for older publications to yellow for more recent). Notably, University of Vigo, University of Porto, and King Saud University are among the most active and recent contributors (yellow nodes), indicating increasing research activity or growing involvement in recent years. On the other hand, institutions like Shenyang Pharmaceutical University, Chinese Academy Medical Science & Peking, and University of Pavia appear in purple, suggesting their main contributions occurred earlier (around 2020 or earlier).

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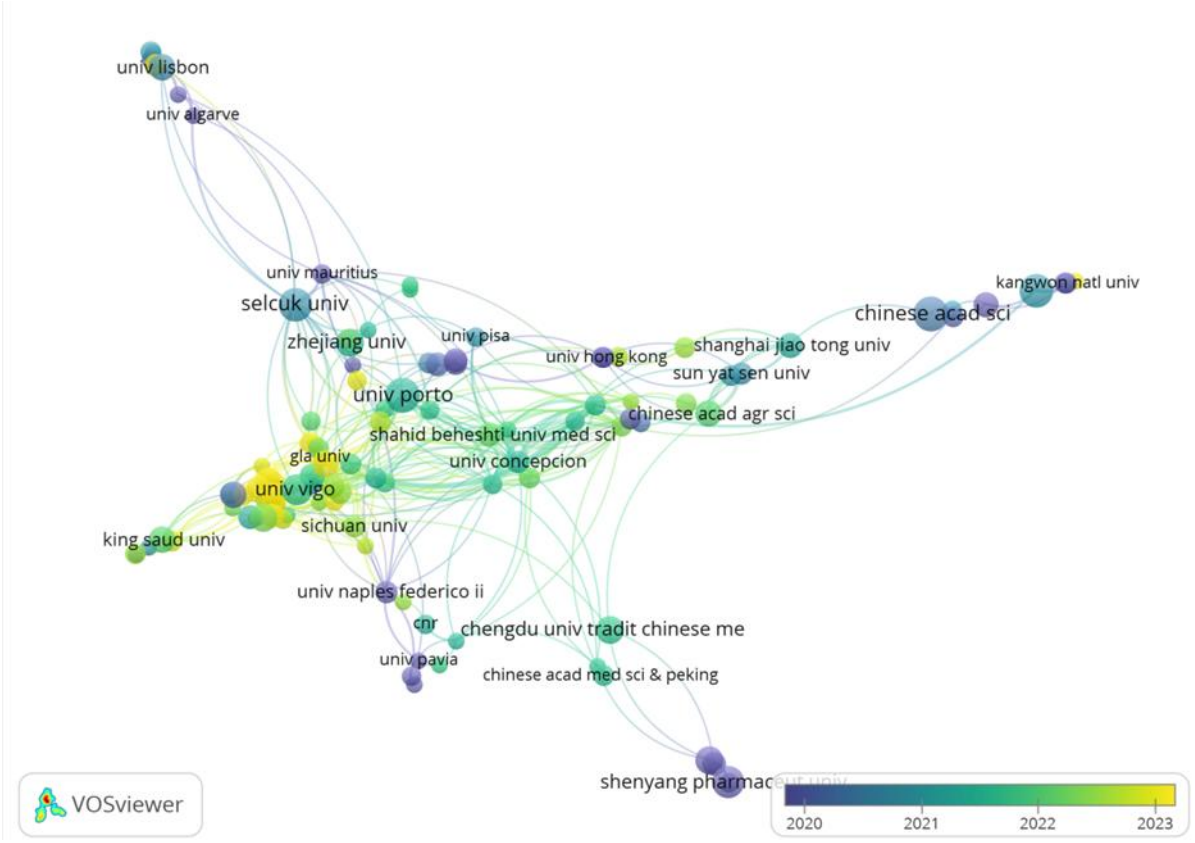

Figure 8. Overlay Visualization for Collaboration Network Between Organization

There is also a dense web of collaboration among central institutions such as University of Vigo, University of Porto, Zhejiang University, and Selcuk University, showing that these universities are acting as key nodes in collaborative networks. Strong connections with multiple partners indicate these are research hubs actively engaged in international or interdisciplinary collaborations. Overall, the network suggests a shift in research activity toward Western European and Middle Eastern universities in recent years. This trend highlights the expanding global research efforts in exploring natural compounds for neuroprotection and the potential for further interdisciplinary collaboration.

Analysing Citation by Country and Organization

Table 3 highlights the top ten countries based on publication output, citation count, and total link strength. China leads in both publications and citations, reflecting strong research productivity and impact. However, India shows the highest total link strength, suggesting extensive international collaboration. Countries like Italy, USA, and Pakistan demonstrate balanced performance in output, citations, and networking. Meanwhile, nations with fewer documents, such as Chile and Iran, still show meaningful citation impact and collaborative engagement, indicating the importance of both quality and connectivity in research influence.

Table 3: Top 10 Citation by Country

Country	Document	Citation	Total Link Strength
India	202	3769	257
China	303	9557	169
Italy	92	2983	147

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USA	83	3077	144
Pakistan	55	1608	132
Saudi Arabia	60	937	129
Egypt	46	1068	110
Spain	78	1802	104
Chile	17	878	91
Iran	47	1720	90

The comparative analysis of research output and citation metrics for various academic institutions reveals significant disparities in their influence and engagement within the scholarly community. Table 4 presents the top 20 organizations based on total link strength, reflecting their collaborative intensity in the research field. The University of Concepción and University of Medicine and Pharmacy Craiova demonstrate the highest total link strength, suggesting strong international or inter-institutional partnerships. Although Sun Yat-sen University recorded the highest citation count (1574), its link strength is moderate, indicating high research impact with relatively fewer collaborative links. Similarly, the Chinese Academy of Agricultural Sciences achieved substantial citations (1089) with lower link strength. This highlights that while some institutions excel in visibility and impact, others are more prominent in collaborative networks, emphasizing different strategies of influence in the research landscape. Overall, this data underscores the varying degrees of recognition and scholarly influence across these institutions, highlighting opportunities for growth and collaboration in the academic landscape.

Table 4: Top 20 Citation by Organization

Organisation	Country	Document	Citation	Total link strength
Universidad de Concepcion	Chile	8	716	77
University of Medicine and Pharmacy of Craiova	Romania	7	407	74
Shahid Beheshti University of Medical Sciences	Iran	9	455	56
Universidad del Azuay	Equador	7	422	55
Queen Elizabeth Hospital	Hong Kong	6	455	48
Sun Yat-sen University	China	8	1574	44
University of Pisa	Italy	6	205	42
University of Santo Tomas	Phillipines	7	194	40
Chinese Academy of Agricultural Sciences	China	11	1089	39
Chengdu University	China	7	517	35
Presidency University	India	7	417	34
University of La Frontera	Chile	5	146	32
Mohammed V University, Rabat	Morocco	11	272	31
University of Mauritius	Mauritius	6	424	31
University of Porto	Portugal	19	629	30
United Arab Emirates University	United	6	229	29

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	Arab Emirates			
Duy Tan University	Vietnam	6	293	28
Shanghai Jiao Tong Univesity	China	10	1332	28
Al Farabi Kazakh National University	Kazakhstan	5	195	25
Selçuk University	Turkiye	18	517	22

The overlay visualisation of citations by organisations in Figure 9 reveals several key institutions that serve as central nodes in the citation landscape. Notably, the Chinese Academy of Medical Sciences, Selcuk University, Zhejiang University, Mahidol University, and Gachon University exhibit large node sizes and occupy central positions, indicating their high citation frequencies and strong inter-organisational connectivity. These institutions likely play pivotal roles in shaping the research discourse within the field.

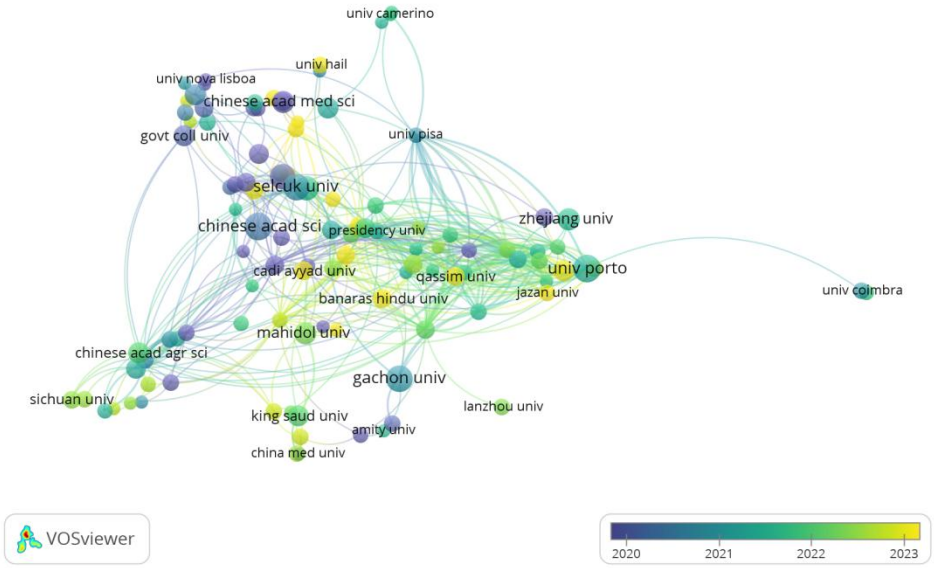

Figure 9. Overlay Visualization Map for Citation Between Organization

The colour gradient, representing the average publication year of cited documents, highlights the temporal evolution of citation impact. Organisations such as Zhejiang University and University of Porto, depicted in yellow, reflect more recent citations (2022–2023), suggesting their growing influence in current research. In contrast, institutions like the Chinese Academy of Medical Sciences show earlier citation activity, with node colours shifting towards blue-green (2020–2021). Interestingly, University of Coimbra appears isolated from the core cluster, which may imply a unique research trajectory or lower integration with other institutions in terms of shared citations. The overall structure of the network suggests that while a core group of organisations consistently anchors the field, emerging contributors are beginning to gain citation momentum, indicating a dynamic and evolving research environment.

Analysing Research Authorship

In the authors' study, a total of 3,763 researchers were identified. Table 5 highlights top 10 authors in the research topic based on the total link strength. The most prolific authors, with the highest-ranked being Gan Ren-you; Rasul Azhar and Sarfraz Iqra, each having a total link

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strength of 65, 62 and 58 respectively, suggesting a strong network of co-authorship and consistent integration within collaborative research clusters. Li Hua Bin (China) leads in citation count, with 1,528 citations from 7 documents, indicating exceptionally high citation impact per publication. In terms of productivity, Sharifi-Rad, Javad (Ecuador) recorded the highest number of documents (11), followed by Gan, Ren-you (Hong Kong) with 9 and Martorell, Miquel (Chile) with 8 documents.

Interestingly, authors from Pakistan, namely Rasul, Sarfraz, and Hussain, represent a significant share of contributions. Each maintains a relatively high citation count and total link strength, indicating both visibility and collaborative activity within the scholarly network. This pattern implies active institutional collaboration, particularly from Government College University. Overall, the data suggest that research in this area is both geographically diverse and network-driven, with emerging hubs in Asia and Latin America showing strong collaborative and citation metrics.

Table 5: Top 10 Authors

Author	Country	Documents	Citation	Total link strength
Gan, Ren-you Hong Kong Polytechnic University	Hong Kong	9	1067	65
Rasul, Azhar Government College University	Pakistan	6	455	62
Sarfraz, Iqra Government College University	Pakistan	5	444	58
Hussain, Ghulam Government College University	Pakistan	6	396	56
Li, Hua Bin Sun Yat-sen University	China	7	1528	54
Sharifi-Rad, Javad Universidad del Azuay	Ecuador	11	756	54
Martorell, Miquel Universidad de Concepcion	Chile	8	716	53
Calina, Daniela University of Medicine and Pharmacy Craiova	Romania	7	407	51
Riaz, Ammara The Khwaja Fareed University of Engineering and Information Technology	Pakistan	5	389	48
Wu, Ding-tao Chengdu University	China	4	394	45

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Analysing Journal Participation

The analysis of the top cited journals in neuroprotective research in Table 6 reveals that *Molecules* is the most productive journal with 58 publications, while *Journal of Ethnopharmacology* stands out with the highest number of citations (1297), despite publishing fewer articles. This suggests that research published in *Journal of Ethnopharmacology* has high impact and relevance in the field, likely due to its focus on bioactive compounds from medicinal plants. *Foods* also demonstrates a notable pattern, with only 19 articles but receiving 1225 citations, indicating its strong influence despite lower output. *International Journal of Molecular Sciences* shows the highest total link strength (41), implying strong bibliographic connections with other publications and journals. Journals like *Antioxidants, Nutrients, and Marine Drugs* also show a good balance between productivity and citation impact. Overall, the data reflects a multidisciplinary landscape in neuroprotective research, with significant contributions from fields such as pharmacology, nutrition, food science, and molecular biology.

Table 6: Top Citation by Sources

Source	Documents	Citations	Total Link Strength
International Journal of Molecular Sciences	32	977	41
Antioxidants	30	1068	37
Nutrients	37	919	34
Molecules	58	1064	26
Foods	19	1225	22
Journal of Ethnopharmacology	40	1297	18
Journal of Agriculture and Food Chemistry	15	685	17
Trends in Food & Technology	14	637	14
Frontiers in Nutrition	16	335	13
Frontiers in Pharmacology	30	844	13
Marine Drugs	20	850	13

The citation network generated by VOSviewer in Figure 10 shows that *Molecules, Nutrients,* and *International Journal of Molecular Sciences* are among the most central and influential journals in neuroprotective research, indicated by their larger node sizes and strong connectivity. Other journals such as *Journal of Ethnopharmacology, Antioxidants,* and *Marine Drugs* are also highly connected, reflecting their important role in the citation landscape. Journals such as *Marine Drugs* and *Journal of Food Biochemistry* appear in lighter colors, suggesting increasing relevance in recent years. This citation map highlights not only the long-standing influence of certain journals but also the growing diversity and evolving focus of neuroprotective research across interdisciplinary domains

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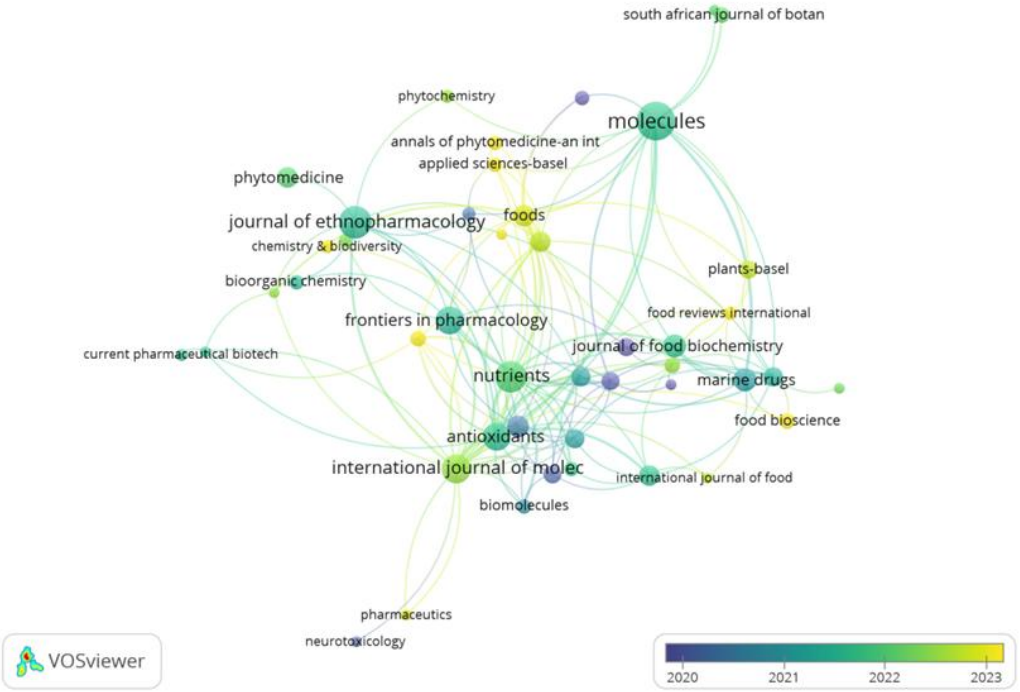

Figure 10. Overlay Visualization Map for Citation by Sources

Analysing Research Area

Analysis on the research area associated with neuroprotective studies of bioactive compounds resulted in a total of 50 research areas. As indicated in Table 7, the research area Pharmacology and Pharmacy notably stands out as the most extensively studied area (26.75 %) within the context of neuroprotective study of bioactive compounds. This observation supports the data's reliability, affirming its alignment with the study's core focus. Following closely are Biochemistry Molecular Biology which contributes 22.90 %.

The area of Food Science Technology and Chemistry Medicinal also contributed significantly with 21.24 % and 16.26 %, respectively. The total percentage based on 1144 documents was greater than 100%, indicating that certain studies are relevant to more than one research area.

Table 7: Top 10 Research Area (Total 50 Areas)

Research Area	Record Count	% of 1144
Pharmacology and Pharmacy	306	26.75
Biochemistry Molecular Biology	262	22.90
Food Science Technology	243	21.24
Chemistry Medicinal	186	16.26
Chemistry Multidisciplinary	144	12.59
Plant Sciences	127	11.10
Nutrition Dietetics	121	10.58
Integrative Complementary Medicine	93	8.13
Neurosciences	69	6.03
Chemistry Applied	44	3.85

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Analysing Co-occurrence of Keywords

This study's selected type of analysis is co-occurrence analysis, which exclusively utilizes Author Keywords. This choice was made primarily due to its ability to provide a more streamlined and focused examination of the bibliometric data, aligning with the study's emphasis on author selections, as opposed to Keyword Plus, which tends to be broader in scope (Zhang et al., 2016). While both types of analysis have their respective advantages, the former was selected for its convenience. The size of the node in the mapping represents the occurrence or the total frequency of the occurrence while the distance between the node relates to its degree of relatability. Meanwhile, the colour represents the category of the cluster shows keywords that are more similar to each other than those of other clusters. The co-occurrence of keywords indicates publications where authors frequently use similar phrases or keywords. These keywords highlight current trends in the field of study and enhance the visibility and searchability of authors' work. Figure 11 presents a network visualisation of author keywords, offering insights into research trends in the field of neuroprotection. The colour gradient suggests that these areas have gained traction in more recent years.

Figure 11a provides a general overview, revealing key focus areas such as “neuroprotection,” “oxidative stress,” “antioxidant,” and “Alzheimer’s disease.” These central keywords are connected to various related terms including “polyphenols,” “flavonoid,” and “phytochemistry,” suggesting a multidisciplinary approach encompassing disease mechanisms, antioxidant strategies, and natural product research.

The network is densely interconnected, reflecting the broad and overlapping nature of studies in this field, although the term “bioactive compounds” appears less prominently in this general view. In contrast,

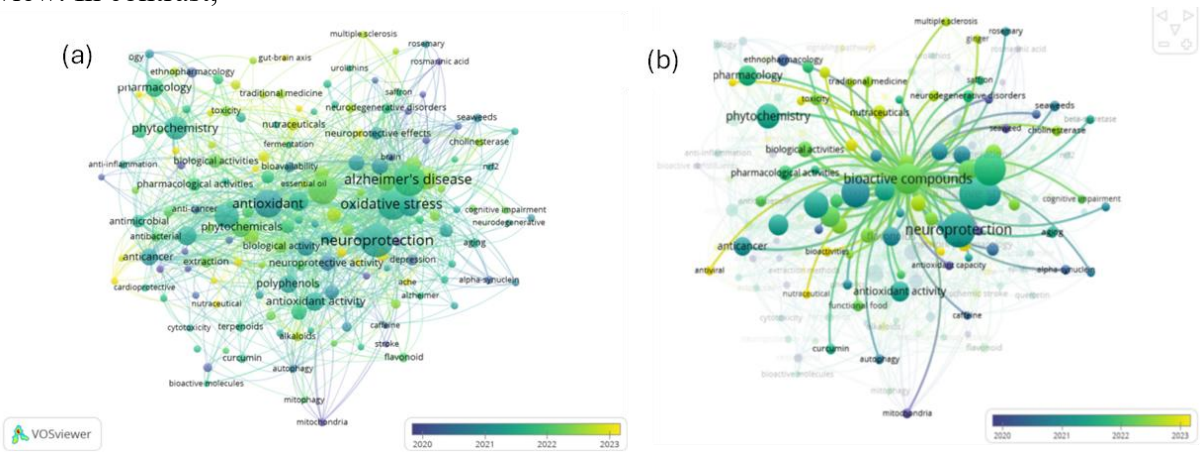

Figure 11. Overlay Visualization for Keywords by Author (a) general overview (b) bioactive compounds

Figure 11b narrows the focus specifically to studies involving “bioactive compounds.” This term emerges as the central hub, with strong co-occurrence links to “neuroprotection,” “antioxidant activity,” and “phytochemistry.” The structure of the network shifts to highlight plant-derived compounds such as “curcumin,” “ginger”, “rosemary” and “saffron”, indicating more targeted research on the therapeutic potential of bioactive substances. Top-ranked authors’ keywords as determined based on their link strength and co-occurrence is illustrated in Table 8. Top keywords include, among others, "neuroprotection" (120), Alzheimer’ disease (108), "oxidative stress" (93), bioactive compounds (89) and "antioxidant" (88). Link strengths

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analysis revealed that "neuroprotection" with a total of 306, exhibited the strongest overall link strength among the keywords.

Table 8. Top Keywords by Authors

Keywords	Occurrence	Total link strength
neuroprotection	120	306
Alzheimer' disease	108	253
oxidative stress	93	243
antioxidant	88	211
bioactive compounds	89	155
neuroprotective	66	141
Parkinson's disease	51	129
neuroinflammation	50	124
phytochemistry	56	123
neurodegenerative disease	39	107
anti-inflammatory	40	100
phytochemicals	41	97
antioxidants	40	94
pharmacology	39	87

Analysing Language of Documents

According to the data shown in Table 9, English is the prevalent language in the study, accounting for a significant 99.65% of the total documents analysed. English's overwhelming prevalence can be due to its general acceptance and comprehensibility, making it the major medium for communication and distribution of academic content in the context of the study. Only a tiny percentage of the publications utilised other national languages, with one publication each in Japanese, Portuguese, and Spanish. Publications using native languages may exist, however the usage of keywords is largely based on English. Thus, publication featuring synonyms for the term "neuroprotective' in other languages were likely omitted. Implementing an intelligent system within the WoS Core Collection database that can read and comprehend the meaning of words in many languages without the need for translation would be a valuable advance in restricting research questions (Yang et al., 2020). It is worth noting that such technology exists in the field of artificial intelligence but has yet to be employed in such applications.

Table 9. Language Used in Publication

Language	Total	Percentage (n-=1144)
English	1140	99.65
Japanese	2	0.17
Portugese	1	0.09
Spanish	1	0.09
Total	1144	100

Analysing Research Funding

The bibliometric analysis reveals that multiple international funding agencies have played a significant role in supporting research on neuroprotective bioactive compounds. The data in Table 10 suggests that China, Europe, and South America are among the most active regions in funding neuroprotection research, potentially due to increasing concerns about

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neurodegenerative diseases and the search for alternative therapeutic strategies. The diversity of funding sources further underscores the growing interdisciplinary and international collaboration in this research domain.

From the total 202 agencies, China emerges as the leading regions supporting this field, reflecting a global commitment to advancing research on neuroprotection. The National Science Foundation of China (NSFC) leads in research funding, with 141 publications, underscoring China's strong investment in neuroprotection studies. This dominance may be attributed to China's national research priorities, increasing prevalence of neurodegenerative diseases, and government-backed initiatives for drug discovery and plant-based medicine. South America, particularly Brazil, demonstrates an emerging research interest, likely due to the region's rich plant biodiversity (da Costa et al., 2023).

Table 10. Top 10 Funding Agencies

Agency	Country	Count
National Science Foundation of China (NSFC)	China	141
Foundation for Science and Technology (FCT) Portugal	Portugal	39
National Research Foundation of Korea	Korea	28
Europian Union EU		27
The National Council for Scientific and Technological Development (CNPq)	Brazil	25
Brazilian Federal Agency for Support and Evaluation of Graduate Education *(CAPES*)	Brazil	24
Spanish Government	Spain	21
National Key Research Development Program of China	China	16
King Saud University	Saudi Arabia	11
Fundamental Research Funds for Central Universities	China	10

Other key contributors include the Foundation for Science and Technology (FCT) Portugal (39 publications), the National Research Foundation of Korea (28 publications) and European Union (EU) (27 publications), These agencies reflect a broad international collaboration, with substantial contributions from Europe and Korea. Additionally, national research agencies such as the Spanish Government (26 publications), the National Council for Scientific and Technological Development (CNPq) of Brazil (25 publications), and the Brazilian Federal Agency for Support and Evaluation of Graduate Education (CAPES) (24 publications) highlight regional efforts in advancing neuroprotective research. The diversity of funding sources reflects growing international collaboration and interdisciplinary research efforts in neuroprotection.

Limitation and Future Studies

Overall, this study has some limitations and constraints. The study only uses data from one database, WoS, and ignores other scientific databases like from Elsevier's Scopus. This limited data source may create bias and reduce the comprehensiveness of the conclusions. However,

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based on rigorous study, the influence will be reduced due to the enormous amount of data acquired from a single database.

Moreover, the limitation of this study is the potential inclusion of predatory journals within the indexed WoS dataset, as their presence in bibliometric databases may distort citation metrics and publication trends. However, this is unlikely because WoS ensures a high standard for publication verification. Future research should focus on developing a methodology to identify and exclude such journals for a more accurate analysis. Moving forward, increased funding transparency, cross-border partnerships, and investment in innovative technologies will be critical for sustaining progress in this field. Further bibliometric studies could assess the direct impact of funding on high-impact publications and clinical advancements.

Conclusion

The article presents a comprehensive tutelage on the bibliometric data so that researchers can look for prospective collaborating partners globally and also understand the dynamics of other publication-related aspects. The analysis shows that there is an upward trend in the publication associated with neuroprotective study. This is due to many factors such as the increasing demand for novel neuroprotective strategy, advancement in biotechnology, greater funding and growing interest in alternative medicine and plant-derived therapeutic agents. The accessibility of large scientific databases and bibliometric analysis tools, such as VOSviewer, has also played a role in identifying research gaps and facilitating more targeted studies. In summary, this trend highlights the need for continued interdisciplinary research to further explore the therapeutic potential of bioactive compounds for neurological disorders.

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