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ORIGINAL PAPER

Bibliometric evaluation of the status of *Picea* research and research hotspots: comparison of China to other countries

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Abstract *Picea* Mill. species are important components of boreal and subalpine forests. They have a wide geographical range in the Northern Hemisphere, extending from the Eurasian continent to North America. In this study, publications on *Picea* species from 2002 to 2016 were identified via the Web of Science (WoS) and the China National Knowledge Infrastructure (CNKI) databases, and subjected to relationship network visualization using CiteSpace software. This study represents the first such analysis of *Picea* and provides a reference for bibliometrics in forest tree species research. The results show that the total number of publications on *Picea* archived in WoS was 20,958 and that the number of papers published annually has increased over time, peaking at 1725 in 2013. The studies were mainly conducted in North America, Europe and Asia; among them, Canada published the most papers and showed the strongest betweenness centrality (0.11). Among research institutions, the Swedish University of Agricultural Sciences in Uppsala had the highest publication record. The research contributions of the Chinese Academy of Sciences, the Chinese Academy of Forestry, and Beijing Forestry University have improved rapidly in recent years, greatly enhancing the international impact of Chinese research in this field. The research contents were grouped into five categories: forest ecosystems, pest resistance, extraction and functional analyses of active ingredients from various plant organs, nursery and afforestation techniques, and timber quality research. In China, the number of papers from the CNKI database was 4532, increasing at an even pace. The research topics on *Picea* included forest ecosystems, seedling and afforestation techniques, basic studies on individual species and populations, and pests and diseases. Within and outside China, hotspots in *Picea* research included the relationships between *Picea* and environmental factors, and the genomic sequences of *Picea*.

Keywords *Picea* · Bibliometrics · Hotspots · Web of science · Chinese National Knowledge Infrastructure

Introduction

Picea (family Pinaceae) species are among the Earth's oldest gymnosperms (Brown et al. 2014) and fossils of *Picea* have been found in late Cretaceous strata. Changes in global temperatures have affected the genus over time, leading to the current distribution (Luo et al. 2012). Some 34 *Picea* species exist worldwide in the cold temperate/temperate alpine and sub-alpine zones of the Northern Hemisphere (Farjon 2001) and constitute the Northern Hemisphere's most important timber resource (Ru et al. 2016). Due to their high economic value and important roles in climate and environment, *Picea* species have been extensively studied, with particular focus on ecology (Pollock and Payette 2010), phylogeny and evolution

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(Lafontaine et al. 2010), community composition (Serafinaviciute and Stakènas 2009), growth and physiological characteristics (Gamache and Payette 2004), and pest and disease resistance (Jönsson et al. 2009). However, there have been no systemic summaries or analyses of *Picea*-related literature.

The progress of civilization has led to rapid growth in scientific fields, accompanied by exponential growth in the number of scientific publications (Vasudevan et al. 2016). In 1966, the term "bibliometrics" was to describe the application of mathematical and statistical methods to analyse books and other printed media (Glänzel 2003). With the development of science and technology, and the arrival of the era of information and networking, bibliometric methods have been extensively applied to various scientific fields, including biology and other life sciences, environmental science, and medicine to investigate developmental courses, forecast trends and identify research hotspots (Hou et al. 2015). For example, Huai and Chai (2016) used bibliometric methods to analyse water security issues, they found that "water security", "water safety" and "climate change" were the most common keywords and that water security and climate change had a closing interaction. By applying similar methods, Xiang et al. (2017) examined the progress of studies on non-point source pollution to increase understanding of the characteristics of such studies, visualize global trends, and define future research directions. Haunschild et al. (2016) demonstrated that, among climate change-related topics, continental biomass and climate modelling were major research areas in recent years, whereas adaptation to, mitigation of, risk of, and vulnerability to global warming had been little studied, although publications on these topics have exhibited exponential growth since 2005. Wei et al. (2016) used bibliometric methods to assess global research productivity in the field of spinal surgery and found that in the last decade, studies on spinal surgery showed gradual growth. The United States contribution was driven by institutions with strong publication records. Great advances have been also made in this field in both China and South Korea. However, according to our review of the literatures, no studies has yet applied bibliometrics to forest plants, including *Picea* species.

In this study, we applied bibliometric methods to the global literatures on *Picea*, focusing on studies published over the last 15 years. We analysed and summarized the progress and trends of research on this genus based on the impact of publications on the scientific community, to reveal the past, present, and future of this field. The results should offer insight into how to approach research gaps and guide *Picea* researchers to the most influential literature. Furthermore, this study examines differences between China and the rest countries of the world in *Picea*. The findings should provide a key reference for new researchers seeking to familiarize themselves with the *Picea* literatures and research trends, and help Chinese research in this field to stay current with research elsewhere.

Materials and methods

Data sources

The Science Citation Index (SCI) database of the Web of Science ™ (WoS) Core Collection, offered by Thomson Reuters, was used as the data source for the foreign language literatures, and the China National Knowledge Infrastructure (CNKI) database was used as the data source for Chinese language literatures. Papers published in 2002–2016, (the data retrieval deadline was set to January 11, 2017), with "*Picea*" or "spruce" in the title, abstract or keywords were retrieved. The searching results were then examined individually to remove irrelevant publications.

Usage of CiteSpace software

The visualization software CiteSpace, which is a Java-based scientific visualization software package developed and provided by Chen (2006), was used for analysis. Three types of network analyses embedded in CiteSpace were used to research the literatures on *Picea*: (1) collaboration network analysis, a type were searched using country and affiliated institution of authors as the analysis units; (2) keyword co-occurrence analysis, in which co-occurrence relationships were established by extracting keywords from the title, abstract, or elsewhere in the text (Song et al. 2016); and, (3) literature co-citation analysis, in which references cited in different articles are used as the analyzed object, and the complex co-citation web-like relationships among the analyzed objects are simplified to relationships among a smaller number of groups (Chen et al. 2015).

Statistical analysis

The main evaluation indexes used in the study were as follows: (1) number of publications, which is the total number of publications on *Picea* published in 2002–2016 by WoS and CNKI databases, and the number of publications published by a scientific research institution or country in 2002–2016; (2) betweenness centrality, is a measurement of the extent to which a node lies on the shortest path between pairs of other nodes, indicating the relative importance of the nodes in the network structure; (3) burst nodes, which is the red nodes in the network, reflecting the increase suddenly of the publications number

or a paper cited frequency in a short time; (4) keywords frequency, referring to the frequency of one word expressing core content of literature; and, (5) high cited literature frequency, index for the times of an article was cited by others.

All the data in this study were analysed by Excel 2010 software. The visualization network diagram was generated using CiteSpace 3.8 R7 and CiteSpace 4.0 R5, and the line graphs of the numbers of publications were plotted by Origin 9.0.

Results

Progress in studies on *Picea* species based on the WoS database

Number of publications on Picea

A total of 20,958 *Picea*-related papers were retrieved for analysis. Research on *Picea* worldwide has risen steadily over the last 15 years (Fig. 1). In 2002–2013, the number of publications showed an overall upward trend, with two small peaks (i.e., 1395 and 1725 papers) in 2008 and 2013. In 2014–2016, the number decreased slightly, possibly because the upper boundary of the literature search was set to January 11, 2017, such that the articles published in 2015 and 2016 had not yet been fully archived. The growth curve of the existing literature suggests that a fluctuating trend might emerge in the future.

Collaboration among countries and institutions on publications of Picea species

To determine the contribution of each country and its institutions to *Picea* research, publications number, betweenness centrality and burst nodes were examined based on the countries and institutions of the authors using a visualized collaboration network generated by CiteSpace (Fig. 2). The results showed that 75 institutions from 44 countries carried out studies on *Picea* during the period of 2002–2016; the top 20 countries and institutions were analysed further (Table 1). The majority of countries in the top 20 were in Europe (16), and a few countries from North America and Asia. Among the countries, Canada had the greatest contribution to the field with 3018 publications and a high betweenness centrality (0.11), followed by the United States (2567). Germany, Finland, and Sweden also produced significant numbers of publications: 1597, 1553 and 1521, respectively. China's contribution was ranked 6th (1098). Among the top 20 institutions, six were Canadian, prompted Canada having the most publications in this area. The Swedish University of Agricultural Sciences was the most prolific institution with 652 publications. The red nodes in Fig. 2, such as China and Poland, and some institutions, are burst nodes. For example, in 2015–2016, the number of publications from China increased sharply with 23.8474 burst strength, mainly because Chinese research institutions, such as the Chinese Academy of Forestry, and Beijing Forestry University, increased their research on *Picea* species.

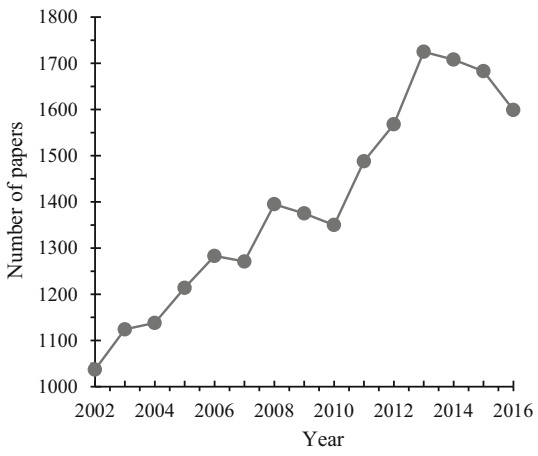

Fig. 1 Number of publications on *Picea* species

Analysis of keywords associated with publications on Picea

The frequencies of keywords were investigated using CiteSpace. The threshold value was adjusted to 130, i.e., the 130 most frequently used keywords in each year were used to generate a co-occurrence visualization network with a total of 330 nodes and 298 connection lines (Fig. 3). Twenty-one clusters comprised the keywords network, which were further categorized into five research topics (Table 2). Keywords from Group 1 were related to the effects of biotic and abiotic factors in ecosystems on growth and to the response by *Picea* to the environment. Group 2 included keywords related to the prevention and control of pests and diseases. The keywords in Group 3 were concerned with active ingredients and their functions extracted from *Picea.* Group 4 keywords related to nursery and afforestation techniques, and Group 5 to the cracks, lignin and wood quality of spruce timber.

To better understand *Picea* research hotspots, 54 keywords with frequencies exceeding 200, were further investigated (Table 3). The results were: (1) *Picea abies* (L.) H. Karst. topped the list at 4532. *P. abies* may be a model species in *Picea*; (2) many high-frequency keywords related to *Picea* ecosystems (e.g., "boreal forest", "growth", "spruce", "forest", "ecosystems", "forest management", "climate-change", "soil", "nitrogen", and "temperature"), and the research scope was

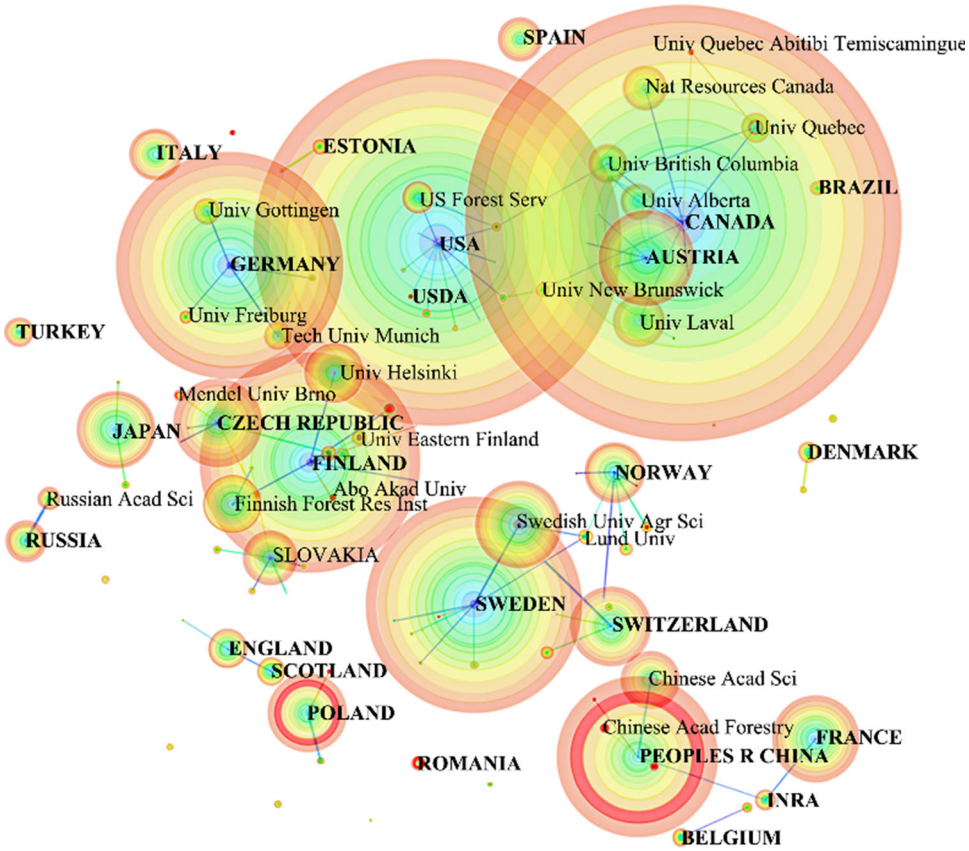

Fig. 2 The collaboration network of countries and institutions that published studies on *Picea* species. In this network, each node (circle) represents a country or institution, (all capital letters denote countries; the first letter capitalized denotes institutions); larger nodes correspond to higher numbers of publications. A line connecting two nodes indicates that the two have a collaborative relationship, and nodes in red are burst nodes

comprehensive. The influence of environmental factors on spruce forests were a focus of more in-depth studies, indicating the importance of environmental factors to the growth of spruce; and, (3) many high-frequency keywords were associated with spruce timber (e.g., "wood", "coarse woody debris", "density" and "lignin").

Analysis of co-citations in highly cited Picea references

Co-citation analysis is a critical part of visualization analysis as it reveals the most influential literature in a given research field. The top 65 most cited publications in each year were used to generate the literature co-citation network (Fig. 4). The network consisted of 817 nodes and 2291 links. Blue to yellow represents the year of publication from 2002 to 2016. The 817 nodes were sorted into 22 clusters and classified into five research areas: (1) genetics and breeding (cluster IDs #0, #13, #19). Many of the nodes were yellow, reflecting the popularity of genome and morphology studies; (2) plant diseases and insect pests, many nodes exhibited cold colours (cluster IDs #2, #20, #23); (3) the economic value of spruce as timber (cluster IDs #11); (4) spruce community structure, the nodes were primarily cool colours (cluster IDs #1, #3, #6, #8, #12, #14, #16); and, (5) the influence of the environment, including climate change, on *Picea* growth (cluster IDs #4, #5, #7, #9, #10, #15, #18, #24). Studies on the interaction between *Picea* and their environment increased over time, many nodes were yellow.

In addition, the most highly cited literature from the 20,958 papers on *Picea* were identified. The top 10 papers are shown in Table 4. The studies cover four of the previously mentioned areas. Five of the 10 highly cited studies were related to spruce wood. Three papers addressed forest ecosystems under climate change. Wermelinger (2004) authored one highly cited article on spruce bark beetle. Among these papers, the most highly cited study was "*The Norway spruce sequence and conifer genome evolution*" by Nystedt et al. (2013), published in the journal *Nature*. This paper described the whole genome sequence of *P. abies*, with 480 citations in a short time since publication and therefore having considerable influence, reflecting the many detailed and molecular studies on *Picea* through the continuous development of technology.

Analysis of the progress in *Picea* research based on the CNKI database

Analysis of the number of publications

A total of 4532 publications by Chinese researchers were in the CNKI (China National Knowledge Infrastruture)

Table 1 Top 20 countries and institutions in terms of publications on *Picea*

Countries	Number of papers	Betweenness centralities	Burst strength	Institutions	Number of papers	Betweenness centralities	Burst strength
Canada	3018	0.11	–	Swedish Univ Agr Sci	652	0.00	7.4989
USA	2567	0.07	–	Univ Helsinki	452	0.00	–
Germany	1597	0.00	–	Finnish Forest Res Inst	434	0.00	–
Finland	1553	0.02	–	Chinese Acad Sci	413	0.00	–
Sweden	1521	0.01	–	Univ Laval	395	0.01	–
China	1098	0.01	23.8474	Nat Resources Canada	357	0.00	–
Austria	714	0.00	–	Univ British Columbia	304	0.04	–
Czech Republic	683	0.01	–	Univ Alberta	298	0.06	–
France	652	0.01	–	Univ Quebec	275	0.00	5.9493
Switzerland	612	0.00	–	US Forest Serv	253	0.00	–
Poland	593	0.00	9.2046	Tech Univ Munich	215	0.00	–
Japan	532	0.06	–	Univ Gottingen	203	0.00	–
Norway	478	0.01	–	Russian Acad Sci	198	0.00	–
Italy	415	0.00	–	Lund Univ	173	0.01	–
Slovakia	402	0.01	3.3061	Univ New Brunswick	146	0.03	–
Spain	353	0.00	–	Univ Freiburg	128	0.00	–
Russia	338	0.00	–	Univ Eastern Finland	116	0.00	–
England	301	0.00	–	Abo Akad Univ	108	0.00	–
Scotland	252	0.00	3.3147	Norwegian Univ Life Sci	103	0.00	–
Turkey	250	0.00	–	Acad Sci Czech Republic	100	0.00	17.375

database between 2002 and 2016 (Fig. 5). For 2002–2003, 152 papers per year were identified. The number of publications increased to 219 in 2006. In 2007, the number rose sharply to 305, whereas over 2007–2016, the numbers increased with fluctuations in 2-year cycles. Although the list was incomplete for 2016, 407 publication were the highest for this year. The results show that the number of publications on *Picea* in China increased steadily over the study period, indicating that increasing numbers of researchers were focusing on *Picea* species.

Analysis of the keywords associated with publications on Picea

The keyword network visualization included 428 nodes and 198 connection lines. In total, 56 keywords with frequencies exceeding 30 were found (Fig. 6). The node of "*P. crassifolia*" was the largest (i.e., this keyword was associated with the most studies). In terms of high-frequency keywords, we found the following: (1) *Picea* species have been extensively studied; associated keywords included "*P. crassifolia*", "spruce", "*P. schrenkiana*", "*P. koraiensis*", "*P. mongolica*", "*P. likiangensis*", "*P. jezoensis*", "*P. abies*", "*P. schrenkiana*", "*P. balfouriana*"; (2) Spruce distribution most intensively investigated were indicated by the keywords "Qilian Mountains" and "Changbai Mountains"; (3) Spruce forest ecosystems have been extensively studied and the associated high-frequency keywords accounted for 51.8% of the 56 keywords (e.g., "spruce forest", "stand", "biomass", "natural regeneration", "forest ecosystem", "litter", "community structure", "carbon storage", "elevation gradient", "tree rings", and "climate change"); (4) Nursery and reforestation techniques of *Picea* have been intensively investigated; high-frequency keywords were "breeding technology", "species introduction" and "afforestation"; (5) Some basic studies on individual plants and populations of *Picea* have also been performed, with keywords such as

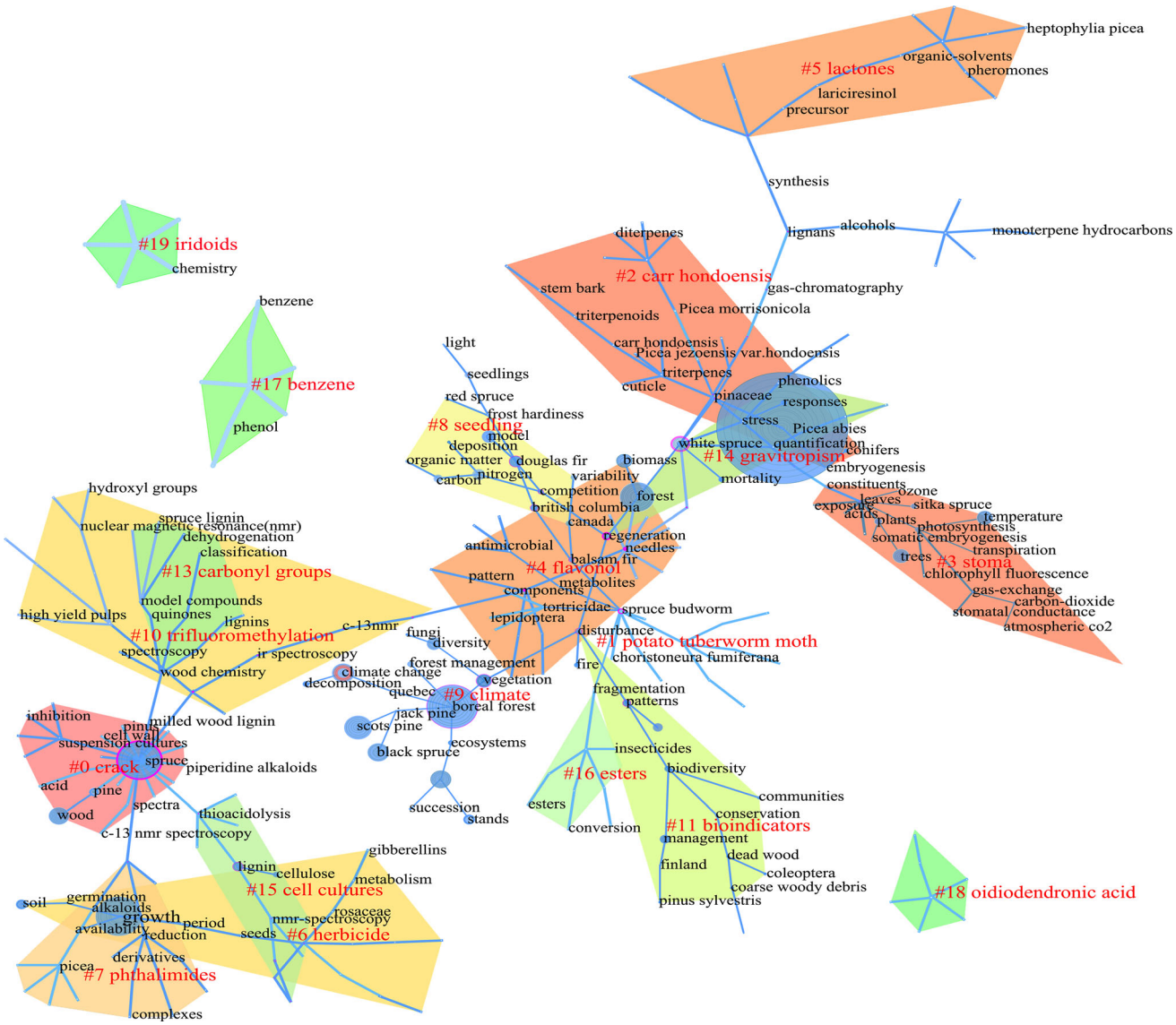

Fig. 3 Keyword co-occurrence visualization network. The size of a node represents the frequency of the keyword and the thickness of a connection line between two nodes reflects the number of co-occurrences of the two keywords. Nodes in areas of the same colour were grouped together (the name of the group is indicated in the red tag)

Table 2 Five research topics based on keywords from Web of Science

Group ID	Group label	Cluster#
1	Interaction between *Picea* and growth environments	#2 carr hondoensis, #18 oidiodendronic acid, #14 gravitropism, #11 bioindicators, #3 stoma, #9 climate
2	Disease and pest resistance	#19 iridoids, #17 benzene, #20 pheromone synthesis, #6 herbicide, #7 phthalimides, #12 enantiomeric composition, #1 potato tuberworm moth
3	Extraction of active ingredients from various organs	#4 flavonol, #5 lactones, #16 esters
4	Sexual and asexual reproduction	#15 cell cultures and #8 seedling
5	Timber	#0 crack, #10 trifluoromethylation, #13 carbonyl groups

Table 3 High-frequency keywords in publications on *Picea*

Keywords	Frequencies	Keywords	Frequencies	Keywords	Frequencies
Picea abies	4532	Diversity	506	Ecosystems	279
Boreal forest	1877	*Pseudotsuga menzies*	485	Canada	270
Growth	1532	Management	462	Drought	268
Spruce	1327	Soil	435	Cellulose	263
Forest	1182	Stands	417	Forest management	260
Scots pine	1036	Carbon	403	Photosynthesis	256
Climate change	936	*Pinus*	398	Fire	249
Picea mariana	864	Lignin	396	Density	246
Dynamics	802	Patterns	382	Coarse woody debris	239
Wood	786	Biodiversity	379	Productivity	233
Temperature	708	Regeneration	360	Conservation	230
Trees	674	Responses	358	Variability	230
Model	635	Plants	352	Quality	226
Vegetation	618	British Columbia	326	Spruce wood	221
Biomass	597	*Picea sitchensis*	314	Spruce budworm	218
Pinus sylvestris	573	Decomposition	300	Mechanical properties	213
Nitrogen	529	Disturbance	299	Deposition	206
Picea glauca	511	Seedlings	287	Populations	203

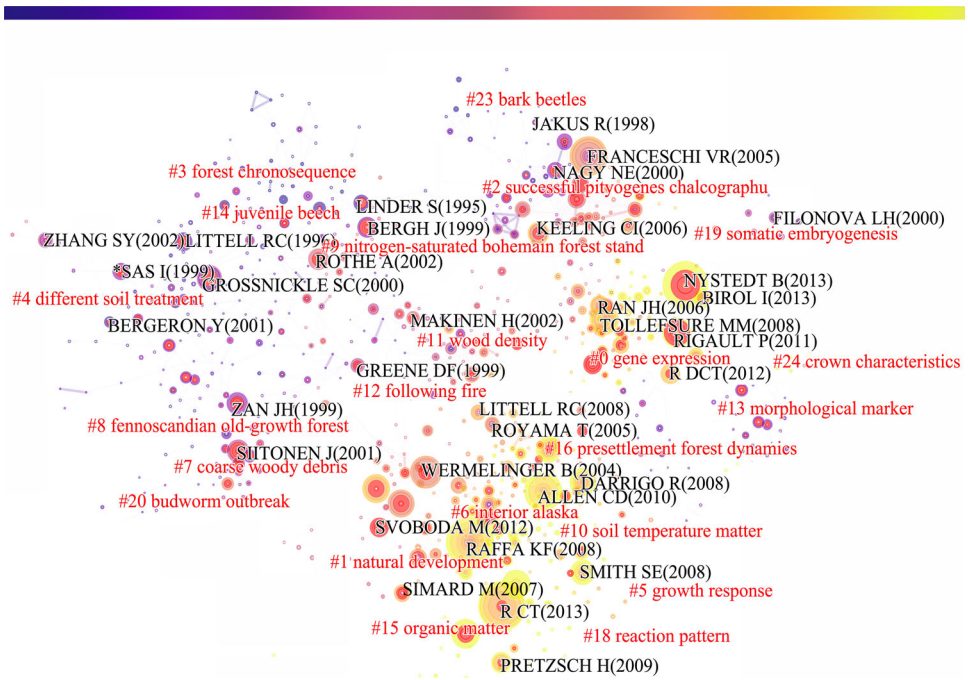

Fig. 4 The largest sub-network of literature co-citation

"species diversity", "biological characteristics", "tree height", and "growth"; and, (6) *Ips typographus* has been intensively investigated in China.

Discussion

Bibliometrics is a tool that allows the objective evaluation, quantification and interpretation of the scientific research level of a nation (Arvanitis et al. 2000). It has been widely applied in many fields; however, to date, it has not been applied to research on *Picea.* Therefore, we performed the

Table 4 Statistics on the top 10 most cited papers

Frequencies	Title	Authors	Journal	Year
480	The Norway spruce genome sequence and conifer genome evolution	Nystedt et al.	Nature	2013
333	Effect of high temperature on the change in color, dimensional stability and mechanical properties of spruce wood	Bekhta and Niemz	Holzforschung	2003
289	Ecology and management of the spruce bark beetle *Ips typographus* - a review of recent research	Wermelinger	Forest Ecology and Management	2004
284	Sulfite pretreatment (SPORL) for robust enzymatic saccharification of spruce and red pine	Zhu et al.	Bioresource Technology	2009
261	Recent climate warming forces contrasting growth responses of white spruce at tree line in Alaska through temperature thresholds	Wilmking et al.	Global Change Biology	2004
260	Methyl jasmonate induces traumatic resin ducts, terpenoid resin biosynthesis, and terpenoid accumulation in developing xylem of Norway spruce stems	Martin et al.	Plant Physiology	2002
226	Nanostructure of cellulose microfibrils in spruce wood	Fernandes et al.	PNAS	2011
220	Biomass expansion factors (BEFs) for Scots pine, Norway spruce and birch according to stand age for boreal forests	Lehtonen et al.	Forest Ecology and Management	2004
218	A long-term record of carbon exchange in a boreal black spruce forest: means, responses to interannual variability, and decadal trends	Dunn et al.	Global ChangeBiology	2007
213	Mechanical and chemical behavior of spruce wood modified by heat	Yildiz et al.	Building and Environment	2006

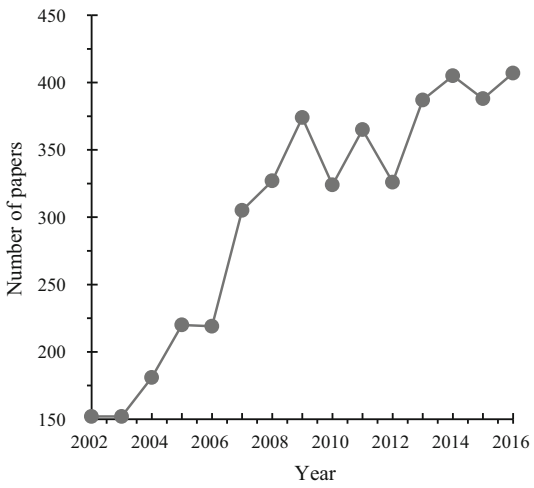

Fig. 5 Number of publications on *Picea* in China

first bibliometric study of the worldwide status of *Picea* research, focusing on the period 2002–2016 using the Web of Science (WoS) and China National Knowledge Infrastruture (CNKI) databases. The results indicate that publications on *Picea* have steadily increased, consistent with the general trend in the number of scientific publications (Ciotti et al. 2016). With economic development, scientific research has been gradually strengthened and the quality of publications improved, with the number of papers archived by SCI (Science Citation Index) increasing. We also examined the differences between China and foreign countries in terms of SCI publications on *Picea*. Although *Picea* species in China account for 50% of the 34 spruce species worldwide (Zou et al. 2012), China's research effort has not been proportional. Only 1098 papers authored by Chinese investigators have been archived, revealing a large difference between China and Canada (3018 publications) and the United States (2567 publications). This difference may likely be attributed to the following: (1) The research levels of different institutions in China were not balanced and major investigators that published in SCI journals were mostly from national-level institutions or advanced universities such as the Chinese Academy of Sciences, the Chinese Academy of Forestry, Beijing Forestry University and Lanzhou University; (2) Many institutions were unable to keep pace with the latest developments abroad and were unaware of cutting-edge research. Indeed, particularly in remote regions, the research strength has generally been weak; and, (3) Many institutions had limited research funding and produced inadequate studies in terms of innovations and breakthroughs. As a result, original and innovative research ideas were lacking and it was difficult to conduct relevant prospective studies (Ding and Lu 2013). In spite of these constraints, China's SCI publications have increased rapidly in recent years with burst nodes appearing in our analysis.

Global trends on *Picea* were researched based on keywords and references from the WoS and CNKI databases. Research on *Picea* forest ecosystems and the impact of climate change on *Picea* species were abundant. Climate change is a global issue which gets a lot of attention these

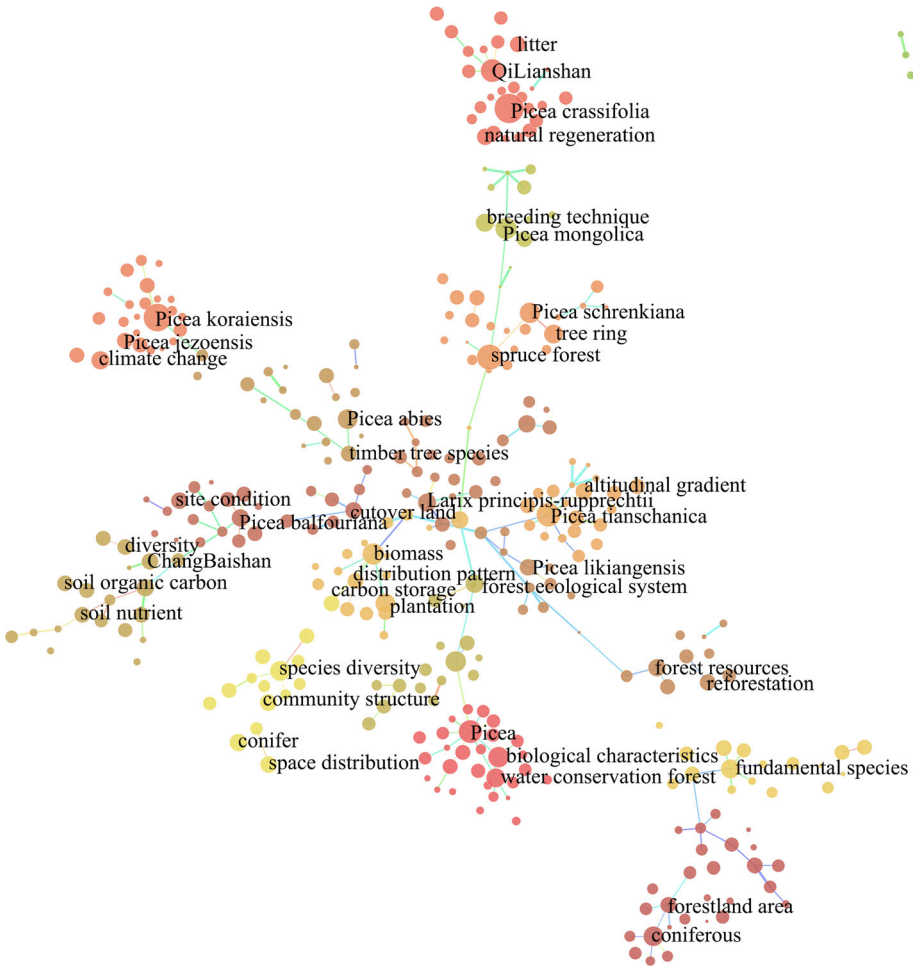

Fig. 6 Visualization network of keyword co-occurrence

days, and one of the challenges that the world is facing. The global temperatures are predicted to rise 2 °C or more by 2050 (Han and Wang 2016). When the climate changes, vegetation is affected (Wang et al. 2017). As relic plants of the late Cretaceous period, the genus *Picea* constitutes a major component of the boreal forest. The species are sensitive to temperature and humidity and are mainly distributed in the cold temperate/temperate alpine and subalpine zones of the Northern Hemisphere where there are fewer environmental factors constraining growth (Vallée and Payette 2004). Learning how *Picea* species respond to long-term climate variability is critical for anticipating climate change (Mcdougall et al. 2012). Researchers such as Yves Bergeron, who has been engaged in studies of forest ecosystems and climate change, have made major contributions. At present, he and his colleagues conducted a project entitled "*The effect of fire cycle and fire severity on the presence of black spruce in the boreal forest of Canada in the context of forest management*". The project aims to reform the forest fire prevention system by simulating the effects of fire cycle and fire severity in a pure stand of black spruce (*P. mariana* Mill.), one of the dominant tree species in boreal forests in Canada. Their research will have significance for predicting the influence of climate change on boreal forests in terms of structure, composition and diversity of forest communities (Bergeron et al. 2004). The responses of spruce forests to global climate change may become a research hotspot. In addition, research on *Picea* has also focused on *Ips typographus* L., the European spruce bark beetle, one of the most destructive insects of coniferous forests in Europe and represents a continuous threat. For example, the storms "Vivian/Wiebke" in February/March 1990 and "Lothar" in December 1999 triggered the propagation of *Ips typographus* in central Europe, causing major economic losses to the forestry sector (Wermelinger 2004). In China, *I. typographus* has mainly affected the large trees in some distribution of *P. koraiensis* (e.g., Wangqing Forestry Bureau and Changbai Forest Management Bureau in Jilin Province). Thus, multiple and large outbreaks of *I. typographus* in spruce forests are causing widespread concern among researchers. How to prevent and control this insect scientifically and effectively has been a major research topic.

Publications on spruce wood were primarily from international journals, with a few articles from Chinese institutions. In the Chinese data, there were few keywords related to wood or timber of *Picea*. The reason is that in China, forest cover is 18.2% (Li et al. 2013), whereas in European and American countries it may be 40–70% (Macdonald and Hubert 2002). China has implemented the the natural forest protection project to expand the areas of forest cover. Plantation wood has been the main material to ease the contradiction between supply and demand in domestic timber market (Zhang and Zhang 2000). However, a high proportion of the juvenile wood in plantation wood lead to poor material. Wood modification is an effective way to improve the physical and chemical properties of the plantation wood (Lin et al. 2006). Modified wood can increase the utilization and service life of wood to alleviate imbalance between supply and demand, but the modification technology in China was developed later than in other countries (Bekhta and Niemz 2003). Thus, there has been relatively little study of spruce wood in China.

Driven by genetic engineering, bioengineering and other "cutting-edge" technologies, genomics has developed into a research frontier and hotspot in the life sciences. Research on tree genomes has been increasing. Genomic studies on *Picea* as a large genus of conifers with high ecological and economic value, have accumulated rapidly in recent years. Members of this genus possess among the largest genomes—typically 20 Gb (b is base pair, 1 Gb = 10^9b) among all organisms. Thus, genome-wide analyses of *Picea* has been challenging and significant (Warren et al. 2015). The complete genome sequence has been obtained for *P. abies* (Nystedt et al. 2013) and *P. glauca* (Birol et al. 2013). The published *Picea* genome sequence not only accelerated the study of gymnosperm biology but also provided extensive information on genetics and evolution. However, genome-related studies of *Picea* have been rare, and no whole genome of any species has been carried out in China. Most related studies have been limited to platforms currently used for genome sequencing developed by foreign companies and introduced into China (Zhang et al. 2014). For the future, Chinese researchers should work together to obtain the complete genome sequences of *Picea* species indigenous to China such as *Picea meyeri* Rehd. & Wilson (Liang et al. 2001) and *Picea wilsonii* Mast. (Ma et al. 2007). The results would provide insight into their origin and history, their mechanisms of adaptation to climate change, and would provide a theoretical basis for genome sequencing of other conifer species (Xu et al. 2013; Wang et al. 2016).

Conclusions

This paper presents the first bibliometric analysis of *Picea* research based on the Web of Science (WoS) and China National Knowledge Infrastruture (CNKI) databases. There were several significant findings regarding global research trends for the period from 2002 to 2016. Publications on *Picea* have been steadily increasing, suggesting that *Picea* research may be gaining worldwide interest. Among the countries involved in *Picea* research, Canada contributed the most publications and exhibited the highest betweenness centrality, with 0.11 of its publications representing collaboration with other countries. Among the institutions, the Swedish University of Agricultural Sciences in Uppsala had the most publications.

Most investigations on *Picea* were on ecosystems and insect pests in both the WoS and CNKI databases. Worldwide, research hotspots include the relationships between *Picea* and environmental factors, and the genomic sequences of *Picea*. Research on spruce wood was less abundant in China than in other countries. China should monitor global research developments and employ up-to-date methods to conduct in-depth investigations on *Picea* species. Around the world, researchers should collaborate with others from various disciplines such as ecology, environmental sciences, biology, climatology, and bibliometrics to further understanding of the genus.

Bibliometric methods were effective for investigating research areas and hotspots related to *Picea.* When applying these methods, attention must be paid to the accuracy of the literature and the completeness of the keyword statistics to ensure that the results will be useful for predicting development trends.

Author Contributions Guozhen Duan and Yu′e Bai designed the overall framework of the research, conducted the literature review, participated in the study design and analysis, and drafted the manuscript. Dongmei Ye, Tao Lin, Shulan Bai, Peng Peng and Min Liu participated in data collection, article writing, and supervision of the research direction. All authors read the final manuscript for final submission.

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