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A Bibliometric Analysis of Bougainvillea Plant: Research Trends, Geographic Distribution and Future Direction

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Abstract: The main aim of this paper is to conduct an exhaustive bibliometric analysis of *Bougainvillea*. A total of 624 publications on *Bougainvillea* were identified from Scopus data ranging from 1937 to 2024. The dataset downloaded from the Scopus database contains contributions from 2140 authors. Data visualization and analysis were carried out using different software: Microsoft Excel, Bibliometrics, BibExcel, VOSviewer, and Biblioshiny in R Studio. Analysis shows that the number of publications on *Bougainvillea* has increased tremendously in recent years, with 243 articles published between 2017 and 2024. India is the most significant contributor to *Bougainvillea* research. This bibliometric analysis helps a researcher gain direction into the key trends and areas of interest while exploring the medicinal attributes of the plant. *Bougainvillea*, a plant more commonly associated with its colourful blooms and ornamental use, has recently been gaining attention for its medicinal applications. The present review attempts to garner such existing knowledge regarding the medicinal attributes of *Bougainvillea* related to its phytochemical composition, traditional uses, pharmacological activities, and therapeutic applications.

Introduction

Bougainvillea is a genus of flowering plants belonging to the Nyctaginaceae family. Originating in South America, *Bougainvillea* represents a group of flowering, thorny vines, bushes, and trees that have become quite popular in many parts of the world for their highly colourful, brilliantly colored bracts, often mistakenly thought to be flowers. The bracts of this plant come in a multitude of colours that include pink, purple, red, orange, white and yellow (Carreón-Hidalgo et al., 2022; Chen et al., 2023a). Its adaptability to diverse climates and soil types, coupled with its resilience, hardiness, and ability to withstand drought, has made *Bougainvillea* a

favourite among landscapers and horticulturists (Ornelas García et al., 2023). Species of *Bougainvillea* thrive in a wide range of ecological environments, which range from arid deserts to tropical rainforests. Its rapid growth rate and easy propagation have increased its use in landscaping and gardening, especially in urban areas lacking greenery (Almutawa, 2022).

Besides its ornamental value, *Bougainvillea* has provoked scientific interest because of its phytochemical and medicinal properties (Asif et al., 2024). Many studies have identified the presence of bioactive compounds in the *Bougainvillea* plant, which include flavonoids, alkaloids, saponins, and tannins with proven activities

having antimicrobial, antioxidant, and anti-inflammatory (Shaheen et al., 2022). For example, *Bougainvillea spectabilis* has been reported to reduce the level of cyclooxygenase enzymes in the anti-inflammatory effect and proinflammatory cytokines production. The plant has also been well-documented in traditional medicine for diseases like diarrhoea, coughs and inflammations (Abo-Elghiet et al., 2023; Kaushik et al., 2023). However, there are continuing gaps in the literature on *Bougainvillea* where there is a need to address an understanding of the plant in its totality (Ghosh et al., 2018). For example, less work has focused on unravelling the molecular mechanisms that underlie their medicinal impact, and much more detailed phytochemical profiling needs to be done to elicit new bioactive compounds. In addition, the impact of *Bougainvillea* on the local biodiversity and its role in the restoration of habitat so far have been studied through little ecological research (Ahmed et al., 2022; Kenari and Razavi, 2022; Swamy et al., 2012). Bibliometric analysis originates from the Library and Information Science. Gephi, Leximancer (Software) Bibexcel, Pajek, Gephi, SciMat, Sci2, and UCINET software are used in the Bibliometrics analysis (Moral-Munoz et al., 2020; Sabirali and Mahalakshmi, 2023). The importance of the *Bougainvillea species* for public health and bibliometric analysis of this plant is not available. In this study, we examined the main areas of interest of the researchers studying *Bougainvillea* around the world and the existing gaps concerning the current research demands, with particular attention to medicinal properties (Nasrat et al., 2022). Bibliometric analysis is a systematic method that effectively shows quantitative data and statistics from publications such as author, co-author, journal and citation (Chen et al., 2023b; Aria and Cuccurullo, 2017). The primary focus of current research is more targeted on the *Bougainvillea* plant. The *Bougainvillea* plant is commonly known only for ornamental purposes. *This* plant is more diverse and easily found in major countries like America, Australia, China, and India. It is well-explored for medicinal and nutritional purposes (Saleem et al., 2020). The main objective of this study is to conduct a bibliometric analysis of the *Bougainvillea* plant. The ultimate purpose of this study is to provide a comprehensive understanding of the current state of knowledge and research gaps that require attention.

Objectives of Bibliometric Analysis

The analysis thus creates the need for a comprehensive overview of the research on *Bougainvillea* in terms of global research trends, significant contributors, and emerging themes. Bibliometric analysis, a statistical approach to analyzing scientific publications, will allow the identification of the most influential research articles, authors, and collaborations and thus give a very substantial account of the research landscape. More precisely, this study seeks to:

2.1. Analyze temporal trends in *Bougainvillea* research publications.

2.2. Identify the field's most prolific authors, institutions, and countries.

2.3. Identify key journals and subject areas.

2.4. Identify and analyze keywords to identify emerging themes and future research directions.

Methodology

It tries to comprehend the patterns of global research, main authors, and other emerging topics in *Bougainvillea* studies. The paper applies the tools of rigorous bibliometric analysis to the data collected methodically.

Collection of Data

The Scopus database is used as the data source because of its advanced feature in covering broad peer-reviewed literature from diverse disciplines of science. The search strategy was the keyword "*Bougainvillea*" which was applied to article titles, abstracts, and keywords to identify relevant literature. In March 2024, it was used by executing the query and considering documents having the keyword in any of these sections. All papers were in English only as part of the limitation made while searching through databases (Donthu et al., 2021). The criteria included peer-reviewed articles, review papers, and conference papers related to *Bougainvillea*. Book chapters, editorials, and other non-peer-reviewed pieces of material were excluded. The extracted metadata included authors, titles, publication years, affiliations, countries, the number of citations, keywords, abstracts, and subject areas. The data was exported in CSV format for further analysis (Aria and Cuccurullo, 2017).

Data analysis

The analysis used two main tools: VOSviewer and the R bibliometrix package. VOSviewer, a network visualization tool, enabled the mapping of collaboration networks, co-authorship patterns, keyword co-occurrence and citation analysis. The 'R' bibliometrix package facilitated data pre-processing, trend analysis and thematic mapping (Aria and Cuccurullo, 2017).

To analyze publication trends over time, annual publication counts were plotted to assess the growth trajectory of *Bougainvillea* research. Linear regression

1937 to 2024, as indicated in Figure 1. In this period, 624 documents have been published in 411 unique sources, which show a relatively modest but constant annual

Timespan 1937:2024	**Sources** 411	**Documents** 624	**Annual Growth Rate** 1.87 %
Authors 2140	**Authors of single-authored docs** 42	**International Co-Authorship** 14.26 %	**Co-Authors per Doc** 4.19
Author's Keywords (DE) 1858	**References** 19974	**Document Average Age** 11.9	**Average citations per doc** 16.81

Figure 1. Overview of collected data on Bougainvillea from the Scopus database from 1937-2024.

analysis was used to identify growth patterns (Donthu et al., 2021). Geographic distribution was evaluated by counting the number of publications per country, and collaboration networks between countries were visualized using VOSviewer. The most prolific authors and institutions were identified based on the number of publications and citation counts, and author collaboration networks were visualized through co-authorship analysis in VOSviewer (Aria and Cuccurullo, 2017). In addition, the analysis identified the leading journals and subject areas publishing *Bougainvillea* research based on publication counts. Keyword co-occurrence analysis was conducted to identify popular research themes and their evolution. Using the R bibliometrics package, a thematic map was generated to categorize research themes based on centrality and density (Alkhammash, 2023). Citation analysis identified the most influential papers, authors, and journals based on citation count, while H-index and G-index were used to evaluate author impact (Thomaz et al., 2011).

Visualization and Interpretation

Network maps illustrating co-authorship, country collaboration, and keyword co-occurrence patterns were visualized using VOSviewer. The maps used colour coding based on clusters or publication years. Statistical analyses were conducted using Microsoft Excel and the R bibliometrics package to identify trends and patterns. Linear regression models were applied to detect temporal trends in *Bougainvillea* research (Donthu et al., 2021; Romero and Portillo-Salido, 2019).

Results

The bibliometric analysis shows the field's overall research trends and features for a very long period, from

growth rate of 1.87%. A total of 2140 distinct authors created this literature, of whom 42 were single authors. Collaboration is a prominent feature in this field, where 4.19 is the average number of co-authors per document, and 14.26% of the documents contain international co-authorship. The authors' keywords reveal 1858 distinct terms to describe their research. These documents collectively referenced 19,974 sources; with an average of 16.81 citations per document, these papers have been quite influential. In addition, the average age of the analyzed documents is 11.9 years, which means it incorporates historical and recent research. Generally, this analysis further emphasizes that research in the field is collaborative and impactful, grows steadily, and contains a high level of international collaboration.

Overall Publication Trends

From 1937 to the late 1990s, the field remained relatively flat, with less than ten published articles in a year, mostly with just one or two publications per annum. This low research activity persisted through the early 20th century into the latter half. However, starting in the early 2000s, the number of publications increased gradually. The increase was more marked in the mid-2000s and continued to accelerate into the 2010s. At the beginning of 2018, there was a sharp increase, peaking from 2020-2023, with over 50 articles per year. This striking upsurge in research output is something about the recent interest in *Bougainvillea* research. In sum, the graph reflects that, in the last twenty years, the volume of scientific literature about *Bougainvillea* has dramatically risen, particularly in the last five years. The tendency could mirror a generally enhanced scientific interest in, and investment in, *Bougainvillea*.
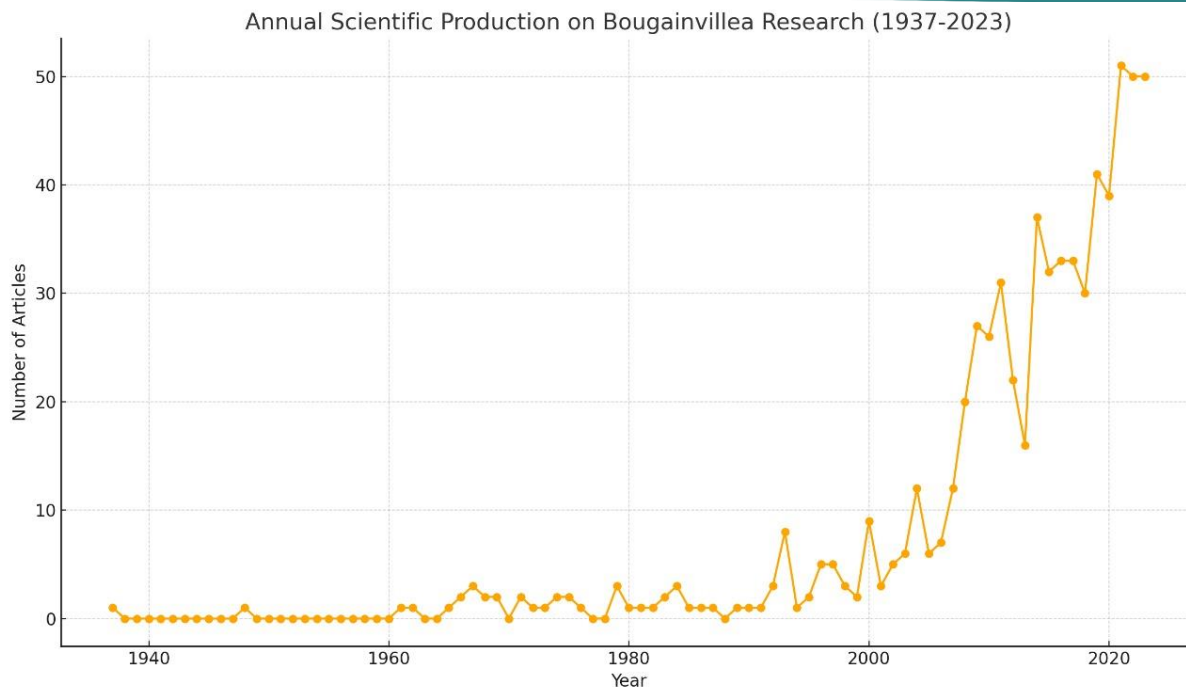
Figure 3. Annual Scientific Production on Bougainvillea Research (1937-2023).
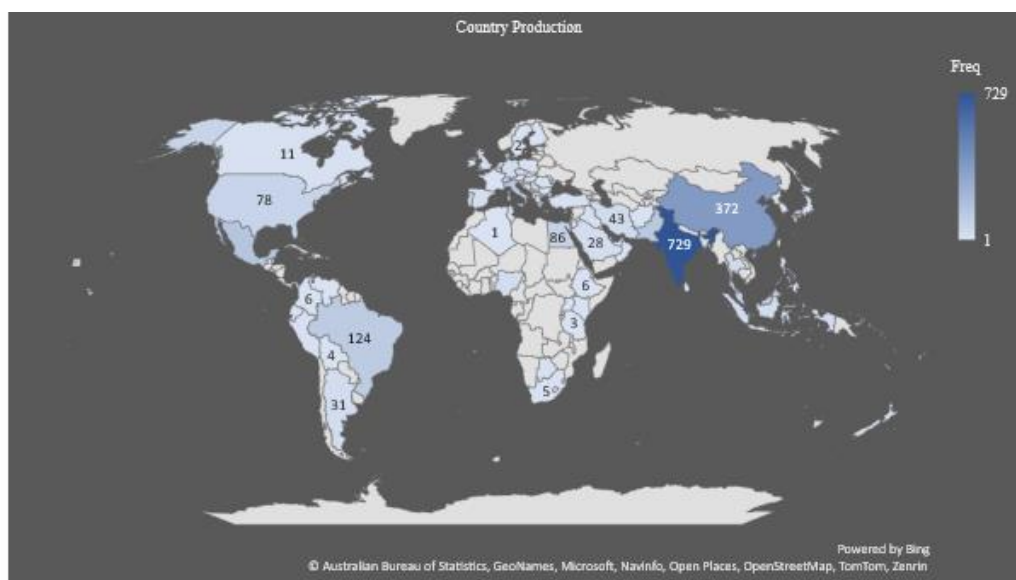

Figure 2. World Map showing the distribution of publications on Bougainvillea research from 1937-2024.
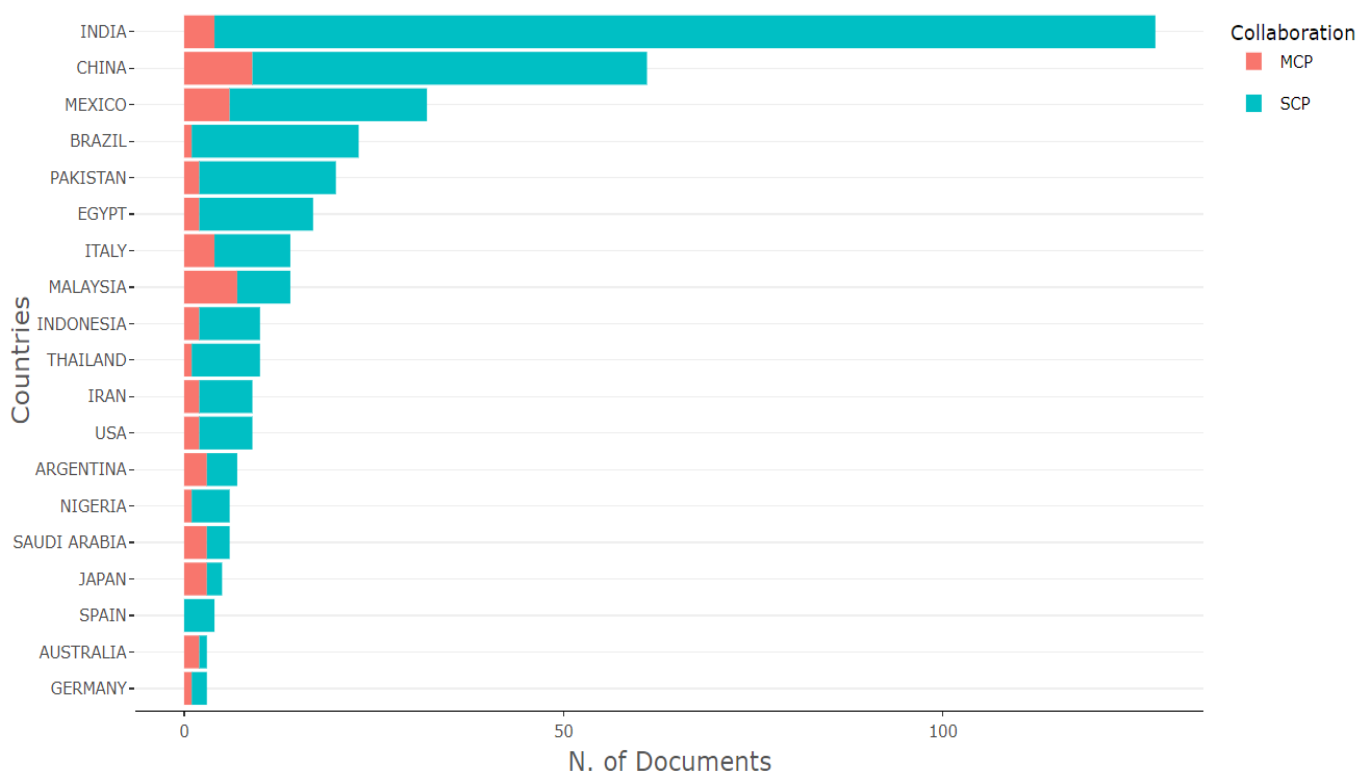
Geographic Distribution

This is the "Country Production" world map, providing an idea of the scientific papers on *Bougainvillea* in a geographic context. India takes the lion's share in the global research effort on this particular topic by far, with 729 articles, since the plant holds substantial economic, ecological, and medicinal value in the region. With 372 articles, China echoes its rising scientific interest in *Bougainvillea* research. Brazil, with 124 articles, emerges as a critical player from South America, where the plant holds excellent value due to its ornamental appeal and adaptability. Mexico, with 86, is a close second, probably based on the native presence of the plant. The United States has produced 78 articles,

drawing attention to the plant concerning landscaping and ecological studies. With 43 articles published, Iran shows rising research in the Middle East. Other participants include Argentina, with 31; Thailand, with 28; Colombia, with 6; Pakistan, with 4; Germany, with 11; and Australia, with 1 published article to the global research repository. These patterns reveal regional interests and priorities, reflecting the plant's worldwide ecological, ornamental, and medicinal significance.

The bar graph in Figure 4 shows the country-wise contribution of research in *Bougainvillea*, differentiating between single-country publications and multi-country publications. India is well ahead, with over 100 documents; most SCPs indicate local solid research.

China is the second country with significant international collaboration, evidenced by the MCPs. Then come Mexico and Brazil, with many documents, but most of these are SCPs, suggesting regional research foci. Pakistan, Egypt and Italy contribute a good number. There is more research on SCPs for Pakistan and Egypt, while Italy has a balanced set of SCPs and MCPs. Malaysia, Indonesia, and Thailand have moderate and higher contributions to SCPs. Iran and the USA have an equal share of SCPs and MCPs, reflecting domestic and international collaborative research efforts. Countries with the lowest number of contributions included Argentina, Nigeria, Saudi Arabia, Japan, Spain, Australia, and Germany, with most of the research focused on single-country research. This chart mainly highlights India's dominant role in the research of *Bougainvillea*, then China, with scanty international collaborations in most of the contributing countries.

collaborating with India, the United States, Argentina, and several other nations, demonstrating its diversified research partnerships. Italy emerges as a central player, connecting European and Asian research networks through solid collaborations with India, the United States, and Vietnam. The United States maintains robust collaborations with India, China, Italy and Brazil, bridging research clusters in Asia and Latin America. Mexico plays a notable role, primarily collaborating with Brazil, Egypt, and Saudi Arabia, reflecting solid ties within Latin America and the Middle East. Brazil, collaborating closely with Mexico and the United States, is pivotal in South American research efforts. Other countries such as Malaysia, Pakistan, Thailand and Egypt actively participate in *Bougainvillea* research, forming significant nodes with strong collaborations involving India, the United States, and China. While less connected, the United Kingdom, Vietnam, and Nigeria show

Figure 4. Distribution of Bougainvillea Research Output by Country, Highlighting Single-Country and Multi-Country Collaboration Patterns.

The collaboration network graph illustrates global research partnerships in *Bougainvillea* studies. India dominates the network, highlighted by the most significant node, signifying its leading role in this research field. The dense connections around India indicate collaborative solid ties with various countries, including Italy, the United States, China, and Thailand. China forms another significant hub, actively

collaboration with significant research hubs like India and Italy. Overall, the network graph underscores India's central role in *Bougainvillea* research, with China, Italy and the United States also acting as key hubs in global partnerships. The network reveals a robust international research community with significant cross-continental connections linking Asia, Europe, and the Americas.
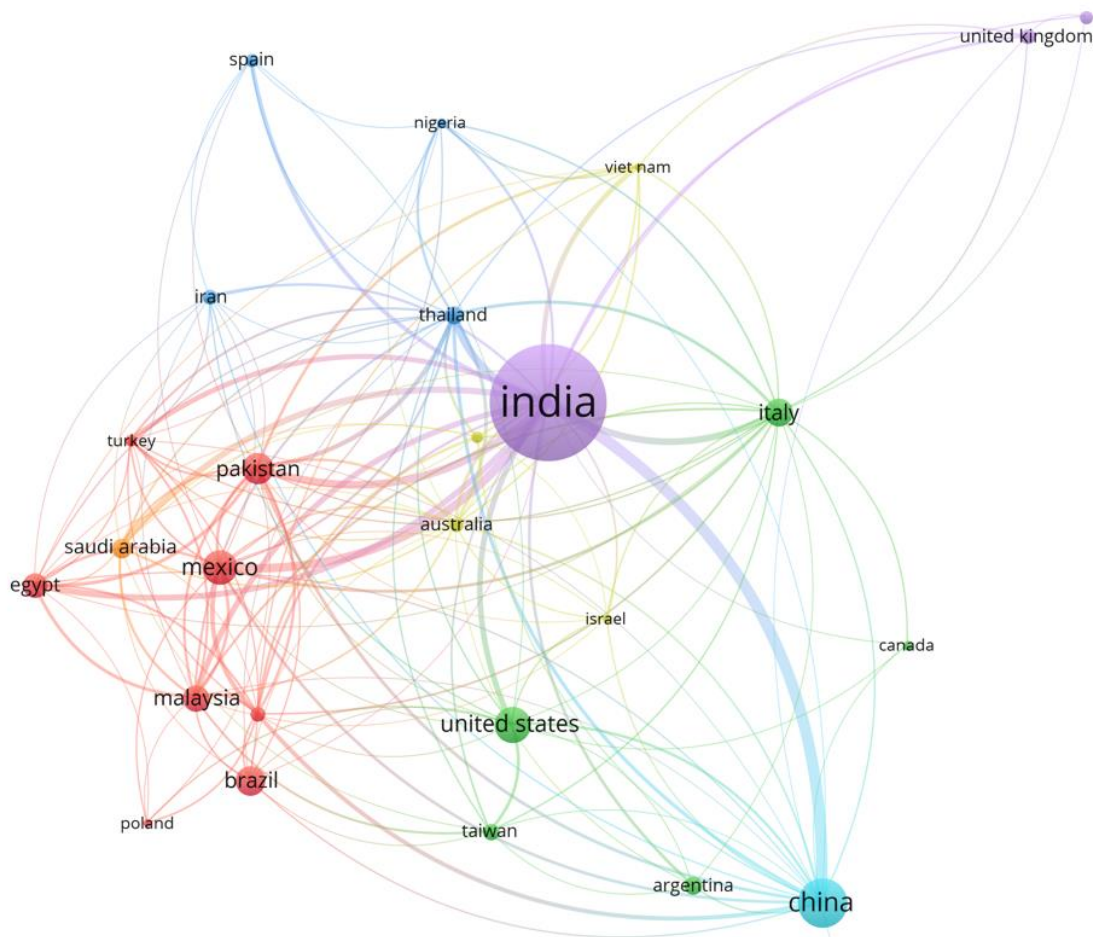
Figure 5. Global Collaboration Network in Bougainvillea Research, Highlighting Key Hubs and Cross-Continental Research Partnerships.

Author & Institutional Analysis

The bibliometric analysis overviews key authors contributing to *Bougainvillea's* research, focusing on productivity and impact metrics. Petricevich Vl leads the group with an h-index of 7 and a g-index of 11, indicating that seven of their publications have been cited at least seven times, and their work is particularly impactful due to high citation counts. Their m-index of 0.538 reflects consistent productivity since their first publication in 2012. Lodha Ml follows closely with an h-index of 6 and a g-index of 8, showcasing steady productivity since 2001 while maintaining an m-index of 0.25. Hossain Abms, Saifuddin M, and Abarca-Vargas R exhibit similar productivity levels, with h-indices of 5, demonstrating consistent citation impact. Abarca-Vargas R stands out with a g-index of 8 and a high m-index of 0.444, indicating substantial influence since starting their work in 2016.

Meanwhile, Ahemad N and Ahmad I, starting in 2019, share an h-index of 4 and a high m-index of 0.667, suggesting rapid and impactful contributions to the field. Jawla S and Khan Msy each have an h-index of 4 and a g-index of 4, indicating moderate influence since their first publications in 2011. Kapoor Hc, with an h-index of

4 and a g-index of 4, stands out for consistent productivity since 2001. These authors have made significant contributions to *Bougainvillea* research, underscoring the field's diverse authorship and the growing interest in this area.
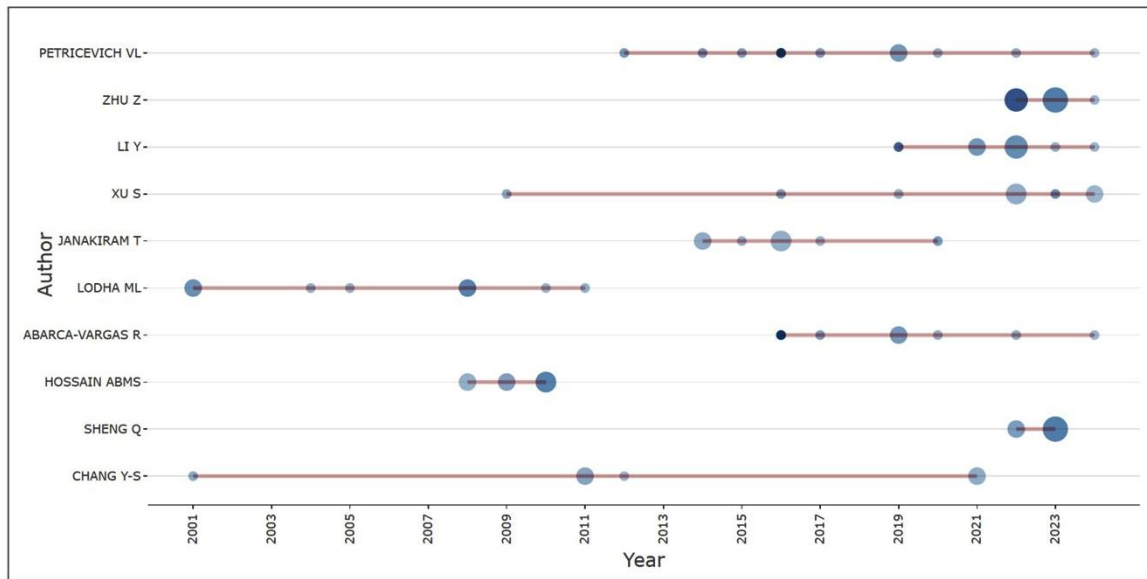
Table 1. Authorship Bibliometric Analysis in *Bougainvillea* Research: Productivity and Impact Metrics of Key Contributors.

Element	h_index	g_index	m_index	TC	NP	PY_start
Petricevich Vl	7	11	0.538	246	11	2012
Lodha Ml	6	8	0.25	156	8	2001
Hossain Abms	5	7	0.294	84	7	2008
Saifuddin M	5	6	0.313	79	6	2009
Abarca-Vargas R	4	8	0.444	178	8	2016
Ahemad N	4	4	0.667	58	4	2019
Ahmad I	4	4	0.667	36	4	2019
Jawla S	4	4	0.286	51	4	2011

| Kapoor Hc | 4 | 4 | 0.167 | 110 | 4 | 2001 |
| Khan Msy | 4 | 4 | 0.286 | 51 | 4 | 2011 |

This graph presents the timeline visualization of the publication activity of the principal authors writing on the theme of *Bougainvillea* and their productivity and impact over the timeline. Each line represents an author's publication history, while the size of the circles represents the citation impact of individual publications; colour intensity indicates the number of citations, the darker the circle meaning it is cited more.

➢ Petricevich Vl's output has been regular since 2012, and several highly cited papers have contributed to its impact. Abarca-Vargas R also evidences regular contributions, mainly since 2016, and some tight clustering of impactful work. Janaki Ram T's output has been concentrated in recent years, whereas Li Y has vdisplayed scattered yet impactful contributions since 2009.

➢ Lodha Ml has a consistent publication record starting in 2001, with some definite peaks in citation impact, while Zhu Z sustains a consistent record, mostly

Figure 7. Publication Timeline of Key Authors in Bougainvillea Research, Showing Productivity and Citation Impact Over Time.
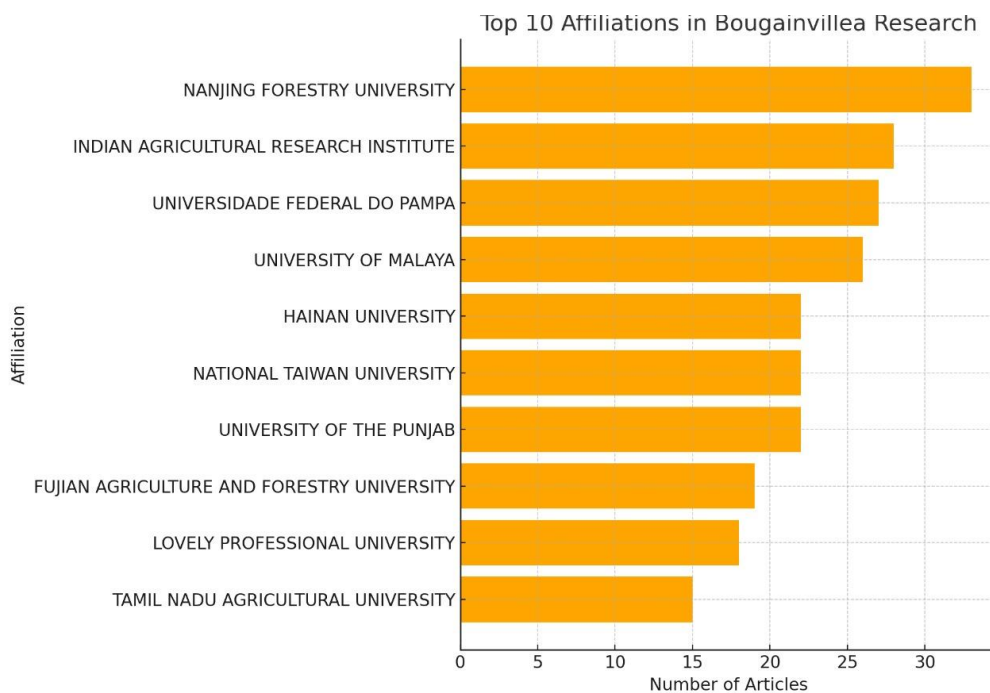
Figure 6. Top 10 Affiliations in the field of Bougainvillea Research based on the number of publications from 1937-2024.

in collaboration with other researchers. Hossain Abms shows a group of highly cited publications around 2008-2011, pointing to a period when the research output was rather significant.

➢ Xu S has made a relatively sporadic contribution, but Chang Y-S has been quite steady in high productivity for an extended period since 2001. Cirillo C is also intermittent in contributions; nevertheless, he has had recent impactful works in *Bougainvillea* research.

Overall, it has been an eye-opener to the collaborative and individual efforts of leading researchers in the field. The circles indicate periods of intense research activity and highlight the influence of a few key publications through their size and colour intensity.

Keyword Analysis

The word cloud visualizes the most frequently occurring keywords in Bougainvillea's research, offering insights into the key themes and areas of interest. The most prominent terms include "Bougainvillea spectabilis," "Bougainvillea glabra," and "nyctaginaceae," reflecting the primary focus on the taxonomy and specific species of Bougainvillea. Terms like "plant extract," "unclassified drug," and "medicinal plant" suggest that a significant portion of the research revolves around the pharmacological and medicinal properties of Bougainvillea extracts. The prominence of "nonhuman," "controlled study," and "animal experiment" indicates that many studies have utilized animal models to investigate the therapeutic potential of Bougainvillea. Other frequently mentioned keywords include "article,"

"plant leaf," and "antioxidant," suggesting that the research literature extensively covers the antioxidant properties of Bougainvillea leaves. Keywords like "flavonoid," "saponin," and "chemistry" hint at the phytochemical compounds isolated and studied from the plant. The appearance of "diabetes mellitus," "air pollution," and "traditional medicine" reflects the diverse applications being explored, such as potential treatments for diabetes and studies on the plant's role in traditional medicine. The word cloud provides a snapshot of the primary themes and research interests in Bougainvillea studies, highlighting its pharmacological potential, phytochemical diversity, and the broad spectrum of medicinal applications.

The graph plot displays a cumulative occurrence of critical terms in *Bougainvillea* research over time, revealing evolution and growth in research interests. Until the early 1990s, these terms remained relatively flat, indicating limited research activity. However, starting in the late 1990s, there was a conspicuous increase, with the growth becoming more pronounced in the 2000s. Terms such as "article," "*Bougainvillea*," "*Bougainvillea glabra*," and "*Bougainvillea spectabilis*" show a steady rise, particularly after 2008, and emphasize a significant increase in research output focused on those specific species and the Nyctaginaceae family. "Controlled study," "nonhuman," and "plant extract" also exhibit similar growth patterns, suggesting a focus on experimental research using plant extracts and nonhuman models. The term "unclassified drug" shows a marked increase after 2010, indicating a growing interest in exploring *Bougainvillea* compounds for potential.
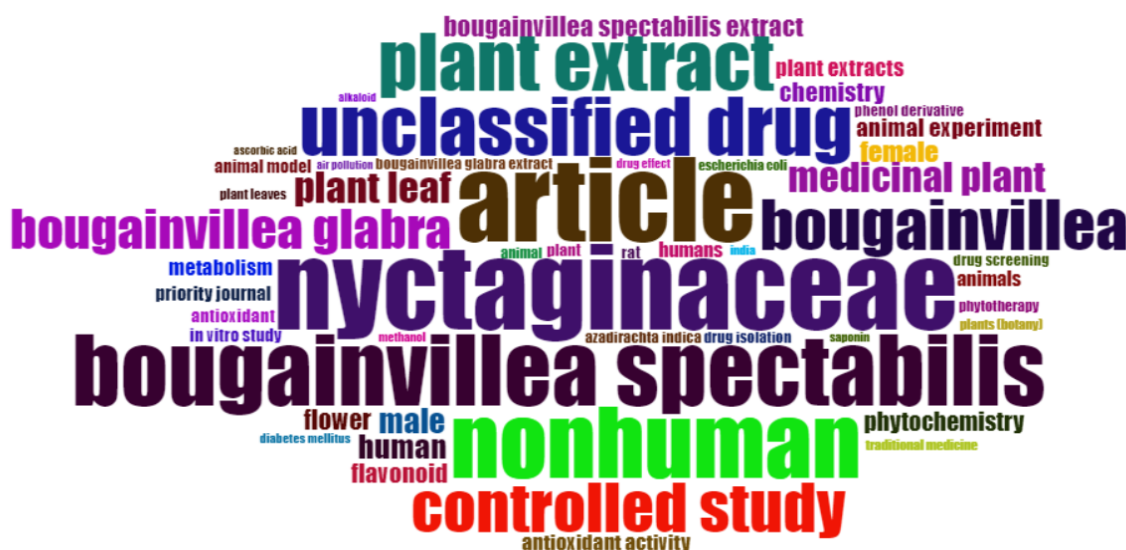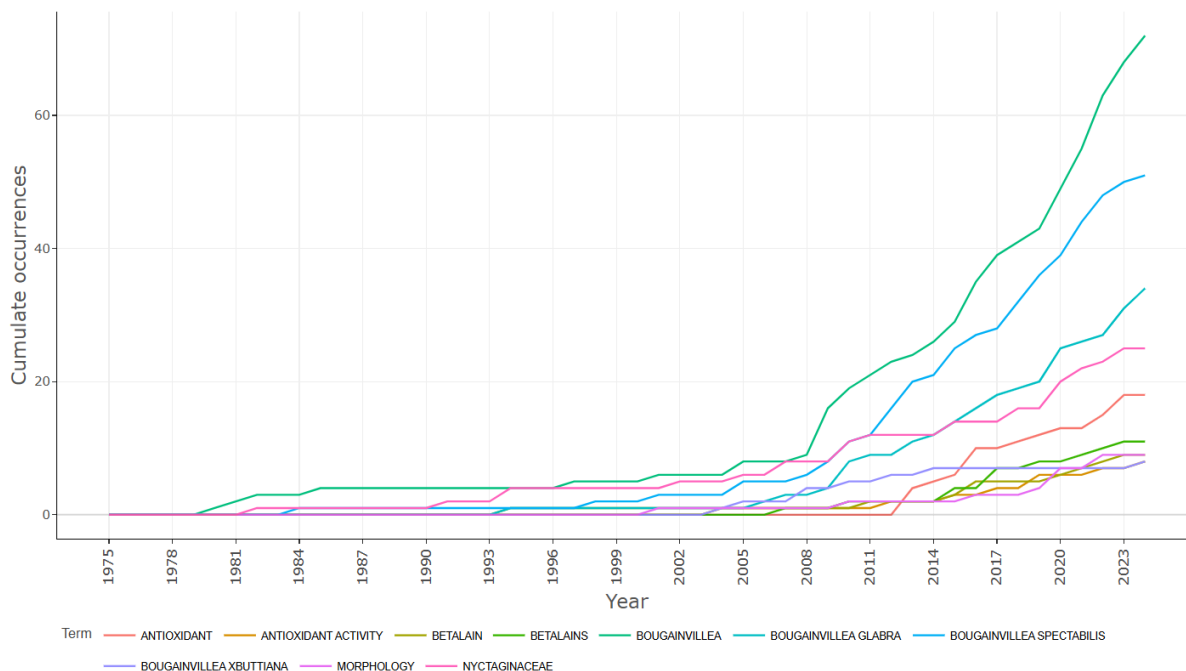

Figure 8. Word Cloud Depicting Key Themes and Research Interests in Bougainvillea Studies Based on Frequently Occurring Keywords.
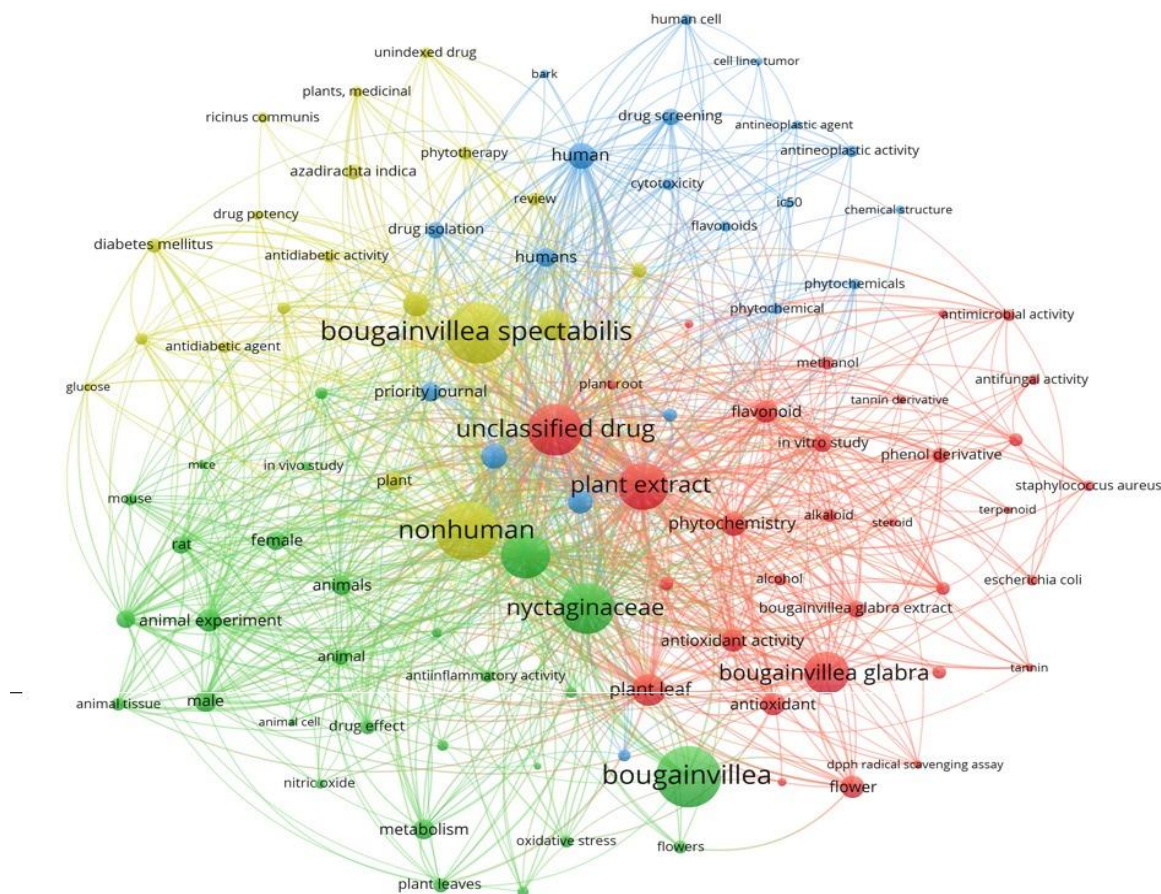
Figure 9. Cumulative Occurrence of Key Terms in Bougainvillea Research Over Time, Highlighting the Evolution and Growth of Research Interests in the Field.

The network visualization map presents the co-occurrence of keywords in Bougainvillea research, providing insights into thematic clusters and relationships within the field. The nodes' size reflects the frequency of a keyword, while the colour and proximity between nodes represent thematic clusters. The Red Cluster focuses on phytochemistry and specific species like Bougainvillea glabra and Bougainvillea spectabilis. Key terms include "Bougainvillea," "nyctaginaceae," "plant extract," "phenol derivative," and "antioxidant activity," reflecting research on phytochemical properties and antioxidant potential. The Green Cluster centres on pharmacological studies using nonhuman models. Prominent terms such as "nonhuman," "controlled study," "animal experiment," and "medicinal plant" suggest that many studies explore Bougainvillea's medicinal properties through animal models. The Blue Cluster encompasses drug screening and human health studies, with critical terms like "unclassified drug," "human," "drug screening," "antimicrobial activity," and "cytotoxicity." This cluster emphasizes Bougainvillea's potential as an unclassified drug in combating microbial infections and cancer. The Yellow Cluster focuses on metabolic diseases and traditional medicine, highlighted by terms like "diabetes mellitus," "glucose," "traditional medicine," and "anti-diabetic agent," reflecting research on Bougainvillea's use in traditional medicine for treating metabolic disorders. Smaller clusters include terms like "Azadirachta indica," "flavonoid," "saponin," and "phytotherapy," indicating specialized research interests.

Overall, the network map reveals the multidisciplinary nature of Bougainvillea research, encompassing phytochemistry, pharmacology, drug discovery, traditional medicine, and nonhuman models. The connections between clusters emphasize the interplay between different research themes, highlighting the overlap between phytochemistry and pharmacological applications.

Trend Topic Analysis

The timeline chart of bubbles represents the year when the given terms were most likely to appear during the research of Bougainvillea. The size of each bubble indicates the frequency with which a given term was detected. It shows how research themes have evolved and diversified since 2005. The earliest research was marked by the appearance of terms such as "air pollution tolerance index," "diabetes mellitus," "relative water content," and "Bougainvillea xbuttiana," representing early studies on environmental tolerance and specific species identification. This is followed by an evident shift in 2009-2011 toward an increased presence of terms such as "antioxidant activity," "dpph," "phytochemicals," "nyctaginaceae," and "Bougainvillea spectabilis," pointing to growing interest in the phytochemical properties and taxonomy of Bougainvillea. Further years reveal an increasing interest in the medical and pharmacological aspects with the prime importance of "antioxidant," "antimicrobial," "cytotoxicity," "anti-inflammatory," and "natural dyes.".

Figure 11. Network Visualization of Co-Occurrence of Keywords in Bougainvillea Research, Highlighting Thematic Clusters and Relationships Between Research Themes.
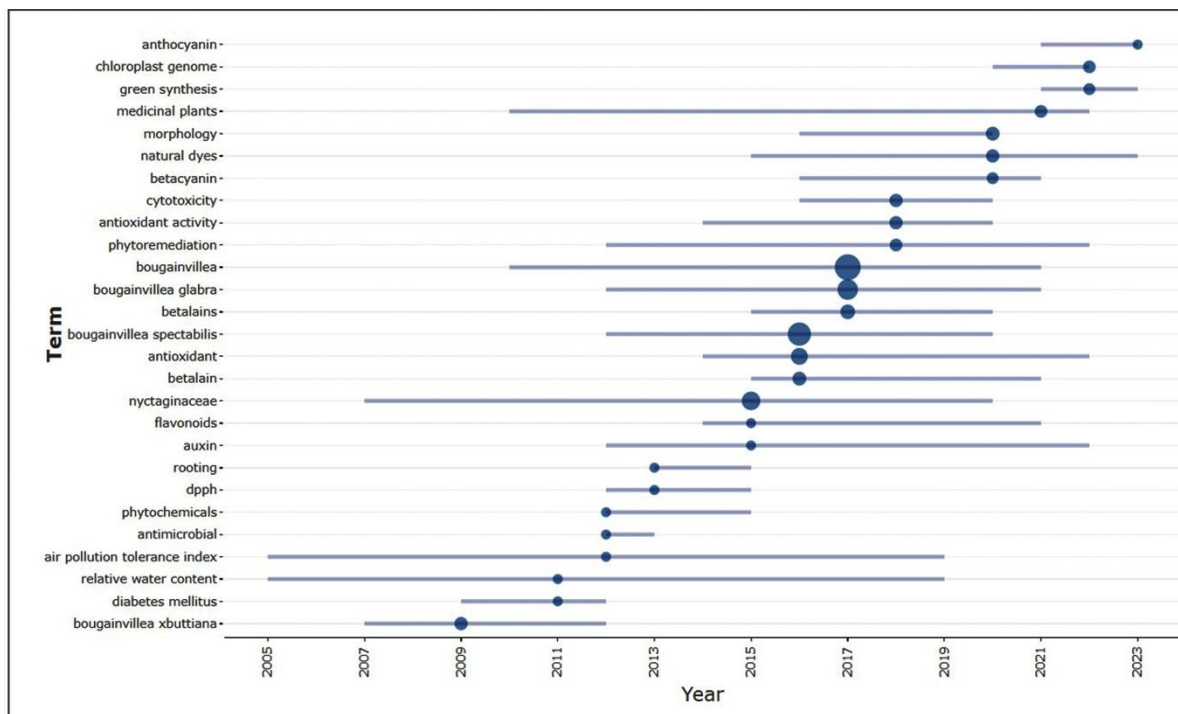
Figure 10. Timeline of Key Terms in Bougainvillea Research, Showing the Evolution and Diversification of Research Themes Over Time.

Some of the recent themes in research include "chloroplast genome," "green synthesis," "flavonoids," "betacyanin," "ornamental plants," and "phytoremediation." These themes show advanced studies related to genetic analysis, sustainable synthesis methods, and environmental applications. Further, there

is a constant interest in both ornamental and medicinal uses, with terms such as "ornamental plant," "*Bougainvillea glabra*," and "medicinal plants" featuring more often.

Thematic Mapping

The strategic diagram provides a thematic mapping of *Bougainvillea* research. Themes are divided into four quadrants based on centrality, degree of relevance, density, or development degree.

The Motor Themes quadrant, on the upper right, represents well-developed, highly relevant themes driving *Bougainvillea* studies. Key themes include "*Bougainvillea spectabilis* extract," "phytochemistry," "flavonoid," "unclassified drug," and "controlled study," which have been considered and show the focus on the phytochemical and pharmacological properties of *Bougainvillea*. Other important terms like "nonhuman," "Nyctaginaceae," and "article" also fall into this quadrant, defining their central role in *Bougainvillea's* research.

The Niche Themes quadrant combines specialized themes that are most developed but less related to the general field. Examples include "antivirus agents," "plant proteins," and "antiviral agents," which indicate specialized research carried out on plant-based antiviral compounds. "Hexapoda," "phenacoccus," and "boerhavia diffusa" reflect niche studies on specific insects and plant species.

The Basic Themes quadrant contains core themes fundamental to *Bougainvillea* research but with lower

studies that are the core of the field. Included here are also "air pollution," "atmospheric pollution," and "chlorophyll," representing studies on environmental stressors impacting *Bougainvillea*.

The Emerging or Declining Themes quadrant, on the bottom left, includes low centrality and density themes, thus indicating emerging or declining research interests. Themes that indicate an emerging interest in sustainable dye production or environmental research are "natural dye," "anthocyanins," and "carbon." In contrast, themes of interest, perhaps in decline, in renewable energy applications include "efficiency," "dye-sensitized solar cells," and "vat dyes.".

Note. From "Sport entrepreneurship: the role of innovation and creativity in sport management," by Hammerschmidt et al., 2023, *Review of Managerial Science*, 1-30(https://doi.org/10.1007/s11846-023-00711-3).

Discussion

This bibliometric analysis of *Bougainvillea* research reveals significant insights into the evolving trends, thematic concentrations, and collaborative networks shaping this field. The annual scientific production has consistently grown, particularly from the early 2000s onwards, with a notable surge in publications from 2010 to 2023. This increase aligns with a growing global interest in Bougainvillea's phytochemical, pharmacological, and environmental applications. The
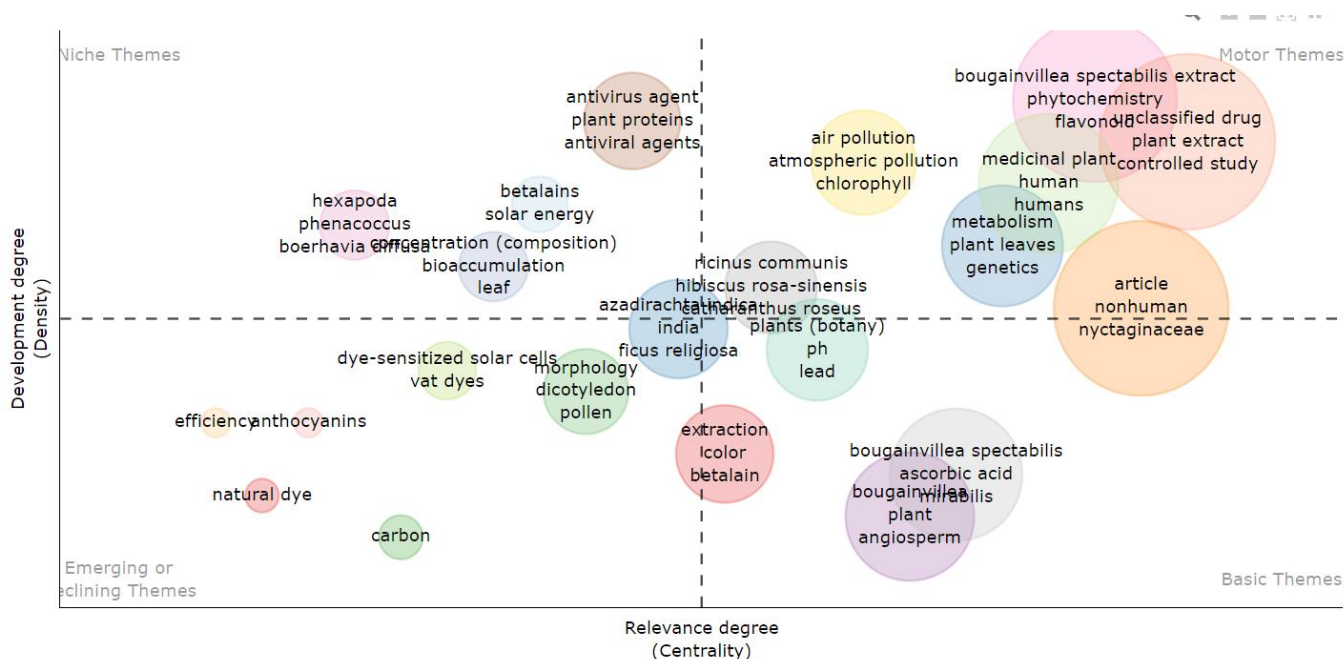
Figure 12. Strategic Diagram of Bougainvillea Research Themes, Highlighting Motor, Niche, Basic, and Emerging/Declining Themes Based on Centrality and Density.

development density. Terms like "*Bougainvillea spectabilis*," "*Bougainvillea glabra*," "angiosperm," and "ascorbic acid" indicate taxonomic and phytochemical

authorship analysis underscores the collaborative and international nature of *Bougainvillea's* research. India leads the field with the most publications, followed by

China, Mexico, and Brazil. The collaboration network reveals that India, China, Italy, and the United States are central hubs, actively partnering with other countries to advance the research. Authors like Petricevich Vl, Lodha Ml, and Hossain Abms have significantly contributed to productivity and impact. The evolution of research themes is evident in the cumulative occurrence of key terms over time. Early research focused on environmental tolerance and ornamental aspects of *Bougainvillea*, but the field has since diversified. Recent themes emphasize Bougainvillea extracts' medicinal and pharmacological potential, particularly their antioxidant, antimicrobial, and anti-inflammatory properties. The word cloud and keyword co-occurrence map further illustrate the breadth of research themes, with prominent terms like "*Bougainvillea spectabilis*," "phytochemistry," "controlled study," "nyctaginaceae," and "unclassified drug" highlighting a multidisciplinary approach. Themes like "nonhuman," "plant extract," and "article" suggest that many studies utilize animal models and in vitro systems to explore *Bougainvillea's* therapeutic potential.

The strategic diagram categorizes research themes into four quadrants, clearly understanding their development and relevance. The Motor Themes quadrant (upper right) represents well-developed, highly relevant themes driving *Bougainvillea* studies. Key themes include "*Bougainvillea spectabilis* extract," "phytochemistry," "flavonoid," "unclassified drug," and "controlled study," reflecting a focus on the phytochemical and pharmacological properties of *Bougainvillea*. Other essential terms like "nonhuman," "nyctaginaceae," and "article" also fall into this quadrant, highlighting their central role in *Bougainvillea's* research. The Niche Themes quadrant (upper left) encompasses specialized themes that are highly developed but less relevant to the broader field. Examples include "antivirus agent," "plant proteins," and "antiviral agents," indicating specialized research on plant-based antiviral compounds. "Hexapoda," "phenacoccus," and "boerhavia diffusa" reflect niche studies on specific insects and plant species. The Basic Themes quadrant (lower right) includes foundational themes essential to *Bougainvillea* research but with lower development density. Terms like "*Bougainvillea spectabilis*," "*Bougainvillea glabra*," "angiosperm," and "ascorbic acid" indicate taxonomic and phytochemical studies that form the core of the field.

Additionally, "air pollution," "atmospheric pollution," and "chlorophyll" represent studies on environmental stressors impacting *Bougainvillea*. The Emerging or Declining Themes quadrant (lower left) identifies low centrality and density themes, representing either emerging or declining research interests. Themes like "natural dye," "anthocyanins," and "carbon" suggest emerging interest in sustainable dye production and environmental research. Meanwhile, "efficiency," "dye-sensitized solar cells," and "vat dyes" may reflect the declining interest in renewable energy applications. This analysis reveals that *Bougainvillea* research is evolving into a multidisciplinary field with increasing global interest. The surge in publications, the diversity of research themes, and the collaborative networks indicate significant potential for future studies. Researchers should focus on strengthening international collaborations and researching niche themes with broader relevance, like producing plant-based antiviral compounds and sustainable dye. Additional research can be pursued in Bougainvillea's genetic, molecular, and phytochemical aspects to develop novel therapeutic applications. The strategic diagram presents a roadmap to researchers to focus on emerging themes and to understand the areas where further investigation is needed to go ahead in the advancement of *Bougainvillea* as a medicinally and ornamentally valuable plant (Behl et al., 2021; Ben-Shabat et al., 2020; Khazir et al., 2024; Thomas et al., 2021).

Limitations

Considering the range of views offered in this bibliometric analysis of *Bougainvillea* research, one should note a few limitations. First, this study depended on a bibliometric database that may have excluded relevant publications not indexed in the same place. This would have a bearing on thematic mapping and authorship trends, given that there is a likelihood of bypassing some studies, especially those in regional or less renowned journals (Che Yahaya et al., 2022; Salam et al., 2017). Secondly, the review's main limitation is that it is based on English-language publications. This might contribute to the fact that works carried out in other languages, in particular, in native places, or in those regions where *Bougainvillea* is largely under cultivation, or conducted by other specialists, would somehow be underrepresented. There may be a language bias that will limit the worldwide scope of this review (Datta et al., 2021). Thirdly, using author-supplied keywords and index terms in co-occurrence mapping and strategic mapping could have some irregularities in reflecting the actual content of the documents. Other terminology or another variation in the choice of keywords could attic clusters, not giving a complete reflection of all aspects of the field. The other limitation is that the time looked into in this analysis covers different decades, and in today's

world, research priorities and methodologies used within studies change (Narong and Hallinger, 2023). One of the limitations regarding temporal diversity is the impact that it might have on the reliability of thematic trends, which may be drawn from the retrieved search output and its interpretation. Finally, the research is focused on the thematic mapping and collaboration networks but needs to describe in detail the methodological approaches used in *Bougainvillea's* research. This further restricts the insight into methodological progress and its impact on the field (Kabir, 2016). Future bibliometric studies should pay more attention to these limitations by exploring multiple databases, extending the coverage to non-English publications, and going more in-depth in analyzing research methodologies and regional contributions. Nevertheless, the research is limited and contributes valuable insight into the current state and future potential of *Bougainvillea species* (Ullah et al., 2022).

Conclusion

This bibliometric analysis provides an overview of Bougainvillea research's evolution and present state. The research outputs in this subject field have increased considerably in the last twenty years, which are very expressive of growing interest worldwide towards the diverse uses of *Bougainvillea*. From the researcher's point of view, the plant is now recognized in diverse fields like ornamental horticulture, medicinal phytochemistry, and environmental studies. The country, India, which contributes most to *Bougainvillea* studies, is followed by China, Mexico, and Brazil. These countries register high productivity levels in terms of publications and act as epicentres for international collaboration networks. At the forefront of this productivity and influence that they are managing to command in the field are key authors who are shaping the field, such as Petricevich Vl, Lodha Ml, and Hossain Abms. The overview of the thematic analysis reflects multipronged *Bougainvillea* research. Initially, it focused on environmental tolerance, ornamental, and garden features. At the same time, at the present stage, the research area has greatly diversified and is now focused on the medicinal and pharmacological characteristics of extracts from *Bougainvillea*. Its phytochemical compounds are flavonoids, betacyanin, and betalains, with antioxidant, antimicrobial, and anti-inflammatory activities. Moreover, there is an enlarged understanding of the plant's therapeutic value from research conducted on animal models and controlled human experiments. The strategic diagram divides the research themes into four quadrants, giving insights into

the fields' structure and development. Such motor themes as "*Bougainvillea spectabilis* Extract," "Phytochemistry," "Controlled Study," and "Unclassified Drug" indicate that the much-emphasized importance is put in place while doing the phytochemical and pharmacological studies. Special but meaningful areas; niche themes that "antivirus agent" and "plant proteins" portray. Simple themes like "*Bougainvillea spectabilis*," "*Bougainvillea glabra*," and "Nyctaginaceae" are the firm taxonomic and phytochemical bases for new themes. A growing interest in sustainable issues concerning dye production and the environment shows in new themes like "Natural dye" and "Anthocyanins." The study points out the multidisciplinary trend of thematic collaboration in the work that emphasizes them. It is in a position to increasingly diversify the thematic and network collaboration, hence showing great potential for making significant scientific and societal contributions.

Areas for future research aimed at unlocking the full potential of the *Bougainvillea* are to focus on strengthening global partnerships. To find new medical applications, further studies should look more in-depth into the plant's genetic, molecular, and phytochemical aspects. Another way will be through sustainable practices, such as producing dyes, applying renewable energy, and environmental remediation in their innovative uses of *Bougainvillea*. The strategic diagram becomes a roadmap for the researcher to pick the emerging themes and the areas where further inquiry is needed. In conclusion, the research of *Bougainvillea* is gradually emerging as a multidisciplinary and dynamic field. Much potential from this very versatile plant is still locked, whereby researchers can unlock its whole potential through solidifying their collaborative networks and checking new thematic frontiers. Ultimately, it will serve to advance this medicinal and ornamental valuable species.

Conflict of Interest

The authors declare no known conflict of interest to publish the article.

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