Analysis of Research Hotspots and Development Trends in *Polygonatum* Based on CiteSpace

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Abstract [**Objectives**] To analyze the research landscape and hotspots in the field of *Polygonatum* using bibliometric methods, with a focus on the evolutionary shift from traditional tonic applications to modern systematic mechanistic studies. [**Methods**] Using the CNKI and Web of Science Core Collection databases, CiteSpace 6.3.R1 was employed for bibliometric visualization of relevant publications from 2002 to 2024. Systematic analyses were conducted on publication trends, collaboration networks among authors and institutions, keyword co-occurrence, clustering, and burst detection. [**Results**] Research on *Polygonatum* has shown a steady increase. The research focuses on bioactive components such as polysaccharides and steroidal saponins, with a progressive deepening from component extraction and pharmacological evaluation to mechanistic aspects including immune regulation, antioxidant activity, and gut microbiota modulation. Keyword evolution reveals that research hotspots have expanded from early resource classification and chemical profiling to systematic regulatory mechanisms underpinned by multi-omics technologies. [**Conclusions**] *Polygonatum* research is undergoing a paradigm shift from "single-component, single-target" to "multi-pathway, holistic regulation". Future studies should further integrate traditional Chinese medicine tonic theory, elucidate the processing-component-efficacy nexus, and strengthen the integration of multi-omics with clinical translation.

Key words *Polygonatum*, CiteSpace, Bibliometrics, Tonic Chinese medicine, Multi-omics, Gut microbiota

1 Introduction

Polygonatum is a medicinal and edible Chinese herbal medicine, known for its effects of replenishing qi and nourishing yin, strengthening the spleen and moistening the lung, and benefiting the kidney and replenishing essence. It mainly contains polysaccharides, steroidal saponins, flavonoids, and anthraquinones, and exhibits pharmacological activities including anti-inflammatory, immunomodulatory, anti-aging, and metabolic regulatory effects[1]. With the development of the comprehensive health industry, the application of *Polygonatum* in the functional food sector has gradually expanded[2]. However, existing studies have largely focused on individual components or localized mechanisms, lacking a systematic interpretation of its "tonic" effects, and the connection between traditional theories and modern research findings remains insufficiently established. In this study, we employed bibliometric methods to conduct a visualization analysis of literature published from 2002 to 2024 using CiteSpace software, based on the CNKI (China National Knowledge Infrastructure) and Web of Science databases, aiming to reveal the evolutionary patterns, frontier hotspots, and future directions in this research field.

2 Data and methods

2.1 Data sources and search strategies Chinese literature was retrieved from the CNKI database. The search strategy was defined as: subject, keyword, or title containing "黄精" (*Polygonatum*). The search timeframe was set from January 1, 2002 to December 31, 2024 (with the actual coverage starting from August 2002). A total of 5 649 records were initially retrieved. After manual screening to remove news items, announcements, newspaper articles, irrelevant documents, and those with unclear publication years, as well as deduplication, a final total of 3 457 valid articles were included for analysis.

English literature was retrieved from the Web of Science Core Collection database. The search strategy was defined as: TS = "Huangjing" OR TS = "*Polygonatum sibiricum*" OR TS = "*Polygonatum kingianum*" OR TS = "*Polygonatum cyrtonema*" NOT TS = "*Polygonatum odoratum*". The search period was from January 1, 2002 to December 31, 2024, with document types limited to Article and Review, and language restricted to English. After manual screening to exclude studies with unclear research subjects or those not targeting the intended species, and after deduplication, a total of 872 valid articles were included. It should be noted that, because some articles had indexed closely related species as controls or associated research subjects in their keywords, a small number of non-target species names remained in the co-occurrence network even after manual screening; however, this does not affect the overall trend interpretation.

2.2 Data processing and visualization methods Chinese literature was exported in RefWorks format, and English literature in plain text format. The files were renamed as "download_.txt" and imported into CiteSpace 6.3.R1 for data conversion and analysis. The parameters were set as follows: the time span was from January 2002 to December 2024, with a time slicing of one year; the node types included Author, Institution, and Keyword; the g-in-

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dex was set to 20, and Top N was 50. Visualization analyses were performed to generate the author-institution collaboration network, keyword co-occurrence network, clustering map, timeline view, and burst detection map, in order to systematically reveal the research hotspots and evolutionary trends in *Polygonatum*.

3 Results and analysis

3.1 Publication trends As shown in Fig. 1, the overall number of Chinese-language publications on *Polygonatum* research exhibited a fluctuating upward trend from 2002 to 2024, increasing from 83 in 2002 to 691 in 2024. From 2002 to 2013, the field experienced a period of slow growth; starting from 2014, it entered a phase of rapid growth, reaching 680 publications in 2021, which was 4.9 times the number in 2013. After a brief decline in 2022, the numbers continued to rise in 2023 and 2024, reaching 654 and 691, respectively. During the same period, English-language publications increased from 5 to 112, with a higher average annual growth rate than that of Chinese-language publications, albeit from a much lower baseline. These trends indicate that *Polygonatum* research has a solid domestic foundation, with gradually increasing international attention, and has overall entered a phase of rapid development since 2014.

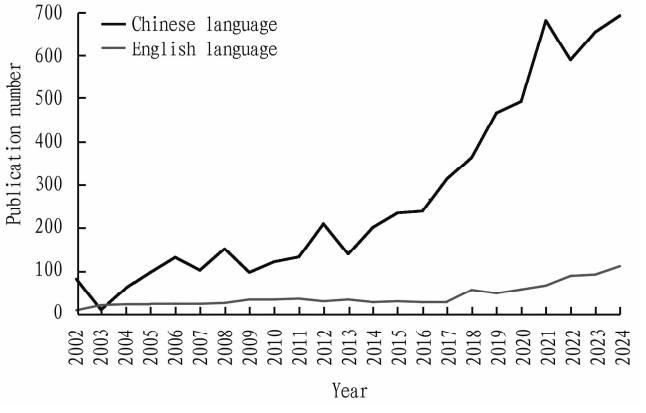


Fig. 1 Trends in annual publication numbers of *Polygonatum* research

3.2 Keyword network characteristics In the keyword co-occurrence network (Fig. 2), the Chinese-language literature (257 nodes, 828 links) exhibited a core-periphery structure. The keywords "黄精" (*Polygonatum*), "多花黄精" (*Polygonatum cyrtonema*), and "黄精多糖" (*Polygonatum* polysaccharides) had high betweenness centrality values (0.74, 0.21, and 0.15, respectively), and showed close co-occurrence with terms such as "炮制" (processing), "皂苷" (saponins), "药食同源" (medicinal and edible), and "免疫调节" (immunomodulation). In the English-language literature (297 nodes, 1 117 links), high-frequency keywords were concentrated on *Polygonatum sibiricum*, *Polygonatum cyrtonema*, oxidative stress, and gut microbiota, while mechanism-related keywords covered a broader range (Tables 1 and 2).

Table 1 High-frequency keywords of *Polygonatum* Chinese-language literature

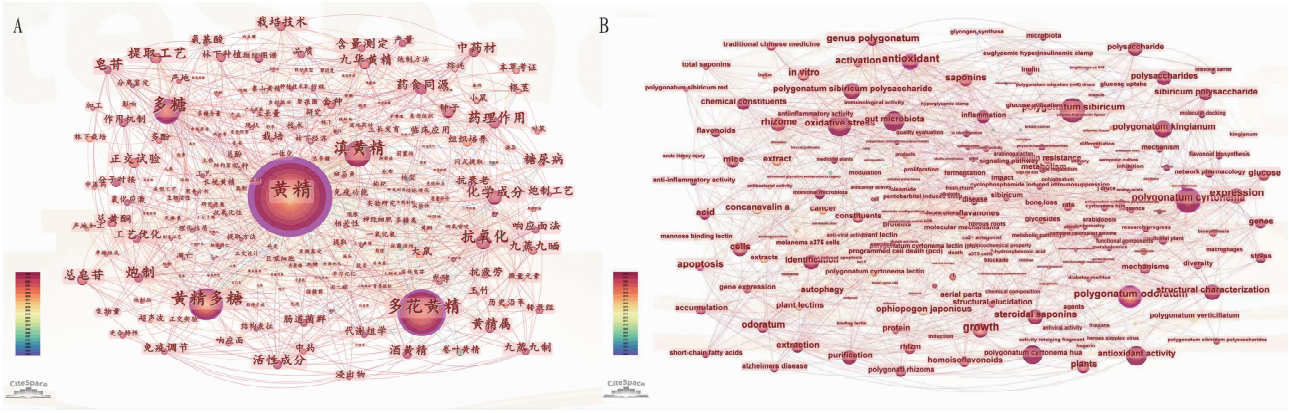
No.	Keywords	Betweenness centrality	Frequency
1	黄精	0.74	1 070
2	多花黄精	0.21	453
3	黄精多糖	0.15	289
4	多糖	0.14	214
5	滇黄精	0.09	177
6	化学成分	0.04	82
7	抗氧化	0.04	69
8	炮制	0.03	67
9	药理作用	0.02	65
10	提取工艺	0.02	57

Table 2 High-frequency keywords of Polygonatum English-language literature

No.	Keywords	Betweenness centrality	Frequency
1	*Polygonatum sibiricum*	0.04	68
2	*Polygonatum cyrtonema*	0.15	60
3	Oxidative stress	0.03	58
4	*Polygonatum odoratum*	0.10	56
5	Antioxidant activity	0.03	44
6	*Polygonatum cyrtonema* Hua	0.00	41
7	Gut microbiota	0.01	40
8	Antioxidant	0.12	39
9	*Polygonatum kingianum*	0.05	34
10	*Polygonatum sibiricum* polysaccharide	0.01	33

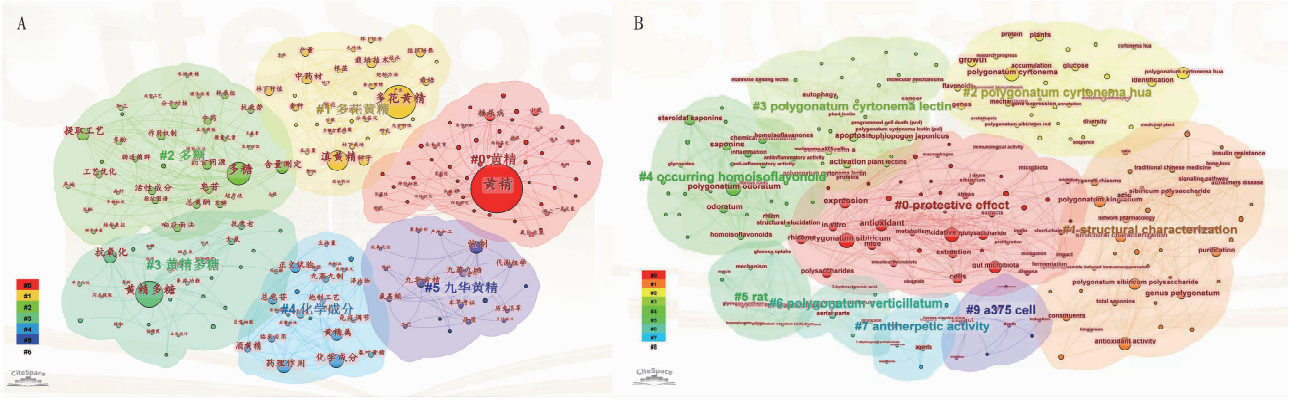
3.3 Keyword clustering and timeline distribution Cluster analysis revealed that the Chinese-language literature formed six clusters (Q = 0.377 6, S = 0.690 2), which could be categorized into three groups: component-processing-pharmacology integration (clusters #0, #4, #5), polysaccharide extraction and activity (clusters #2, #3), and species resources (cluster #1). The English-language literature formed nine clusters (Q = 0.531 6, S = 0.818 3), covering four categories: pharmacological mechanisms (clusters #0, #5, #7, #9), component structure (clusters #1, #4), species physiology (clusters #2, #6), and lectin-related cellular mechanisms (cluster #3), indicating a more refined and in-depth mechanistic exploration.

The timeline view (Fig. 4) shows that keywords such as "polysaccharides" and "saponins" span the entire period in both Chinese- and English-language literature, whereas terms like "data mining", "gut microbiota", and "metabolomics" became significantly denser on the right side of Chinese clusters #0 and #3 during 2020 – 2024. In the English literature, keywords such as "gut microbiota" and "metabolomics" have recently exhibited enlarged nodes and a rightward shift within cluster #0 ("protective effect"), indicating that multi-omics and microecological regulation are emerging as common frontiers.



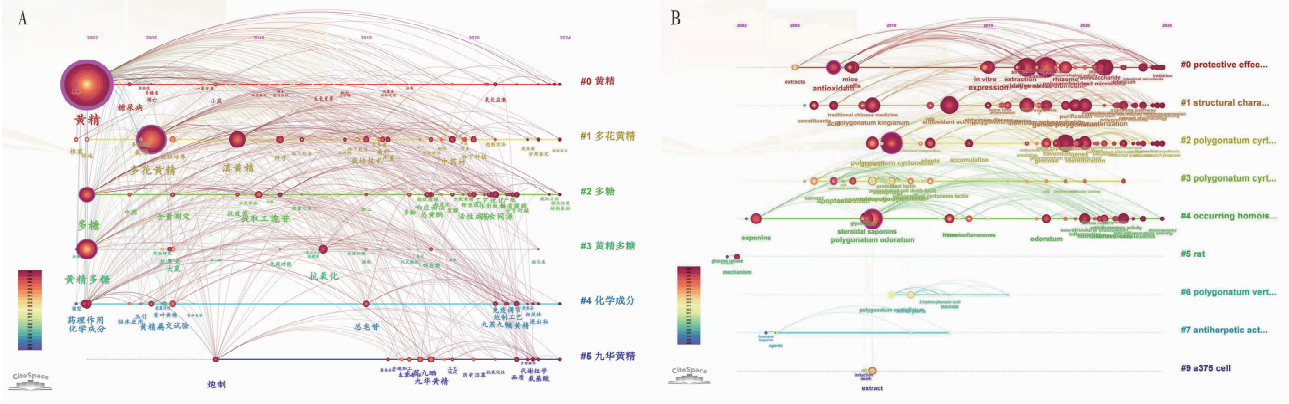
NOTE A. keywords of Chinese-language literature; B. keywords of English-language literature.

Fig. 2 ***Polygonatum*** **Chinese-language and English-language keyword co-occurrence analysis**



NOTE A. Chinese-language literature keywords; B. English-language literature keywords.

Fig. 3 **Keyword clustering map of Chinese-and English-language literature on** ***Polygonatum***

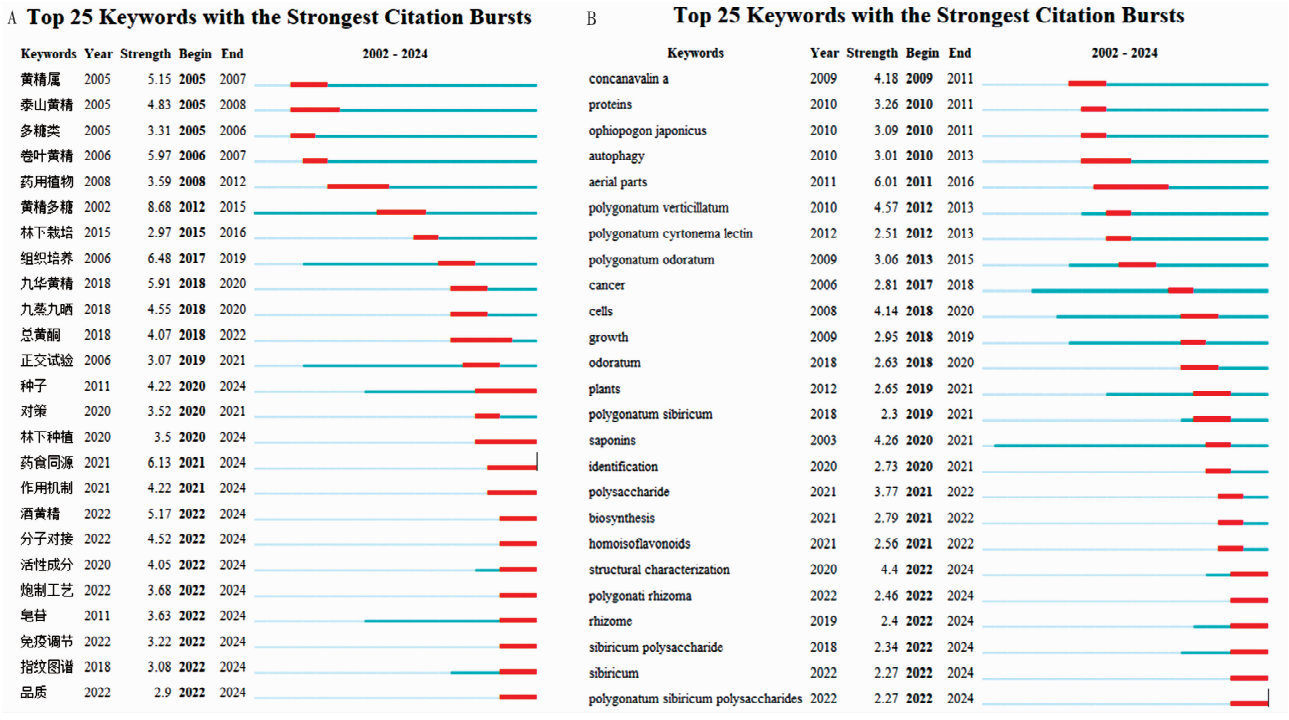


NOTE A. Chinese-language literature keywords; B. English-language literature keywords.

Fig. 4 **Timeline view of keywords in Chinese- and English-language literature on** ***Polygonatum***

3.4 Burst keywords Burst detection analysis identified 25 burst keywords in both the Chinese- and English-language literature (Fig. 5). In the Chinese literature, early bursts (2005 – 2007) were dominated by species-related terms such as "*Polygonatum* genus" and "*Polygonatum* from Mount Tai". During 2012 – 2015, the term "*Polygonatum* polysaccharides" exhibited the highest burst strength (8.68). From 2017 to 2020, the focus shifted to cultivation and processing-related terms such as "under-forest cultivation" and "repeated steaming and drying" (nine cycles). In the period from 2020 to 2024, burst keywords were predominantly application- and quality assessment-oriented, including "medicinal and edible", "molecular docking", and "fingerprint analysis". In the English literature, early bursts (2009 – 2013) centered on cellular mechanism-related terms such as "concanavalin A" and "autophagy", followed by a shift toward disease model-related terms such as "cancer" and "growth" during 2017 – 2020. Recently (2020 – 2024), bursts have been highly concentrated on structural characterization and biosynthesis of bioactive

components, including "saponins", "polysaccharide", and "structural characterization". Overall, Chinese hotspots have expanded from species resources to cultivation, processing, and medicinal-edible applications, whereas English hotspots have shifted from cellular mechanisms toward structural characterization of components. In recent years, both bodies of literature have demonstrated a trend toward empirical and fine-grained research.

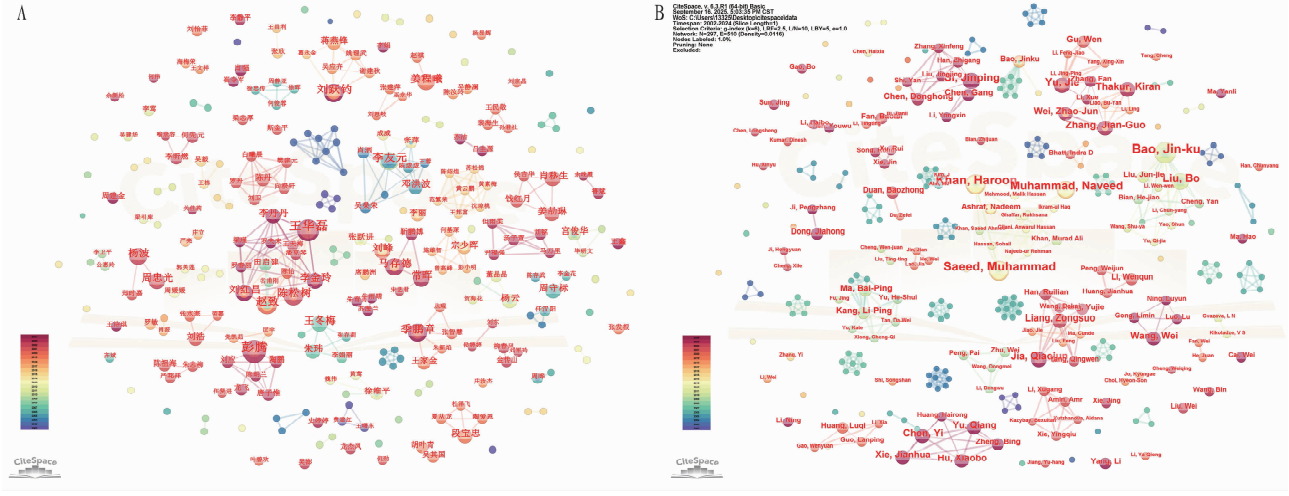


NOTE A. Chinese-language literature keywords; B. English-language literature keywords.

Fig. 5 Burst keyword analysis in Chinese- and English-language literature on *Polygonatum*

3.5 Collaboration networks of authors and institutions

The author collaboration network (Fig. 6) shows that the core authors in the Chinese-language literature are Peng Teng (22 articles), Wang Hualei (19 articles), Liu Yuejun (15 articles), and others, forming several teams centered around core nodes. However, inter-team connections are sparse, with many isolated nodes at the periphery, resulting in overall limited connectivity. In the English-language literature, the core authors are Bao, Jin-ku (14 articles), Saeed, Muhammad (13 articles), Khan, Haroon (13 articles), and others, with small and scattered subgroups, and international collaboration primarily taking the form of bilateral links.



NOTE A. Chinese-language literature authors; B. English-language literature authors.

Fig. 6 Author collaboration network in Chinese- and English-language literature on *Polygonatum*

In the institution collaboration network (Fig. 7), Chinese institutions are predominantly traditional Chinese medicine colleges and research institutes, with the College of Pharmacy of Anhui University of Chinese Medicine (33 articles), the Institute of Medicinal Plants of Yunnan Academy of Agricultural Sciences (25 articles), and the College of Agriculture of Guizhou University (22 articles) ranking among the top, exhibiting a regional clustering pattern centered around the main production areas (Anhui, Yunnan, Guizhou, and Hunan). In the English-language literature, the Chinese Academy of Sciences (38 articles), Hunan University of Chinese Medicine (31 articles), and Sichuan University (28 articles) are among the most productive, indicating a relatively high level of participation by domestic institutions in international journals. However, the connections among institutional nodes in both Chinese- and English-language networks are sparse, with limited inter-institutional and inter-regional collaboration, presenting an overall fragmented pattern characterized by "small-scale clustering and large-scale dispersion".

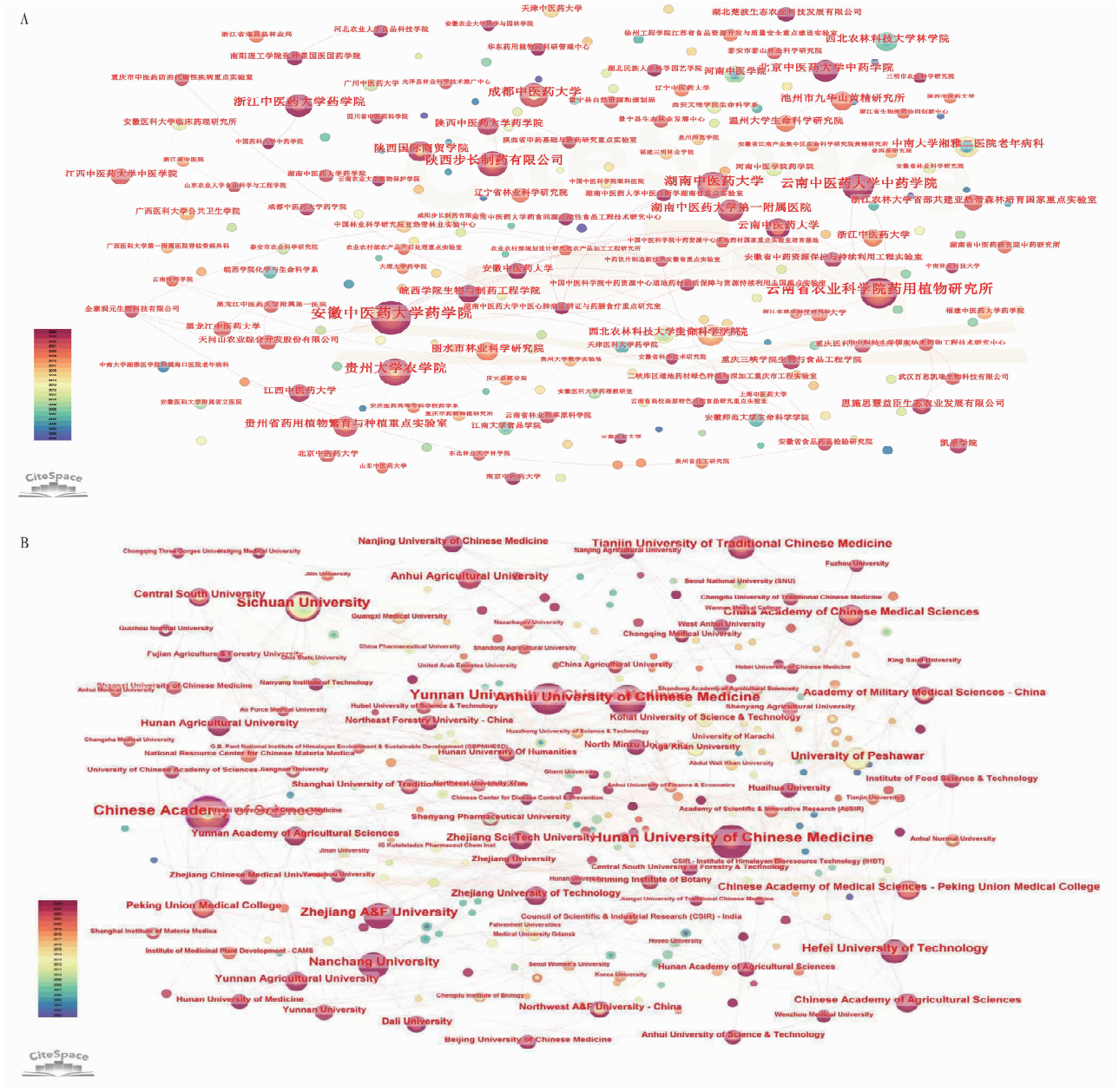


Fig. 7 Institution collaboration network in Chinese- and English-language literature on *Polygonatum*

4 Discussion

4.1 Multiple driving factors for the rapid rise of *Polygonatum* research The rapid rise of *Polygonatum* research after 2013 was not a result of linear academic accumulation, but rather the concerted effect of three driving forces: policy, industry, and technology. In 2002, *Polygonatum* was included in the list of medicinal

and edible substances, which institutionally dismantled the barrier between medicinal and food applications. The expansion of the comprehensive health industry activated research demands in the field of functional foods. Meanwhile, the maturation of high-throughput sequencing and multi-omics technologies enabled *Polygonatum* research to bypass the "single-compound-single-target" phase and enter the realm of systems biology integration at an early stage[3-4].

4.2 Comparison of research pathways with other tonic Chinese medicines Compared with *Astragalus membranaceus* and *Panax ginseng*, *Polygonatum exhibits* a "late-comer differentiation" pathway. The research on *A. membranaceus* and *P. ginseng* has long followed the classic paradigm of "single-component isolation to clinical validation", with sustained focus on signature compounds such as astragaloside IV and ginsenosides[5-6]. In contrast, owing to the structural complexity of its polysaccharides and the difficulty in preparing individual components, *Polygonatum* research has predominantly taken its complex polysaccharide mixtures as research subjects, with emphasis on elucidating its holistic effects from the perspectives of structural diversity, gut microbiota metabolism, and systemic regulation[7]. However, *Polygonatum* research has lagged considerably in randomized controlled trials (RCTs) and real-world studies[8], and its advantage of "multi-component, multi-target" has paradoxically become a burden in evidence-based evaluation[9-10].

4.3 Evolutionary characteristics of research hotspots and Sino-foreign differences From the perspective of hotspot evolution, both Chinese- and English-language literature have centered on polysaccharide research, yet with marked divergence in pathways. International research is progressively shifting from crude extract activity screening toward precise structural elucidation and structure-activity relationship investigation, as evidenced by burst keywords such as "structural characterization" and "biosynthesis", indicating that component refinement and exploration of biosynthetic pathways have become frontiers. In contrast, Chinese literature exhibits distinctive focal strengths in component quality control and processing-related transformation, with burst keywords such as "processing technology", "wine-processed *Polygonatum*", and "fingerprint analysis" being particularly prominent, although the depth of structural characterization still lags behind the international level. In terms of pharmacological mechanisms, English-language cluster #0 ("protective effect") spans across all time periods, with a recent high concentration on system-level regulatory themes such as oxidative stress, gut microbiota, and inflammation, reflecting an evolution from micro-cellular mechanisms to macro-systemic regulation. In Chinese literature, terms such as "immunomodulation" and "antioxidant" have remained stable over the long term, whereas "gut microbiota" only became significantly denser after 2020, lagging behind the international community by approximately 2-3 years. Notably, the burst keyword "Alzheimer's disease" in the English literature echoes the node "neuroprotection" within cluster #0, while the corresponding cluster and burst keywords in Chinese literature are comparatively weak, suggesting that the neuroprotective mechanisms in Alzheimer's disease may represent an international frontier that has not yet been fully pursued domestically.

4.4 Gut microbiota research provides an opportunity for modern translation of TCM theory The focus on gut microbiota in *Polygonatum* research offers an opportunity for the modern translational interpretation of the TCM theory of "spleen governs transportation and transformation". The degradation of polysaccharides by gut microbiota and the production of short-chain fatty acids (SCFAs) can be regarded as a microbiological expression of the "transportation and transformation" function[11-12]. The selective fermentation characteristics of *Polygonatum* polysaccharides in the colon make them an ideal vehicle for bridging the "spleen-tonifying" theory with the "microbiota-metabolism" axis[13-14]. However, the current connection remains at the level of conceptual analogy. To elevate this theoretical association from metaphorical correspondence to scientifically testable hypotheses, it is necessary to deeply integrate TCM syndrome indicators with multi-omics data of the gut microbiota[15].

4.5 Fragmented collaboration networks and bottlenecks in interdisciplinary synergy The fragmented pattern of collaboration networks reflects the underlying predicament of disciplinary organization. Research efforts are predominantly concentrated in local institutions located in the main production areas, exhibiting a "resource-based geographical agglomeration". This configuration has become increasingly limiting in the current phase of multiomics integration: the microbiological expertise, bioinformatics capabilities, and clinical resources required for gut microbiota research are distributed across different institutions, and the decentralized, multi-centric structure impedes cross-institutional synergy[16-17]. As a result, studies often remain at a routine level of "administration-microbiota diversity measurement", lacking longitudinal functional tracking and closed-loop verification[18].

4.6 The structural contradiction between the medicinal and edible attribute and evidence-based evaluation The dual identity of *Polygonatum* as both a medicinal and edible substance has expanded its application scenarios, yet it has also blurred the boundary between "food" and "drug". Food-oriented research emphasizes qualitative exploration of bioactive components, whereas pharmaceutical development demands rigorous dose-response validation, with a lack of effective integration between the two approaches[19-20]. More fundamentally, the "tonifying qi and nourishing yin" effect of *Polygonatum* falls within the domain of holistic functional regulation, corresponding to suboptimal health and chronic disease recovery, which makes it difficult to fit into the single-disease diagnostic framework of modern medicine[21-22]. This predicament poses a dilemma in the selection of endpoint indicators for RCT design, trapping the field in a long-standing structural contradiction of "abundant mechanisms, scarce evidence"[23].

4.7 Future research directions and prospects Future research should establish a progressive validation framework linking "bioactive component clusters-biomarkers-clinical endpoints" to

provide evidence for the precise application of *Polygonatum* in the prevention and treatment of specific chronic diseases[24-25]; promote cross-regional and interdisciplinary collaborative efforts to overcome the bottlenecks in cooperation networks; and deepen the investigation of the associations between TCM syndromes and gut microbiota phenotypes[26]. This study is a bibliometric analysis based on the CNKI and Web of Science databases; owing to the limitations in database coverage and the sensitivity of algorithm parameters, the relevant conclusions should be interpreted in conjunction with experimental and clinical evidence.

5 Conclusions

Polygonatum research has gradually evolved from traditional empirical applications into a multidisciplinary and integrated research system. Research hotspots have shifted from chemical component analysis to system-level regulatory mechanisms, demonstrating an evolutionary trend from "single-component, single-target" to "multi-component, multi-pathway, holistic regulation". In the future, guided by the TCM tonic theory, efforts should be made to deepen investigations into the processing-component-efficacy relationship, and to integrate multi-omics technologies with clinical evaluation systems, thereby promoting the development toward precision application and high-quality translational research.

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