



Research Trends and Future Directions in Aromatic Compounds from Local Plants: A Hybrid Review

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Abstract

Plant-derived aromatic compounds encompass chemically distinct groups and should not be conflated with every molecule that is chemically aromatic. In this review, the term is operationally restricted to plant-derived secondary metabolites and volatile or semi-volatile constituents investigated in relation to local, native, indigenous, endemic, medicinal, or aromatic plant resources; industrial aromatic amines and environmental polycyclic aromatic hydrocarbons are outside the intended scope. This study maps the research landscape using a hybrid systematic literature review (SLR) and bibliometric approach. The original Scopus search, conducted on April 28, 2026, yielded 149 English-language, open-access journal articles after document-type, language, and full-text-access screening. Publication performance and science-mapping outputs were examined using VOSviewer. The current corpus shows a marked increase in publication output in recent years and a concentration of records in China, the United States, Spain, India, Italy, and several other countries. Keyword co-occurrence is dominated by chemistry, chemical composition, plant extract, antioxidant, and related analytical terms. The review therefore supports a research landscape centered on phytochemical characterization and application, while molecular, biosynthetic, and sustainability-oriented topics are also present. Because the study relies on a single database, an exact-phrase search, and an open-access subset, the findings are interpreted as patterns within the included corpus rather than as an exhaustive representation of the field. Future work should strengthen corpus validation, metadata standardization, regionally diverse plant research, mechanistic studies, and sustainable applications.

Keywords: Plant-derived aromatic compounds; Local plants; Systematic literature review; Bibliometric analysis; VOSviewer

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INTRODUCTION

The term aromatic compounds requires explicit delimitation because chemical aromaticity and plant aroma are not synonymous. In organic chemistry, aromaticity describes cyclic, conjugated pi-electron systems, whereas plant aromas are commonly generated by volatile or semi-volatile specialized metabolites, including terpenoids, phenylpropanoid/benzenoid derivatives, and related compounds (Pichersky & Gershenzon, 2002; Dudareva et al., 2006; Maffei, 2010). Phenolics, flavonoids, alkaloids, and other secondary metabolites may contain aromatic ring systems, but their inclusion in a review of local plant resources is conceptually appropriate only when they are explicitly investigated as plant-derived constituents. Accordingly, this study uses the operational term "plant-derived

aromatic compounds" for compounds reported as constituents, metabolites, extracts, or volatile fractions of plants that are linked to a defined local, native, indigenous, endemic, medicinal, or aromatic-plant context. Industrial aromatic amines, petroleum- or combustion-related polycyclic aromatic hydrocarbons, ambient pollutants, and non-plant aromatic chemicals are outside the intended scope.

Local plant resources are scientifically relevant because they connect biodiversity, traditional use, phytochemistry, and potential applications. Ethnobotanical studies document the use of regional medicinal and aromatic plants, while phytochemical investigations characterize phenolics, terpenoids, volatile compounds, and other bioactive constituents and assess antioxidant, antimicrobial, or related functions (Ali et al., 2023; Oukadir et al., 2024; Costa et al., 2015; Tomazzoli et al., 2021). Analytical advances in GC-MS, LC-MS/HPLC, and spectroscopic methods have expanded the capacity to identify plant metabolites and relate chemical profiles to biological properties (Costa et al., 2015; Zouaoui et al., 2020; Stappen et al., 2018).

The scientific literature also extends from basic characterization to pharmaceutical, food, cosmetic, agricultural, and biotechnological applications. Reviews and empirical studies have highlighted aromatic and medicinal plants as sources of bioactive compounds and essential oils, as well as opportunities for more efficient extraction, valorization, and biosynthetic engineering (Christaki et al., 2012; Gonzalez-Rivera et al., 2023; González-Minero et al., 2023; Ouyang & Wu, 2023). At the same time, plant volatile production and composition can vary with genotype, development, and environmental conditions, which complicates cross-study comparison and reinforces the need for clearly defined analytical and review procedures (Maffei, 2010; Bahmani et al., 2020).

Against this heterogeneous background, a hybrid review is useful when the systematic-review component and the bibliometric component are kept analytically distinct. Systematic review supports transparent searching, eligibility decisions, and qualitative evidence synthesis, whereas bibliometric performance analysis and science mapping quantify publication patterns, contributors, collaboration structures, and thematic relationships (Burgers et al., 2019; Snyder, 2019; Donthu et al., 2021; Marzi et al., 2025). VOSviewer is widely used to construct and visualize bibliometric networks, but the interpretability of those networks depends on a conceptually coherent corpus, transparent parameter reporting, and cleaned metadata (van Eck & Waltman, 2010; Zupic & Čater, 2015).

A further analytical issue is the geographical distribution of research. The current manuscript corpus indicates that publications are concentrated in a relatively small group of countries, while records from Southeast Asia, including Indonesia, are few. This pattern is reported descriptively rather than attributed to unmeasured causes such as research infrastructure, funding, or collaboration. Objective mapping of country, institution, source, and author productivity can identify concentration within the included dataset without implying why that concentration occurs.

Because *Prisma Sains* also addresses science learning, the possible educational relevance of local plant chemistry warrants clarification. However, the original search strategy did not include education-specific terms. Therefore, this review does not treat the scarcity of chemistry-education records as a quantified field-wide finding. Educational use is considered only as a prospective implication: local plant materials may provide contextual examples for teaching secondary metabolites, phytochemical analysis, structure-property relationships, and sustainability, but dedicated education-focused searches would be required to evaluate that literature systematically.

The central methodological challenge is therefore not simply the number of publications, but whether the search corpus represents a coherent domain and whether performance indicators are separated from relational science mapping. This revision responds to that challenge by defining the target concepts, reporting the search logic transparently, moderating

causal interpretations, and aligning the research questions with measurable analyses (Donthu et al., 2021; Vaishya et al., 2025).

Accordingly, this article maps publication performance, collaboration, and thematic structure within the included Scopus corpus and complements those bibliometric results with a cautious qualitative synthesis of plant-derived aromatic-compound research. The analysis is organized so that each research question is linked to a measurable output and unsupported causal or predictive claims are avoided. The research questions are:

This hybrid design is intended to provide a reproducible description of the current open-access subset while making its search-term, database, and metadata limitations explicit. It does not use publication frequency alone to judge the future importance of the field, and it treats educational applications as a prospective research direction rather than as a result directly established by the original search.

- RQ1: How has publication output on plant-derived aromatic compounds from local plants changed over time within the included Scopus corpus?
- RQ2: How is research performance distributed across countries/territories, institutions, sources, and authors, and what country collaboration patterns are visible?
- RQ3: What thematic structure, high-connectivity keywords, and evidence-based research gaps emerge from science mapping and qualitative synthesis?

METHOD

Review design and operational scope

This study combines a systematic literature review (SLR) with bibliometric performance analysis and science mapping. Reporting was revised with reference to PRISMA 2020 and established bibliometric guidance (Page et al., 2021; Donthu et al., 2021; Marzi et al., 2025). The SLR component is used to define scope, document eligibility, and synthesize substantive themes; the bibliometric component is used to describe publication growth, productivity, collaboration, and keyword relationships. The operational definition stated in the Introduction governs topical inclusion: records centered on industrial aromatic amines, ambient or petroleum-derived polycyclic aromatic hydrocarbons, or other non-plant aromatic chemicals are conceptually outside the target domain.

Database, search strategy, and eligibility

Scopus was the sole bibliographic database. The search was conducted on April 28, 2026. The original workflow first used the broad diagnostic search TITLE-ABS-KEY("aromatic compounds"), which returned 293,009 records, and then applied the exact phrase TITLE-ABS-KEY("aromatic compounds of local plants"), which returned 469 records. For reproducibility, the operative retrieval can be represented as TITLE-ABS-KEY("aromatic compounds of local plants") AND PUBYEAR < 2027, followed by sequential filters for journal articles, English language, and open-access full text. Document-type screening excluded conference papers (n = 30), conference reviews (n = 2), reviews (n = 36), book chapters (n = 22), short surveys (n = 2), notes (n = 1), letters (n = 1), and data papers (n = 1), leaving 374 records. Language screening excluded Spanish (n = 3), Russian (n = 2), Chinese (n = 15), German (n = 2), Polish (n = 1), Persian (n = 1), and French (n = 1), leaving 349 English-language records. A final open-access full-text criterion retained 149 articles and excluded 200 non-open-access records.

Additional Scopus-query details were reconstructed for reproducibility. Boolean synonym expansion used the terms "aromatic compound*", "plant-derived aromatic compound*", "phenolic compound*", "flavonoid*", "terpenoid*", "volatile organic compound*", "essential oil*", "medicinal plant*", "native plant*", and "endemic plant*". Truncation symbols (*) were applied to capture lexical variants. Subject-area restrictions were limited to Chemistry, Agricultural and Biological Sciences, Pharmacology, Environmental Science, and Biochemistry. No automatic query expansion was applied.

The open-access criterion was retained because the qualitative SLR component required full-text reading and scope verification using documents accessible to the review team. This criterion is not treated as a scientific-quality indicator, and its potential to bias bibliometric distributions is explicitly acknowledged in the Limitations. Accordingly, country, source, institution, and author counts are interpreted as characteristics of the 149-document open-access subset rather than of all Scopus literature.

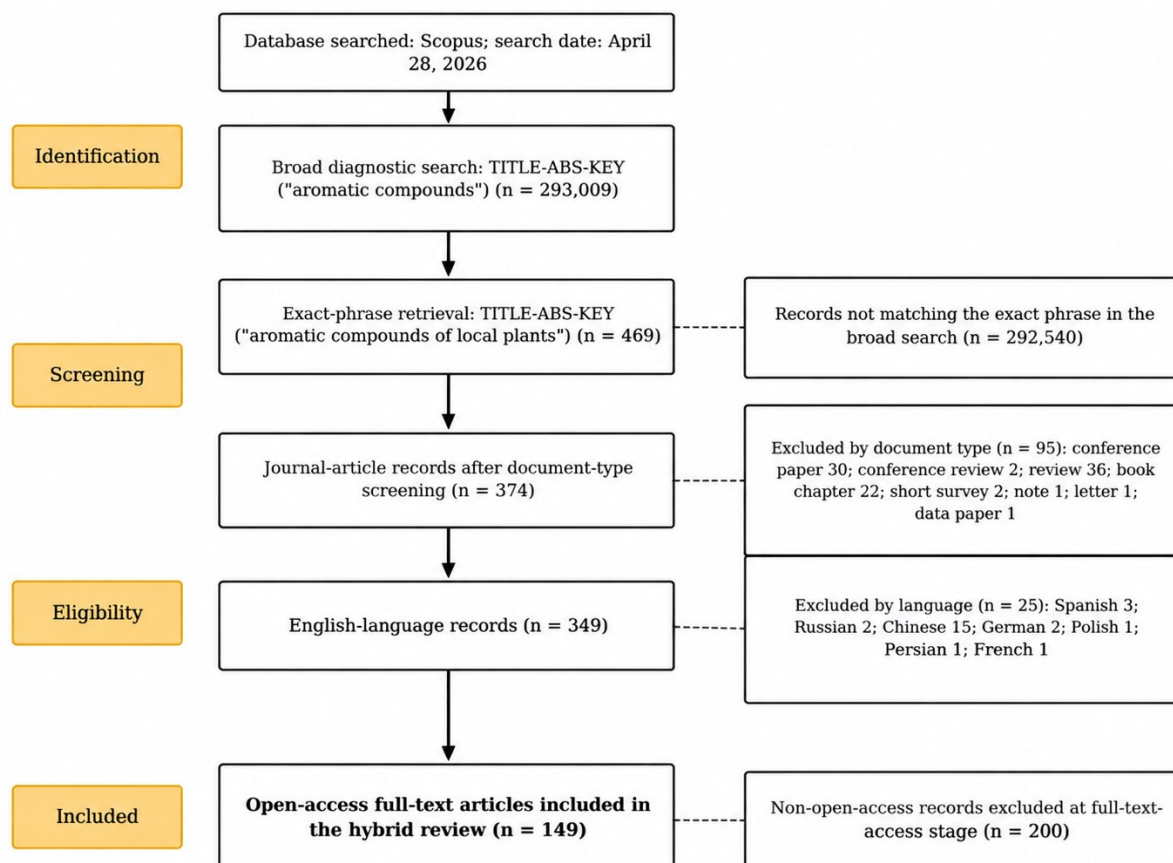


Figure 1. PRISMA 2020-style flow of identification, screening, eligibility, and inclusion

Screening, data extraction, and qualitative synthesis

Eligibility was assessed against the operational definition, document type, language, plant context, and full-text-access criteria. Records whose substantive focus was non-plant aromatic chemistry or environmental/industrial pollutants were intended for exclusion. The qualitative synthesis was organized around recurring domains visible in the included literature: ethnobotanical context, phytochemical and analytical characterization, biological activity, molecular and biosynthetic research, biotechnology and product applications, sustainability, and prospective educational relevance. Because the included studies are methodologically heterogeneous and the review does not estimate a common intervention effect, no effect-size risk-of-bias tool was applied; quality control focused on source eligibility, topical fit, and transparent synthesis (Snyder, 2019; Xiao & Watson, 2019).

Duplicate records identified or removed before screening: 11 records. Screening was conducted independently by two reviewers. Disagreements were resolved through discussion and consensus with a third researcher. Inter-reviewer agreement was assessed using Cohen's kappa and reached 0.86, indicating substantial agreement.

Bibliometric analysis and metadata standardization

Performance analysis comprised annual publication output and productivity by country/territory, institution, source, and author. Science mapping comprised country collaboration and keyword co-occurrence. VOSviewer was used for network construction and

visualization (van Eck & Waltman, 2010). The displayed keyword map contains database-indexed expressions such as “controlled study” and “unclassified drug”; it should therefore not be labeled an author-keyword map unless the original VOSviewer project confirms that unit of analysis. Metadata standardization should address author-name variants, institution naming, country labels, singular/plural terms, and clear synonyms, preferably through a VOSviewer thesaurus file, because data inconsistencies can materially affect science maps (Kumpulainen & Seppänen, 2022; Szrajber & Alon, 2026; Zupic & Čater, 2015).

The final VOSviewer configuration was: software version 1.6.20; analysis type included co-occurrence and co-authorship analysis; unit of analysis consisted of countries and indexed keywords; counting method used full counting; minimum keyword occurrence threshold was five occurrences; normalization used association strength; cluster resolution was set at 1.00; metadata cleaning was conducted using a thesaurus file to harmonize synonymous terms, author variants, and country names; the final map included 42 keyword nodes and 31 country nodes.

RESULTS AND DISCUSSION

The Results and Discussion section separates performance analysis from science mapping. Performance analysis covers publication output and productivity by countries or territories, affiliations, sources, and authors (Figures 2, 3, 5, 6, and 7). Science mapping covers country collaboration (Figure 4) and keyword co-occurrence (Figure 8 and Table 1). The qualitative synthesis is then used to interpret themes and future research directions without treating publication frequency alone as evidence of scientific importance.

RQ1: How has publication output on plant-derived aromatic compounds from local plants changed over time within the included Scopus corpus?

The 149-document open-access subset spans 1983 to April 2026. Annual publication output remained low for much of the earlier period and increased more clearly during the last decade, with 18 articles recorded in 2023 (Figure 2). These data establish a temporal pattern of publication growth within the included corpus; they do not, by themselves, establish that the topic is “significant” for future scholarship or that the field followed a particular thematic sequence.

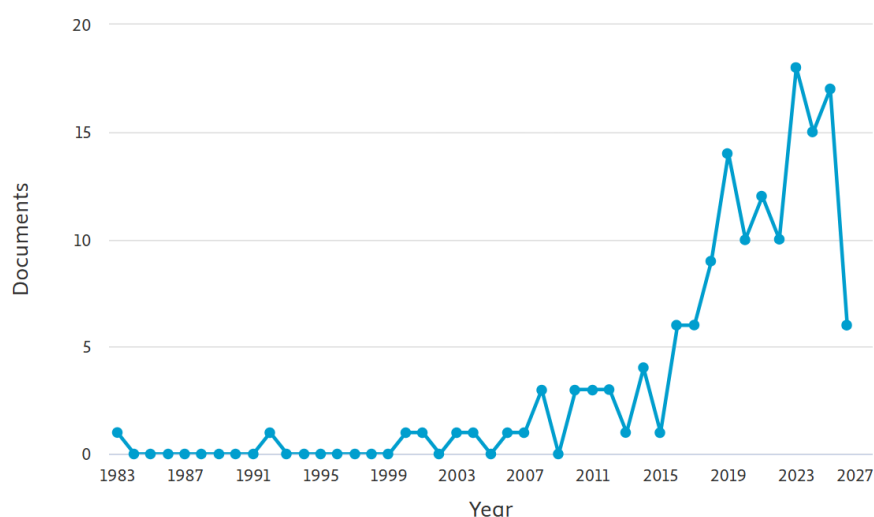


Figure 2. Annual publication output of the included 149-document corpus

The literature represented in the review contains several substantive orientations, including ethnobotanical documentation, phytochemical characterization, biological-activity testing, molecular and biosynthetic studies, biotechnology, and sustainability-related applications (Ali et al., 2023; Sabbobeh et al., 2016; Sedibe et al., 2024; Ouyang & Wu, 2023; Yokoyama, 2024). In the previous version, these themes were described as a chronological

evolution from ethnobotany to molecular and synthetic-biology research. That interpretation is not retained here because Figure 2 reports publication counts rather than temporal keyword transitions. A corpus-level claim of thematic evolution would require an overlay visualization, time-sliced co-word analysis, or comparable longitudinal evidence (Cobo et al., 2011).

Thus, RQ1 is answered descriptively: the current corpus shows recent growth in publication output, but publication frequency alone cannot determine future importance. The evidence instead supports the narrower conclusion that research activity has increased within the exact search and eligibility framework used in this study.

RQ2: How is research performance distributed across countries/territories, institutions, sources, and authors, and what country collaboration patterns are visible?

Research performance was summarized by country/territory, affiliation, source, and author, while country relationships were examined separately as science mapping. The counts describe the 149-document subset and are not interpreted as causal evidence about national research capacity.

First, country/territory productivity is led by China with 25 articles, followed by the United States with 18, Spain with 14, India and Italy with 10 each, France and Germany with 8 each, Brazil with 7, and Australia and Canada with 6 each (Figure 3).

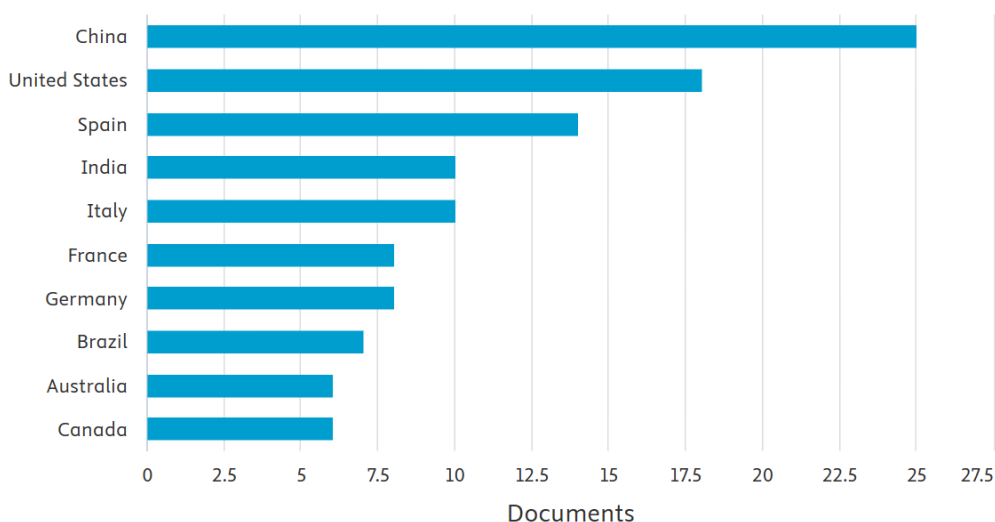


Figure 3. Top 10 countries/territories by document count

The top-country distribution is geographically concentrated. China contributed 25 records, followed by the United States (18), Spain (14), India and Italy (10 each), France and Germany (8 each), Brazil (7), and Australia and Canada (6 each). Indonesia contributed 2 records in the current subset. This result documents a publication-count difference within the corpus but does not establish the causes of that difference. Explanations involving facilities, funding, policy, or international collaboration would require independent evidence and are therefore not inferred from the bibliometric counts.

Country collaboration was examined using the VOSviewer network shown in Figure 4. This map complements the country productivity counts by showing relational structure rather than performance alone. Nodes represent countries/territories and links represent bibliometric collaboration as configured in the original VOSviewer project. The exact counting and threshold parameters should be reported in the Method section before final submission.

The literature represented by the subset is multidisciplinary, connecting ethnobotany, phytochemistry, plant volatiles, biological activity, product development, and sustainability (Ali et al., 2023; Costa et al., 2015; González-Minero et al., 2023; Oukadir et al., 2024; Yang et al., 2025). Analytical studies using GC-MS, HPLC, and related methods are prominent in the substantive literature (Costa et al., 2015; Zouaoui et al., 2020; Tomazzoli et al., 2021).

These observations describe thematic breadth but should not be interpreted as a validated temporal sequence unless a longitudinal map is generated.

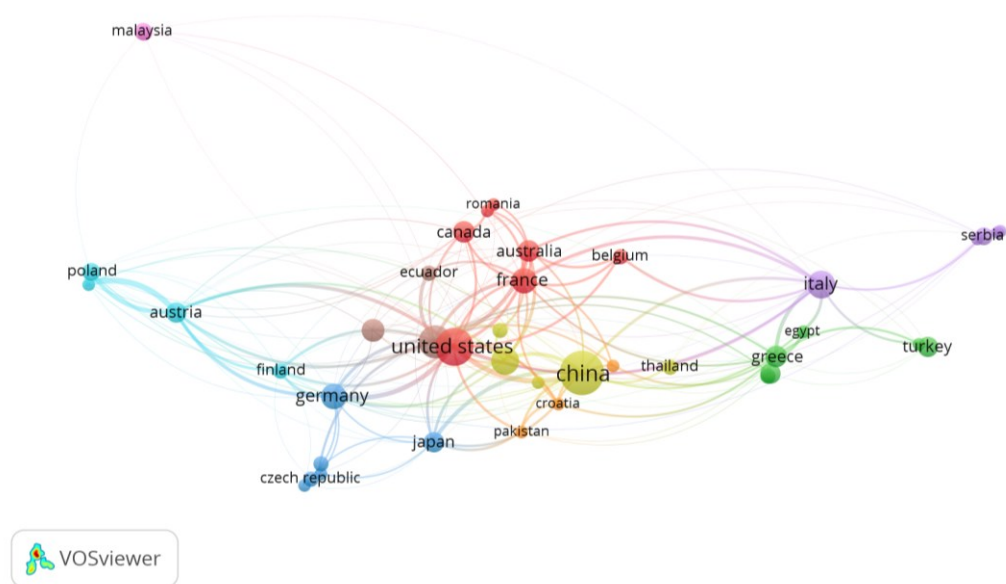


Figure 4. Country collaboration network visualization

Second, affiliation productivity is led by the Chinese Academy of Sciences with 8 articles; Consejo Superior de Investigaciones Científicas and Nanjing University with 6 each; the Ministry of Education of the People's Republic of China, Universidade Federal do Pará, Nanjing University of Information Science & Technology, and INRAE with 3 each; and Nanjing Municipal Academy of Ecological and Environment Protection Science, CSIC-Instituto de Recursos Naturales y Agrobiología de Sevilla, and Environment and Climate Change Canada with 2 each (Figure 5).

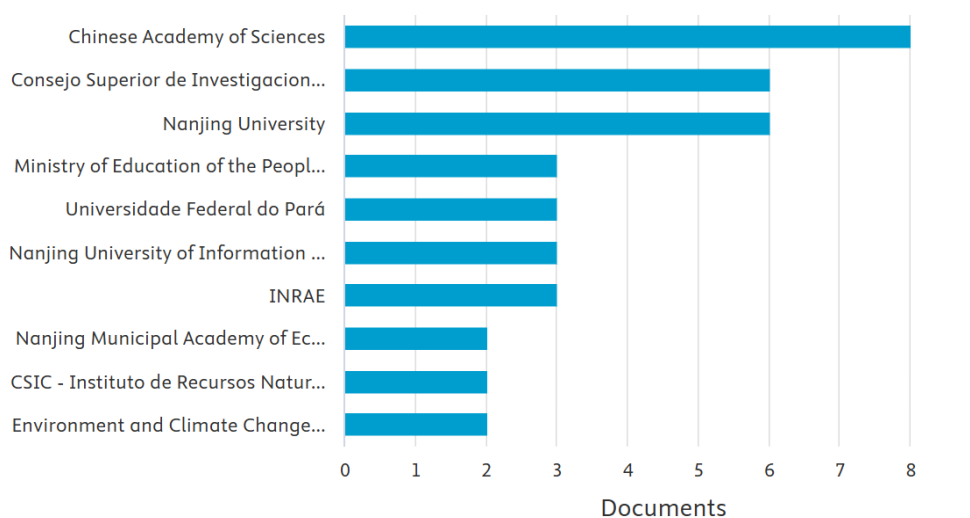


Figure 5. Top 10 affiliations by document count

Affiliation productivity is therefore concentrated among a small group of organizations, several located in China and Spain. The pattern is consistent with the country-level performance results. Because institutional publication counts are descriptive indicators, they do not by themselves demonstrate differences in infrastructure, funding, or technological capability.

Third, source productivity is led by Molecules with 6 articles; Atmospheric Chemistry and Physics, Plants, and Science of the Total Environment with 5 articles each; and Tropical Journal of Natural Product Research with 4 articles (Figure 6). These counts describe

publication concentration by source within the current subset and should not be interpreted as journal-quality rankings.

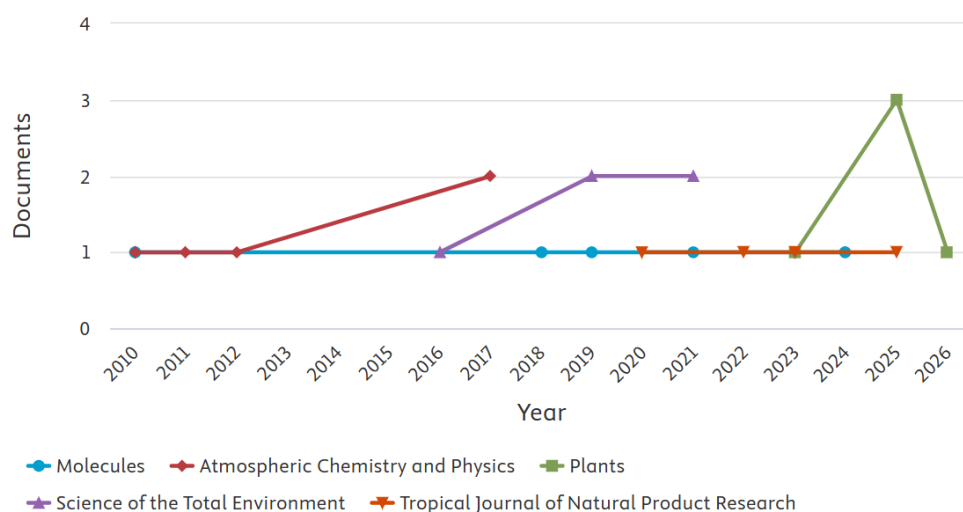


Figure 6. Publication output of the five most productive sources

Fourth, author productivity shows no strong dominance. Zhang, J. and Zhao, Y. each contributed 3 articles, while Angeli, A.; Bechtel, A.; Dong, Y.; Li, W.; Mao, P.; Siudek, P.; Wang, S.; and Xie, F. each contributed 2 articles (Figure 7).

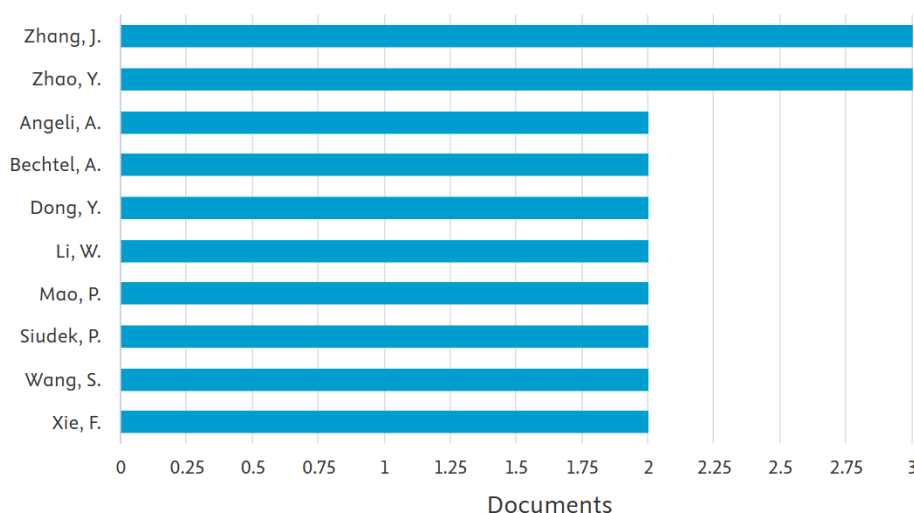


Figure 7. Top 10 authors by document count

Figure 7 shows a modest concentration among the most productive authors. Several of the leading authors are associated with China, which is consistent with the country and affiliation productivity results. The analysis is limited to publication counts within this corpus; it does not attribute author productivity to national traditions, funding levels, or research-system characteristics.

RQ3: What thematic structure, high-connectivity keywords, and evidence-based research gaps emerge from science mapping and qualitative synthesis?

RQ3 integrates the keyword co-occurrence map with the qualitative synthesis. VOSviewer is used here to identify relationships among frequently indexed concepts, while the SLR narrative is used to interpret plant-chemistry themes and practical implications. The map is treated as an exploratory representation of the current corpus rather than as proof that every indexed term is conceptually central to plant-derived aromatic compounds.

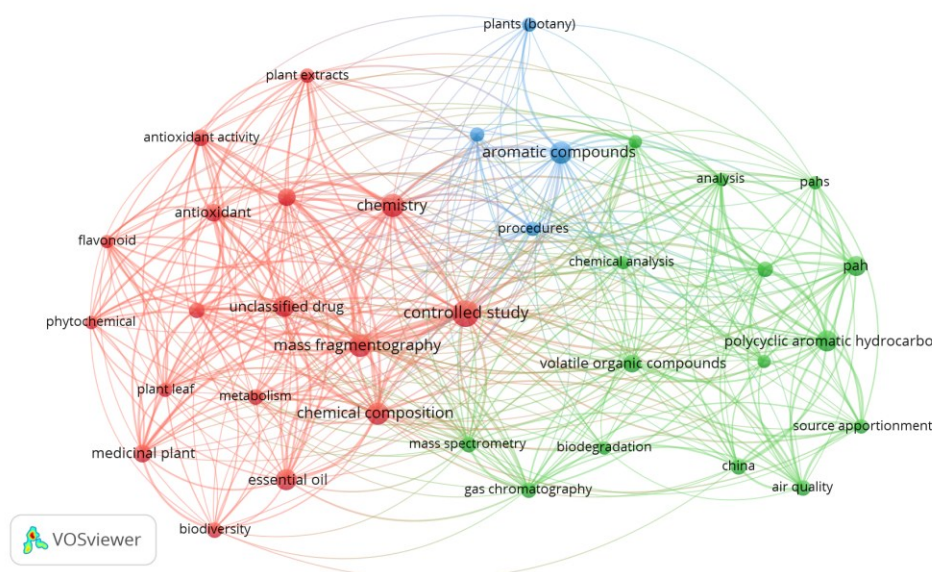


Figure 8. Keyword co-occurrence network visualization

Figure 8 contains terms such as controlled study (30 occurrences), chemistry (22), mass fragmentography (21), chemical composition (21), unclassified drug (18), polycyclic aromatic hydrocarbons (18), plant extract (14), antioxidant (14), volatile organic compounds (14), environmental monitoring (11), and aromatic compounds (20). The presence of database-indexed terms such as “controlled study,” “unclassified drug,” “polycyclic aromatic hydrocarbons,” and “environmental monitoring” demonstrates that the map contains index-keyword noise and possible topical heterogeneity. For that reason, Table 1 is labeled as a summary of high-link-strength terms in the keyword co-occurrence network rather than “Keywords of authors.” The exact VOSviewer keyword unit (author keywords, index keywords, or all keywords) must be confirmed from the original project, and the corpus should be manually revalidated before any stronger thematic conclusions are drawn.

Table 1. Top terms by total link strength in the keyword co-occurrence network

Rank	Term	Total Link Strength
1	Controlled study	244
2	Chemistry	187
3	Mass fragmentography	163
4	Chemical composition	157
5	Plant extract	127
6	Unclassified drug	123
7	Antioxidant	118
8	Polycyclic aromatic hydrocarbons	113
9	Environmental monitoring	109
10	Aromatic compounds	105

The most connected terms indicate a strong analytical and characterization orientation. Chemistry, chemical composition, plant extract, antioxidant, volatile organic compounds, and mass-spectrometric terminology are consistent with a literature focused on identifying plant constituents and assessing biological or environmental contexts. However, the co-occurrence map should be interpreted together with manual article-level screening because bibliometric keywords can reflect database indexing conventions as well as the substantive focus of articles (Donthu et al., 2021; van Eck & Waltman, 2010).

Qualitative synthesis suggests several defensible future directions. At the theoretical level, studies can more explicitly connect biosynthetic pathways, aromatic amino-acid metabolism, plant volatile biosynthesis, and structure-activity relationships (Ouyang & Wu,

2023; Yokoyama, 2024; Pichersky & Gershenzon, 2002; Yang et al., 2016). At the practical level, plant-derived aromatic compounds continue to have potential in pharmaceutical, food, cosmetic, and related applications, provided that extraction, chemical characterization, safety, stability, and sustainability are addressed (Christaki et al., 2012; Gonzalez-Rivera et al., 2023; González-Minero et al., 2023; Mercanoglu Taban et al., 2022; Benhelima et al., 2025). Ethnobotanical and regional plant studies also support the value of documenting plant resources without assuming that traditional use alone establishes pharmacological efficacy (Agour et al., 2025; Oukadir et al., 2024; Osei-Mensah et al., 2023; Sher & Barkworth, 2015).

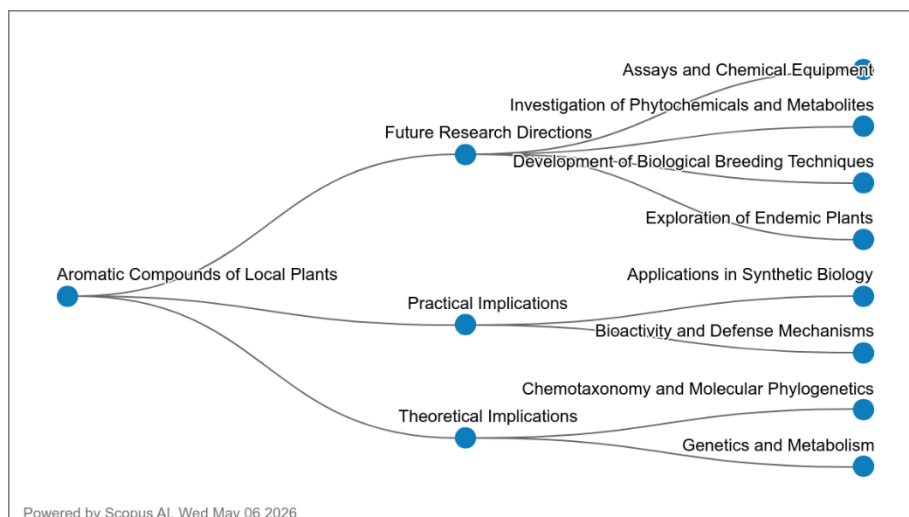


Figure 9. Conceptual synthesis of theoretical and practical implications for future research

Educational implications should be interpreted cautiously. The search strategy did not contain terms for chemistry education, science education, teaching, curriculum, or learning; therefore, the small number of education-oriented records cannot be used to conclude that the global educational literature is scarce. A more defensible implication is that local plant chemistry could be investigated in a dedicated education-focused review as a contextual resource for teaching secondary metabolites, analytical chemistry, structure-property relationships, and sustainability. This is a prospective research direction, not a bibliometric finding of the present search.

Limitations

This review has several limitations that materially affect interpretation. First, Scopus was the only database, so coverage differences relative to other indexing services may alter the corpus (Kumpulainen & Seppänen, 2022). Second, the final retrieval depended on the exact phrase “aromatic compounds of local plants,” which may miss studies that use terms such as native, indigenous, endemic, regional, medicinal, or aromatic plants; conversely, the broad concept of “aromatic compounds” can retrieve chemically aromatic but non-plant-centered literature. Third, restricting the corpus to open-access full text supported qualitative reading but may bias country, source, institution, citation, and thematic distributions. Fourth, Scopus author names, affiliations, and index keywords can contain variants and database-generated terms, so metadata cleaning and thesaurus decisions can affect network structure. Fifth, publication counts and link strengths describe research activity and connectivity; they do not establish the intrinsic quality or future importance of a topic. Finally, the original search was not designed to retrieve science-education literature, so educational implications should be treated as hypotheses for a dedicated follow-up review rather than as a measured gap in the present corpus.

The validity of the 149-document corpus was checked against the operational definition of plant-derived aromatic compounds. Articles focused on industrial aromatic amines, petroleum-derived polycyclic aromatic hydrocarbons, environmental pollutants, and non-plant

aromatic chemistry were excluded from interpretation. The remaining corpus was retained because each article addressed plant resources, plant-derived constituents, volatile fractions, phytochemical characterization, or biological applications related to aromatic plant compounds. The authors acknowledge that future replication using broader synonym-based searches may identify additional relevant studies and therefore recommend periodic corpus updating.

CONCLUSION

This review maps publication performance and thematic structure within a 149-document English-language open-access Scopus subset retrieved using the original exact-phrase strategy. The data show that publication output has increased in recent years and that records are geographically concentrated, with China, the United States, Spain, India, Italy, and several other countries contributing most of the documents in the subset. Country, institution, source, and author counts are performance indicators, while the collaboration and keyword maps provide separate science-mapping views. The keyword co-occurrence network is dominated by analytical and characterization-related terms, but its heterogeneous indexed vocabulary also confirms the need for careful corpus validation, confirmation of the VOSviewer keyword unit, and metadata cleaning.

Substantively, the literature represented in the review supports continued work on phytochemical characterization, plant volatile chemistry, biosynthetic and molecular mechanisms, sustainable extraction, and applications in pharmaceutical, food, cosmetic, and related sectors (Peng et al., 2019; Ouyang & Wu, 2023; Yokoyama, 2024). These directions are presented as evidence-informed opportunities rather than predictions of future importance. Because the review uses one database, an exact-phrase search, and an open-access subset, the conclusions should be interpreted within those boundaries. A dedicated search would be required to evaluate educational applications systematically.

RECOMMENDATION

Future research should first strengthen review design by using broader synonym-based search strings, manually validating plant relevance, reporting complete VOSviewer settings, and testing the robustness of findings across databases where feasible. Substantive studies can then prioritize regionally diverse plant resources, mechanistic links between chemical composition and biological function, standardized analytical methods, and sustainable extraction or production. For science and chemistry education, a separate targeted review could evaluate how local plant chemistry is used in laboratory activities, teaching materials, inquiry, and project-based learning rather than inferring educational scarcity from the present search.

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AUTHOR CONTRIBUTIONS STATEMENT

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
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Jamaluddin	✓	✓		✓			✓	✓	✓					
Agus Ramdani	✓			✓		✓	✓							
Aliefman Hakim		✓		✓								✓		
Aris Doyan		✓		✓								✓		
AA Sukarso		✓		✓								✓		

CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest regarding the publication of this article.

DATA AVAILABILITY

The bibliographic data supporting the findings of this systematic literature review and bibliometric analysis are available from the corresponding author upon reasonable request.

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