Review

Bibliometric-based Analysis of the Last Twenty Years of Research on *Lagerstroemia*

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Keywords: Lagerstroemia; bibliometric analysis; VOSviewer; CiteSpace; Web of Science; research progress1. Introduction

Review

Bibliometric-Based Analysis of the Last Twenty Years of Research on *Lagerstroemia*

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Abstract: *Lagerstroemia* is a genus of deciduous and evergreen shrubs and trees belonging to the family Lythraceae. Due to the attention paid to environmental and health issues, *Lagerstroemia* has become increasingly important in ecological environment protection, drug development, genetic resource protection, and application research. In order to gain an in-depth understanding of the current status and cutting-edge trends of *Lagerstroemia* research in the world, and objectively reflect the scientific capabilities and influence of relevant research countries, institutions, authors, and journals in this field. Using the visual analysis software VOSviewer and CiteSpace, a statistical analysis of the literature on *Lagerstroemia* in the Web of Science database was performed from 2002 to 2022. The results showed that the number of articles published on *Lagerstromia* in the world was increasing. Four of the five articles with the highest citation frequency were from the United States, and the number of articles published in Hortscience was the highest. In terms of subject distribution, the most frequently published subjects were plant sciences, pharmacology and pharmacy. These two disciplines focused on the cultivation of *Lagerstroemia* species and medicinal research on *Lagerstroemia* extracts. In terms of categories, science accounted for 41% of the top 10 subjects. Technical science accounted for a relatively large proportion. However, the amount of relevant literature in engineering science needs to be improved. India, the United States, and China were the main research forces in this field. In terms of international cooperation, China had close collaborations with many countries such as the United States, Japan, India, Russia, and the United Kingdom. Beijing Forestry University ranked first in terms of total number of publications, and the Chinese Academy of Sciences had the highest total citations and average citations. Meanwhile, most of the authors at the top of the list were Chinese scholars. Cluster analysis showed that the research of keywords such as "oxidative stress", "protein" and "corosolic acid" were the research hotspots in recent years. Research on the chemical components and pharmacological effects of *Lagerstroemia* will be the focus of the research on *Lagerstroemia*.

Keywords: *Lagerstroemia*; bibliometric analysis; VOSviewer; CiteSpace; Web of Science; research progress

1. Introduction

Lagerstroemia plants are phylogenetically positioned in the family Lythraceae of the rosids among the core eudicots, which has approximately 56 species worldwide, with a distribution ranging from tropical to northern temperate zones[1,2]. *Lagerstroemia* originates from China and is mainly found in regions including Yunnan, Guizhou, Sichuan, Guangdong, Guangxi, and the eastern coastal region of Fujian. In these areas, 24 species have been discovered[3,4]. As woody ornamental plants, *Lagerstroemia* is famous for its long-lasting summer flowering, rich colors, and abundant flower types. These species are well-adapted to diverse habitats, have extensive applications in landscaping, and exhibit low susceptibility to pests and diseases, making them ideal for forestry cultivation[2]. They also have a long history of being utilized in Chinese gardens[5]. In addition to their ornamental value, *Lagerstroemia* also plays an important role in industrial materials, disease treatment and land improvement[6]. With the increasing attention to environmental and health issues, the research significance of *Lagerstroemia* in air purification and disease treatment is becoming more prominent.

There is currently a large and growing number of research achievements on *Lagerstroemia* both nationally and internationally. The key technical point of literature data analysis is how to organize and summarize the vast amount of literature data. Bibliometrics, as a statistical method, can reveal the direction and dynamic situation of disciplinary development from multiple aspects and

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perspectives[7]. It has been widely used in the statistical analysis of various disciplines. When there is a large amount of cited literature data, bibliometrics can extract information such as keywords, sources, authors, and publication dates from the literature, integrate and correlate them, and visually display the analysis results. This is conducive to interpreting large amounts of information and exploring research hotspots[8]. Therefore, in this study, the scientific literature related to *Lagerstroemia* obtained from the Web of Science (WOS) core collection databases using VOSviewer and CiteSpace visualization analysis software. The aim is to identify the research status, hotspots, and trends in the field and provide references for the study of *Lagerstroemia* both nationally and internationally.

2. Data Sources and Research Methods

2.1. Data Sources

The WOS database is a comprehensive and multi-disciplinary core journal citation retrieval platform, which is one of the most authoritative databases in the world[9]. To ensure the comprehensiveness of this review, data were collected from the internationally recognized authoritative WOS database Core Collection TM, and the data retrieval was performed on 18 October, 2022, using a basic retrieval method with "*Lagerstroemia*" as the search subject, "article" and "review" as the literature types. The search period was from 2002 to 2022. We exported the data using the "Full Records and Cited References" in the WOS document information management format. Finally, a total of 483 literatures were retrieved.

2.2. Research Methodology

In this paper, we used VOSviewer and CiteSpace for the visual analysis of knowledge maps. VOSviewer, a free software developed by Van Eck and Waltman, is specifically designed for the construction and visualisation of bibliometric networks[10,11]. It excels in graph representation, particularly in clustering. In this study, the VOSviewer software was used to construct network relationship graphs of researchers, institutions, keywords, and publications in order to evaluate research directions and area in the field. CiteSpace is a bibliometric tool that uses co-citation analysis theory and path-finding network algorithms to analyze literature databases. It is primarily used to explore key paths and knowledge inflection points in research fields, to identify cutting-edge directions and hot issues, and to recognize key researchers and institutions[12,13]. In this study, CiteSpace software was used to construct a knowledge map of research hotspots and trends.

3. Results and Analysis

3.1. Analysis of the Literature Published and High Frequency Cited Literature

Time is a universal dimension that reflects the objective existence[14], and some theories have shown regularity in the sequence of temporal development[15]. Therefore, the amount of literature changes over time, reflecting the speed of advancement in the research field. According to the WOS core collection database, a total of 483 English literatures on *Lagerstroemia* research were published worldwide in the 20 years from 2002 to 2022, showing an overall upward trend (Figure 1). Among them, the journal Hortscience had the highest number of articles (12 articles).

Over the 15-year period from 2002 to 2016, the number of articles showed slow and fluctuating growth, with a maximum difference of 10 articles per year and an average annual number of 18. This indicated that the research field has been increasingly valued by scholars. In the three years from 2016 to 2018, the number of published literature continued to decrease, with a maximum difference of 4 literatures per year and an average annual number of 30. In the three years from 2019 to 2021, the number of publications increased rapidly and fluctuated, reaching a maximum of 52 publications in 2021, which represented the peak of the field in this period. Unfortunately, in 2022, the number of references decreased by 20 to 32.

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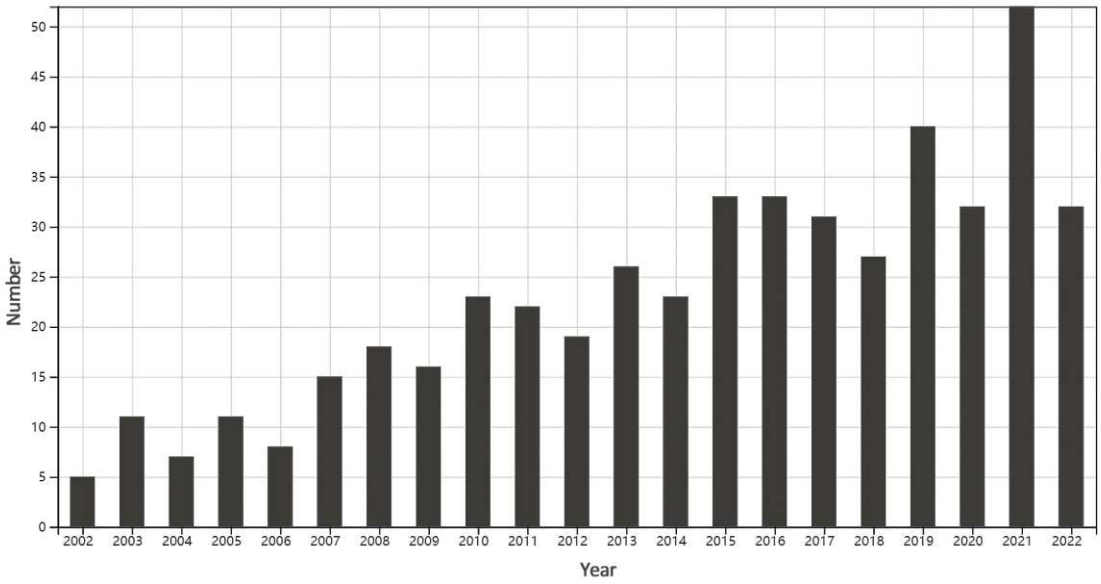

Figure 1. Number of publications on *Lagerstroemia* between 2002 and 2022.

The five literatures with the highest citation frequency in the WOS database were analyzed (Table 1). The research fields covered by the literature with the highest citation frequency in the WOS database mainly focused on the chemical components and pharmacological effects of *Lagerstroemia*. In addition, four of these five literatures were from the United States, indicating that the relevant research in this country had a significant international influence.

Table 1. Top 5 most-cited documents on *Lagerstroemia.*

Ranking	Title	First author	First organization	Frequency
I	Alpha-amylase inhibitory activity of some Malaysian plants used to treat diabetes; with particular reference to *Phyllanthus amarus*	Ali H	Kings Coll London	443
II	Synthesis, biology and clinical significance of pentacyclic triterpenes: a multi-target approach to prevention and treatment of metabolic and vascular diseases	Sheng HM	Purdue University	220
III	Tannic acid stimulates glucose transport and inhibits adipocyte differentiation in 3T3-L1 cells	Liu XQ	Ohio Univ	144
IV	Triterpene Acids Isolated from *Lagerstroemia speciosa* Leaves as alpha-Glucosidase Inhibitors	Hou WL	Dezhou University	138
V	Adverse effects of herbal medicines: an overview of systematic reviews	Posadzki P	Nanyang Technological University	135

3.2. Disciplines

The top 10 disciplines in terms of the number of publications were: plant sciences, pharmacology and pharmacy, agriculture, environmental sciences and ecology, chemistry, biochemistry and molecular biology, entomology, forestry, integrative and complementary medicine, science and technology. Among these, plant sciences and pharmacology and pharmacy had the highest publication frequencies, with 91 times and 68 times respectively. These two disciplines focused on the cultivation of *Lagerstroemia* species and medicinal research on *Lagerstroemia* extracts.

In terms of subject categories, science, medicine, agronomy, and engineering were involved. Among them, science accounted for 41%, followed by agriculture accounting for 27%, medicine 20%, and engineering 12% respectively (Table 2). In terms of disciplinary division, technical science accounted for 61%, followed by basic science accounting for 27%, and engineering science for only 12%. This formed a relatively complete system of technical science-basic science-engineering science. However, the number of engineering science literature needs to be improved. It is necessary to

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transform the achievements of technical science research and basic science into applications in engineering science and to increase the support from technical science and basic science to engineering science.

Table 2. Top 10 disciplines in *Lagerstroemia* research.

No.	Subject areas	Frequency	Subject category	Subject gradation
1	Plant Sciences	91	Science	Technological science
2	Pharmacology & Pharmacy	68	Medicine	Technological science
3	Agriculture	64	Agronomy	Fundamental science
4	Environmental Sciences & Ecology	59	Engineering	Engineering science
5	Chemistry	40	Science	Technological science
6	Biochemistry & Molecular Biology	37	Science	Technological science
7	Entomology	35	Agronomy	Fundamental science
8	Forestry	28	Agronomy	Fundamental science
9	Integrative & Complementary Medicine	26	Medicine	Technological science
10	Science & Technology Other Topics	26	Science	Technological science

3.3. Analysis of the Main Forces of the Study

3.3.1. Main Countries Active in This Filed

The literatures retrieved from the WOS core collection database was sourced from 54 countries, and the top 3 countries with the highest number of published literature were India (129 articles), the United States (127 articles), and China (114 articles). These three countries account for 70.3% of the total number of literature published in the WOS database, indicating that they were the main force in this area of research. China ranked third in terms of publications on *Lagerstroemia*, after India and the United States, accounting for 21.7% of global publications, reflecting the important influence of Chinese scholars in this research area.

The thickness of the lines between countries in Figure 2 can reflect the degree of cooperation between countries. The thicker the lines, the closer the cooperation, and vice versa. It can be seen that this research field is closely linked among countries. For example, China had close exchanges with the United States, Japan, India, Russia, the United Kingdom, and many other countries; there were also strong working relationships between India and the United States, Germany and Bangladesh, Portugal and Thailand, as well as Japan and Thailand.

3.3.2. Analysis of Key Research Institutions

Analyzing research institutions helps us understand the level of academic support and recognition in the field, thus facilitating collaboration between institutions. This study counted the top 10 research institutions in the WOS database (Table 3), including 5 from the United States, 3 from China, and 2 from India. The institution with the largest number of publications was Beijing Forestry University (26 articles), followed by the Chinese Academy of Sciences (24 articles) and the Sani Institute of Palaeobotany in Lucknow, India (20 articles). In terms of the total number of citations, the Chinese Academy of Sciences had the highest impact with 468 citations, followed by Florida State University with 308 citations and the United States Department of Agriculture with 274 citations. Beijing Forestry University also had a significant international impact with 253 citations. In terms of average citations, the Chinese Academy of Sciences had the highest average citation with 19.5 times, followed by Florida State University with an average of 16.21 times and the United States Department of Agriculture with an average of 16.12 times.

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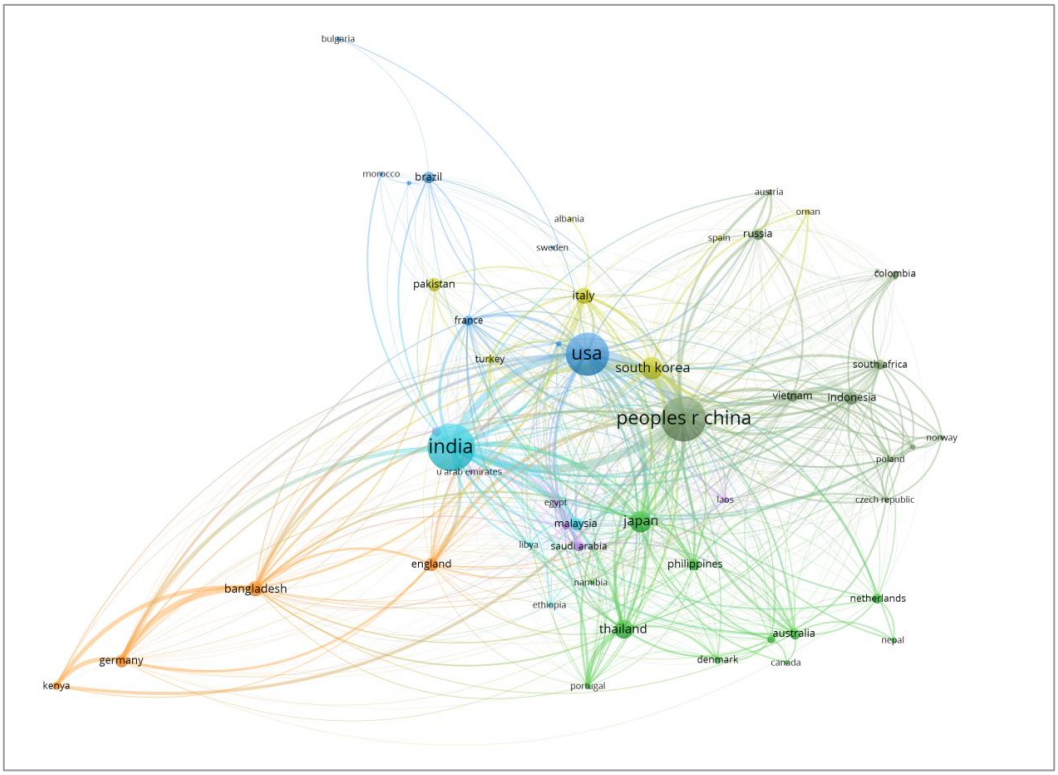

Figure 2. The network of country cooperation on *Lagerstroemia*.

Table 3. Top 10 research institutions in the number of publications on *Lagerstroemia*.

Institution	Country	Publications	Total citation	Average citation
Beijing Forestry University	China	26	253	9.73
Chinese Academy of Sciences	China	24	468	19.5
Birbal Sahni Institute of Palaeobtany	India	20	239	11.95
Department of Science Technology India	India	20	239	11.95
Texas A&M University System	The United States	20	134	6.7
State University System of Florida	The United States	19	308	16.21
United States Department of Agriculture	The United States	17	274	16.12
University of Florida	The United States	17	191	11.24
Texas A&M University College station	The United States	14	35	2.5
Zhejiang A&F University	China	14	94	6.71

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3.3.3. Key Authors and Author Co-Citation Information

There were 1000 authors who had contributed to 483 articles in the WOS database. The majority of them were Chinese scholars, including Zhang Qixiang, Pan Huitang, Cai Ming, Liu Yang, He Dan, Cheng Tangren, and Lin Qifang, which indicating that China had reached an advanced level in *Lagerstroemia* research worldwide. The author cooperation diagram (Figure 3) showed that this authors formed five closely linked research groups in their collaboration for *Lagerstroemia* research.

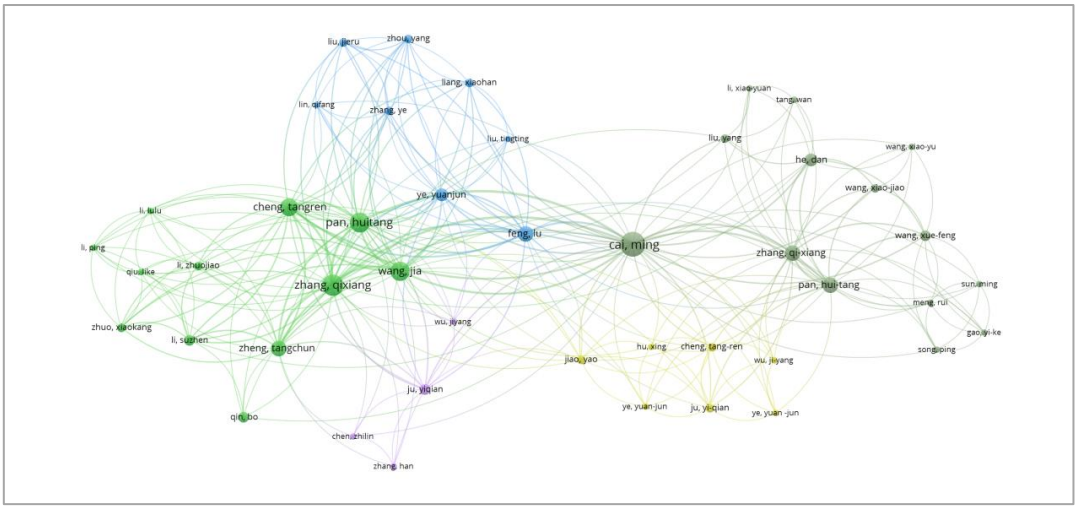

Figure 3. Key Authors and Author Co-Citation Information on *Lagerstroemia*.

3.4. Keyword Visualization Analysis

3.4.1. Co-Occurrence of Keywords

Keywords are words that describe the key topics of articles, reflect the core content of research results and express the theme of the research literature. High-frequency keywords can, to some extent, be considered as research hotspots in the field[16]. In this study, the keyword clustering function in VOSviewer was used to obtain a knowledge map of the keyword distribution in the research field of *Lagerstroemia* in the WOS database (Figure 4). Common themes in the published literature included "growth", "cultivars", "Lagerstroemia speciosa", "resistance", "genetic diversity", "performance", "corosolic acid", "antidiabetic activity", and so on. This indicated that *Lagerstroemia speciosa* was the focus and representative species of *Lagerstroemia*, and the main directions in this field include species breeding, stress resistance, germplasm genetic diversity, environmental interaction, chemical composition, and medicinal value.

3.4.2. Research Hotspots

The research frontier refers to the conceptual combination of a specific research topic and its fundamental research questions that are temporarily formed. By analyzing the trend of the research frontier, we can grasp the dynamic changes in research and predict future research trends[17]. Therefore, in this study, a comprehensive temporal analysis of the relevant research literature in the WOS database was carried out using the mutation word detection technology in CiteSpace, resulting in a surge keyword graph (Figure 5) and a temporal view of the research frontier (Figure 6).

Abrupt words refer to the sudden increase of professional terms in the published literature in some years, which can effectively illustrate the forefront of research and the latest trends[18]. 10 key abrupt keywords in the literature were derived and discovered through CiteSpace. Some of the early high-impact keywords include "glucose transport", "adipocyte differentiation" and "chloroplast genome" remained prominent for a longer period of time. Over time, keywords such as "oxidative stress", "protein" and "corosolic acid" emerged as hot topics in recent years. This indicated that recent research on *Lagerstroemia* had focused on molecular biology and biochemistry, while the emerging research had been centered on the history of species differentiation, phylogenetic relationships of species, chemical composition, and medicinal value.

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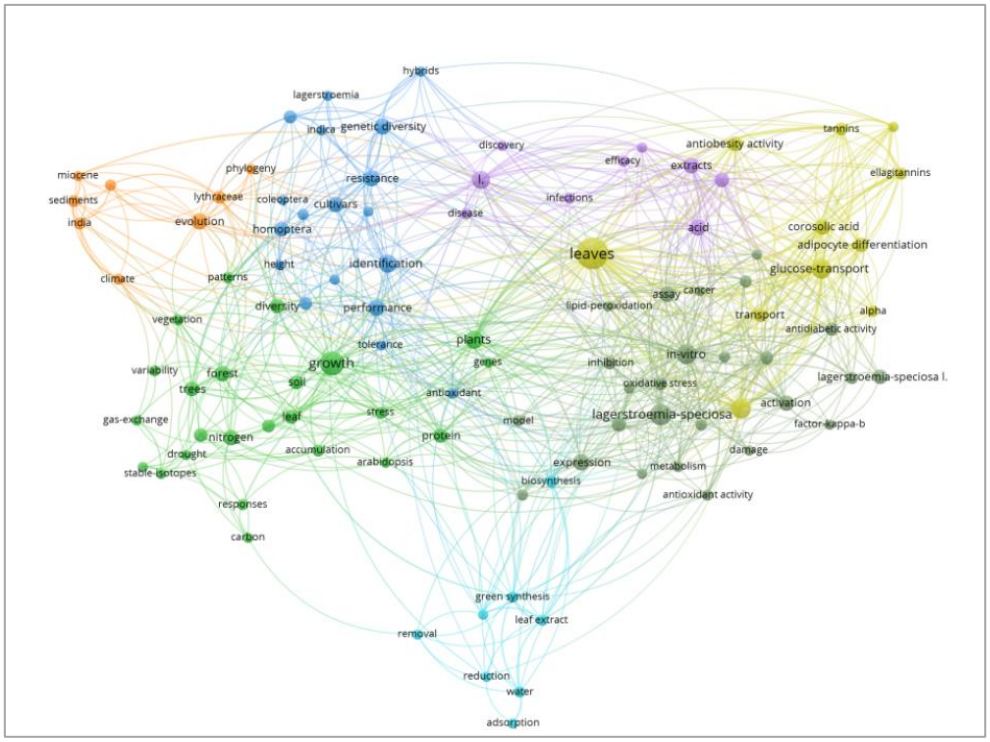

Figure 4. Co-occurrence distribution of keywords on *Lagerstroemia*.

Keywords	Year	Strength	Begin	End	2002 - 2022
glucose transport	2002	3.16	**2003**	2006	
adipocyte differentiation	2002	3.05	**2005**	2009	
extract	2002	3.97	**2011**	2014	
identification	2002	2.96	**2015**	2019	
chloroplast genome	2002	2.57	**2016**	2022	
oxidative stress	2002	2.78	**2017**	2022	
green synthesis	2002	2.72	**2017**	2018	
protein	2002	3.7	**2019**	2022	
in vitro	2002	2.85	**2019**	2020	
corosolic acid	2002	3.97	**2020**	2022	

Figure 5. List of keywords with high burst strength from 2002 to 2022 on *Lagerstroemia*.

3.4.3. Cluster Analysis of Keywords

The research on the frontier time zone view is designed according to the interaction relationship and evolution path of frontier hotspots, which is a unique function of CiteSpace software compared to other visualization software[16]. In this study, the technology of mutant word detection provided by CiteSpace was adopted to analyze the trend in the research field of *Lagerstroemia*[12]. After 323 iterations, 502 nodes and 1321 links were obtained. Based on the analysis, we found that the keywords with high frequency include “Lagerstroemia speciosa”, “leaf”, “Lagerstroemia indica”, “corosolic acid”, “extract”, “growth”, “plant”, “acute inflammation”, “activation”, “antiobesity activity”, “chloroplast genome”, “glucose transport” and so on. In summary, the research on *Lagerstroemia* focused on various aspects such as plant cultivation and breeding, phylogenetic relationships, chemical composition, and medicinal value. In addition, more keyword nodes appeared from 2002 to 2010, which showed that the research field of *Lagerstroemia* had a high popularity and diversification during this period.

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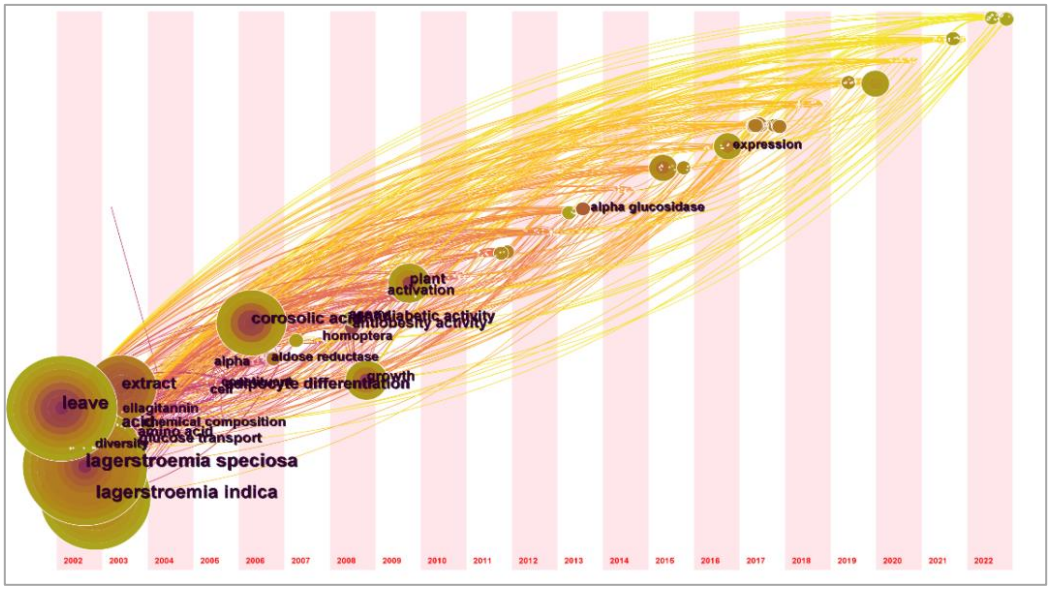

Figure 6. The time-zone evolution map of hot keywords on *Lagerstroemia*.

4. Discussion

Lagerstroemia speciosa, as a representative species of *Lagerstroemia*, has relatively high research hotspot and certain research depth in the world. However, insufficient attention has been paid to other types of resources. The excessive mining of ancient varieties has resulted in severe resource depletion, which strongly restricts the development of *Lagerstroemia* industrialization. In the future, scholars should strengthen the conservation and research of *Lagerstroemia* germplasm resources, and establish a comprehensive conservation and research center for *Lagerstroemia* germplasm resources[19].

Keyword analysis revealed a shift from early stage research focused solely on medicinal value to several areas including genetic resources, cultivation and breeding, and medical research. High-impact keywords in the early phase included “glucose transport” and “adipocyte differentiation”, indicating that medical research had made initial progress. *Lagerstroemia speciosa*, commonly known as Banaba, has been used in Indian traditional medicine for the treatment of a variety of diseases, including diabetes and obesity[20–22]. The extract of banaba possesses activities that both stimulate glucose transport and inhibit adipocyte differentiation in 3T3-L1 cells, and it may have the potential to become the lead compound in the development of new types of antidiabetic pharmaceuticals[23]. The aqueous extract of its leaves contains quercetin dilactone and ellagic acid, both of which inhibit xanthine oxidase, thereby lowering of blood sugar[24]. The leaves of banaba also have pharmacological activities such as antioxidation, antifungus, lipid reduction and anti-proliferation[25]. Therefore, previous studies have focused on its active constituent.

Now there are two important areas where new insights are emerging. Research focuses on phylogenetic relationships, chemical components and medicinal value. The first area focuses on the study of phylogenetic relationships. For instance, the application value of the complete cp genomes of *Lagerstroemia* was explored mainly through comparative analysis of differences between the cp genomes of Lythraceae species. This provided genetic resources for future research in this genus. Additionally, the reference genes in *Lagerstroemia* were systematically analyzed for the first time, giving meaningful insights into the genetic basis of flower development in *Lagerstroemia*[26–28]. The second area of research is centered on chemical components and medicinal value. Phytochemical analyses have been carried out on the leaves and flower extract of banaba, which has been successfully used in cancer treatment. For example, Xu et al. showed that corosolic acid, an extract of banaba, can induce loss of mitochondrial membrane potential and caspase activation in cervical adenocarcinoma[29], colon cancer[30], leukemia[31], and osteosarcoma cells[32]; Woo et al. improved that corosolic acid can also induce non-apoptotic death in other types of cancer cells such as renal cancer (ACHN and A498), breast cancer (MDA-MB231), and hepatocellular carcinoma(SK-Hep1 and Huh7) cells[33]; Amresh et al. revealed that the leaves and flower extract of banaba had hepatoprotective effects against a variety of liver injury models including hepatic fibrosis, non-

alcoholic steatohepatitis, and oxidative stress in hepatocytes[34–36]. In addition, Rohit et al. found that its leaf extracts (EBLE) had the cell cycle arresting potential in liver cancer cells, and apoptosis inducing potential in HepG2 cell lines[37,38]. At the same time, relevant research on *Lagerstroemia*, which is used in the treatment of diabetes[39] and obesity[40], continues to be deepen.

With the increasing global ecological and environmental problems, there is a growing interest in future research on emerging green synthesis technologies in this field. Significant efforts have been made in the application of *Lagerstroemia* plant extracts in nano-materialformation. For instance, the ZnO NPs were synthesised by a green method using the aqueous leaf extract of *Lagerstroemia speciosa*[41]; AuNPs was prepared using an aqueous extract of *Lagerstroemia speciosa*[42]; a non-toxic and eco-friendly route was employed to synthesize a graphene oxide-silver nanocomposite (GO-Ag) using a floral extract of *Lagerstroemia speciosa*[43]. In addition, silver nanoparticles were synthesized by a green approach using the fruits of *Lagerstroemia speciosa*. These nanoparticles were then used to develop an agar-AgNPs composite film for antimicrobial food packaging application[44]. Therefore, how to better serve emerging technologies such as nanomaterials and new biochar[45] and apply them to more fields is a hot and challenging scientific issue for scholars.

In addition, it can be seen that the visual analysis of the knowledge graph using VOSviewer and CiteSpace software can intuitively illustrate the development path and trend of this field. Combined with specific analysis methods, it provides a valuable reference for in-depth exploration of scientific research and discipline construction in the target object field. However, this study has limitations due to its focus on "*Lagerstroemia*" as the main search topic and its reliance on only the WOS core collection database as the source of literature data, which is constantly being updated. Nevertheless, the results of this study are to a certain extent consistent with the content of relevant research and the needs of the social context. At that time, most of the authors were mainly engaged in theoretical and practical research in this field. Therefore, the research results could basically reflect the problem orientation and social demands related to *Lagerstroemia*. According to the research results, different countries, institutions and scholars have made uneven contributions to research in this field. What are the reasons for this result? Is it affected by national policies or economic factors? Is there any difference in the progress research of literature in other databases? These problems are worthy of further study and discussion. In the future, the continuously updated VOSviewer and CiteSpace should be used to provide a richer and clearer map of research progress[46].

5. Conclusions

During 2002-2022, the number of papers published on *Lagerstroemia* worldwide showed an overall upward trend over time, which was also consistent with the growth trend of papers in other directions[47–49]. The international research on *Lagerstroemia* was in an active state, and the number of published literature was at a high level, but it needs to be further improved in breadth and depth. Most of them were focused on basic science and technical science. Therefore, the support for engineering science should be increased. In terms of the number of publications and the influence of research institutions, China's research in the field of *Lagerstroemia* was at a leading level and had significant international influence. However, the top four most cited articles were from the United States, indicating that China needs to further improve its publication of high quality literature. Cluster analysis showed that the research of keywords such as “oxidative stress”, “protein” and “corosolic acid” were the research hotspots in recent years. The research on the chemical components and medicinal value will be the focus of *Lagerstroemia*.

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