

T. Maryyam<sup>1</sup> , S. Rahayu<sup>2</sup> , D. Sukmawati<sup>2</sup> , A.H. Anvar<sup>3</sup> ,  
H.A. Shakir<sup>4</sup> , M. Khan<sup>4</sup> , J. Ul-Haq<sup>1</sup> , M. Irfan<sup>1\*</sup> 

<sup>1</sup>University of Sargodha, Sargodha, Pakistan

<sup>2</sup>State University of Jakarta, Jakarta, Indonesia

<sup>3</sup>Khazar University, Baku, Azerbaijan

<sup>4</sup>University of the Punjab, Lahore, Pakistan

\*e-mail: Irfan.ashraf@uos.edu.pk

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## Bibliometric and co-occurrence study of the production of cellulase from *Bacillus* (2000–2025)

**Abstract:** Cellulase refers to a group of enzymes that can break down cellulose, the most widespread organic polymer on Earth. It is one of the most important industrial enzymes due to its application in the production of valuable products such as biofuels, papers and textiles. Many microorganisms naturally produce cellulase, including *Bacillus* species. This study presents detailed bibliometric analysis of *Bacillus* cellulase. The core objective of this study is to provide global research trends related to *Bacillus* cellulase. It highlights leading authors, institutions, countries and sources that have major contributions in this area of research. The Scopus Dataset of 2212 documents was included for analysis. VOSviewer and Biblioshiny software were employed for bibliometric analysis and visualization. The most prolific author was Zhang Y. with highest number of publications (45) and citations. China ranked first among top contributing countries, followed by India with second position. This study will help researchers in understanding global research trends on *Bacillus* cellulase.

**Keywords:** *Bacillus*, cellulase, Bibliometric study, VOSviewer, Biblioshiny.

### Introduction

Enzymes are special proteins that catalyze metabolic processes in living organisms. Hence, enzymes are very essential for sustaining life [1]. Their applications extend beyond biological systems to various industrial processes. Enzymes are utilized in medical diagnostics, waste treatments, food production, and chemical synthesis [2]. Cellulases are a group of enzymes which are produced by many living organisms such as fungi, bacteria and algae [3]. They degrade cellulose which is the most abundant biological mass on earth [4]. Cellulase is known to be one of the most valuable enzymes that is used in textile, paper, detergent, food and feed industries [5]. One of the key industrial uses of cellulase enzymes is in the production of biofuels [6].

Cellulose is considered as the most abundant natural biopolymer on Earth. It is found as a key structural element of plant cell wall in the form of lignocellulose [7, 8]. Cellulases are enzymes that can degrade cellulose in lignocellulosic biomass. Thus, it plays a crucial role in conversion of plant waste into useful products like sugars and biofuels [9, 10]. As lignocellulosic biomass is the alternative of fossil fuels and can be used in the production of Biofuels.

Microorganisms including bacteria, fungi, and actinomycetes are capable of producing cellulases that can be utilized in the degradation of biomass. Bacterial Cellulases are reported to have higher growth rate and versatility in genetic composition which makes them advantageous [11].

As majority of microorganisms have been reported for their cellulolytic potential. Among them *Bacillus* species have higher growth rate and can be easily genetically engineered [13, 14]. Furthermore, cellulases produced from *Bacillus* species are stable and can withstand a broad range of temperatures (30 to 100 °C) and pH levels (pH 8-10) [15]. Furthermore, enzyme production in *Bacillus* species can be improved as they are amenable to genetic engineering. These species can also survive in varying environmental conditions [16]. *Bacillus* strains are identified as good sources of cellulase enzymes. These strains have been isolated from many sources including compost and soil. *Bacillus* species, along with other bacteria like *Pseudomonas* and *Klebsiella* produce cellulases and play role in biodegradation of organic materials in compost [17]. Thus, *Bacillus* species hold significant importance as promising sources of cellulases and hemicellulases, enzymes

crucial for lignocellulosic biomass degradation. In comparison with fungi, these bacteria are more efficient in productivity [18]. In 2019, Manzum and Mamun have demonstrated the potential of *Bacillus* isolates from soil to produce cellulase. In their study, *Bacillus* bacteria were isolated from 24 soil samples and some isolates showed enzyme activity up to 0.17 U/ml. One isolate, 1RW, showed the highest cellulase activity and was identified as likely being *Bacillus licheniformis* or *Bacillus subtilis* [5].

Research on *Bacillus* cellulase has made significant strides. Various studies have been conducted focusing on optimizing fermentation conditions for cellulase enzyme production from *Bacillus sp.* [19-21]. Islam et al. [22] reported that maximum cellulase production occurred at pH 3.5, 35°C, and 150-rpm agitation after 24 hours. Due to optimized conditions, enzyme yield was increased. While, highest enzyme activity was observed at pH 5.5 and 50°C. Hence, they are suitable for industrial uses in biomass conversion. Research efforts have also been made to improve *Bacillus* strains. Ega et al [23]. improved cellulase production in *Bacillus subtilis* VS15 through genome shuffling. They created mutant strains of *Bacillus subtilis* VS15 by mutagenesis and then combined them through protoplast fusion.

To the best of our knowledge, there is no bibliometric analysis has been done specifically on *Bacillus* cellulase research. Although, many scientific studies have been published on cellulase and *Bacillus* species. However, there is no complete summary that shows how this research has developed over time and which countries and authors have made major contributions in this field. In addition, the collaboration pattern between countries and authors is important to be identified. The purpose of this study is to fill this gap by performing a detailed bibliometric analysis on *Bacillus* cellulase from the year 2000 to 2025. This study will provide an overview of global research trends, prolific authors and countries, top journals and most frequent keywords in the field of *Bacillus* cellulase. Moreover, this analysis will develop a roadmap to assist future researchers.

## Materials and methods

The first stage in the bibliometric analysis was data collection. For this purpose, the Scopus database (www.scopus.com) was used, as it is the comprehensive and internationally recognized source of scientific literature. To retrieve relevant publications specific keywords related to the research topic were used. These keywords included “cellulase”, “bacteria”, “bacterial cellulase”, “microbial cellulase”. In the Scopus search bar, these keywords were entered using

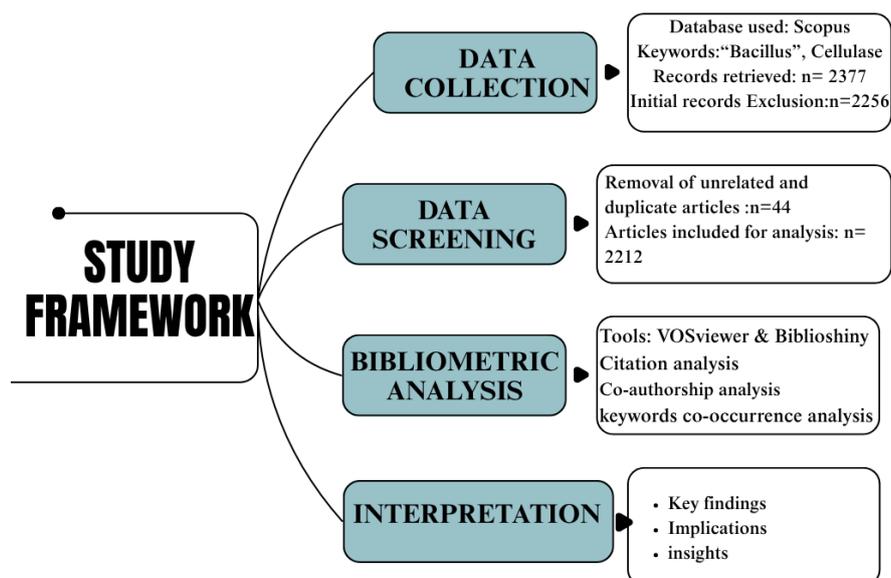
appropriate Boolean operators such as AND and OR to combine terms and refine results (e.g., “cellulase” AND “bacteria”). Data was retrieved on 20 June 2025, spanning publications from 2000 to 2025. Data was refined to narrow down the search results and select the most relevant articles for the study. Only research publications and review studies were included in the analysis. The following final query was entered into the main search bar of the Scopus database:

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TITLE-ABS-KEY (“Bacillus” AND “cellulase”)
AND PUYEAR > 1999 AND PUBYEAR < 2026
AND (LIMIT-TO (SRCTYPE , “j”)) AND (LIMIT-TO (PUBSTAGE , “final”)) AND (EXCLUDE (SUBJAREA , “PHYS”) OR EXCLUDE (SUBJAREA , “COMP”) OR EXCLUDE (SUBJAREA , “EART”) OR EXCLUDE (SUBJAREA , “ECON”) OR EXCLUDE (SUBJAREA , “NURS”) OR EXCLUDE (SUBJAREA , “MATH”) OR EXCLUDE (SUBJAREA , “SOCI”) OR EXCLUDE (SUBJAREA , “HEAL”) OR EXCLUDE (SUBJAREA , “BUSI”) OR EXCLUDE (SUBJAREA , “ARTS”) OR EXCLUDE (SUBJAREA , “DECI”)) AND (LIMIT-TO (DOCTYPE , “ar”) OR LIMIT-TO (DOCTYPE , “re”)) AND (LIMIT-TO (LANGUAGE , “English”))
```

After refining the dataset, the entire list of resulting 2256 documents was downloaded in three different formats: BibTeX (.bib), CSV (.csv) and plain Text (.txt). These formats were used in different softwares for analysis.

In the next step, preliminary dataset was imported into EndNote to perform duplicate check. EndNote identified and removed duplicates based on author, year and title. Duplicate records were found. Then, the titles and keywords of the documents were reviewed to assess relevance. This step was important for eliminating articles that were irrelevant to the research topic. Out of 2256 documents, 44 were excluded. The resulting dataset was then used for further analysis. This study used MS Excel, R studio, Biblioshiny and VOSviewer software to conduct bibliometric analysis and data visualization.

The dataset was analyzed using version 1.6.20 VOSviewer by uploading .csv format of the data. VOSviewer can be used to generate co-authorship network between authors and countries that collaborate in the specific research area. It can also establish networks of scientific publications, SCIENTIFIC journals, keywords, or terms. This study also employed R studio for conducting bibliometric analysis and visualization. R studio in an open-source software. The bibliometric analysis was undertaken through utilizing packages in R studio which are “bibliometrix” and “bibliometrix-Data”. These packages enabled the execution of Biblioshiny software, which was used in order to analyze and visualize the data.



**Figure 1** – Flow diagram of methodology of bibliometric and co-occurrence study of the production of cellulose from *Bacillus* (2000-2025)

## Results and discussion

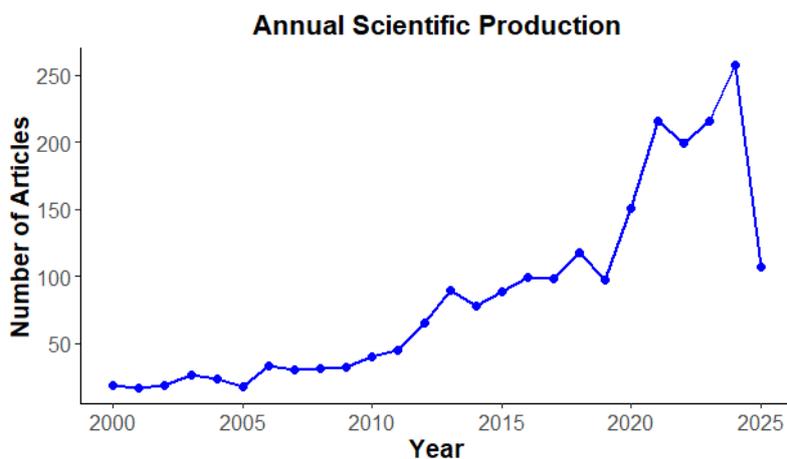
Results of bibliometric analysis include publication trends, productive authors and countries, and Potential journals. Moreover, co-authorship networks among authors and countries have also been discussed. The descriptive analysis of the chosen data is given in Table 1. The analysis was conducted using the Meta data of 2212 articles from the period 2001-2025. The number of publications is increasing every year, with an annual growth rate of 7.16%. This shows the ongoing interest in this research field.

**Table 1** – Main information about the Scopus dataset regarding cellulase production by *Bacillus* species (2000-2025)

Description	Results
Timespan	2000-2025
Sources	651
Documents	2212
Annual Growth Rate	7.16%
<b>Document Types</b>	
Research Articles	2106
Review Articles	106
<b>Authors</b>	
Total	7913
Authors of single-authored docs	35
<b>Authors Collaboration</b>	
Average no. of authors (Each Doc.)	5.57
International co-authorships, %	22.06

### 1.1. Analysis of annual scientific production (2000–2025)

By analyzing publication trends in topic of *Bacillus* cellulase, it was observed that number of documents were increased over the years, which indicates a growing interest in research. Figure 2 shows the annual scientific production from 2000 to 2025. It can be observed that scientific activity was quite low in the early 2000s, with fewer than 40 articles published each year. This phase represents the early developmental stage. It was also observed that scientific production increased between 2010 and 2018, from 40 to 118 publications. This steady growth indicates that more researchers were getting involved in the topic. A notable acceleration in publications output was observed after 2019. The most productive years were observed between 2020 and 2024. In 2021 and 2023, 216 publications were recorded, while 2022 – 199 documents. Production reached its peak in 2024, where 258 articles were published in a single year. This sharp rise in recent years indicates that cellulase enzyme research has become very important and active. The plot shows decline in 2025 with 107 articles. This is likely not because interest in the topic has increased. It is more likely that the data for 2025 is not yet complete in the database, as the year is still ongoing at the time of analysis

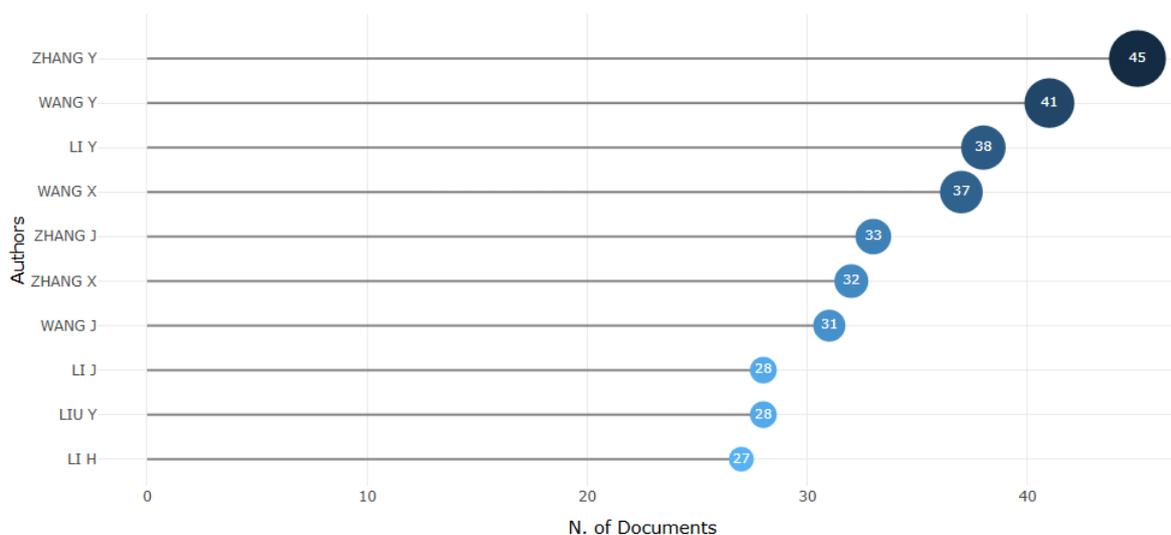


**Figure 2** – Number of articles published per year on the *Bacillus cellulase* by Scopus database (2000-2025)

### 1.2. Most prolific authors

Figure 3 presents the leading authors who have published the most articles in the field of *Bacillus cel-*

*lulase*. Among them Zhang Y. is the top contributing author with 45 publications. Whang Y. contributed 41 articles and stands at the second.



**Figure 3** – Most productive authors on basis of publications number about *Bacillus cellulase* by Scopus database (2000–2025)

Table 2 includes the additional measures in deciding the top 10 most productive authors who actively participated in research area of *Bacillus cellulase*. A total of 7913 authors have contributed to the research in this domain. The top authors

were determined based on key indicators such as number of publications, h-index, and total citations. These measures are essential to understand both the productivity and the scientific impact of each author

**Table 2** – Impact metrics of top contributing authors in field of *Bacillus* cellulase by Scopus database (2000–2025)

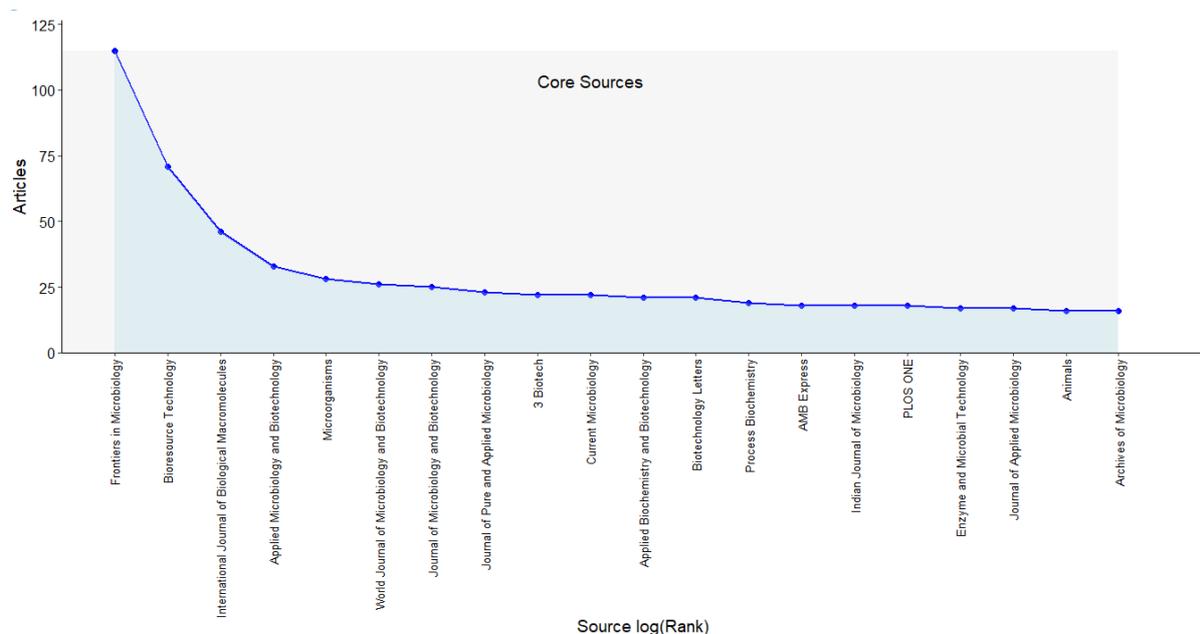
Authors	Number of publications	Articles fractionalized	h index	Total citations
Zhang Y.	45	6.67	17	958
Wang Y.	41	6.57	17	958
Li Y.	38	5.47	17	699
Wang X.	37	5.16	15	802
Zhang J.	33	4.77	14	420
Wang J.	31	4.51	10	716
Kumar V.	18	4.30	13	428
Zhang X.	32	4.28	12	671
Li J.	28	4.20	14	714
Liu Y.	28	3.59	12	375

Zhang Y. is ranked first among the top 10 most prolific authors in the field of *Bacillus* cellulase research. He has the highest number of publications (45) and his work has been widely cited. h-index has reached 17, which shows his research is both productive and well recognized. The second author, Wang Y. follows closely with 41 publications and an h-index as 17, similar to Zhang Y. It means both authors have similar level of citation impact. Li Y is the third most productive author, with 38 publications and an

h-index of 17, which is the same as the top two authors. This suggests that his work is equally impactful. Wang X. ranks fourth with 37 publications and an h-index of 15, which also indicates a strong citation impact. Interestingly, Wang X. has received 802 total citations, which is higher than Li Y, despite having one fewer publication and a slightly lower h-index. This means X. Wang's individual papers may have received more citations on average, highlighting the relevance and impact of their research. The subsequent authors include Zhang J., Wang J., Kumar V., Zhang X., Li J., Liu Y. They have also made significant contributions in the field and appear among the top 10. Overall, Zhang Y. is the main contributor in this research area.

### 1.3. Potential journals

Analysis of academic journals can be useful for scholars and researchers to find the most active and latest sources. The potential journals that published the most articles on *Bacillus* cellulase have been illustrated here. To identify the most influential journals in the research area, Bradford's Law was applied. Bradford's Law used in bibliometric analysis helps identify core journals by dividing journals into 3 zones: A core zone with few but highly productive sources; a second zone with moderately producing sources, and a third zone with many sources that produce relatively few relevant journals.

**Figure 4** – Distribution of Core Sources (zone 1) about *Bacillus* cellulase by Scopus database (2000–2025) according to Bradford's Law

There is total 651 sources in the dataset. The statistical data reveals that not all sources are equally significant. In this study only the topmost productive sources have been presented, who have the most data published in *Bacillus cellulase* domain. As per Bradford's law, zone 1 represents the core sources that are most productive and have the highest number of pub-

lications on *Bacillus cellulase*. Many other journals have relatively fewer publications and come under subsequent zones such as zone 1 and zone 2. Figure 4 shows the core sources that come under zone 1 in accordance with Bradford's law. Zone 1 contains 20 sources from the dataset. The "Frontiers in Microbiology" holds the record of highest productive journal.

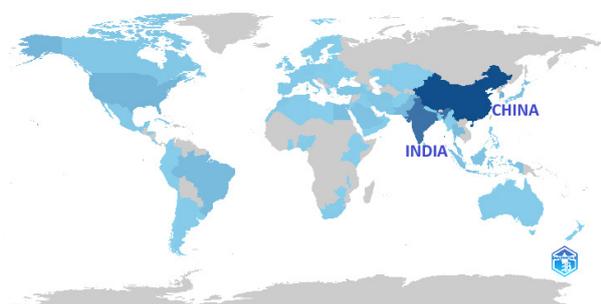
**Table 3** – Journal ranking based on Bradford's Law with publications about *Bacillus cellulase* by Scopus database (2000–2025) according to Bradford's Law

Source	Rank	Frequency	Cumulative frequency	Zone
Frontiers in Microbiology	1	115	115	1
Bioresource Technology	2	71	186	1
International Journal of Biological Macromolecules	3	46	232	1
Applied Microbiology and Biotechnology	4	33	265	1
Microorganisms	5	28	293	1
World Journal of Microbiology and Biotechnology	6	26	319	1
Journal of Microbiology and Biotechnology	7	25	344	1
Journal of pure and applied Microbiology	8	23	367	1
BioTech	9	22	389	1
Current Microbiology	10	22	411	1

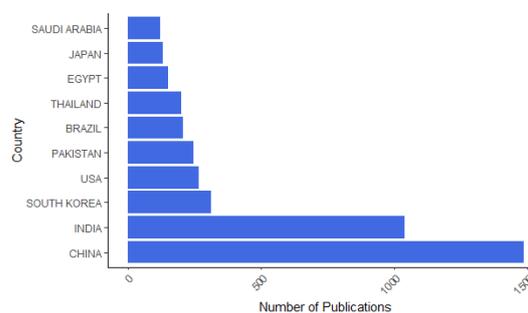
#### 1.4. Top contributing countries and institutions

Figure 6 illustrates the top 10 countries who have produced maximum number of articles on research area of *Bacillus cellulase*, spanning the duration from 2000 to 2025. Based on publications count, the China stands at the top of list with the highest number of publications (1484), followed by India with 1039 publications. Among the top ten productive coun-

tries, Only CHINA and INDIA has published more than 1000 articles. This suggests the significant contribution of these countries in the research. South Korea secured the third position with 313 papers. This distribution indicates that Asian countries, especially China and India, are at the forefront of research in this area. Overall, this analysis was performed to highlight global interest in the field.



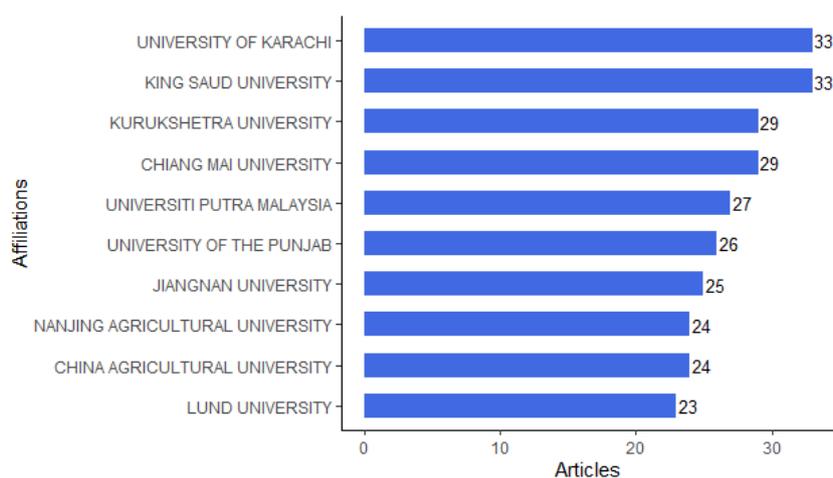
**Figure 5** – Country wise scientific production on *Bacillus cellulase* by Scopus database (2000–2025), where darker colors represent higher scientific output, notably India and China



**Figure 6** – Country-wise distribution of scientific publications on *Bacillus cellulase* by Scopus database (2000–2025)

This study highlights the most productive affiliations as well. Analyzing the most influential institution shows where the key research developments have taken place. In Figure 7 are shown the top most influential institutions having significant contribution in the topic. Institutions were arranged based on total number of publications and were identified 10 lead-

ers. These top institutions with the most publications included three Universities from China and two from Pakistan. King Saud University (Saudi Arabia) and University of Karachi (Pakistan) lead with 33 publications each, followed closely by Kurukshetra University (India) and Chiang Mai University (Thailand) with 29 each.



**Figure 7** – Top 10 prominent institutions having publications on *Bacillus cellulase* by Scopus database (2000–2025)

To avoid confusion, it is important to explain that scientific production by country and by institution are two separate aspects in bibliometric analysis. Country-level data shows how many publications come from each country overall, while institution-level data highlights the contributions of specific universities or research centers. For example, a country may have many institutions publishing moderately, or a few publishing heavily. Therefore, both types of analysis are included to provide a complete view of research output.

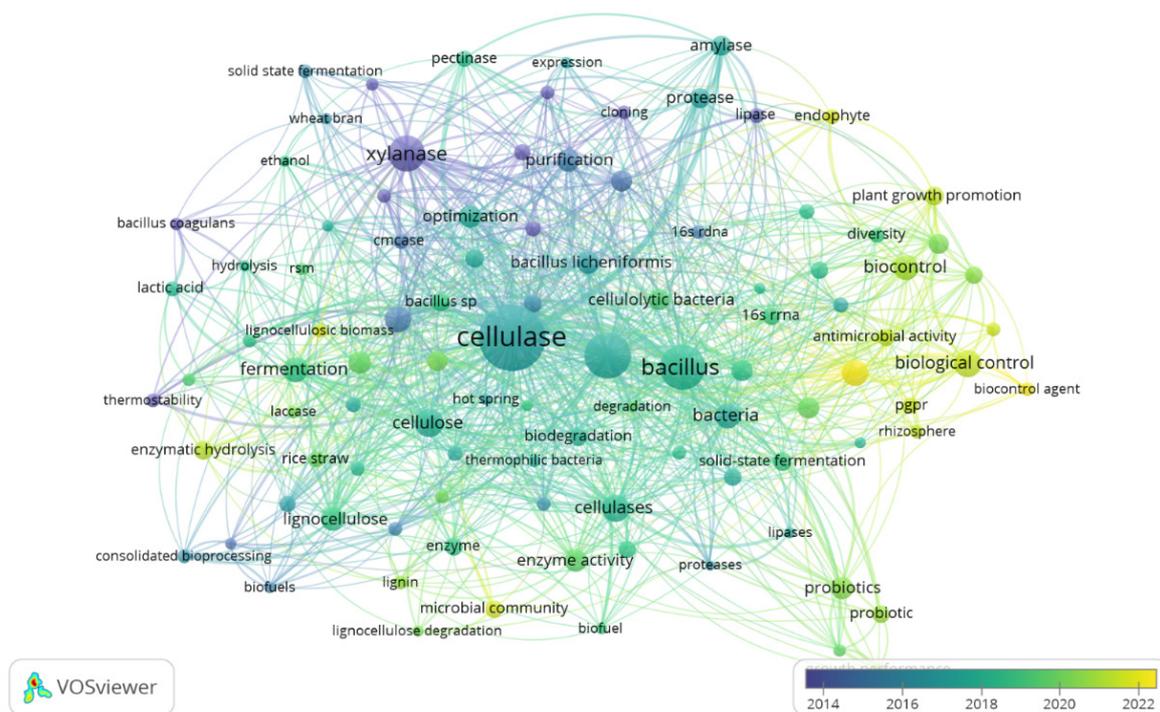
### 1.5. Highly cited documents

Among the total of 2212 documents, top 10 most cited publications were collected using Biblioshiney software. This analysis is important as it emphasizes the most impactful research in the field. The most cited article in data set with 1027 citations was “Silage review: Recent advances and future uses of silage additives”, published in Journal of dairy science in the year 2018 by .

### 1.6. Most Frequent Keywords

The word cloud (Figure 8) of the most frequently used words in the topic of *Bacillus cellulase* was obtained from Biblioshiney. During the data analysis prominent keywords were identified. The keyword analysis identifies research trends and maps the focus areas. Keywords map also guide future researchers to focus on specific areas. In the Figure 8, it can be observed that the keyword “cellulase” emerged as the most frequently used word with the highest frequency of 1308. As it is central to the research field. The next terms are “article” and nonhuman” which are more general metadata terms, but they reflect the nature of the literature as most studies are based on nonhuman organisms. Among the discovered keywords, “Bacillus” and “*Bacillus subtilis*” are also prominent. These bacteria are the primary subjects and important sources of cellulase production. Overall, “Cellulase” and “Bacillus” are the core focus of the research topic’s discourse.





**Figure 9** – The Overlay visualization map of most frequently used author’s keywords of publications related to the field of *Bacillus* cellulase in Scopus database (2000–2025)

#### 4. Collaboration Analysis

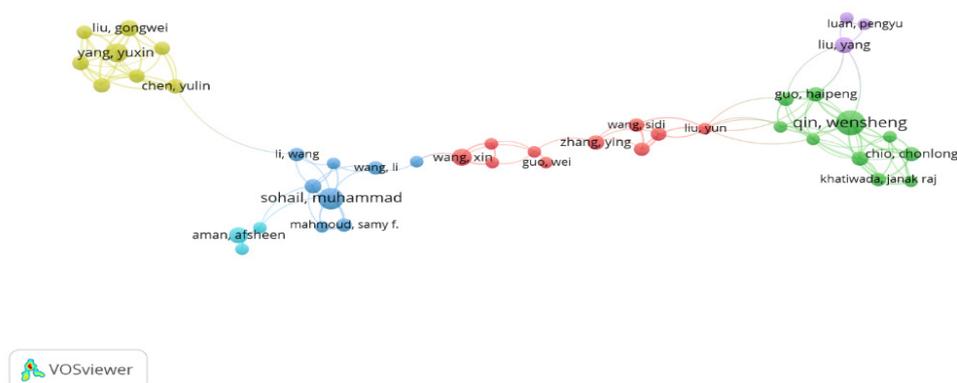
Co-authorship analysis is an important part of bibliometric studies. It helps to understand how authors collaborate in a specific research field. A co-authorship network was constructed using VOSviewer. In the network, authors who had published at least three documents were included. As a result, total of 424 authors met the threshold and were included in the visualization. Each circle (node) in the network represents an author and the size of the circle indicates the number of publications by that author. Larger node depicts the more publications of relevant author. The links between the circles indicate collaboration among authors. A cluster in a network is a group of authors with strong collaboration.

In the network visualization shown in Fig.10, there are six clusters of authors that relate to each other on *Bacillus* cellulase research. The green cluster is the largest, led by Qin Wensheng, who is strongly connected with authors such as Guo Haipeng, Chen Yuantong, and Chio Chonglong. This green cluster is linked with other clusters shown in purple and red clusters. These inter group connections suggest collaboration between different research groups. Two

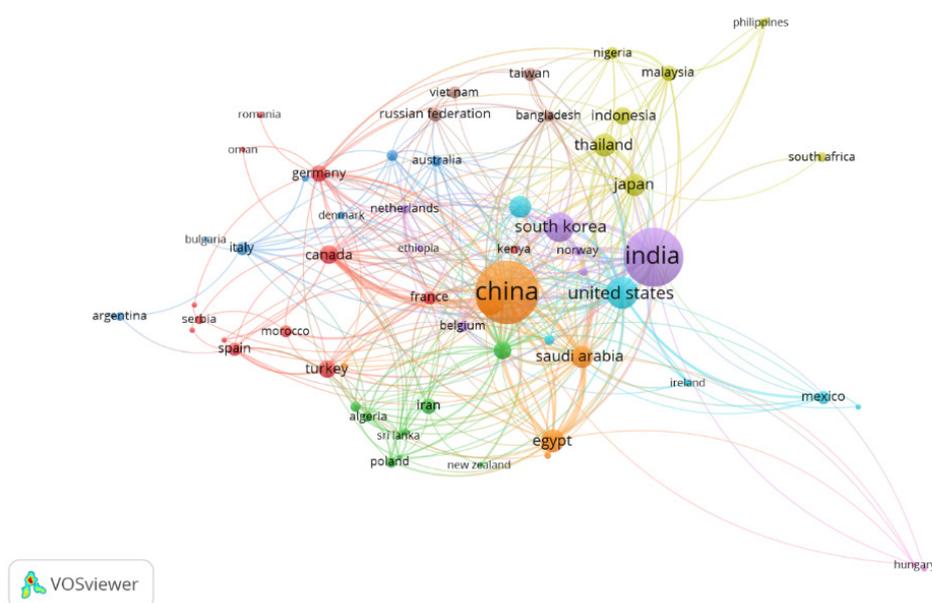
groups that are linked can have joint research projects.

Zhang Ying and Wang Xin are the main authors in the red cluster which shows that these two researchers play a key role in the collaborative work within this group. Other researchers in this cluster include Guo Wei, Wang Kui, and Liu Yun. A yellow cluster includes Yang Yuxin and Liu Gongwei, also working closely with each other. The blue cluster is led by Muhammad Sohail, showing intensive cooperation with authors such as Samy F. Mahmoud, Wang Li. Another light blue cluster, led by Afsheen Aman, is relatively small but showing significant collaboration.

Collaboration network is a visual map that depicts how countries work together in research field. This network is important because it shows global connections in research. In Figure 11, each Node (circle) represents a country. While connecting lines depict strength of co-authorship between countries. The size of node accounts for collaboration level. In the network, it can be observed that China has the largest node which shows its strong global collaborations. China and India are the top collaborating countries with strong collaboration



**Figure 10** – Co-authorship network among authors of publications related to the field of *Bacillus cellulase* in Scopus database (2000–2025)



**Figure 11** – Collaboration network among countries of publications related to the field of *Bacillus cellulase* in Scopus database (2000–2025)

Clusters in the collaboration network represent groups of countries that have strong research collaboration. As China, Saudi Arabia and Egypt are in the same color cluster showing close connections. Out of 104 countries, only 63 were included in the network.

### 5. Limitations of the study

There are certain limitations related to this study which need to be mentioned. Firstly, the study utilized only one database (Scopus) for data collection. Although Scopus is trusted and well recognized da-

tabase. But there is a likelihood that some relevant publications indexed in other renowned databases such as Web of Science or Google Scholar might be missing in the dataset. This sampling bias may cause gaps in the analysis. Despite these limitations, this study provides a useful overview of global research trends on *Bacillus cellulase*.

### Conclusion

This study has provided the current status of research on *Bacillus cellulase*. The collaboration net-

works among authors and countries have also been presented. It was observed that research on this subject is continuously growing with every passing year. The duration of most recent years from 2020 and 2024 was the most active phase in conducting research. Bibliometric and co-occurrence analysis have identified trends in research and research gaps that need to be addressed. The global research interest in the topic was revealed by identifying contributions of researchers and countries in the field. This study acknowledged the impact of prominent authors, countries, affiliations in progressing the field of *Bacillus* cellulase. Overall, this analysis contributed to the existing knowledge and will assist scholars and future scholars.

Moreover, the results of this bibliometric analysis offer a systematic basis for future research endeavors to focus on more application-based and interdisciplinary research. Greater collaboration

between the academic and industrial communities could help expedite technological development and subsequent applications of *Bacillus* cellulase in the biofuel industry, waste treatment, agriculture, and biotechnology. Future research endeavors should aim to experimentally verify and scale up research, as well as combine it with current biotechnological advances to fill the research gaps. The observation of publication trends and collaboration patterns will continue to be important for monitoring scientific developments. In this manner, bibliometric analyses, such as the current study, not only act as analytical tools but also as guides for the advancement of the field.

### Conflict of Interest

All authors are aware of the article's content and declare no conflict of interest.

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#### Information about authors:

Tehreem Maryyam – Master Student, Department of Biotechnology, University of Sargodha, (Sargodha, Punjab, Pakistan, e-mail: [maryyamtehreem@gmail.com](mailto:maryyamtehreem@gmail.com))

Sri Rahayu – Associate Professor, Department of Biology, Faculty of Mathematics and Natural Sciences, State University of Jakarta (Jakarta, Indonesia, e-mail: [sri.rahayu@unj.ac.id](mailto:sri.rahayu@unj.ac.id))

Dalia Sukmawati – Professor, Department of Biology, Faculty of Mathematics and Natural Sciences, State University of Jakarta (Jakarta, Indonesia, e-mail: [dalia-sukmawati@unj.ac.id](mailto:dalia-sukmawati@unj.ac.id))

Afsana Huseynova Anvar – Lecturer, Department of Life Science, Khazar University (Baku, Azerbaijan, e-mail: [afsanalab212@gmail.com](mailto:afsanalab212@gmail.com))

Hafiz Abdullah Shakir – Associate Professor, Institute of Zoology, University of the Punjab (Lahore, Pakistan, e-mail: [hashakir@yahoo.com](mailto:hashakir@yahoo.com))

Muhammad Khan – Associate Professor, Institute of Zoology, University of the Punjab (Lahore, Pakistan, e-mail: [khan\\_zoologist@ymail.com](mailto:khan_zoologist@ymail.com))

Jabbar Ul-Haq – PhD, Assistant Professor, Department of Economics, University of Sargodha, (Sargodha, Punjab, Pakistan, e-mail: [jabbar.ulhaq@uos.edu.pk](mailto:jabbar.ulhaq@uos.edu.pk))

Muhammad Irfan – Associate Professor, Master Student, Department of Biotechnology, University of Sargodha (Sargodha, Punjab, Pakistan, e-mail: [Irfan.ashraf@uos.edu.pk](mailto:Irfan.ashraf@uos.edu.pk))