Review article

UDC 582.583:025.4.03
https://doi.org//10.26907/2542-064X.2025.1.37-52

Comprehensive evaluation of the global research on Zingiberaceae (1943–2022): A bibliometric study

S.I. Abdelwahab[1] ✉, M.M.E. Taha[1], A.A. Mariod[2]

[1]Medical Research Centre, Jazan University, Jazan, Saudi Arabia
[2]College of Science, University of Jeddah, Jeddah, Saudi Arabia

✉*sadiqa@jazanu.edu.sa*

Abstract

Zingiberaceae has long been used medicinally, culinarily, and cosmetically, especially in tropical and subtropical regions. However, despite attracting substantial funding and research interest, they remain unexplored from a bibliometric perspective. Using the Scopus database, this study summarizes the global research output on Zingiberaceae from 1943 to 2022. The Scopus search resulted in 3589 English-language journal articles and conference proceedings. The bibliometric networks were visualized with the VOSviewer software. The analysis revealed that the most published author is J.K. Hwang affiliated with Yonsei University (South Korea), while the Chinese Academy of Sciences (China) holds the largest number of publications among the institutions. The works on Zingiberaceae cover multiple topics from 27 disciplines, with agricultural and biological sciences contributing the most (23.5 %). Other key research areas and subjects include ethnobotany, traditional knowledge, botanical and taxonomic studies, essential oils, pure chemicals, and individual species. India emerged as the most collaborative country, and S. Nayak from Siksha O Anusandhan University (India) stands out as the most collaborative researcher. The Journal of Ethnopharmacology leads in the publication and citation counts. The above results define the current status and future hotspots of the research on Zingiberaceae plants.

Keywords: Zingiberaceae, bibliometric analysis, visualization, Scopus, research output

Acknowledgments. The Saudi Digital Library (Saudi Arabia) is gratefully acknowledged for providing the full access to the Scopus database.

For citation: Abdelwahab S.I., Taha M.M.E., Mariod A.A. Comprehensive evaluation of the global research on Zingiberaceae (1943–2022): A bibliometric study. *Uchenye Zapiski Kazanskogo Universiteta. Seriya Estestvennye Nauki*, 2025, vol. 167, no. 1, pp. 37–52. https://doi.org/10.26907/2542-064X.2025.1.37-52.

Обзорная статья

УДК 582.583:025.4.03
https://doi.org/10.26907/2542-064X.2025.1.37-52

Комплексная оценка мирового опыта в изучении сем. Zingiberaceae (1943–2022): библиометрическое исследование

С.И. Абдельвахаб[1] ✉, М.М.Э. Таха[1], А.А. Мариод[2]

[1] Центр медицинских исследований, Университет Джазана, г. Джазан, Саудовская Аравия
[2] Колледж наук, Университет Джидды, г. Джидда, Саудовская Аравия

✉*sadiqa@jazanu.edu.sa*

Аннотация

Растения из сем. Zingiberaceae широко используются в медицине, кулинарии и косметологии, особенно в тропических и субтропических регионах. Однако, несмотря на значительное финансирование и большой иссследовательский интерес, анализ библиометрических данных по этой группе до сих пор не проводился. В настоящей работе, на основе глобального поиска по международной библиометрической базе данных Scopus за период с 1943 по 2022 гг., проанализировано 3589 англоязычных публикаций, посвященных сем. Zingiberaceae в научных журналах и материалах конференций. Визуализация полученных результатов выполнена с использованием программного обеспечения VOSviewer. Список авторов, имеющих наибольшее количество публикаций, возглавил Ч.К. Хван из Университета Ёнсе (Южная Корея). Среди исследовательских учреждений по этому показателю первое место занимает Китайская академия наук (Китай). Всего выявлено 27 тематических кластеров, в которые наибольший вклад вносят сельскохозяйственные и биологические науки (23.5 %). Среди ключевых тематических направлений выделяются: этноботаника, традиционные знания, ботанические и таксономические исследования, а также исследования эфирных масел, химически чистых соединений и отдельных видовых групп. Наиболее развитая сеть международных коллабораций сформирована Индией. По числу авторских коллабораций лидирует С. Найак из Университета Сикша О Анусандхан (Индия). Journal of Ethnopharmacology имеет наибольшее количество цитирований и число статей по тематике. Полученные результаты позволяют оценить текущее состояние и перспективные направления в исследовании растений сем. Zingiberaceae.

Ключевые слова: Zingiberaceae, библиометрический анализ, визуализация, Scopus, результативность научной деятельности

Благодарности. Авторы выражают благодарность Цифровой библиотеке Эр-Рияда (Саудовская Аравия) за полный доступ к международной библиометрической базе данных Scopus.

Для цитирования: *Abdelwahab S.I., Taha M.M.E., Mariod A.A.* Comprehensive evaluation of the global research on Zingiberaceae (1943–2022): A bibliometric study // Учен. зап. Казан. ун-та. Сер. Естеств. науки. 2025. Т. 167, кн. 1. С. 37–52. https://doi.org/10.26907/2542-064X.2025.1.37-52.

Introduction

Zingiberaceae, or ginger, is one of the largest families of herbaceous perennials consisting of about 1000 species and 47 genera widely distributed from India and tropical Asia to northern

Australia (Table 1). It has a long history of use in tropical village gardens, culinary, traditional medicine, and phytotherapy [1–3]. The data available from existing studies show that Zingiberaceae plants possess multiple biological activities and medicinal potential, which sparks growing international interest [4–6]. Their key bioactive compounds are curcumin, zerumbone, cardamonin, pinocembrin, 5,6-dehydrokawain, alpinetin, 5,6-dehydrokawain, 3-deacetylcrotepoxide, and xanthorhizol [7–9]. Due to pronounced anti-inflammatory, anti-ulceration, antioxidant, antimicrobial, antihyperglycemic, antiplatelet, antitumor, and anthelmintic properties, they are effective in treating stomach aches, indigestion, rheumatism, fever, and swelling. However, more research, including systematic and comprehensive reviews, is needed to further confirm and better analyze these benefits.

Table 1. Zingiberaceae family: keystone genera and their major species (with scientific and common names)

Key genera	Total species number	Major species	
		Scientific name	Common name
Alpinia	200	*Alpinia zerumbet*	Shell ginger
Etlingera	110	*Elettaria cardamomum*	Green cardamom
Curcuma	100	*Curcuma longa*	Turmeric
Globba	100	*Globba winitii*	Dancing lady ginger
Zingiber	100	*Zingiber officinale*	Ginger
Renealmia	75	*Renealmia alpinia*	Mardi gras, garden ginger
Amomum	65	*Amomum subulatum*	Black cardamom
Aframomum	60	*Aframomum melegueta*	Grains of paradise
Boesenbergia	60	*Boesenbergia rotunda*	Fingerroot
Hedychium	50	*Hedychium coronarium*	White ginger lily
Hornstedia	50	*Hornstedia scottiana*	Scott's ginger

Scientometrics and bibliometrics, clustered in the broader field of infometrics, are the two major methods to study scientific literature. Known as the science of science, scientometrics investigates and quantifies the value of academic publications, authorship patterns, and different processes behind scientific discoveries [10–12]. Generally, both methods allow analyzing the research history and trends, assessing the scientific contribution of authors, journals, and publications, as well as mapping the distribution of scientific information. To fit with these aims, numerous techniques, such as citation analysis, collaboration network analysis, co-word analysis, content analysis, and text mining, are utilized. In addition, bibliometrics sorts out data about titles, abstracts, full-text books, journal articles, and conference proceedings based on keywords provided by editors or librarians [13, 14]. It helps track knowledge evolution, hotspots, and future directions in various academic fields and subjects [15, 16].

This article summarizes the published findings on Zingiberaceae plants: it defines the focus of current research trends, shares an update on some problems that still exist and await solution, emphasizes approaches that are being considered desirable and feasible for studying various species, offers new avenues for medicinal plant use and investigation, and encourages manufacturers and experts who acknowledge their colleagues' work and strive to embrace the global scope of ideas and practices. To our knowledge, no review has examined the Zingiberaceae family using a bibliometric analysis.

1. Material and Methods

The current state, general progress, and future trends of the research on the Zingiberaceae family were analyzed quantitatively [17, 18] by studying research collaboration networks, global and individual scientific outputs and contributions, institutional partnerships and impacts, national research inputs, etc. Global collaborations among authors, institutional affiliations, and journals were explored. A complete online search was carried out to collect the relevant data published from 1943 to January 2022. The focus was placed on ensuring the consistency and accuracy of the selected data.

1.1. Database selection. All data (n = 3974) were retrieved from Scopus (Elsevier) in accordance with the terms and conditions of this database. The choice fell on Scopus for its more comprehensive (over 70 million documents) and broader, compared to Web of Science or PubMed, coverage of scientific content, as well as for its simplicity in navigation and widespread use in academic community [19, 20, 21]. Unlike, PubMed, which focuses on health-related content and is not a primary tool to search for botanical data, Scopus extends to a wider range of disciplines, particularly in the life and natural sciences [22–24]. It also features author profiles and affiliations, fundings, citation metrics, publication counts, and leading countries in each research area.

1.2. Content selection criteria. The bibliometric data were limited to English-language journal articles and conference proceedings (n = 3589), and books were excluded. No specific restrictions were applied to the selection of researchers and journals, which instead relied on the existing indexing mechanisms.

1.3. Search criteria and bibliometric analysis. The data were extracted from Scopus using the search query "Zingiberaceae" in article titles. The search command was as follows: publication year (TITLE-ABS-KEY (Zingiberaceae) AND (LIMIT-TO (LANGUAGE, "English") (AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp"))). The search results were exported in CSV (Microsoft Excel), RIS, plain text (HTML), and BibTex formats. For more details on the approach used, see Fig. 1.

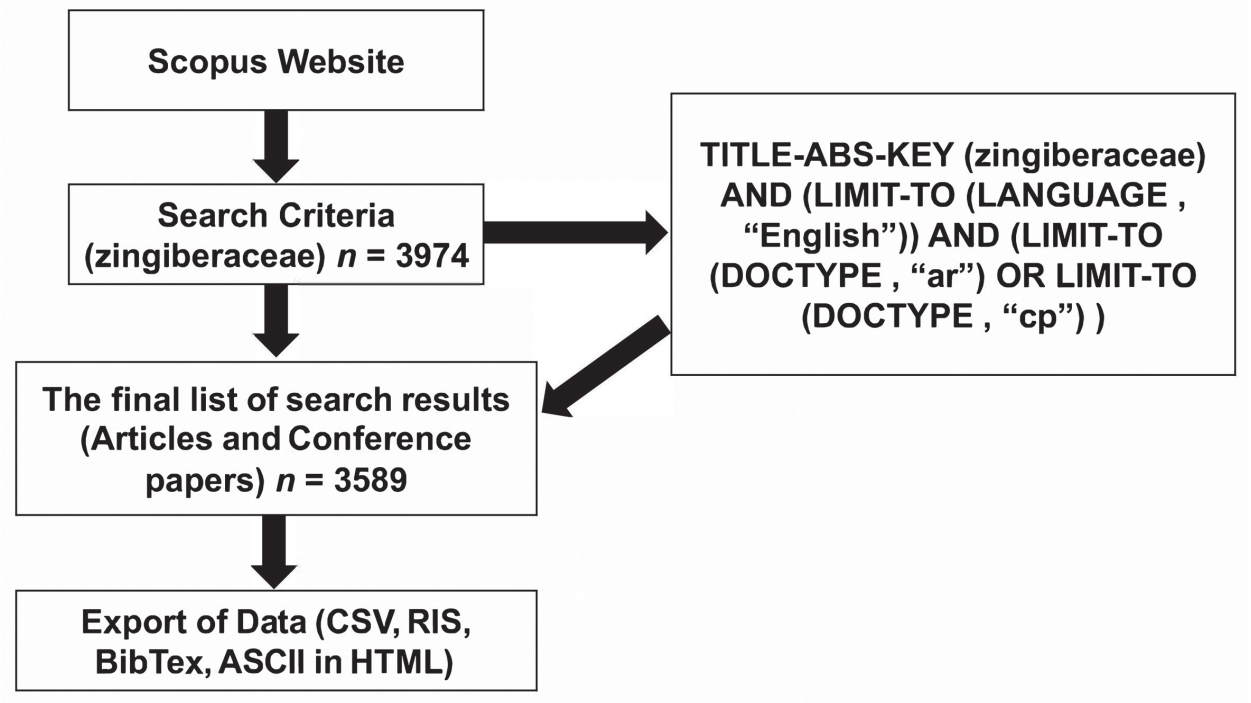

Fig. 1. Content selection and search strategies during the bibliometric study

1.4. Construction and visualization of bibliometric networks. The VOSviewer software (Version 1.6.15, Leiden, Netherlands) was used to create and visualize bibliometric networks via the analysis of citation, bibliographic coupling, co-citation, and co-authorship. Such networks encompass the connections between individual articles, researchers, journals, institutions, or countries. This tool also offers text mining functions, thus making it possible to generate co-occurrence networks from key phrases in scientific literature [25, 26].

2. Results and Discussion

With the oldest article dating back to 1943 [17], the Zingiberaceae family has been extensively explored, and the amount of published data is increasing, thus substantiating the need for understanding the historical progression, current status, and future prospects in the research on this group.

As shown in Table 2, a total of 3974 publications, including articles (87.57 %), reviews (6.77 %), conference papers (2.74 %), and book chapters (1.46 %) were initially extracted. Publication types such as note letters, errata, data papers, editorials, books, short surveys, retracted articles, and conference reviews had smaller percentages. These records were further filtered to select 3589 English-language publications: articles (87.57 %) and conference papers (2.74 %).

Table 2. Results of the primary search in Scopus (n = 3974)

Document type	Search results	Percentage, %
Article	3480	87.57
Review	269	6.77
Conference paper	109	2.74
Book chapter	58	1.46
Note	13	0.33
Letter	12	0.30
Erratum	9	0.23
Data paper	6	0.15
Editorial	6	0.15
Book	4	0.10
Short survey	4	0.10
Retracted article	3	0.08
Conference review	1	0.03
Total	3974	100

2.1. Descriptive analysis of publication years, countries, disciplines, journals, and authors. Since the first publication in 1943 until the early 1980s, there was little interest in Zingiberaceae plants, with an average of one publication every year (Fig. 2). In 1991, a total of 18 (1.06 %) studies were published. This upward trend continued. In 2018, 2019, 2020, and 2021, the percentage of publications increased to 5.95 %, 6.15 %, 7.18 %, and 7.76 %, respectively. In 2022 so far, 13 studies have been published. The peak in publication numbers was observed in 2021.

India has been the leading contributor in terms of the number of publications (20.57 %): almost one-fifth of all studies on Zingiberaceae have been published by Indian authors. Thailand, China, Japan, and Malaysia contributed 13.97 %, 10.98 %, 10.26 %, and 8.28 %, respectively. The United States (6.35 %), Indonesia (5.4 %), South Korea (5.26 %), Brazil (4.4 %), and the United Kingdom (3.53%) round out the list.

Considering that Zingiberaceae species are native to tropical and subtropical areas across Africa, Asia, and the Americas, being most diverse in Southeast Asia [18], where it has been used as medicine and flavoring [19], the national patterns and volumes of research output were determined. The most fruitful authors (with over 30 published studies) are J.K. Hwang, H. Ibrahim, M. Sabu, and S. Nayak. From 20 to 30 studies were published by 17 authors, and 51 authors contributed from 10 to 20 publications. J.K. Hwang affiliated with Yonsei University (South Korea) was found to be the leading author.

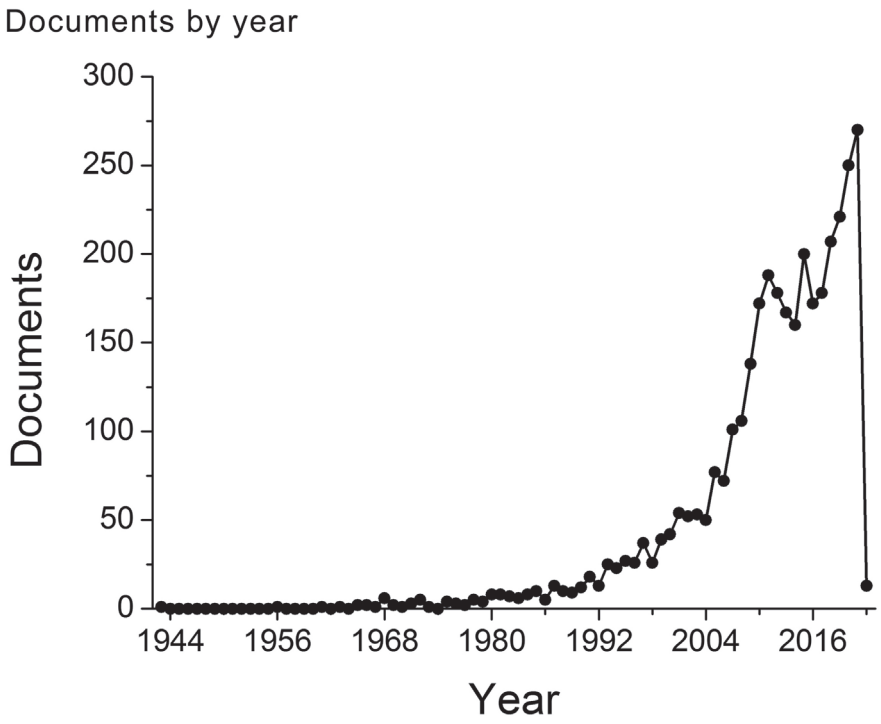

Fig. 2. Total number of publications on Zingiberaceae plants (1943–2022)

The publications selected for this study cover multiple topics from 27 fields of science (Fig. 3). Agricultural and biological sciences account for 23.5 % of all documents. Other major research domains (61.7 %) involve: pharmacology, toxicology, and pharmaceuticals (19 %); biochemistry, genetics, and molecular biology (18.4 %); chemistry (13.1 %); and medicine (11.2 %). The above research focus mainly revolves around drug discovery because plant-derived compounds, such as that contained by Zingiberaceae plants, have long been used for medical purposes and are still the main source of affordable pharmaceuticals [20]. Many publications are also devoted to chemical engineering, immunology and microbiology, nursing, engineering, earth and planetary sciences, physics and astronomy, materials science, computer science, veterinary, energy, neuroscience, social sciences, health professions, mathematics, economics, econometrics, and finance. The breadth of research undertaken across a variety of disciplines, including the non-medical ones, is explained by numerous applications of Zingiberaceae plants.

Publications on Zingiberaceae are scattered around the world, with 160 institutions involved in the research activities. The Chinese Academy of Sciences (China) leads in terms of publication volume (132 documents), followed by Mahidol University (Thailand), Universiti Putra Malaysia (Malaysia), Universiti Malaya (Malaysia), Chiang Mai University (Thailand), and Khon Kaen University (Thailand). See Fig. 4 for the top 15 institutions by the number of publications. It is important to note that five Malaysian universities have collectively published 230 articles:

in Malaysia, Zingiberaceae plants are not only commonly used to make spices, condiments, food and drink ingredients (from 16 to 20 % of the ginger varieties in Peninsular Malaysia are edible, and they can be consumed raw, cooked, pickled, or boiled), but also serve as ornamentals, often associated with the rituals based on religious beliefs and customs [21, 22].

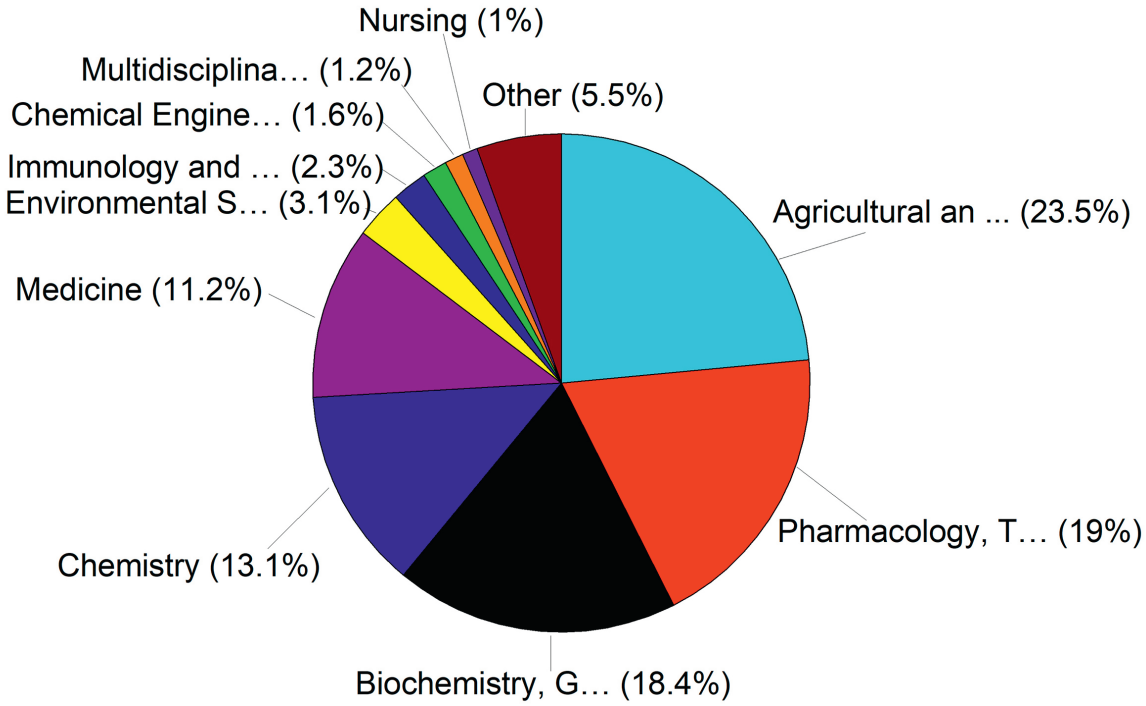

Fig. 3. Distribution of the articles published on Zingiberaceae plants in terms of subject area (1943–2022)

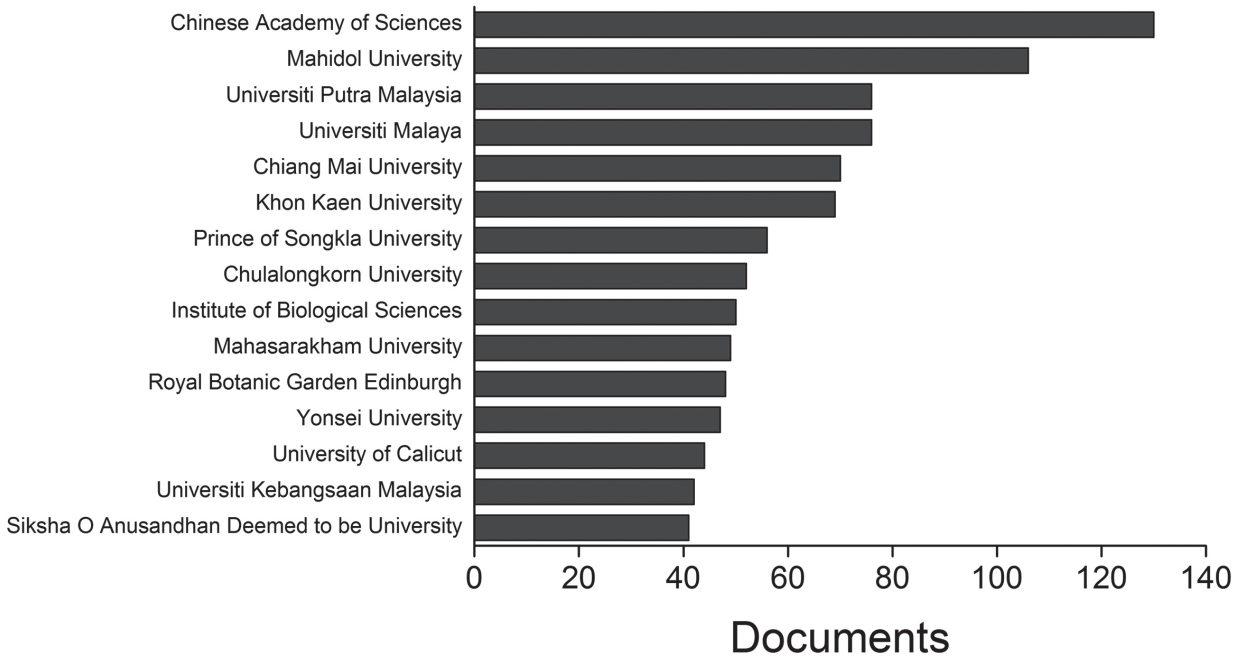

Fig. 4. Distribution of the articles published on Zingiberaceae plants in terms of author affiliations (1943–2022)

2.2. Co-authorship networks and international research collaborations. Research collaborations, their patterns and strength, are influenced by many factors, such as national specif-

ics, region, institution, and individual perspectives of scientists. While these collaborations bring many benefits, it is critical to first identify which of them are the most effective [23].

In Fig. 5, the results of the VOSviewer visualization of co-authorship networks among countries with at least 10 publications on Zingiberaceae (n = 40) are shown. These countries were categorized into six clusters, with 323 links and a total link strength of 1057, respectively. Cluster 1 (red), the largest one, includes 11 countries, each with more than 10 publications. The country that ranks at the top is India (720 documents, 32 links, and total link strength of 32). The second major contributor is Malaysia, which has developed a very strong collaboration with Indian colleagues, as evidenced by the red lines connecting the two countries. Cluster 2 (green) consists of ten countries led by Brazil, along with Belgium, Cameroon, Colombia, France, Italy, Nigeria, Portugal, South Africa, and Spain. Cluster 3 (blue) is formed by China, Thailand, and the USA, with a total link strength of 28, 31, and 38, respectively. Although the United States has fewer publications, it has achieved exceptional success in collaborative research activities. The strongest collaboration was observed between Clusters 3 and 5, represented by the Japanese and Thai groups, with a total link strength of 39, which indicates that there are many joint research projects between these two groups, focusing particularly on the biological effects of compounds and extracts from Zingiberaceae [24, 25].

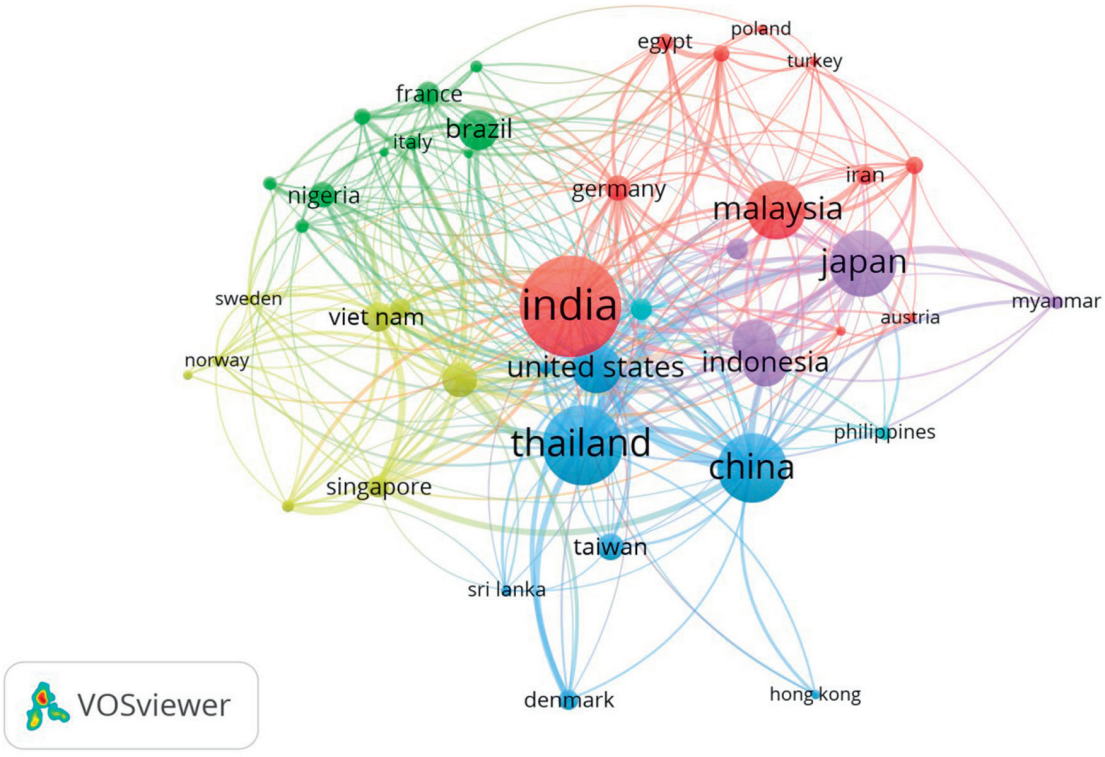

Fig. 5. Collaborative research networks among different countries, each with ten or more publications. Only countries with the identified research networks (n = 44) were mapped. The thickness of the connecting lines indicates the strength of research cooperation

Numerous studies suggest that the diversity of research collaborations determines the research output, as well as promotes the active exchange of skills, experiences, and information [23, 26, 27]. Any discrepancies between collaborators can have a negative impact on their performance

by hindering the flow of information and ideas. From this perspective, a total of 25 clusters were identified, each with at least 10 publications, 140 links, and a total link strength of 759 (Fig. 6). Malaysian, Japanese, and Thai researchers showed the highest collaboration performance. S. Nayak turned out to be the most collaborative researcher, with 35 documents and a total link strength of 106. She is affiliated with Siksha O Anusandhan University (India) and specializes in the plant tissue culture and phytochemistry of medicinal and aromatic plants. B. Kar, A. Ray, S. Jena, A. Sahoo, H. Matsuda, P.C. Panda, H. Morita, and M. Yoshikawa, each with a total link strength exceeding 50, also exhibit strong collaborative relationships. Here it should be noted that a researcher can score a total link strength even if the number of publications is relatively small. For example, H. Ibrahim (38 publications) and M. Sabu (36 publications) have a total link strength below 30.

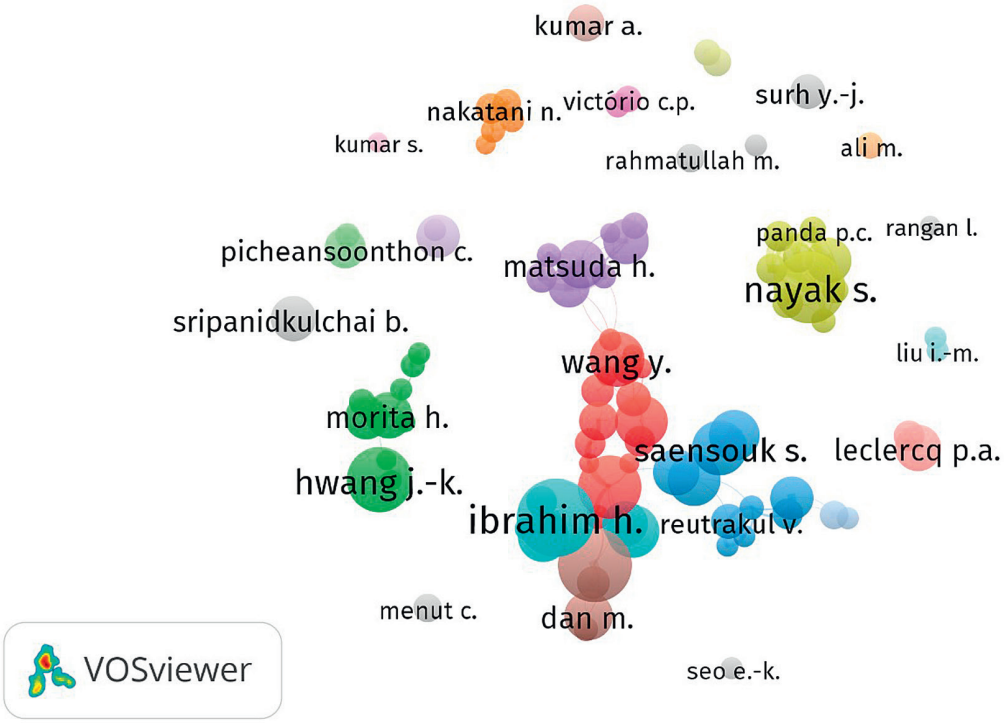

Fig. 6. Collaborative research networks among 25 authors having at least ten publications and divided into three clusters on the map, each with a distinct hue. The clusters show the groups of researchers who are closely linked

2.3. Visualization of keyword co-occurrence. Keywords are the elements facilitating the search for relevant content in scientific databases. They are also used to identify the pattern for a subject area through classification or clustering, thus revealing the current state of research and areas that need to be prioritized [28].

Our bibliometric analysis yielded a total of 7687 and 18250 author and index keywords, respectively. From 1943 to 2022, researchers in the field of Zingiberaceae plants used 23440 keywords. The title and abstract keywords with minimum occurrences were mapped on a network using the VOSviewer software. Overall, eight clusters of terms (research themes), with 1731 links and a total link strength of 4770, were singled out. The research themes include ethnobotany, traditional knowledge, botanical and taxonomical studies, essential oils, pure compounds, individual plants (*Zingiber officinale*, *Curcuma longa*, *Alpinia galanga*, *Hedychium coronarium*, *Zingiber zerumbet*, *Curcuma zedoaria*, *Kaempferia galanga*, *Boesenbergia rotunda*, *Alpinia zerumbet*, *Curcuma aeruginosa*, *Curcuma aromatica*, and *Kaempferia parviflora*), antioxidants, and oxidative stress.

Some keywords (Zingiberaceae, essential oil composition, essential oil, 1,8-cineole, zingiber officinale, ginger, *Curcuma longa*, β-pinene, antimicrobial activity, antioxidant, curcumin, new species, cytotoxicity, medicinal plants, and *Curcuma*) have a total link strength above 100 (Fig. 7), which is due to the widespread use of Zingiberaceae plants in food products, pharmaceuticals, medicine, and cosmetics [29–32].

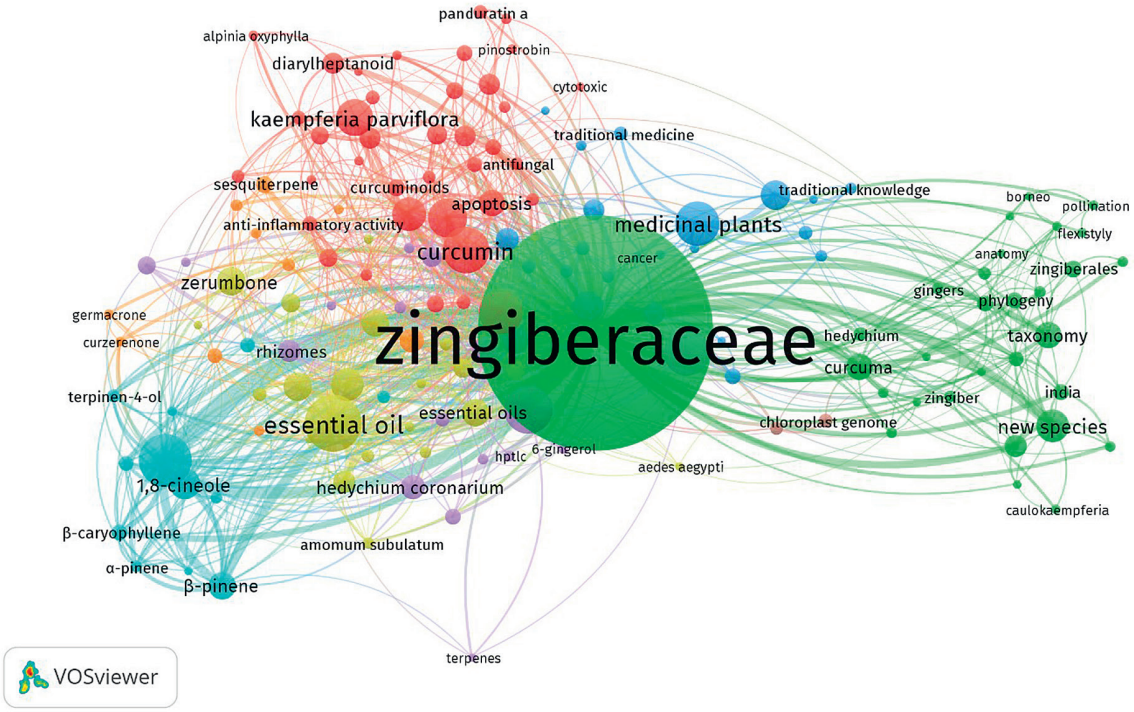

Fig. 7. Network visualization map of the author keywords (at least 10 occurrences) divided into eight clusters. The node size corresponds to the keyword frequency in the selected documents

2.4. Citation analysis. Citations can be analyzed in various ways. The age of citations, or their distribution over time, is a valuable indicator of the dynamics and evolution of the field and knowledge in general. This approach can be used to build a bibliometric monitoring system capable of measuring and tracking aspects such as research impact.

In the research on Zingiberaceae plants, the top-cited source is the Journal of Ethnopharmacology (7477 citations), which focuses on the usage of plants, fungi, animals, microbes, and minerals, as well as their biological and pharmacological effects, in line with international standards. There have been many studies investigating how Zingiberaceae plants are used [33, 34]. The top-cited article, with 1375 citations, was published by Young-Joon Surh affiliated with Seoul National University (South Korea). This article examines the molecular mechanisms underlying the anti-inflammatory activities of curcumin, a yellow pigment in turmeric (*Curcuma longa*) [35]. Young-Joon Surh is also the most cited author (n = 3523). He has published more than 400 articles, with 21878 citations and 806 co-authors. His main research interests include the molecular aspects of the pharmacology and toxicology of natural compounds. Among institutions, Prince of Songkla University (Thailand) has the highest citation count. In the broader context, India is the most cited country. Citation analysis is an important tool based on the evaluation of a research's impact and expected quality from the number the publications and/or authors have been referenced by others [36]. The most frequently cited articles, journals, institutions, and countries studying Zingiberaceae plants are listed in Table 3.

Table 3. Top-cited articles, journals, institutions, and countries

Top-cited articles				
Article title	Journal	Author (year)	Citations	Links
Molecular mechanisms underlying chemopreventive activities of anti-inflammatory phytochemicals: Down-regulation of COX-2 and iNOS through suppression of NF-κB activation [35]	Mutation Research	Y.-J. Surh (2001)	1375	2
Influence of piperine on the pharmacokinetics of curcumin in animals and human volunteers [37]	Planta Medica	G. Shoba (1998)	1271	0
A systematic screening of total antioxidants in dietary plants [38]	Journal of Nutrition	B.L. Halvorsen (2002)	879	0
Comparative evaluation of 11 essential oils of different origin as functional antioxidants, antiradicals and antimicrobials in foods [39]	Food Chemistry	G. Sacchetti (2005)	847	0
Health-promoting properties of common herbs [40]	American Journal of Clinical Nutrition	W.J. Craig (1999)	751	0
Top-cited journals				
Journal name	Impact factor	Published articles	Citations	Total link strength
Journal of Ethnopharmacology	4.360	153	7747	3227
Journal of Essential Oil Research	1.963	116	1787	3833
Phytochemistry	4.072	97	4553	1872
Planta Medica	3.352	75	3277	2129
Chemical and Pharmaceutical Bulletin	1.645	65	2366	1501
Top-cited institutions				
Institution name, country	World ranking	Documents	Citations	Total link strength
Prince of Songkla University, Thailand	1201	8	520	23
Kyoto Pharmaceutical University, Japan	NA	10	468	1
Chiang Mai University, Thailand	1200	9	316	9
Yonsei University, South Korea	151	5	292	23
University of Tokyo, Japan	35	5	289	6
Top-cited countries				
Country	GDP ranking [41]	Documents	Citations	Total link strength
India	5	720	181	781
Japan	3	357	247	1284
South Korea	12	183	1453	459
Thailand	25	488	277	1296
United States	1	221	820	620

2.5. Bibliometric coupling and co-citation: Intellectual structure and links through bibliographic and co-citation mapping. Using the VOSviewer software, the intellectual structure of the publications on Zingiberaceae over the studied period was mapped. The bibliographic coupling analysis was based on studying the normalized relationships and complete counting, during which the commonly-shared references between a set of publications were quantified [42–44]. Three clusters were identified from a total of 29 journals, each with at least 20 documents (Fig. 8). The analysis yielded 386 links, with a total link strength of 20849. The identified clusters represent the following three research domains: pharmacology and traditional knowledge, the chemistry of essential oils, and botany. The Journal of Ethnopharmacology contains 159 documents, with a total link strength of 4227. The co-citation relations, or the extent to which two articles are cited together in other articles, were explored between the sets of publications. The resulting intellectual links were aggregated into co-citation clusters based on the structure and content of the publications. As shown in Fig. 9, a total of 65 journals were grouped into six clusters, with 2007 links and a total link strength of 145565. The minimum number of citations was 150.

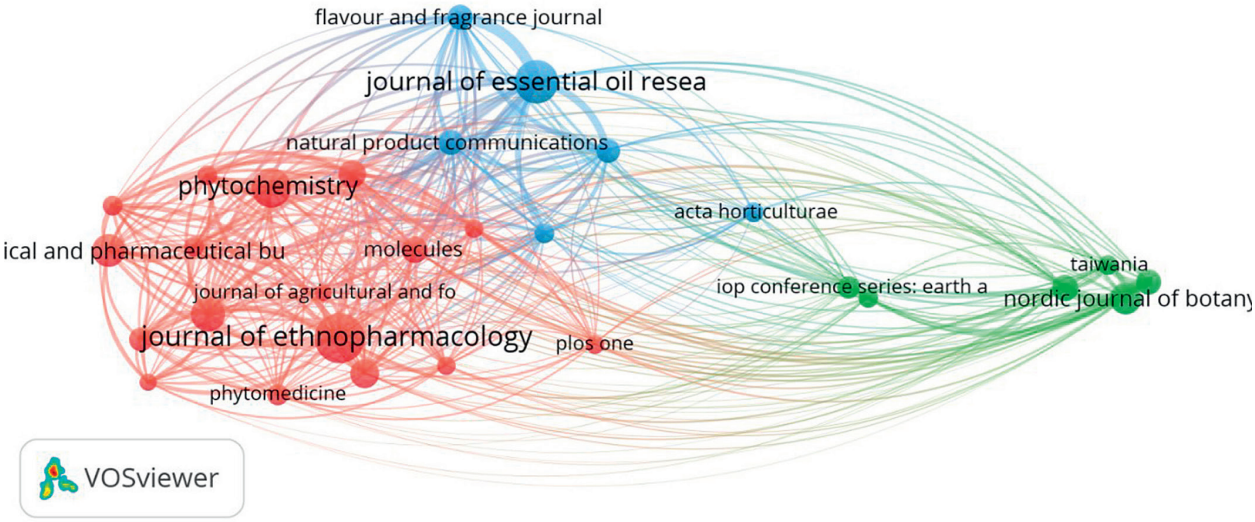

Fig. 8. Network visualization map of the journals having at least 20 documents and divided into three clusters

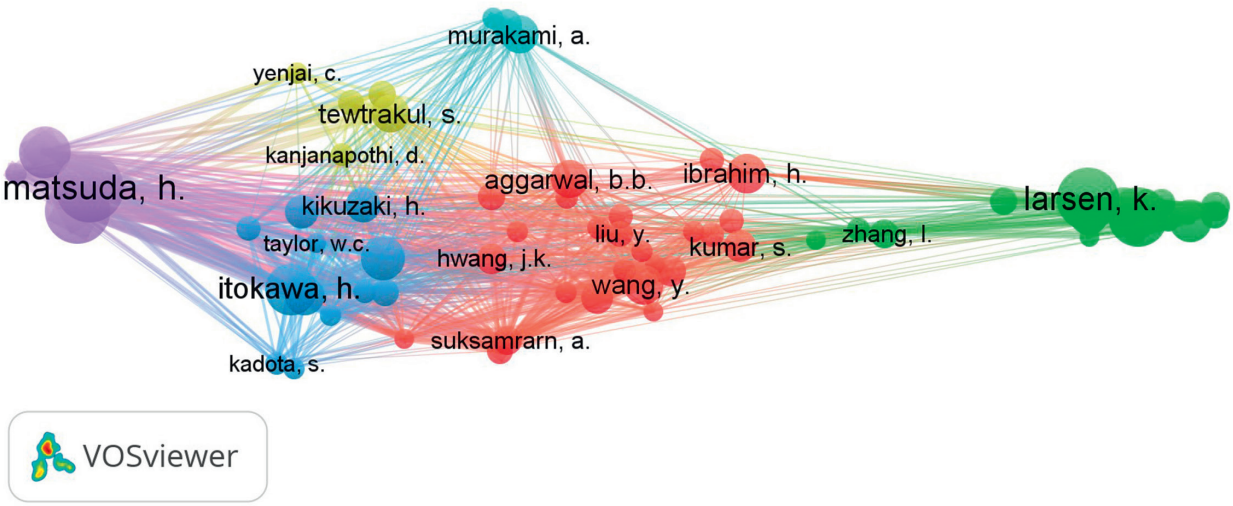

Fig. 9. Network visualization map of the co-cited authors having at least 150 citations and divided into six clusters

Conclusions

This study presents a thorough bibliometric analysis that offers valuable insights into the changing research landscape of the Zingiberaceae plant family. The research output has significantly increased over the years, reaching the record levels in 2021. Asia, particularly India, has emerged as the leading global contributor in terms of the number of published works. The most influential authors in the field were identified. The collaborative networks among different authors, institutions, and countries were visualized and explored, revealing a complex scientific cooperation. The main research themes reflecting the broad range of disciplines were established: ethnobotany, traditional knowledge, as well as the analysis of essential oils and pure compounds. The results obtained are expected to guide future research directions, promote collaborations across different disciplines, strategically develop this field, tackle emerging challenges, and open up new possibilities.

Conflicts of Interest. The authors declare no conflicts of interest.

Конфликт интересов. Авторы заявляют об отсутствии конфликта интересов.

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Author Information

Siddig Ibrahim Abdelwahab, PhD, Associate Professor, Medical Research Center, Jazan University
E-mail: *sadiqa@jazanu.edu.sa*
ORCID: https://orcid.org/0000-0002-6145-4466

Manal Mohamed Elhassan Taha, PhD, Associate Professor, Medical Research Center, Jazan University
E-mail: *manalroa@yahoo.com*
ORCID: https://orcid.org/0000-0003-0166-8929

Abdalbasit Adam Mariod, PhD, Full Professor, Department of Biology, College of Science, University of Jeddah
E-mail: *basitmariod58@gmail.com*
ORCID: https://orcid.org/0000-0003-3237-7948

Информация об авторах

Сиддиг Ибрагим Абдельвахаб, PhD, ассоциированный профессор, Центр медицинских исследований, Университет Джазана
E-mail: *sadiqa@jazanu.edu.sa*
ORCID: https://orcid.org/0000-0002-6145-4466

Манал Мохамед Эльхассан Таха, PhD, ассоциированный профессор, Центр медицинских исследований, Университет Джазана
E-mail: *manalroa@yahoo.com*
ORCID: https://orcid.org/0000-0003-0166-8929

Абдулбасит Адам Мариод, PhD, профессор, кафедра биологии, Колледж наук, Университет Джидды
E-mail: *basitmariod58@gmail.com*
ORCID: https://orcid.org/0000-0003-3237-7948

Received July 20, 2024
Accepted August 3, 2024

Поступила в редакцию 20.07.2024
Принята к публикации 03.08.2024