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Trends on Biocontrol Potential of *Metarhizium*: A Bibliometric Analysis

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Abstract

Metarhizium is widely recognized as an entomopathogenic fungus with a natural ability to control insects and pests. It has the dual ability to act as a biopesticide and a significant plant growth promoter. This bibliometric analysis was conducted to study global research trends on *Metarhizium* biocontrol from 2001 to 2024, based on the 772 publications indexed in the Scopus database. VOSviewer and the R Bibliometrix package have been used to examine publication trends, citation patterns, influential authors, journals, institutions, and international collaborations. The results show consistent research productivity with an annual growth rate of 7.6%, which has significantly increased after 2015. The analysis revealed that the highly cited studies are focused on host-pathogen interactions, comparative genomics, and ecological safety of *Metarhizium* species. Countries like China, Brazil, and the United States are the global centers, while India, Spain, and Kenya are the emerging contributors to the *Metarhizium* biocontrol research. In recent years, the research themes have evolved from taxonomy and pathogenicity studies to molecular biology and applied pest management for integrated pest management strategies. The analysis reveals strong global progress; however, gaps remain at the stages of formulation stability, field-level trials under diverse climatic conditions, and non-target ecological safety. The integration of advanced genomics with formulation technology and improving international collaborations are vital to enhancing the practical use of *Metarhizium* species for eco-friendly biocontrol. This study presents the first comprehensive bibliometric mapping of biocontrol research using *Metarhizium* species over a 24-year period, providing valuable insights for researchers, policymakers, and industry stakeholders to inform future innovations in biological pest control.

Keywords – Biological control – Entomopathogenic fungi – Integrated pest management – Sustainable agriculture.

Introduction

Biocontrol is the use of living organisms or their products to suppress pests, weeds, insects, and other organisms causing plant diseases. In agriculture, biocontrol is an environmentally safe and effective method to reduce the impact of insects on crops, without much reliance on chemical pesticides (Ayaz et al. 2023, Quesada-Moraga et al. 2023). *Metarhizium* is one of the most extensively studied groups of entomopathogenic fungi, for their natural ability to infect and kill a wide spectrum of insect pests such as beetles, locusts and grasshoppers. This is a large group of fungi

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belonging to the phylum Ascomycota, class Sordariomycetes, order Hypocreales, and the family Clavicipitaceae (Yu Q et al. 2011). Soil is the primary natural reservoir for *Metarhizium,* where they colonize on plant roots as endophytes (Karthi et al. 2024). The genus *Metarhizium* includes more than 110 species of entomopathogenic fungi (Yapa AT et al. 2025, Mongkolsamrit et al. 2020). The most important and well-studied species is *Metarhizium anisopliae*, found worldwide. It infects over 200 insect species, covering various agricultural pests (Peng et al. 2022). Another key species, *Metarhizium acridum*, with a narrower host range, targeting locusts and grasshoppers primarily, is used for their biocontrol, especially in Africa and Australia. These fungi are found in various environments, with soil being their main reservoir (Yapa PAB et al. 2025). At present, many *Metarhizium* biocontrol products, such as Met52® and Tick-Ex®, are in commercial use for their role as biopesticides and plant growth promoters in different parts of the world (Boaventura & Quintela 2025, Sullivan et al. 2022).

In recent decades, the demand for environmentally sustainable pest management strategies has led the research focus towards biocontrol agents. The concern of environmental demands reduction in the application of broad-spectrum synthetic insecticides, as these compounds persist in the environment and cause non-target effects, and the insects develop resistance later (Zhou et al. 2025). *Metarhizium* species are an eco-friendly and sustainable option for integrated pest management (IPM) (Yapa PAB et al. 2025, Sharma & Sharma 2021). *Metarhizium* products developed for commercial purposes utilize fungal spores, which require favorable environmental conditions, such as humidity, temperature, and soil conditions, to be effective. These environmental factors influence the efficacy of the product. Scaling up production, improving formulation stability, and ensuring farmer adoption are certain challenges to be addressed to further promote *Metarhizium*-based products (Yapa PAB et al. 2025).

Bibliometric analysis is a systematic approach to uncovering patterns and trends in scientific publications within a field and a specific time frame, based on the large volume of data from scientific publications (Donthu et al. 2021). Bibliometric tools enable the assessment of publication outputs, collaboration networks, influential authors, and thematic evolutions. Bibliometric analysis reveals the emerging areas and pattern of evolution of research (Ninkov et al. 2022). Bibliometric tools facilitate systematic mapping of research areas and help in the identification of knowledge gaps, factors influencing research, and the pattern of international collaboration shaping the concerned research field. The findings from a bibliometric analysis are useful for researchers, industry, and policymakers to identify emerging topics and technologies for further research (Mesquita et al. 2023, Yapa PAB et al. 2025). The rationale behind applying the bibliometric approach in this work is its ability to provide a thorough, robust, and evidence-based summary of the genus *Metarhizium* as a biocontrol agent.

This study is based on the timeframe from 2001 to 2024, which is a period marked by growing global interest and expansion in research and development of *Metarhizium* based biopesticides at a commercial scale, despite the longer history. The last 24 years reveal an increasing trend in papers focused on the biocontrol of agricultural plant pathogens (Geremew et al. 2024, Kortsinoglou et al. 2024). This article presents an analysis of the growth of research papers based on *Metarhizium* biocontrol and identifies authors, journals, and institutions having the greatest contribution to the research, presenting a map of key research areas and emerging trends during the last twenty-five years. The article examines international collaboration and research networks. The study intends to provide an understanding of the evolution trends of *Metarhizium* research and highlights the areas for future investigation.

Materials & Methods

Source of the dataset

The Scopus database was used to obtain a bibliographic dataset for this study (Elsevier 2025). Scopus has advanced features for the wide coverage of peer-reviewed scientific literature (Burnham 2006). Initially, a total of 772 articles were found using the search terms "*Metarhizium*" and

"Biocontrol" within a time span of 2001 to 2024 (Scopus database 2025). To obtain most relevant articles to the topic article titles, abstracts, author keywords, authorship and affiliations, citation counts, DOIs, and source information fields were selected from the metadata. Further, the dataset was screened according to "Preferred Reporting Items for Systematic Reviews and Meta-Analyses" **(PRISMA)** guidelines. The inclusion criteria involved, peer-reviewed journal articles and reviews, articles written in English, and articles focused on the application of *Metarhizium* for biocontrol (Figure 1). The dataset obtained was exported and downloaded as .csv file for further analysis by VOSviewer and R bibliometric package.

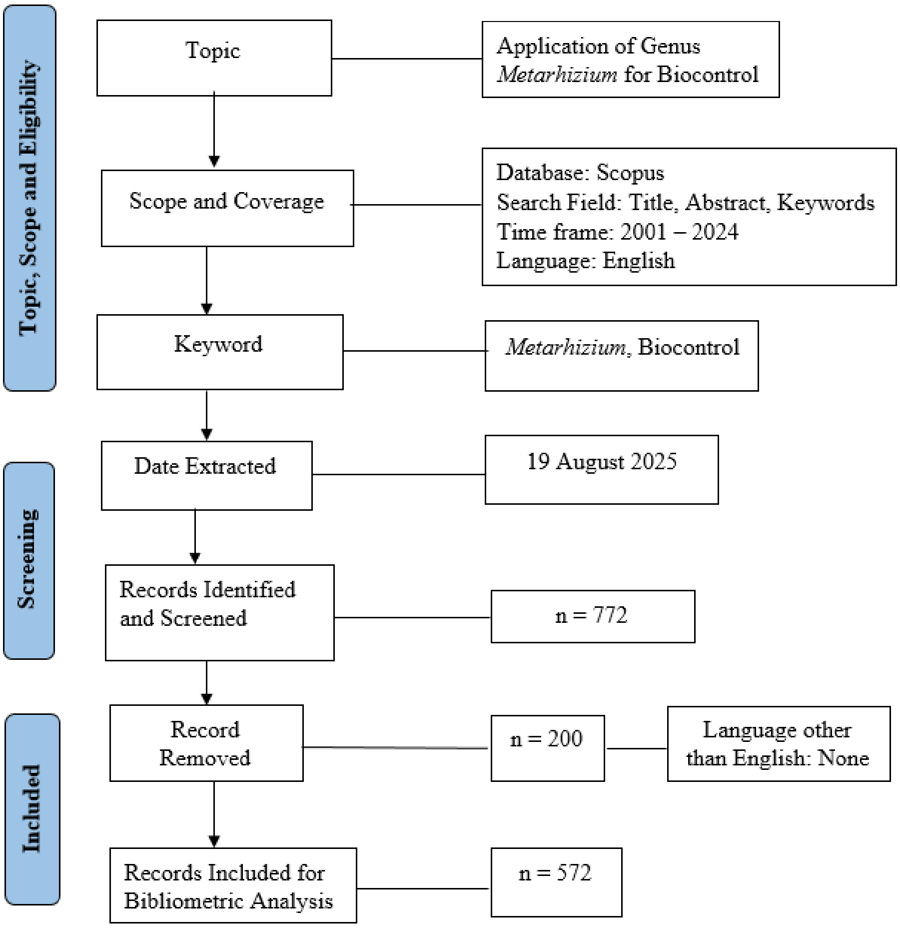

Fig. 1 – Flow diagram showing the search strategy of publications (2001–2024). Modified from PRISMA (Moher et al. 2009).

Tools and data analysis

VOSviewer (1.6.20) and Biblioshiny of the R Bibliometrix package were used for bibliometric analysis of the dataset. VOSviewer (1.6.20) was used for the mapping and analysis of co-authorship networks, keyword co-occurrence and citation, and co-citations (Van Eck & Waltman 2010). While the analysis and visualization of descriptive trends, advanced conceptual mapping of thematic evolution, and multiple correspondence were performed by R biblioshiny (Aria & Cuccurullo 2017).

The network and collaboration of authors, institutions and countries involved in the research were visualized using VOSviewer. The prominent authors and institutions were identified based on the number of publications and their respective citation counts. The analysis highlights the leading journals and subject areas publishing most of the research articles on *Metarhizium* biocontrol. Identification of popular research themes and their evolution trend was done by the analysis of keyword co-occurrence in VOSviewer. The R bibliometrics package was used to obtain a thematic map for categorization of research themes based on their density and centrality. The most influential papers, authors, and journals were identified based on citation count by citation analysis. Author impact was evaluated by using H – index and G – index.

Results

Bibliometric analysis provides a quantitative overview of the literature available on the application of *Metarhizium* as biocontrol within the defined time range of 2001–2024, as shown by the Table 1 and Fig. 2.

Table 1 Key Bibliometric Indicators (2001–2024).

Parameter	Indicator/Value	Description
Total Publications	772	Research articles and reviews on *Metarhizium* biocontrol indexed in Scopus
Study Period	2001–2024	Duration of bibliometric analysis
Annual Growth Rate	7.62%	Average yearly increase in publications
Total Authors	2,746	Distinct contributors to the field
Single-Authored Papers	16	Indicates the collaborative nature of the field
Co-Authors per Document	4.91	Average number of authors per publication
International Collaboration	28.5%	Papers involving authors from multiple countries
Total Sources (Journals)	269	Distinct journals publishing in this domain
Average Citations per Article	28.29	Reflects a moderate to high impact level
Total References Cited	5,186	Cumulative references across all documents
Average Article Age	8.99 years	Suggests recent and active research output
Top Contributing Countries	China, Brazil, USA, India, UK	Leading nations in *Metarhizium* research
Most Productive Institution	Universidade Federal do Rio Grande do Sul (Brazil)	86 publications
Most Prolific Author	Butt, Tariq M.	22 publications, h-index 14

Fig. 2 – Overview of the analysis of the collected data from the Scopus database from 2001 – 2024.

The Fig. 2 shows that a total of 772 articles were published across 269 unique sources, with a constant annual growth rate of 7.62%, and average citation rate 28.29 per article, from 2001 to 2024. In total, 2746 distinct authors have worked to publish these articles, of whom 16 authors have worked as single authors. The Co-Authors per Doc value of 4.91 indicates that, on average, each article was written by five authors. Among them, 28.5% articles were produced through international collaboration between authors from two or more different countries. A total of 5,102 author keywords show the distinct terms used by authors to describe their research. The 28.29 is the average number of times these articles have been cited by other publications. An average article age is 8.99 years, which indicates that these articles are recent. A total of 5186 unique references were cited in these articles collectively. This analysis reveals that the field of research on *Metarhizium* biocontrol has been growing, over the years, under a significant level of international collaboration.

Overall trend of article production

During the early years from 2001 to 2007, the trend of annual article production was low. Till the year 2007, the number of articles produced per year remained below 20 per year. This reveals the growing interest in *Metarhizium* research, but at a slower pace.

The period from 2008 to 2018 shows a noticeable upward trend till the year 2012, and the annual number of articles per year reached 37. The next three years show a gradual decline in the annual article production, but by the year 2018, the maximum number of articles produced per year reached 44. It reveals that during this phase, the field of *Metarhizium* biocontrol started gaining interest of researchers. From 2019 onwards, there is a surge in research activity in this field, and the number of articles produced per year reached 67 in the year 2023. It indicates that *Metarhizium* biocontrol is a highly active research area over the past five years. The field of biological control research has been active since the 1980s, targeting arthropod pests with entomopathogenic nematodes and microbial agents (San-Blas 2013). The field of research on biocontrol by Genus *Metarhizium*, itself an entomopathogenic fungus, is in line with this trend and shows continuous growth, especially after 2015. It is evident from Figure 3 that the *Metarhizium* biocontrol is a mature field, with consistent research and widespread commercial adoption. Its ability to target a broad range of pests, along with remaining beneficial for plant growth, is the factor behind its established status, in contrast to the research trend in general biological control research, with comparatively slower growth. The effectiveness of *Metarhizium* biocontrol has been recognised in pioneering research works, which supports its significance in sustainable agriculture.

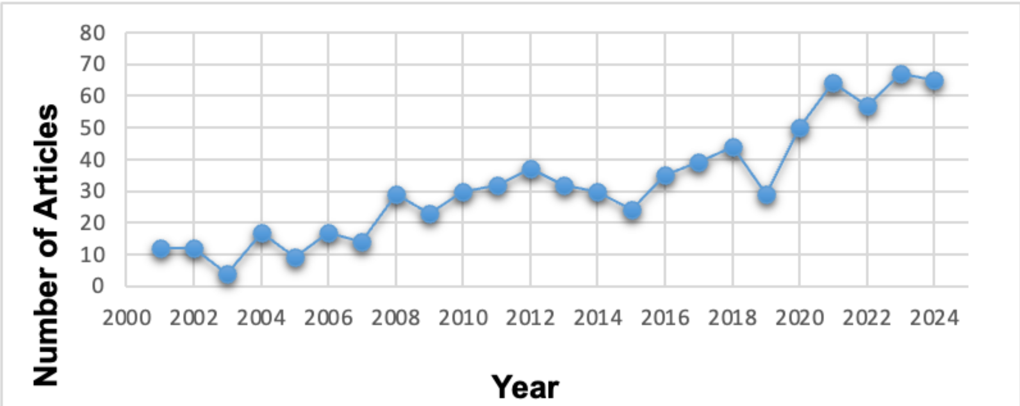

Fig. 3 – Annual article production on *Metarhizium* biocontrol research (2001–2024).

Most global cited documents

The bibliometric analysis provides the foundational articles of the *Metarhizium* biocontrol research. Ten prominent documents, as presented in Table 2, have been published from 2001 to 2011. The research article ranked first, among the top three (with total citation value 37.60 per year), by Gao Q., titled "(Genome Sequencing and Comparative Transcriptomics of the Model

Entomopathogenic Fungi *Metarhizium anisopliae* and *M. acridum*),” is the most-cited document, with the highest number of citations 564. This paper is based on a comparative genomic study of two *Metarhizium* strains to develop an understanding of pathogenicity and virulence, which are key indicators of a fungal strain's effectiveness in killing insects. The highest citations of the document reveal that genomic research methodologies are being focused on most for pathogenicity and virulence studies of *Metarhizium* strains. Similarly, the focus areas of documents ranked on second and third reveal genomic studies, and environmental safety of using *Metarhizium* species as a biocontrol agent have been the prominent research focus during the decade of 2001 to 2011.

Table 2 Ten most cited documents.

S. No.	Title	Journal	Citations	Total citations per year	Reference
1	Genome sequencing and comparative transcriptomics of the model entomopathogenic fungi *Metarhizium anisopliae* and *M. acridum*	PLOS Genetics	564	37.60	Gao et al. (2011)
2	A multilocus phylogeny of the *Metarhizium anisopliae* lineage	Mycologia	553	32.53	Bischoff et al. (2009)
3	Review on safety of the entomopathogenic fungus *Metarhizium anisopliae.*	Biocontrol Science and Technology	486	25.58	Zimmermann (2007)
4	Metagenomic biomarker discovery and explanation	Genome Biology	399	26.60	Segata et al. (2011)
5	Ecological factors in the inundative use of fungal entomopathogens	Biocontrol	364	22.75	Jaronski (2009)
6	Field studies using a recombinant mycoinsecticide (*Metarhizium anisopliae*) reveal that it is rhizosphere competent	Applied and Environmental Microbiology	279	11.63	Hu & St Leger (2002)
7	Coping with crowds: Density-dependent disease resistance in desert locusts	Proceedings of the National Academy of Sciences	261	10.88	Wilson et al. (2002)
8	Fungal endophytes: Beyond herbivore management	Frontiers in Microbiology	364	31.88	Bamisile et al. (2018)
9	Development of transgenic fungi that kill human malaria parasites in mosquitoes	Science	229	15.27	Fang et al. (2011)
10	Habitat association in two genetic groups of the insect-pathogenic fungus *Metarhizium anisopliae*: uncovering cryptic species	Applied and Environmental Microbiology	227	9.08	Bidochka et al. (2001)

Scientific collaboration networks and geographic distribution

The analysis of institutional productivity shows that more than 750 institutions worldwide have been engaged in *Metarhizium* biocontrol research over the years, but only a small number of institutions have made major contributions to the field. The productivity is concentrated in a few leading universities and research centers.

Out of 10 prominent institutions, a core group of leading institutions is primarily located in China only (five institutions), while others are from Brazil (1), Spain (1), the United Kingdom (1), Kenya (1), and Russia (1) (Table 3). The Universidade Federal do Rio Grande do Sul (Brazil) has the highest contribution of 86 publications, followed by the Chinese Academy of Agricultural Sciences (China, 78 articles) and the Universidad de Córdoba (Spain, 73 articles). Other active contributors include the South China Agricultural University (72 articles), Chongqing University (66 articles), and Swansea University (56 articles). International organizations such as the International Centre of Insect Physiology and Ecology (ICIPE, Kenya), along with Zhejiang University and Anhui Agricultural University (China), also appear among the leading institutions. The Institute of Systematics and Ecology of Animals, Siberian branch of the Russian Academy of Sciences (Russia) occupies the last place in the list of the top ten. Document production trend of five prominent affiliations over time reveals steady growth in institutional research output over the past two decades (Fig. 4).

Table 3 Most relevant affiliations by total number of publications.

Affiliation	Articles	Country
Universidade Federal do Rio Grande do Sul	86	Brazil
Chinese Academy of Agricultural Sciences	78	China
Universidad de Córdoba	73	Spain
South China Agricultural University	72	China
Chongqing University	66	China
Swansea University	56	United Kingdom
International Centre of Insect Physiology and Ecology, Nairobi	49	Kenya
Zhejiang University	49	China
Anhui Agricultural University	36	China
Institute of Systematics and Ecology of Animals of the Siberian Branch of the Ras	35	Russia

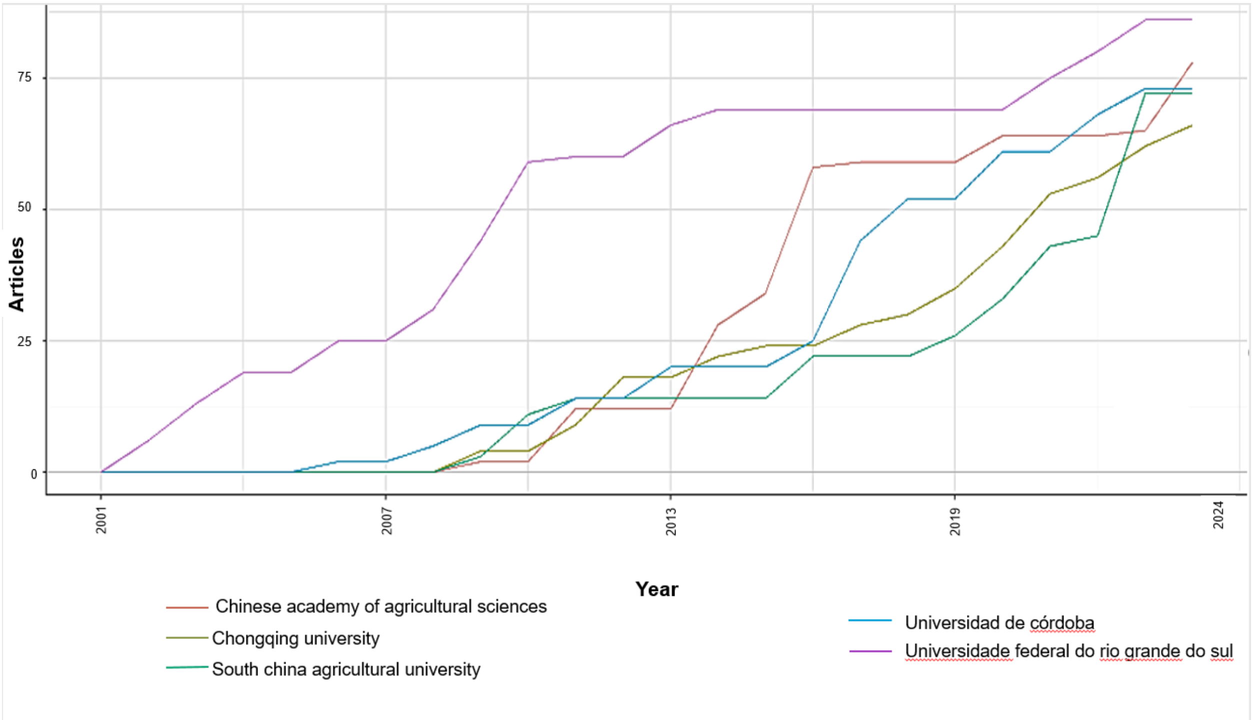

Fig. 4 Affiliations' production over time (2001–2024), showing the publication growth of five leading institutions.

The Universidade Federal do Rio Grande do Sul has the most consistent upward trend, while Chinese institutions such as the Chinese Academy of Agricultural Sciences and South China

Agricultural University display a rapid increase in productivity during recent years, reflecting growing research efforts of China on fungal biocontrol. European and Latin American institutions, including the Universidad de Córdoba and Universidade Federal do Rio Grande do Sul, also make frequent contributions. Further, the network analysis of Institutions reveals international and regional collaborations of the institutions (Fig. 5). The clusters of interlinked affiliations indicate strong partnerships between Latin American (e.g., Universidade Federal do Rio Grande do Sul, Universidad de Córdoba), European (e.g., Swansea University), and Asian institutions (e.g., Chinese Academy of Agricultural Sciences). The temporal color gradient highlights the active research engagement of some institutions as Universidade Federal do Rio Grande do Sul, since 2012, while others (Chongqing University) began conducting *Metarhizium* biocontrol research only after 2016. These collaboration clusters highlight the Chinese and Brazilian institutions as major hubs of *Metarhizium* research activity. These findings highlight the unequal distribution of institutional productivity worldwide. The majority of the documents are being produced by a small set of universities and research centers, often supported by extensive international collaborations.

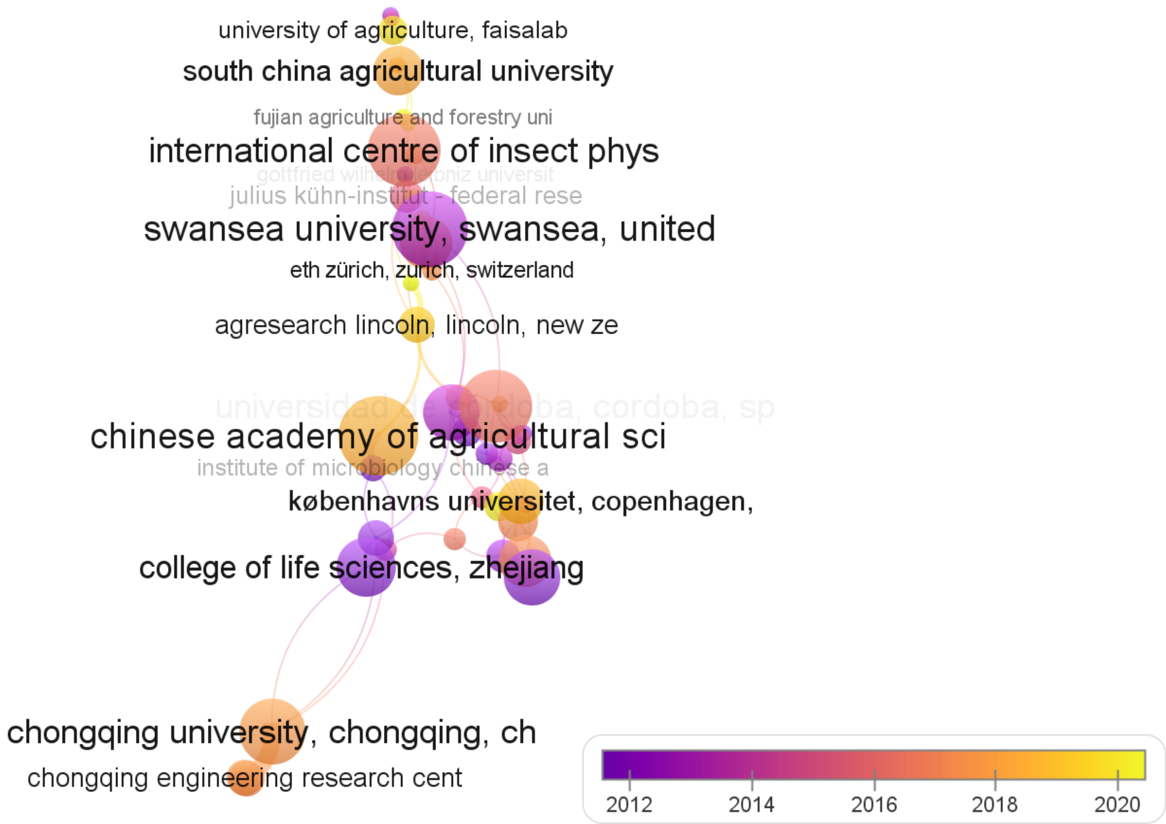

Fig. 5 – Co-authorship network of institutions showing international collaboration.

The analysis and visualization of collaboration patterns of countries reveals more than 80 countries involved in *Metarhizium* research, only 44 countries are actively involved in international collaboration, as reflected in the network (Fig. 6). The cluster analysis shows three dominant clusters, with China leading the first yellow cluster with the largest central node, suggesting the highest productivity and strong international collaborations with other countries as Brazil, the United States, India, Mexico, Kenya, and Russia. In the second cluster, the United States, in sky-blue, is the prominent country having collaboration with China, India, Brazil, Turkey, and many other countries. The third cluster, dominated by Brazil, shows large nodes and extensive connections with the United States, China, Spain, Mexico, and other countries, indicating its role in international collaborations on *Metarhizium* research. In contrast, 45 countries conduct research independently without engaging in cross-national partnerships. The link strength analysis reveals the highest intensity collaborative relationship of the United States with Brazil, the United Kingdom, and Germany. China has the strongest collaborative relationships with the United States, the United Kingdom, and Germany, while Brazil has the strongest collaboration with the United States, China, and Argentina.

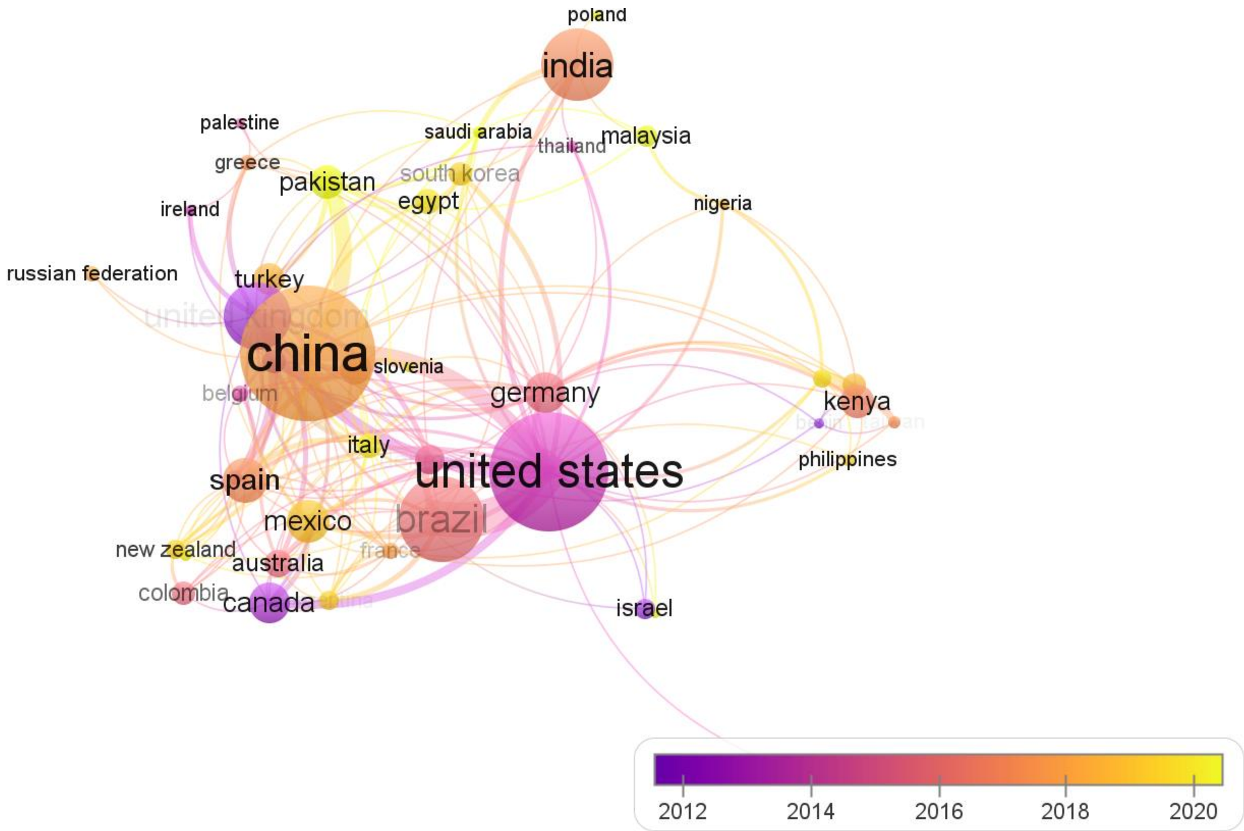

Fig. 6 – Co-authorship network of countries involved in international collaboration.

Within the network, the top 10 most productive countries occupy central positions, forming the primary hubs of *Metarhizium* biocontrol research globally (Table 4). India, Iran, Turkey, Mexico, Spain, South Korea, Italy, Japan, and France emphasize building strong internal research networks but engaging less internationally. These observations highlight the institutional priorities and geopolitical strategies shaping the field of *Metarhizium* research.

Table 4 Leading countries involved in international collaboration.

S. No.	Country	Documents	Citations	Total Link Strength
1	United States	117	6554	88
2	China	137	4481	49
3	United Kingdom	57	2413	48
4	Brazil	77	1983	39
5	Germany	30	1259	30
6	Italy	16	223	26
7	Pakistan	24	320	24
8	Kenya	24	770	22
9	Switzerland	22	592	21
10	Mexico	32	560	19

Analysis of the overall research output of countries shows China and Brazil dominate the field, with article contributions of 714 and 360, respectively, between 2001 and 2024. Other key contributors include the USA (306 articles), India (240 articles), the United Kingdom (161 articles), Mexico (153), Spain (108), Pakistan (93), Switzerland (83), and Germany (80). The leading ten countries dominating the *Metarhizium* research field, are shown by Fig. 7.

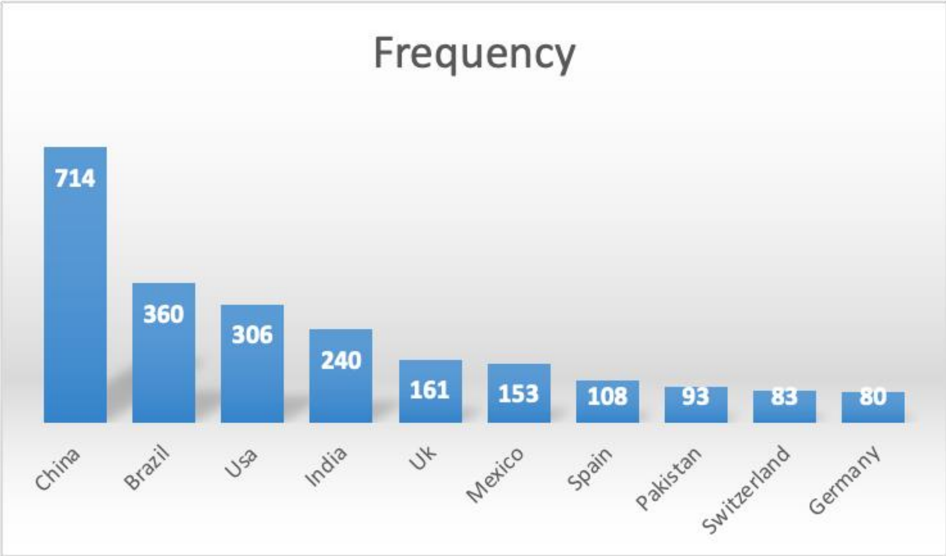

Fig. 7 – Country-wise research output (2001–2024).

Conclusively, China, the USA, and Brazil emerge as major research hubs, followed by other strong contributors such as India, United Kingdom, Mexico and Spain. Fig. 8 provides a visual representation of the publication growth of the five most productive countries between 2001 and 2024. The Figure shows a continuous rising trend across all nations, with China showing the steepest increase, particularly after 2010, reflecting its rapid expansion in biocontrol research. The USA and Brazil demonstrate moderate but steady growth, while the United Kingdom maintains a gradual upward trend. These observations explain how certain countries have strengthened their leadership positions while others have made gradual progress. The scientific production in this field is concentrated within a relatively small set of countries.

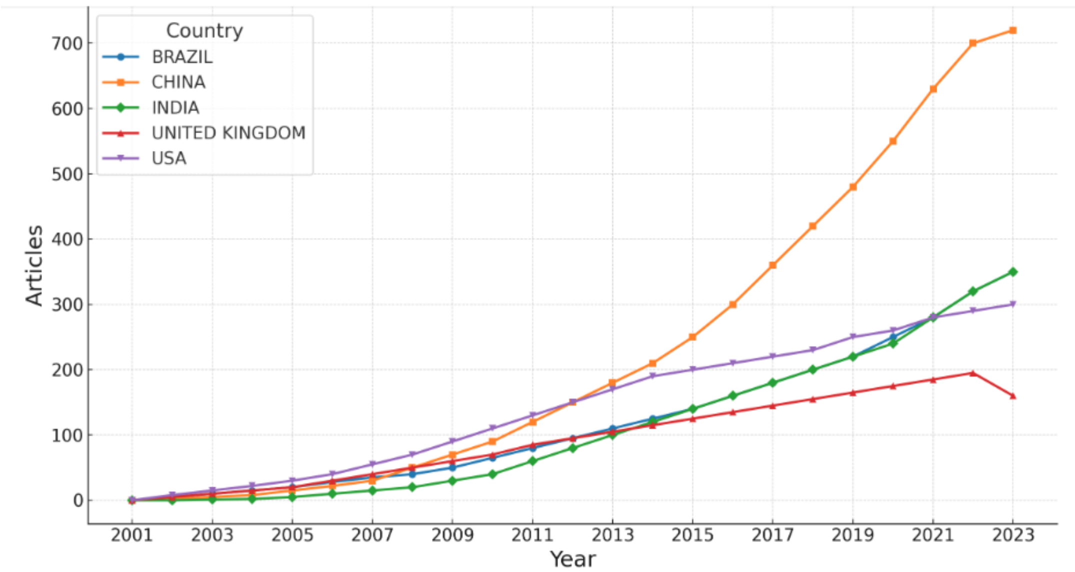

Fig. 8 – Research output of top five countries (2001–2024).

The analysis emphasizes the requirement of enhancing the cooperation between the leading institutions and smaller contributors to further diversify and promote *Metarhizium* biocontrol research.

Scientific production by authors

A bibliometric analysis of authors in *Metarhizium* biocontrol research highlights both the individual contributions and international collaborations. The production of articles on *Metarhizium* biocontrol research has been concentrated from 2009 to 2017 (Fig. 9). Butt Tariq M. is first among leading authors in scientific production with 22 articles, followed by Quesada-Moraga Enrique, and Garrido-Jurado Inmaculada, with the production of 19 and 15 articles from 2001 to 2024, respectively. Butt Tariq M. shows the distribution of article productivity throughout the period under study. Other authors, including Schrank Augusto, Vainstein Marilene Henning, Ansari Minshad Ali, Jaronski Stefan T., and Xia Yuxian, have contributed to most of the articles from 2009 to 2012. Jaronski Stefan T. is the leading author with the maximum number of total citations, followed by Quesada-Moraga Enrique, Feng Mingguang, and Garrido-Jurado Inmaculada.

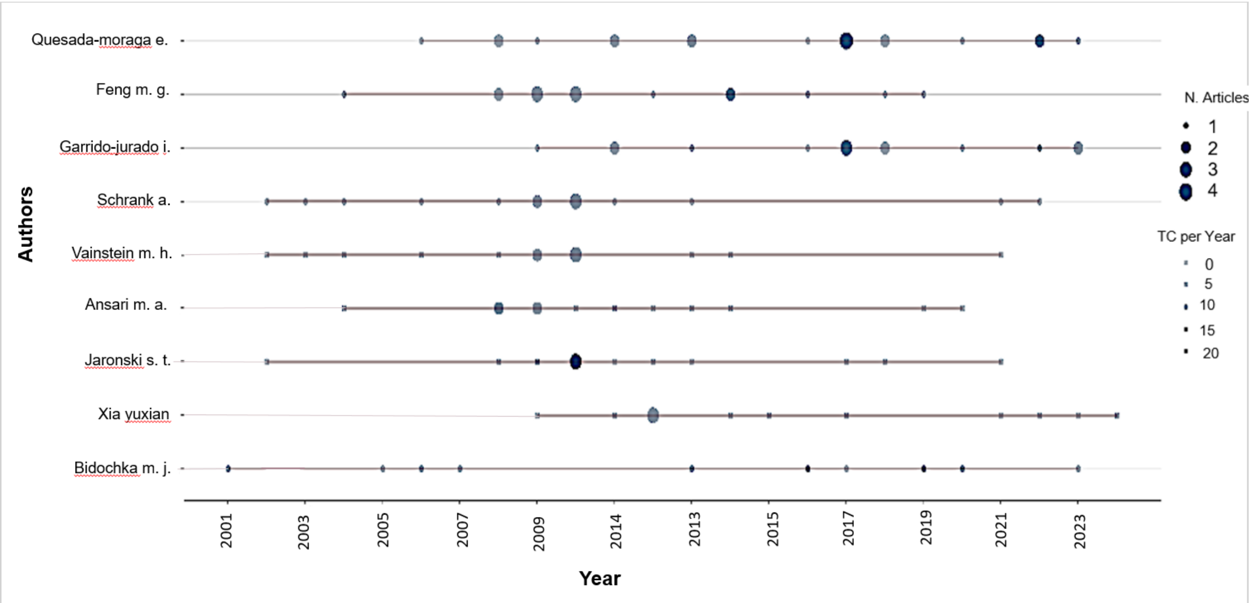

Fig. 9 – Authors' production over time.

A collaborative network of authors (Fig. 10) visualizes 110 authors, where 69 authors do not show working in international collaboration; rather, they are focused on internal or regional connections, while the 41 authors show a collaborative network. Three interconnected clusters are visible around the leading authors Butt, Quesada-Moraga, Schrank, and Vainstein, representing collaboration of authors working on biocontrol agent development, ecological impact, and applied biopesticide science. The central green-yellow cluster has multiple prominent authors like Butt Tariq M., Roberts Donald Wilson, and Feng Mingguang. The color variation of links and nodes, varying from green to yellow, shows that these are the recent and evolving group of authors in collaboration. This cluster acts as a bridge between different research groups, where Enkerli Jürg and Strasser Hermann also play a significant role. The left cluster in purple-blue color, centered around Schrank Augusto and Vainstein Marilene Henning, shows that the collaboration occurred during 2010 onwards. The right cluster turning green to yellow, centered around Quesada-Moraga Enrique and Meyling Nicolai V, suggests relatively recent collaborations among this group of authors. This cluster has high connection density internally but limited or no collaboration with other groups in the network, which is an indicator of a focus on regional collaborations rather than at the international level.

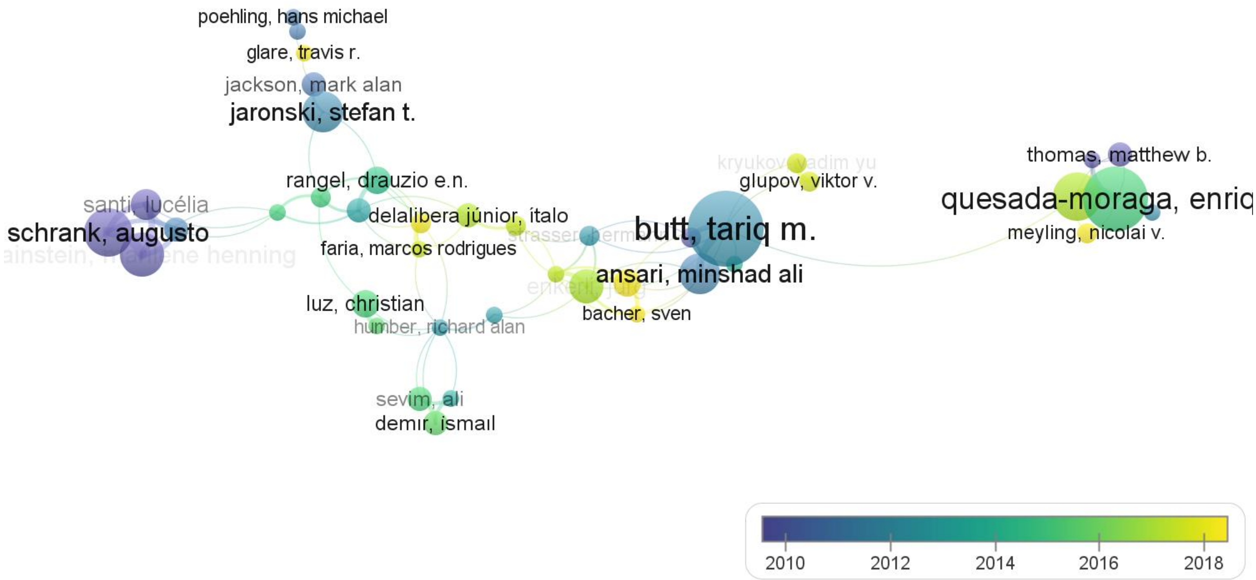

Fig. 10 – Collaborative network map of key authors in fungal biocontrol.

The bibliometric evidence from these Figures demonstrates that *Metarhizium* biocontrol research is driven by a small group of highly productive authors. Their output is characterized by sustained publication, influential citation patterns, and robust collaborative networks. Authors Butt Tariq M., Feng Mingguang, and Quesada-Moraga Enrique are holding the highest citation counts, 768, 670, and 566, respectively (Table 5). All three leading authors are highly productive with publications (NP) 22, 19, and 15, and have the highest g-index, indicating a high impact of their most cited articles. Bidochka Michael J. has the highest citation to publication ratio with 871 citations of just 10 publications. This data presents an overview of the citation impact and authors' productivity within *Metarhizium* biocontrol research field.

The bibliometric analysis of author's productivity by Lotka's laws reveals that the majority of authors contribute only a small number of papers in the area of *Metarhizium* biocontrol research (Fig. 11) (Lotka 1926). Among them, 81.8% of the authors have published only one document. A very few (3.6%) have published three or more, while only the 0.8% authors which are the prominent or the prolific authors of the field, have written more than five papers. This finding suggests for only a few highly productive authors, while the majority is with minimal contributions to the field of *Metarhizium* biocontrol. Quesada-Moraga Enrique has an h-index of 15, which means the author has 15 articles, cited at least 15 times (Table 5). Similarly, the h-index of Butt Tariq M. and Feng Mingguang have been observed as 14 and 13, respectively, followed by Garrido-Jurado Inmaculada, Schrank Augusto, Vainstein Marilene Henning and Ansari Minshad Ali. The data reveal that only a small number of authors (prominent authors) have a significant h-index.

Table 5 Metrics of most productive authors.

Author	h-index	g-index	m-index	TC	NP	PY-start
Quesada-Moraga Enrique	15	19	0.75	566	19	2006
Butt Tariq M.	14	22	0.583	768	22	2002
Feng Mingguang	13	15	0.591	670	15	2004
Garrido-Jurado Inmaculada	11	14	0.647	408	14	2009
Schrank Augusto	11	14	0.458	420	14	2002
Vainstein Marilene Henning	11	13	0.458	416	13	2002
Ansari Minshad Ali	10	12	0.455	546	12	2004

Table 5 Continued.

Author	h-index	g-index	m-index	TC	NP	PY-start
Bidochka Michael J.	9	10	0.36	871	10	2001
Ekesi Sunday	9	10	0.36	251	10	2001
Enkerli Jürg	9	10	0.6	399	10	2011

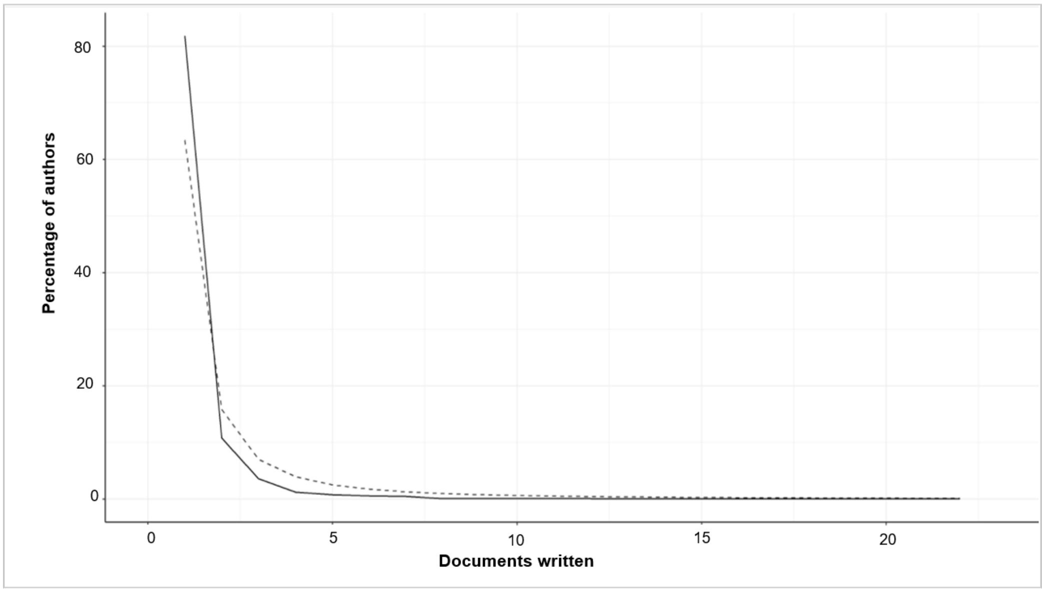

Fig. 11 – Author's productivity of *Metarhizium* biocontrol research (Lotka's law).

Scientific production by sources

The analysis of publishing sources highlights the journals that are the primary outlets for *Metarhizium biocontrol* research (Table 6). The journal Biocontrol Science and Technology is the leading source with the highest productivity of 64 publications, the highest h-index (26), g-index (47), and total citations (2,318). Biocontrol and the Journal of Invertebrate Pathology follow with high h-index values of 21 and 18, respectively, and significant total citations of 1,387 and 897. According to the m-index analysis (for the age of the journals), Biocontrol Science and Technology, with a citation rate of 1.04, has a steady impact throughout the period. Certain journals like Fungal Biology, despite having a lower number of publications (15), have a relatively high h-index of 10 and a strong m-index of 0.625, showing their noticeable contribution and high citation rate within their shorter publication history (PY-start 2010). This indicates that scientific production in this field is concentrated in both high-impact journals with a long history and specialized journals with growing influence.

Table 6 Ranking metric of sources with the highest scientific production.

Source	h-index	g-index	m-index	TC	NP	PY-start
Biocontrol Science and Technology	26	47	1.04	2318	64	2001
Biocontrol	21	37	0.84	1387	39	2001
Journal of Invertebrate Pathology	18	24	0.818	897	24	2004
Biological Control	17	22	0.773	839	22	2004
Pest Management Science	15	27	0.652	743	30	2003
Crop Protection	14	20	0.56	632	20	2001

Table 6 Continued.

Source	h-index	g-index	m-index	TC	NP	PY-start
Experimental and Applied Acarology	11	13	0.44	431	13	2001
Mycological Research	11	11	0.458	835	11	2002
Fungal Biology	10	15	0.625	383	15	2010
Journal of Pest Science	10	10	0.526	392	10	2007

The co-citation network of the sources (Fig. 12) shows the links between different sources. Many strong clusters are there having the Journal of Invertebrate Pathology at the centre, which connects Biocontrol Science and Technology, Biological Control, and Pest Management Science. It highlights the important role of the journal 'Journal of Invertebrate Pathology' in applied biocontrol, pest management, and fungal biology. The clustering indicates that some journals focus specifically on fungal pathogens, while others, like Pest Management Science and Crop Protection, offer broader information related to agriculture.

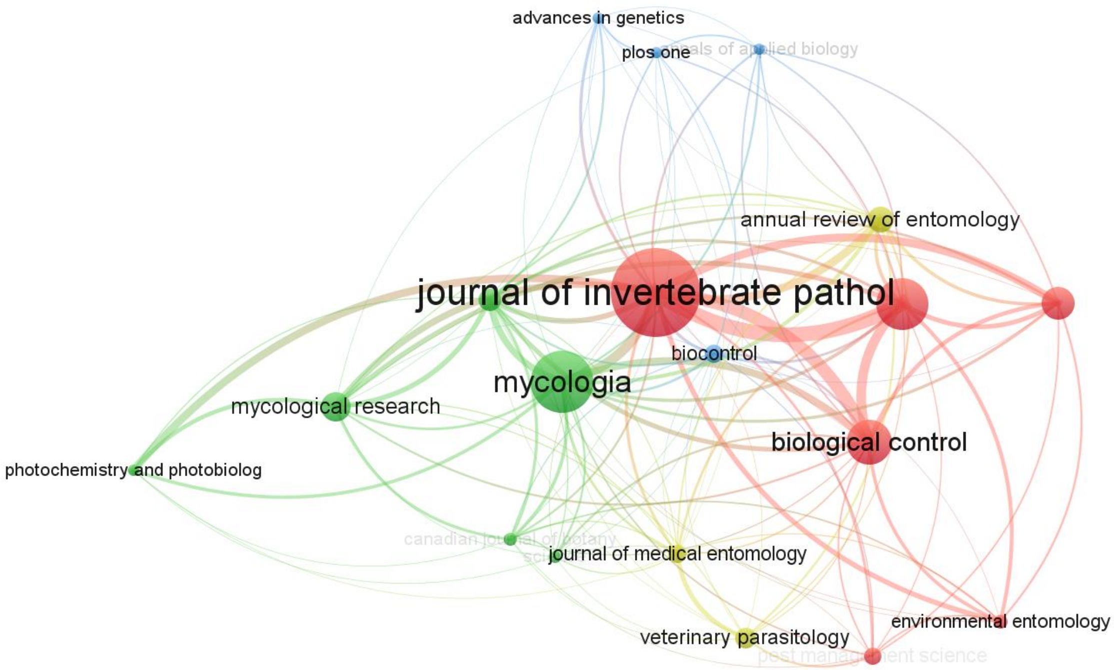

Fig. 12 – Journal co-citation network of sources in *Metarhizium* biocontrol research, visualizing intellectual linkages and collaboration patterns among journals.

Emerging themes based on keyword analysis

The keyword analysis is based on the author's keywords from the Scopus database. These are the terms representing the main focus of authors and are the main source for identification of central themes and topics in the field of *Metarhizium* biocontrol (Fig. 13).

Analysis of emerging themes reveals that fundamental aspects related to terms as fungal infection, *Schizophora gregoria*, and *Hypocreales* have been in focus during the period from 2001 to 2005, as these terms show high frequency during that period. It suggests an initial focus on basic taxonomy, classification, and host-pathogen interactions of *Metarhizium*. The phase from 2006 to 2012 shows a clear shift towards more applied and ecological research, as indicated by the emergence and increasing frequency of keywords such as "biocontrol," "entomopathogenic fungi," and "mycelium". This reveals growing research interest in the practical application of *Metarhizium* as a biological control agent against insects. During the recent years, from around 2017 to 2023, the research trend has had a transition towards detailed molecular-level studies, as revealed by the prominence of terms like "entomopathogenic fungus", "DNA extraction", "insecticides", and "insect pests". The presence of terms like "pest control" and "biocontrol" at a higher frequency in recent years shows that the relevance of this research field is increasing, inspired by the need for sustainable alternatives to chemical pesticides.

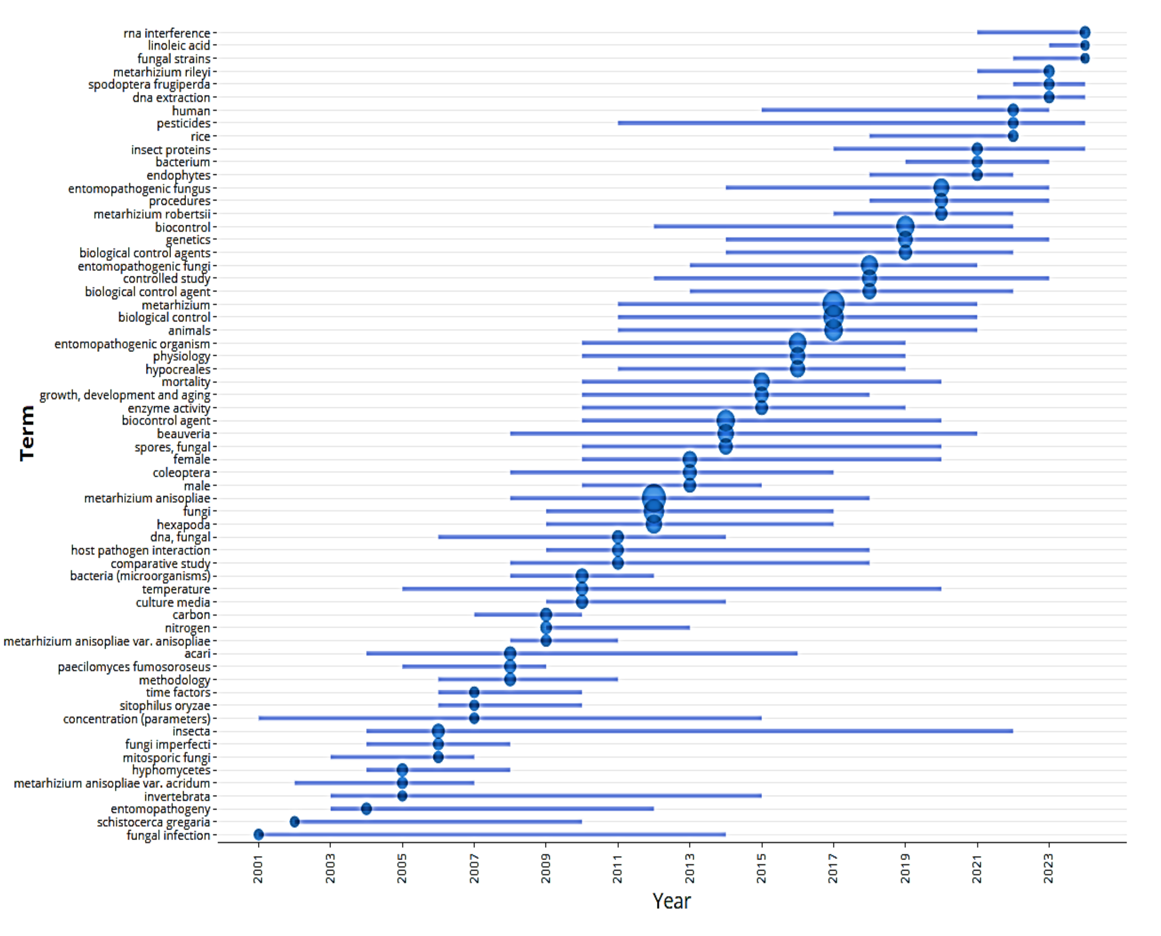

Fig. 13 – Word frequency over time indicating emerging and declining themes.

Moving from top to bottom in the plot, the three-field plot analysis categorizes the overall *Metarhizium* biocontrol research (2001–2024) into three main themes (Fig. 14). The first plot, at the top, connects the highly cited work of Butt Tariq M. and Feng Mingguang to the keywords like *Metarhizium* and fungus. These words indicate the fundamental biology and general biocontrol applications of *Metarhizium* as a central research theme in the focus of these prominent authors. The second cluster of authors, including Quesada-Moraga Enrique and Garrido-Jurado Inmaculada, is linked to the keywords as *Metarhizium anisopliae*, which is a particular *Metarhizium* species, and other words like “entomopathogenic fungi” and “microbiology” belong to the broader themes. This finding suggests that the research focuses on specific species and their use as biocontrol agents. Similarly, the connectedness of the third cluster at the bottom, having authors like Schrank Augusto and Vainstein Marilene Henning to the keywords biocontrol, entomopathogenic fungi, and pathogenicity, reveals that the specific aspects of *Metarhizium* physiology, biocontrol mechanisms, and its pathogenicity against different hosts, have been in the research focus of these authors. These findings are supported by the trending author’s keyword analysis, which highlights a shift toward host-pathogen interactions and virulence mechanisms (Fig. 15). This analysis shows rising cumulative occurrences of keywords like “pathogenicity” and “physiology, between 2010 and 2016, indicating the mechanism exploration of entomopathogenic fungi. Overall, the analysis implies a change in the working research theme from wide and general research on *Metarhizium* biocontrol to studies focused on in-depth investigation, focused on a particular species, its ecological functions, use as a biocontrol agent, and molecular mechanisms.

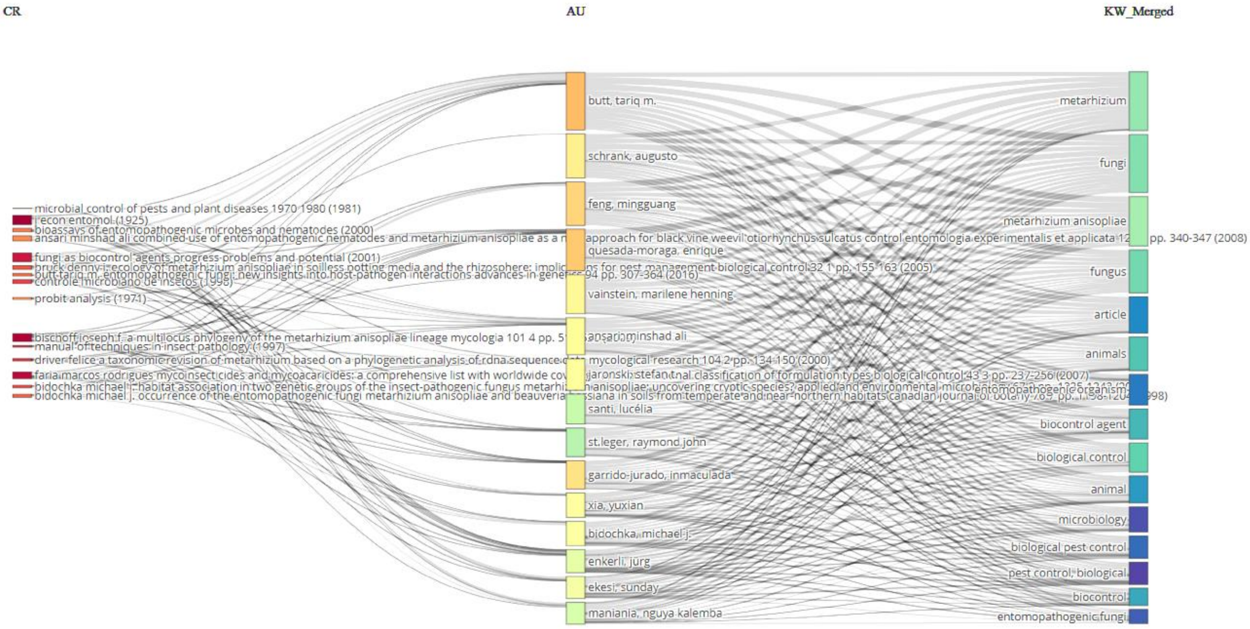

Fig. 14 – Three-plot analysis of keywords.

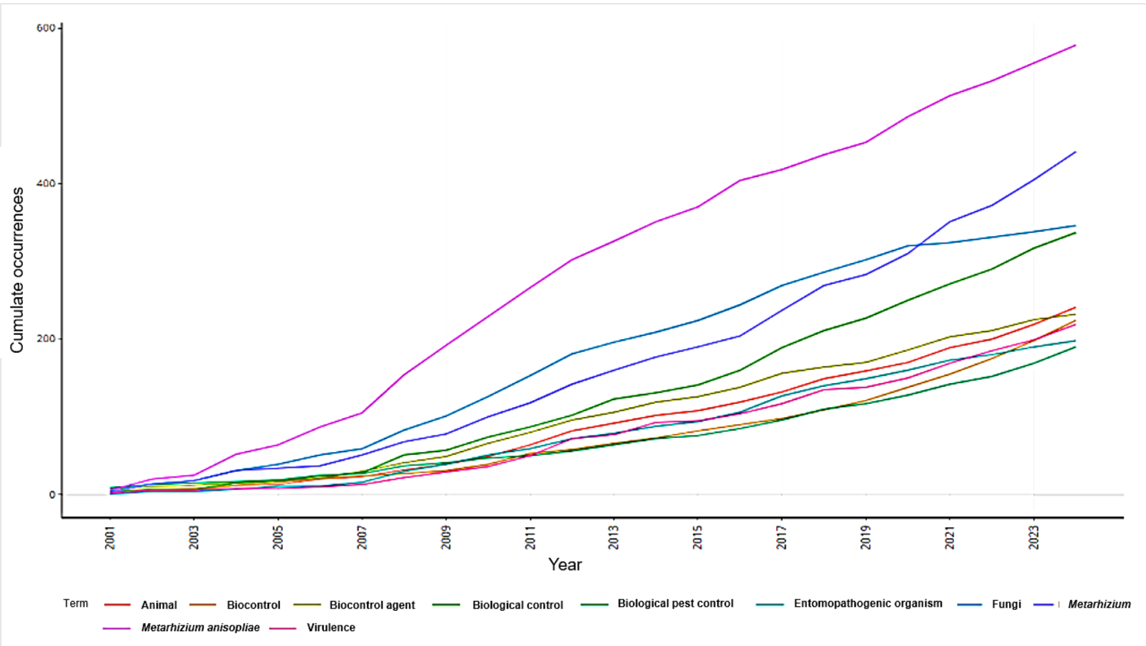

Fig. 15 – Trend topics by author keywords highlighting thematic shifts over time.

The analysis of the most frequently used author's keywords and Tree map also supports the findings of early studies, emphasizing specific species as *Metarhizium anisopliae*, application techniques, and pest targeting common in foundational studies on fungal entomopathogens (Figs. 16 and 17).

The network map of keyword co-occurrence (Fig. 18) reveals three interconnected thematic clusters. The red cluster consists of keywords as biological control, entomopathogenic organism, *Metarhizium anisopliae*, crop pest, beetle, *Lepidoptera*, *integrated pest management*, highlighting the application of *Metarhizium* as a microbial biopesticide. The green cluster, being a group of keywords like genetics, metabolism, fungal proteins, enzyme activity, spores (fungal), phylogeny, and virulence, suggests molecular and biochemical studies into strain diversity and pathogenic mechanisms. Ecological and host interaction-based research themes are highlighted by the keywords, microbiology, physiology, parasitology, host–pathogen interaction, Arthropoda, tick, Ascomycota, highlighting ecological and host interaction research in the blue cluster. Overall, they reflect an interdisciplinary path that incorporates ecological context, mechanistic exploration, and applied control.

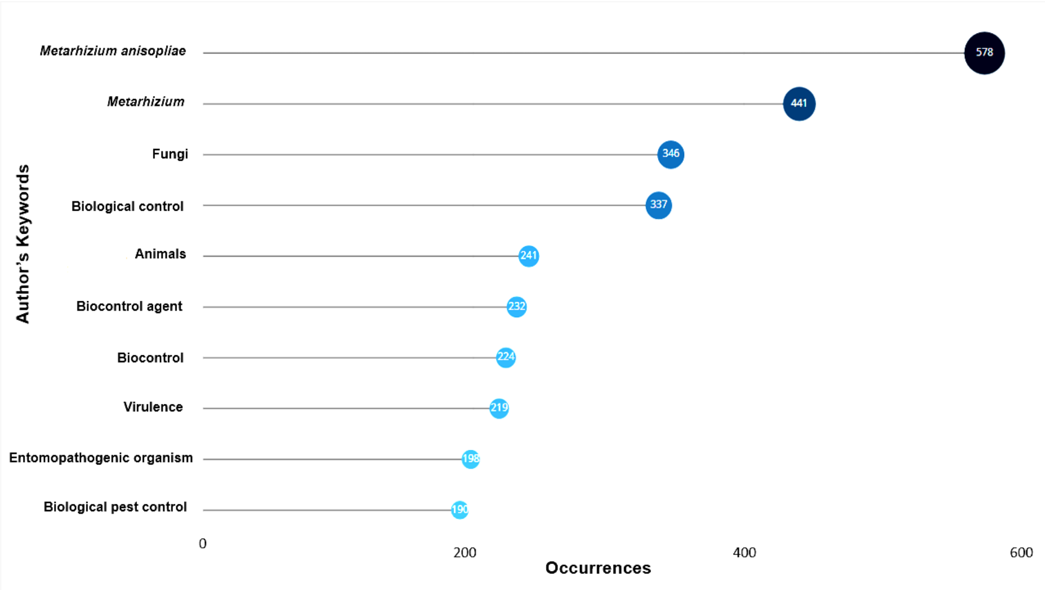

Fig. 16 – Most frequently used author keywords in *Metarhizium* biocontrol research.

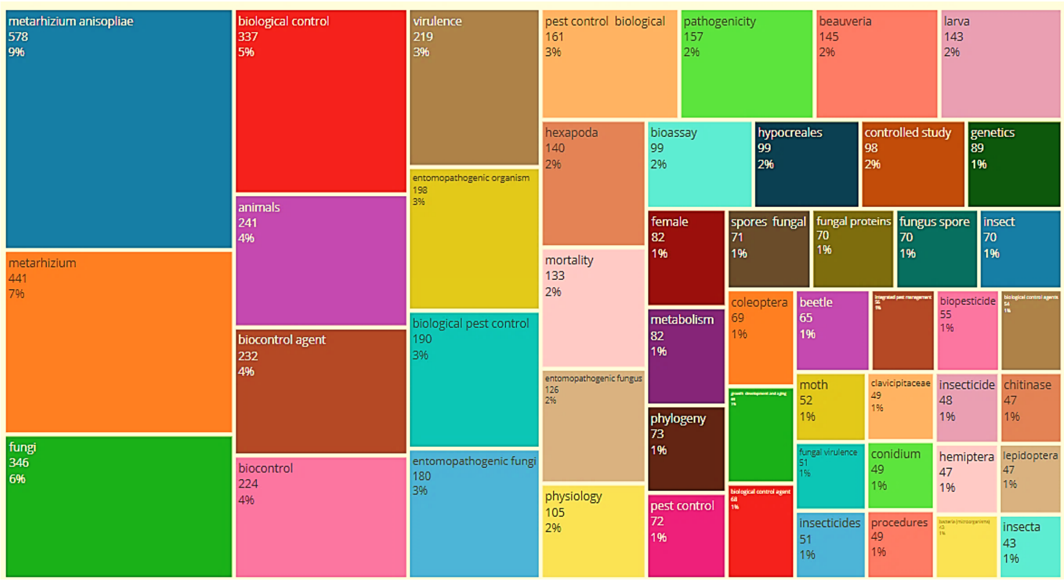

Fig. 17 – Tree map of major keyword clusters showing thematic areas.

The temporal evolution analysis (Fig. 19) demonstrates research focused on the practical use of *Metarhizium* species, with terms like "entomopathogenic organisms", "fungi", "biological control", and "biopesticides" during the early years around 2013 and 2014. From 2015 to 2017, terms like "virulence," "genetics," "metabolism," "phylogeny," and "fungal proteins" show the change in research focus to the studies based on the molecular and genetic basis of the pathogen-host interaction. From 2018 onwards, researchers have been exploring *Metarhizium* as both a bioinoculant and a biocontrol agent. Also, *Metarhizium* species with biocontrol potential have been observed improving plant growth and pest resistance. Comparative genomics and integrative taxonomy provide a base to develop an understanding of species boundaries and the genes related to virulence. Further, the studies on destruxin-binding proteins and volatile organic compounds that target mites expand the practical uses of *Metarhizium*.

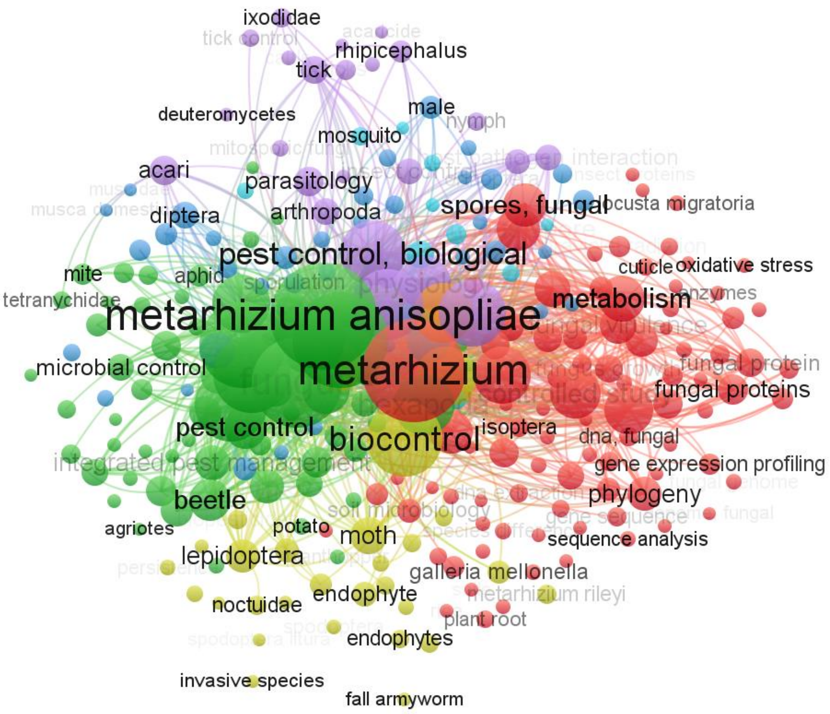

Fig. 18 – Author's keywords network map.

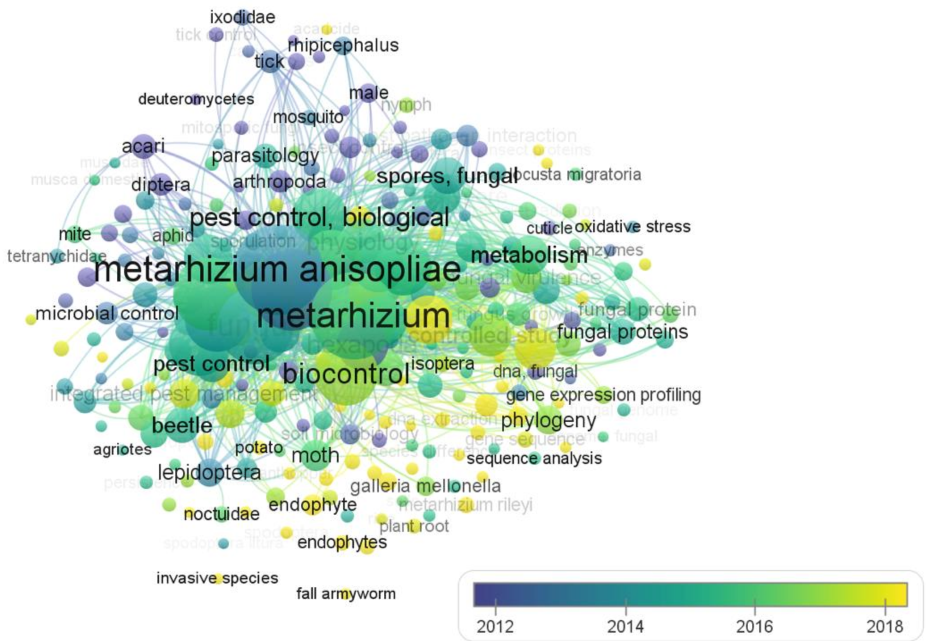

Fig. 19 – Temporal analysis of keywords.

Discussion

This study was conducted to get an overview of the global research landscape and trends on *Metarhizium* as a biocontrol agent from 2001 to 2024. The study identifies influential authors, publication trends, collaboration networks, and thematic evolutions for comprehensive mapping of

Metarhizium research. The findings of the study reveal a continuous annual publication growth rate of approximately 7–8% with a noticeable increase in publication volume during the years after 2015 (Fig. 3). Such growth indicates both the expansion and the diversification of the *Metarhizium* biocontrol research field (Jaronski 2009, Meyling & Eilenberg 2007). The highly cited articles of the field are focused on the studies based on host-pathogen interaction mechanisms, pathogen genome, and environmental safety aspects. These findings are supported by the other studies based on entomopathogenic fungi. A half-century scientometric review study reports a similar diversification trend in fungal biocontrol research themes globally (Yuan et al. 2025).

Infection rates and immune escape have been focused on in studies of *Metarhizium*-host interactions, particularly in the case of locust (Hu et al. 2014, Valero-Jiménez et al. 2016, Wang & St. Leger 2007). Further, the comparative genomics studies reveal the adaptive gene families along with the modes of evolution from specialist to generalist fungi (Gao et al. 2011, Du et al. 2024). The studies focusing on *M. anisopliae* demonstrate its role as both a mycoinsecticide and a plant growth enhancer (Bamisile et al. 2018, Joo & Hussein 2022, Chaudhary et al. 2023, Yapa RH et al. 2025). The ability to play these dual roles supports the broader integration of *Metarhizium* species into Integrated Pest Management programs focused on bringing sustainability to agricultural systems (Jaber & Ownley 2018, Mesquita et al. 2023, Ortiz-Urquiza & Keyhani 2013). Growing concerns of ecological safety, pesticide resistance, and global food security have intensified the research efforts and investment in the field of biocontrol research (Ayaz et al. 2023, Butt et al. 2001).

The innovation in molecular biology and formulation technologies, such as UV-protective formulations, strain-specific markers, and synergistic delivery methods, has improved the efficiency and functionality of *Metarhizium* products in the field (Fang & St. Leger 2012, Batta 2016, Lovett & St. Leger 2018). The bibliometric clusters identified, reveal an opportunity to relate host-pathogen interactions and genomic studies-based research to the advanced tools such as metagenomics, crispr-cas–based genome editing, and AI-driven pest management modeling. This advancement is required to enhance the efficiency of *Metarhizium* based biocontrol products. Integration of metagenomics would be helpful improving the understanding of *Metarhizium* interactions with plant microbiomes within the soil, required to identify the functional genes related to virulence, plant symbiosis, and stress tolerance. Similarly, crispr-cas systems would allow to produce engineered *Metarhizium* strains with improved virulence, spore stability, and environmental resilience (Magan & Medina 2021, Kobmoo et al. 2024). Application of artificial intelligence-based predictive models to integrated pest management would help in determination of optimal conditions for *Metarhizium*-based product application, forecasting disease outbreak and weather changes.

These achievements support the goal of achieving ecological safety and climate resilience in pest management (Zimmermann 2007). The collaboration patterns as described in the results highlight the supremacy of a few groups of institutions in China, Brazil, and the USA, in *Metarhizium*-based biocontrol research. It sheds light on the underlying global disparities in research productivity. The Brazil-based studies also report a rich diversity of *Metarhizium* strains but limited commercial availability of the *Metarhizium* biocontrol products, which requires improvement in cross-continental partnerships (Yapa AT et al. 2025). The clusters of collaboration linking Latin America, Asia, and Europe have contributed to the knowledge generation, but many countries continue to contribute to isolation, which is the main reason behind the persistent imbalances of productivity (AbdelGhany 2015).

Despite technological advancements, there are still large gaps because of comparatively little knowledge about the stability of formulation, non-target ecological safety, and field-level efficiency under different climatic conditions (Batta 2016, Inglis et al. 2001). Multi-omics datasets such as transcriptomics, proteomics, and metabolomics, could offer solution by assisting the discovery of virulence determinants, functional traits, and stress-response pathways. Future research efforts must focus on biocontrol field trials under different climatic conditions, along with a comprehensive evaluation of ecological safety for non-target organisms (Butt et al. 2001, Zimmermann 2007). Enhancing global partnerships is required for diversified innovation and improving the individual outcomes in the underrepresented regions. Advances in genomics and biotechnology should be integrated with formulation science to create climate-resilient and stable biocontrol agents (Hu et al. 2014, Wang J et al. 2023). Interdisciplinary studies to explore multifunctional applications of the fungus as biopesticides, plant bioinoculants, and soil health promoters, must be taken into account (Mesquita et al. 2023, Chaudhary et al. 2023).

This study is the first to provide a comprehensive bibliometric map of *Metarhizium* research over the past 24 years, showing its intellectual history, collaborative structures, and emerging themes. The integration of emerging technologies will redefine the development and application of the *metarhizium* species, as a better approach towards sustainable pest management systems. These findings deliver ground-level insights for researchers, industry stakeholders, and policymakers to overcome gaps, enhance collaborations, and promote eco-friendly pest management globally.

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Accessibility of data

The datasets generated during and/or analysed during the current study are available in the Scopus repository (www.scopus.com).

References

AbdelGhany TM. 2015 – Entomopathogenic fungi and their role in biological control. OMICS Group eBooks, Foster City, CA, USA

Aria M, Cuccurullo C. 2017 – Bibliometrix: An R-tool for comprehensive science mapping analysis. Journal of Informetrics 11, 959–975.

Ayaz M, Li CH, Ali Q, Zhao W, et al. 2023 – Bacterial and fungal biocontrol agents for plant disease protection: Journey from lab to field, current status, challenges, and global perspectives. Molecules 28(18), 6735.

Bamisile BS, Dash CK, Akutse KS, Keppanan R, et al. 2018 – Fungal endophytes: Beyond herbivore management. Frontiers in Microbiology 9, 544.

Batta YA. 2016 – Recent advances in formulation and application of entomopathogenic fungi for biocontrol of stored-grain insects. Biocontrol Science and Technology 26(9), 1171–1183.

Bidochka MJ, Kamp AM, Lavender TM, Dekoning J, et al. 2001 – Habitat association in two genetic groups of the insect-pathogenic fungus *Metarhizium anisopliae*: Uncovering cryptic species? Applied and Environmental Microbiology 67(3), 1335–1342.

Bischoff JF, Rehner SA, Humber RA. 2009 – A multi-locus phylogeny of the *Metarhizium anisopliae* lineage. Mycologia 101(4), 512–530.

Boaventura H, Quintela E. 2025 – The multifunctionality of the fungus *Metarhizium* spp. and its use in Brazilian agriculture. Bragantia. (Accessed on January 10, 2025).

Burnham JF. 2006 – Scopus database: A review. Biomedical Digital Libraries 3(1), 1–8.

Butt TM, Jackson C, Magan N. 2001 – Fungi as biocontrol agents: Progress, problems and potential. CABI Publishing. (Accessed on January 10, 2025).

Chaudhary PJ, BL R, Patel HK, Mehta PV, et al. 2023. Plant growth promoting potential of entomopathogenic fungus *Metarhizium pinghaense* AAUBC M26 under elevated salt stress in tomato. Agronomy 13(6), 1577.

Donthu N, Kumar S, Mukherjee D, Pandey N, et al. 2021 – How to conduct a bibliometric analysis: An overview and guidelines. Journal of Business Research 133, 285–296.

Du Y, Li J, Chen S, Xia Y, Jin K. 2024 – Pathogenicity analysis and comparative genomics reveal the different infection strategies between the generalist *Metarhizium anisopliae* and the specialist *Metarhizium acridum*. Pest Management Science 80(2), 820–836.

Elsevier. 2025 – Scopus: Abstract and citation database [Database]. Elsevier. Retrieved August 19, 2025, from https://www.scopus.com (Accessed on January 10, 2025).

Fang W, St. Leger RJ. 2012 – Enhanced UV resistance and improved killing of Malaria mosquitoes by photolyase transgenic entomopathogenic fungi. PLOS ONE 7(8), e43069.
Fang W, Vega-Rodríguez J, Ghosh AK, Jacobs-Lorena M, et al. 2011 – Development of transgenic fungi that kill human malaria parasites in mosquitoes. Science 331(6020), 1074–1077.
Gao Q, Jin K, Ying SH, Zhang Y, et al. 2011 – Genome sequencing and comparative transcriptomics of the model entomopathogenic fungi *Metarhizium anisopliae* and *M. acridum*. PLoS Genetics 7(1), e1001264.
Geremew D, Shiberu T, Leta A. 2024 – Evaluation of endophytic colonization and establishment of entomopathogenic fungi against *Tuta absoluta* (Lepidoptera: *Gelechiidae*) in tomato plants. F1000Research 13, 800.
Hu G, St. Leger RJ. 2002 – Field studies using a recombinant mycoinsecticide (*Metarhizium anisopliae*) reveal that it is rhizosphere competent. Applied and Environmental Microbiology 68(12), 6383–6387.
Hu X, Xiao G, Zheng P, Shang Y, et al. 2014 – Trajectory and genomic determinants of fungal-pathogen speciation and host adaptation. Proceedings of the National Academy of Sciences 111(47), 16796–16801.
Inglis GD, Goettel MS, Butt TM, Strasser H. 2001 – Use of hyphomycetous fungi for managing insect pests. In: T. M. Butt, C. Jackson, N. Magan (Eds.), Fungi as biocontrol agents: Progress, problems and potential (pp. 23–69). CABI Publishing. (Accessed on January 10, 2025).
Jaber LR, Ownley BH. 2018 – Can we use entomopathogenic fungi as endophytes for dual biological control of insect pests and plant pathogens? Biological Control 116, 36–45.
Jaronski ST. 2009 – Ecological factors in the inundative use of fungal entomopathogens. BioControl 55(1), 159–185.
Joo JH, Hussein KA. 2022 – Biological control and plant growth promotion properties of volatile organic compound-producing antagonistic *Trichoderma* spp. Frontiers in Plant Science 13, 897668.
Karthi S, Vasantha-Srinivasan P, Senthil-Nathan S, Han YS, et al. 2024 – Entomopathogenic fungi promising biocontrol agents for managing lepidopteran pests: Review of current knowledge. Biocatalysis and Agricultural Biotechnology 58, 103146.
Kobmoo N, Mongkolsamrit S, Khonsanit A, Cedeño-Sanchez M, et al. 2024 – Integrative taxonomy of the *Metarhizium anisopliae* species complex based on phylogenomics combined with morphometrics, metabolomics and virulence data. IMA Fungus 15, 30
Kortsinoglou AM, Wood MJ, Myridakis AI, Andrikopoulos M, et al. 2024 – Comparative genomics of *Metarhizium brunneum* strains V275 and ARSEF 4556: unraveling intraspecies diversity. G3 (Bethesda, Md.) 14(10), jkae190.
Lotka AJ. 1926 – The frequency distribution of scientific productivity. Journal of the Washington Academy of Sciences 16(12), 317–324.
Lovett B, St. Leger RJ. 2017 – Genetically engineering better fungal biocontrol agents. Pest Management Science 73(1), 10–17.
Magan N, Medina A. 2021 – Climate change and resilience of biological control agents. In: how research can stimulate the development of commercial biological control against plant diseases (pp. 83–93). Cham: Springer International Publishing.
Mesquita E, Hu S, Lima TB, Golo PS, et al. 2023 – Utilization of *Metarhizium* as an insect biocontrol agent and a plant bioinoculant with special reference to Brazil. Frontiers in Fungal Biology 4, 1276287.
Meyling NV, Eilenberg J. 2007 – Ecology of the entomopathogenic fungi *Beauveria bassiana* and *Metarhizium anisopliae* in temperate agroecosystems: Potential for conservation biological control. Biological Control 43(2), 145–155.
Moher D, Liberati A, Tetzlaff J, Altman DG, et al. 2009 – Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. PLoS Medicine 6(7), e1000097.

Mongkolsamrit S, Khonsanit A, Thanakitpipattana D, Tasanathai K, et al. 2020 – Revisiting *Metarhizium* and the description of new species from Thailand. Studies in Mycology 95, 171–251.
Ninkov A, Frank JR, Maggio LA. 2022 – Bibliometrics: Methods for studying academic publishing. Perspectives on Medical Education 11(3), 173–176.
Ortiz-Urquiza A, Keyhani NO. 2013 – Action on the surface: Entomopathogenic fungi versus the insect cuticle. Insects 4(3), 357–374.
Peng ZY, Huang ST, Chen JT, Li N, et al. 2022 – An update of a green pesticide: *Metarhizium anisopliae*. All Life 15(1), 1141–1159.
Quesada Moraga E, Garrido Jurado I, González Mas N, Yousef Yousef M. 2023 – Ecosystem services of entomopathogenic ascomycetes. Journal of Invertebrate Pathology 201, 108015.
San-Blas E. 2013 – Progress on entomopathogenic nematology research: A bibliometric study of the last three decades: 1980–2010. Biological Control 66(2), 102–124.
Scopus database. 2025 – Available at: www.scopus.com, (Accessed on August 19, 2025).
Segata N, Izard J, Waldron L, Gevers D, et al. 2011 – Metagenomic biomarker discovery and explanation. Genome Biology 12(6), R60.
Sharma R, Sharma P. 2021 – Fungal entomopathogens: A systematic review. Egyptian Journal of Biological Pest Control 31, 57.
Sullivan CF. 2022 – A review of commercial *Metarhizium*- and *Beauveria*-based products in the USA. Insects 13(2), 158.
Valero-Jiménez CA, Wiegers H, Zwaan BJ, Koenraadt CJM, et al. 2016 – Genes involved in virulence of the entomopathogenic fungus Beauveria bassiana. Journal of Invertebrate Pathology 133, 41–49.
Van Eck NJ, Waltman L. 2010 – VOSviewer: A computer program for bibliometric mapping. Scientometrics 84(2), 523–538.
Wang C St, Leger RJ. 2007 – The MAD1 adhesin of *Metarhizium anisopliae* links adhesion with blastospore production and virulence to insects, and the MAD2 adhesin enables attachment to plants. Eukaryotic Cell 6(5), 808–816.
Wang J, Weng Q, Zhang K, Hu Q. 2023 – Binding proteins of destruxin A from *Metarhizium* against insect cell. BMC Microbiology 23(1), 96.
Wilson K, Thomas MB, Blanford S, Doggett M, et al. 2002 – Coping with crowds: Density-dependent disease resistance in desert locusts. Proceedings of the National Academy of Sciences of the United States of America 99(8), 5471–5475.
Yapa AT, Thambugala KM, Samarakoon MC, de Silva N. 2025 – *Metarhizium* species as bioinsecticides: potential, progress, applications & future perspectives. New Zealand Journal of Botany 63(2–3), 439–461.
Yapa PAB, Silva R, Jayasena H. 2025 – Global trends and applications of *Metarhizium* in sustainable pest management. Journal of Applied Microbiology 138(2), 511–526.
Yapa RH, Silva GA, Perera S. 2025 – Multifunctional role of *Metarhizium anisopliae* in crop health and pest management. Journal of Fungi 11(3), 356.
Yu Q, Liu YX, Liu ZY. 2011 – Advances in classification of *Metarhizium*. Guizhou Agricultural Sciences. Available at: https://www.cabidigitallibrary.org/doi/full/10.5555/20123077140 (Accessed on August 11, 2025).
Yuan Z, Shen Q, Yu K, Liu Y, et al. 2025 – Half-Century Scientometric Analysis: Unveiling the Excellence of Fungi as Biocontrol Agents and Biofertilisers. Journal of Fungi 11(2), 117.
Zhou W, Li M, Achal V. 2025 – A comprehensive review on environmental and human health impacts of chemical pesticide usage. *Emerging Contaminants 11*(1), 100410.
Zimmermann G. 2007 – Review on safety of the entomopathogenic fungus *Metarhizium anisopliae*. Biocontrol Science and Technology 17(9), 879–920.